Essays in resource market imperfections and their impacts on firm behaviour and the environment

Miao Dai

Department of Economics
McGill University
Montréal, Québec, Canada

June, 2023

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Doctor of Philosophy.

Abstract

This dissertation consists of two chapters that study resource market imperfections caused by political lobbying and cross-ownership, and aims to improve public policy-making through understanding resource use and its implications for market competition and the environment.

In Chapter 1, concerned with the growing North-to-South waste shipments and environmental degradation, I examine whether strengthening environmental lobby groups can represent an important strategy to reduce the international waste trade. To do so, I first develop a theoretical model, emphasizing the potential impact of green lobbies on environmental and trade policies and how waste trade flows are affected through these policy channels. Then, I take the theory to the data to causally identify the effects of environmental lobbying on the waste trade. I find compelling evidence that environmental lobby groups exert a statistically significant impact on North-to-South waste export reduction. It thus may be worthwhile for international donor organizations to provide support for the development of environmental NGOs all over the world.

In Chapter 2, motivated by the large cross-ownership activities in the nonrenewable resource sector, I investigate the incentives of rival firms to participate in cross-ownership and the levels of cross-shareholdings that will be profitable. I first examine the profitability of cross-ownership in a static game framework, and then I extend it to a dynamic game model to study the impact of cross-ownership on market outcomes when the resources' scarcity and dynamics are considered. Further, I contrast cross-ownership with horizontal mergers and conduct a welfare analysis. My findings highlight that cross-ownership can be preferable to a horizontal merger in terms of Cournot competition, and may turn out to be relatively less detrimental to society in a nonrenewable resource industry than in other industries. These results thus suggest that antitrust authorities should consider adapting their guidelines and conduct a specific examination when dealing with industries where inter-temporal constraints play an important role.

Résumé

Cette thèse se compose de deux chapitres qui étudient les imperfections du marché des ressources causées par le lobbying politique et la propriété croisée, et vise à améliorer l'élaboration des politiques publiques en comprenant l'utilisation des ressources et ses implications pour la concurrence sur le marché et l'environnement.

Au Chapitre 1, préoccupé par la croissance des envois de déchets du Nord au Sud et la dégradation de l'environnement, j'examine si le renforcement des groupes de pression environnementaux peut représenter une stratégie importante pour réduire le commerce international des déchets. Pour ce faire, je développe d'abord un modèle théorique, mettant l'accent sur l'impact potentiel des groupes de pression écologiques sur les politiques environnementales et commerciales et sur la façon dont les flux commerciaux de déchets sont affectés par ces canaux politiques. Ensuite, j'applique la théorie aux données pour identifier de manière causale les effets du lobbying environnemental sur le commerce des déchets. Je trouve des preuves convaincantes que les groupes de pression environnementaux ont un impact statistiquement significatif sur la réduction des exportations de déchets du Nord vers le Sud. Il peut donc être utile pour les organisations internationales de donateurs de soutenir le développement d'ONG environnementales dans le monde entier.

Au chapitre 2, motivé par les importantes activités de propriété croisée dans le secteur des ressources non renouvelables, j'étudie les incitations des entreprises rivales à participer à la propriété croisée et les niveaux de participation croisée qui seront rentables. J'examine d'abord la rentabilité de la propriété croisée dans un cadre de jeu statique, puis je l'étends à un modèle de jeu dynamique pour étudier l'impact de la propriété croisée sur les résultats du marché lorsque la rareté et la dynamique des ressources sont prises en compte. En outre, je compare la propriété croisée aux fusions horizontales et je réalise une analyse du bien-être. Mes résultats mettent en évidence que la propriété croisée peut être préférable à une fusion horizontale en termes de concurrence de Cournot, et peut s'avérer relativement moins préjudiciable pour la société dans une industrie de ressources non renouvelables que dans d'autres industries. Ces résultats suggèrent donc que les autorités

de la concurrence devraient envisager d'adapter leurs lignes directrices et de procéder à un examen spécifique lorsqu'elles traitent des industries où les contraintes intertemporelles jouent un rôle important.

Acknowledgements

This thesis would not have been possible without the unlimited support from all my advisors, Hassan Benchekroun, Francesco Amodio, Laura Lasio and the late Professor Ngo Van Long. I have benefited significantly from their immense knowledge and expertise as well as their patience and enthusiasm along my Ph.D. journey.

I am specifically grateful to Hassan Benchekroun for his continued guidance and generous financial support. Without him, I would not have been able to attend so many conferences and workshops. Nor would I be able to gain first-hand experience in publishing journal articles and writing referee reports. All of these experiences are especially important for a new researcher just starting out in his career. I highly appreciate his support in providing these valuable opportunities and helping me grow as a credible and independent researcher in the field.

I would also like to express my gratitude to the late Professor Ngo Van Long, who had been very supportive and encouraging at the early stages of my thesis. I still remember how fast he responded to me when I asked some questions about the paper and how he would take his time to really read each part of the paper and write a 25-page note on how I should improve and how he thought about the issue. He is a truly humble but knowledgeable mentor who is always willing to help. I also had the privilege to coauthor with him and Professor Hassan Benchekroun on two papers that got published last year, which gave a very start to my career. His passing is a pity for all of us, but he will be tremendously missed, and his spirit will continue to inspire and guide me in my future research endeavours.

I am also very grateful to Francesco Amodio, who has taken the leading role in supervising me to finish my job market paper and guiding me through the whole job market process. He is such an excellent mentor and advisor who is not only knowledgeable and responsible but also very approachable and supportive. I am really lucky to have him as part of my academic journey.

I am also very fortunate to have Laura Lasio as my advisor. She has been incredibly supportive along the way in developing my research skills and pursuing my research interests with confidence. I am able to communicate openly and regularly with her about my research progress and any challenges I encounter, despite her own busy schedule. She has always been excellent in providing me with valuable insights and motivation and has shaped how I think about my research, which is indispensable to my doctoral study and professional goals.

I would also like to specifically thank my best friend and colleague Aranya Chakraborty, who has always been there for me. Living together as roommates for six years and living through the challenging Ph.D. journey together is just such an unforgettable experience, which has made me think of him more as a brother and part of my family. Many thanks also to my other fellow colleagues: Adam Aberra, Fan Yang, Yongxu Yao, and the 'elder brother' Yan Wang, with whom I have shared my joy, sadness, success and failure along the way. I am also grateful to Professor Christopher Ragan who provided me with the opportunity to work as a Graduate Teaching Assistant at the Max Bell School of Public Policy, which has enabled me to gain extensive and valuable teaching experience.

I also thank Jevan Cherniwchan, Justin Kakeu, Nicholas Li and participants at the 30th and 32nd Annual Conference of Canadian Resource and Environmental Economics Association (CREEA), the 2021 and 2022 Montreal Environmental and Natural Resource Economics workshop, McGill-CIREQ Lunch Seminar, the 15th Australasian Trade Workshop (ATW), the 56th Annual Conference of the Canadian Economics Association (CEA), the 8th Canadian PhD and Early Career Researcher Workshop in Environmental and Resource Economics, the 17th annual meeting of the Asia Pacific Trade Seminars (APTS), and the 2023 Chinese Economists Society (CES) North America Conference for their insightful comments.

My gratitude also extends to Co-editor Andreas Lange and an anonymous reviewer from the *Journal of Environmental Economics and Management (JEEM)* for their valuable comments on the manuscript of my second chapter in the thesis. I am indebted to Wesley Longhofer from Emory University for sharing his Environmental NGO data with me. I acknowledge the financial support from Fonds de recherche du Québec - Société et culture (FRQSC) and the Canadian Social Sciences and Humanities Research Council (SSHRC).

Finally, I would like to thank my parents and Xiufen He for their unconditional trust and unlimited support in finishing my Ph.D. I would also like to express my gratitude to all my friends here in Canada and in China for their invaluable moral comfort and inspiration. I am lucky to have you all.

Contribution to Original Knowledge

This thesis makes several contributions to original knowledge. Chapter 1 focuses on the international waste trade in the presence of lobby groups, and looks at how the volume of waste trade is shaped by the interactions between different lobby groups and the government, and how the former influences the latter's policy decisions. To my knowledge, this is the first work that studies the effects of environmental lobbying within the context of international waste trade. Using both theory and empirics, the paper not only provides a micro-foundation by highlighting the role of environmental lobbies in the North-to-South waste trade, but also empirically identifies environmental lobbying as an effective way to reduce the growing waste shipments.

Theoretically, I add to the large literature on the political economy approach of endogenous trade and environmental policy-making by providing some new insights into the politically distorted equilibrium. I show that when environmentalists and capitalists are organized as lobby groups to affect the government's waste policies while they only care about the local environment, the politically chosen policies can be even tighter than the socially optimal levels if the environmental damage is large enough, a new finding in the literature. In addition, I demonstrate explicitly how lobby groups might affect the waste trade through the mechanism of a politically determined tax and tariff rate, something that has never been done in the literature. Empirically, I contribute to the empirical trade literature that studies various factors that affect trade in waste. I fill the literature gap by taking the political economy approach and investigating the role of environmental lobbies in waste trade. Also, my findings add to the policy discussions on how to reduce the waste trade by providing the first such evidence of the positive effects of environmental lobbying on reducing waste trade.

Chapter 2 focuses on the impact of cross-ownership in the presence of resource constraints, and looks at how changes in ownership structure affect strategic resource use and its implications for competition policy. The paper starts by analyzing the profitability of cross-ownership in a static Cournot game – a benchmark framework that has not even been addressed in the literature and that is well suited to describe conduct in a generic industry. By shedding light on the complex tradeoff between reduced competition among competing firms due to rival cross-shareholdings and increased free-riding incentives of non-participants in terms of strategic substitutability, I demonstrate the existence of a cross-ownership paradox. This interesting finding enables me to draw a direct comparison with the seminal result of the merger paradox in the industrial organization literature and uncover the intuition behind the phenomenal growth of cross-ownership activities across nearly every sector.

Further, the paper investigates the impact of cross-ownership in nonrenewable resource markets when firms face resource stock constraints. Despite the well-established and extensive literature on resource economics, no previous studies have investigated how the presence of cross-ownership will affect market competition and thus firms' extraction paths in the nonrenewable resource sector, and whether it will give rise to market power. Using a dynamic game model in which each firm faces a resource stock constraint and adopts an open-loop strategy by committing to a fixed time path of extraction, I show that the dynamic profitability of cross-ownership crucially depends on the level of the stocks available to resource owners. While large stocks replicate the outcome in the static model, the static result when stocks are small is reversed. In addition, I demonstrate that the presence of cross-ownership will induce the non-participants to exhaust their resource stocks before the cross-owners, leading to an increased degree of concentration in supply. Apart from these, I illustrate that cross-ownership may turn out to be relatively less detrimental to society in a nonrenewable resource industry than in other industries. These findings thus highlight the importance of considering the unique characteristics of the nonrenewable resource sector when evaluating the impact of market imperfections, and the need for tailored policy solutions that address industry-specific challenges.

Contribution of Authors

This thesis is composed of two chapters. The first chapter is my sole work, but Professor Ngo Van Long helped me with the initial conceptualization of the research idea. The second chapter is joint work with both Professor Hassan Benchekroun and Professor Ngo Van Long. I am the first author of the paper. I contributed by proposing the initial research idea after attending a summer school on competition policy, conducting the main theoretical modelling and all the numerical simulations, writing the initial manuscript, preparing the authors' response and revising the manuscript for paper publication. Professor Hassan Benchekroun and Ngo Van Long both contributed to the proofs of the theoretical models and manuscript editing. The paper has been published in the *Journal of Environmental Economics and Management* in 2022, which is available at https://doi.org/10.1016/j.jeem.2021.102597.

Contents

List of Figures

List of Tables

Introduction

We are currently facing a multitude of intricate and urgent environmental concerns spanning a wide range of issues, including climate change, loss of biodiversity, sustainable use of natural resources, waste management, pollution control, equitable access and management of land and water resources, and many others. However, addressing these pressing environmental challenges requires a comprehensive understanding of the nature of these problems. This thesis investigates how various market imperfections in the resource markets affect the behaviour of firms and their implications for market competition and the environment. Specifically, Chapter 1 focuses on the market distortions caused by lobby groups in the international waste market, and investigates the role of environmental lobby groups in shaping government policies and firms' decisions on waste trade. Chapter 2 focuses on the market distortions caused by cross-ownership in the nonrenewable resource sector, and examines how changes in ownership structure affect firms' strategic resource use and its implications for competition policy.

In the first chapter titled "Environmental Lobbying on International Trade in Waste: Theory and Evidence", I investigate the effects of environmental lobbying on international trade in waste. I develop a theoretical framework that emphasizes the potential impact of green lobbies on environmental and trade policies and how North-to-South waste flows are affected through these policy channels. I show that the politically chosen policies are ambiguous relative to the socially optimal levels, depending on the heterogeneity of environmental preferences and the degree of pollution damages from waste. This in turn leads to ambiguous effects of environmental lobbying on the North-to-South waste trade. Further, I take the theory to the empirics using panel data on the bilateral waste trade and the number of environmental NGOs (ENGOs) as a proxy for the environmental lobbying strength. I employ two different empirical strategies. The first one is a gravity specification that exploits within-country and cross-country variations. The results show that a 10% increase in the number of ENGOs in the North will lower North-to-South waste exports by 3.52%, whereas a similar increase in the South can reduce waste exports by 8.74%. The second approach uses a triple-difference estimation strategy that exploits plausibly exogenous variation created by waste exports restriction following the introduction of the EU Waste Shipment Regulation in 2006. I find that countries with 10% more ENGOs tend to decrease their waste exports by 6.7% more after the implementation of the regulation. These findings thus suggest that strengthening ENGOs can represent an important strategy to reduce the international waste trade.

In the second chapter titled "On the Profitability of Cross-ownership in Cournot Nonrenewable Resource Oligopolies: Stock Size Matters", we examine the profitability of cross-ownership in a nonrenewable resource oligopolistic industry where firms compete as Cournot rivals. Assuming a subset of the oligopolists own a share in each other's profits, we show that a symmetric cross-ownership can be profitable for any number of participating firms, provided that the initial resource stock owned by each firm is small enough. This is in sharp contrast with the static case where for any levels of non-controlling minority shareholdings, a symmetric cross-ownership is never (always) profitable if the relative number of participating firms is below (above) some lower (upper) threshold. When the relative number of participating firms is in between the two thresholds, profitability of cross-ownership depends on the level of shareholdings. We also highlight that cross-ownership can be preferable to a horizontal merger in terms of Cournot competition. Not only is it more profitable to do so, more importantly, it constitutes a shrewd strategy to avoid the possible legal challenges. Finally, we show that cross-ownership may turn out to be relatively less detrimental to society in a nonrenewable resource industry than other industries where resource constraints are absent. Thus, a specific analysis is needed when dealing with industries where resource constraints play an important role.

Chapter 1

Environmental Lobbying on International Trade in Waste: Theory and Evidence

1.1 Introduction

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

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

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

This paper investigates the role of green lobbies in the international waste trade and seeks to understand whether strengthening environmental lobby groups can represent an important strategy to reduce the North-to-South waste trade. To address this question, I first develop a political economy model of the kind introduced by Grossman and Helpman (1994). Using this model, I investigate how green lobbies affect the determination of environmental and trade policies and how waste trade flows are affected through these policy channels. I focus on two representative small open economies that are linked by trade in waste, where waste is modelled as an environmentally harmful byproduct generated during the production process in a developed-country market. This byproduct is tolerated at some level and subjected to a pollution tax and can be exported to a developing country for disposal but with a fee. The developing country may want to restrict some waste imports and thus imposes a tariff rate to prevent the country from becoming a garbage dump. In each country, an organized environmental and industry lobby group with heterogeneous environmental preferences confronts the incumbent government with contribution schedules contingent on its waste policies. The respective governments then try to balance the competing interests of various lobby groups and choose the policy to maximize a weighted sum of the social welfare and campaign contributions received from lobby groups.

I show that the politically chosen policy (i.e., tax in the North and tariff in the South) is ambiguous relative to the socially optimal level, depending on the heterogeneity of environmental preferences and the degree of pollution damages from waste. This political distortion arises from two facts: one is that lobby groups offer campaign contributions to an electorally motivated government in exchange for particular political favours (Aidt, 1998); the other is that lobby groups with heterogeneous environmental attitudes respond differently to various degrees of waste-induced environmental damages. Because of the relatively lower environmental valuations and the additional incentive to reduce the negative policy effect on profits that do not accrue to environmentalists, capitalists will typ-

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

ically lobby more aggressively for a less stringent policy, which eventually dominates any countervailing efforts from environmentalists. The resulting equilibrium policy level will be lower than the socially optimal one. However, if environmental damage caused by waste is significant enough, it will play an increasing role in both lobby groups' welfare calculations, inducing capitalists to diminish their lobbying efforts while triggering a more aggressive response from environmentalists. Consequently, the political equilibrium policy may equal or even overshoot the social optimum.

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

I show that when capitalists have a dominating lobbying power, which leads to a downward distorted policy that is inefficiently weak, strengthening environmental lobbies in the North will lead to a higher tax and therefore result in more waste being exported, while doing so in the South will increase the tariff rate but lead to less North-to-South waste exports. Indeed, as more people become environmentally concerned and join the green lobbying while the number of capitalists is fixed, this translates into more power exercised by the environmental lobby group. As a result, the government will respond to this boosted political pressure by increasing regulations on the externality. This in turn leads to a higher tax in the North and a higher tariff in the South, where the former increases the cost of disposing waste domestically and thereby induces firms to export more waste out of the country for disposal, and the latter effectively deters more waste from being imported. Using a different model, McAusland (2008) draws a similar conclusion, demonstrating that when facing increased political pressure from lobby groups, regulators have an incentive to increase regulation on pollution that is a by-product of consumption activities and thereby induce firms to export waste to locations with lower environmental regulations. This result resembles the so-called "Green Paradox" (Jensen et al., 2015; Sinn, 2008; Van der Ploeg and Withagen, 2015). Within the waste trade context, a well-intended movement to strengthen environmental protection leads to increased domestic environmental stringency and more waste – often highly toxic – to be shipped to countries that are less equipped to deal with it, possibly exacerbating the environmental damages.

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

The model provides us with some insights into the relationship between environmental lobbying strength, policy stringency, and firms' decisions on waste trade. However, the theory does not yield unambiguous predictions without making further assumptions. Thus, it becomes an empirical question as to whether environmental lobby groups can play a role in reducing the waste trade. To address this question, I build a comprehensive dataset that combines two decades of bilateral waste trade data at the aggregate country level with the number of environmental NGOs (ENGOs) as a proxy for environmental lobbying strength. My analysis leverages data across 35 developed and 87 developing countries in the period from 1992 to 2011. I then employ two different empirical strategies to identify the effects of environmental lobbying on North-to-South waste exports. The first strategy is a gravity specification that explores within-country and cross-country variations; the second approach uses a triple-difference estimation strategy that exploits plausibly exogenous variation created by waste exports restriction following the introduction of the EU Waste Shipment Regulation (WSR) in 2006.

The gravity estimation results suggest that strong environmental lobby groups in either developed or developing countries will result in less North-to-South waste exports. More specifically, a 10% increase in the number of ENGOs in developed countries will lower waste exports by 3.52%, whereas a similar increase in developing countries can reduce waste exports by 8.74%. Exploring differences in waste exports between EU developed countries and non-EU developed countries, before and after the EU-WSR as well as in environmental lobbying strength across countries, I find compelling evidence that environmental lobby groups exert a statistically significant impact on waste export reduction by EU developed countries. More precisely, countries with 10% more ENGOs tend to decrease 6.7% more of their waste exports after the implementation of the regulation. These empirical results provide robust evidence that strengthening ENGOs can represent an important strategy to reduce the international waste trade. Therefore, it may be worthwhile for international donor organizations to provide support for the development of ENGOs all over the world (Binder and Neumayer, 2005; Fredriksson et al., 2005).

My paper contributes to several strands of literature. The first is to the large literature on the political economy approach of endogenous trade policy[3] that has been later extended to endogenous environmental policy-making (Aidt, 1998; Conconi, 2003; Fredriksson, 1997; Fredriksson et al., 2005; Fünfgelt and Schulze, 2016; Schleich, 1999). However, these studies generally assume that only environmentalists are concerned about the environment or that all individuals have identical environmental preferences while neglecting the fact that people with the same income may also have heterogeneous preferences for environmental quality. The strength of such feelings toward the environment is not correlated with income levels and the diversity of such attitudes is largely considered as a source of social conflict (Cassing and Long, 2021). I add to the literature by incorporating heterogeneous environmental preferences and providing some new insights into the politically distorted equilibrium.

My paper is closely related to Cassing and Long (2021), but extends their work in a number of dimensions. First, I supplement their model by including a waste-receiving country, whose optimal choice of the tariff rate on imported waste is also governed by a politically determined process. Second, I relax some of their restrictive assumptions on the ranking of environmental attitudes among lobby groups, which allows me to provide some new findings about the political economy equilibrium. That is, the politically chosen policy can be even tighter than the socially optimal one if waste-induced environmental damages are large enough. Third, my model enables me to investigate and demonstrate explicitly how lobby groups might affect waste trade through the mechanism of a politically determined tax and tariff.[4] Finally, I take the theory to the data to empirically clarify the effects of environmental lobbying on trade in waste.

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

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

My research also contributes to the empirical trade literature that examines factors affecting international trade in waste.[5] Previous studies have estimated the effects of various economic factors on transboundary waste shipments, including income and capital-labour ratio (Baggs, 2009), recycling cost (Kellenberg, 2012), environmental regulation (Baggs, 2009; Kellenberg, 2012), wage and population (Higashida and Managi, 2014) and Basel Convention (Kellenberg and Levinson, 2014). However, these econometric analyses are built upon the conventional economic line that governments are benevolent in always maximizing social welfare while ignoring other factors such as lobby groups and political contributions (Gawande and Bandyopadhyay, 2000; Goldberg and Maggi, 1999; Pacca et al., 2021). I contribute to this literature by taking the political economy approach and investigating the role of environmental lobby groups in the international waste trade.

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

[5] For an overview of this literature, see Kellenberg (2015).

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

The remainder of the paper is structured as follows. Section 2 presents the theoretical framework. Section 3 describes the data and summary statistics. Section 4 illustrates the empirical strategies and main results. Finally, Section 5 concludes.

1.2 The theoretical framework

In this section, I present a political economy model with the simplest possible structure that captures much of the essential elements of international trade in waste. I analyze two representative small open economies in the highly-integrated world markets, which thus do not affect the market prices of waste, e.g. consider Canada and the Philippines.[7] This is a sensible assumption that I consider true for most economies in terms of waste trade. Indeed, on the waste supply side, suppliers are fairly competitive in taking the price of waste treatment as given; on the waste demand side, there is considerably more competition as many firms in the developing countries vie for those waste-disposal contracts. I model waste as a production externality generated in the global North that can be exported to the South for disposal but with a fee. In both North and South, there is an organized environmental lobby group and industry lobby group that seek to influence the governments' environmental and trade policies. The governments do not simply maximize social welfare, but balance competing interests in their support-maximizing calculus according to the political influence of different lobby groups (Grossman and Helpman, 1994). I then characterize the political economy equilibrium in each country and compare it with the socially optimal level. Finally, I investigate the effects of environmental lobbying on policy stringency and how the waste trade is affected through these policy channels.

1.2.1 The North: waste supply

A small open competitive economy in the North has 2 sectors. The first one is a clean sector, which produces a numeraire good using labor only with constant returns to scale and a one-to-one input-output ratio. The other one is a polluting sector that uses capital and labor to produce a manufacturing output according to the neoclassical production function $Y = F(K, L)$ that exhibits constant returns to scale with positive and diminishing marginal products and convex isoquants. During the manufacturing process, a negative

[7] See Cassing and Kuhn (2003) for the case of market power when both waste-importing and waste-exporting countries act strategically to utilize national environmental policies to attach rents arising from trade in waste.

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

The economy is populated by a large number of individuals n, each endowed with $\bar{l}$ units of labor, where $\bar{L} = n\bar{l}$. Each individual i derives utility from the consumption of both goods, denoted by a quasi-linear and additively separable utility function: $U_i = x_i + u(y_i)$, where x_i, y_i denotes the consumption of numeraire and manufactured good, respectively, and $u' > 0, u'' < 0$. However, discomfort arises from seeing the pollution caused by waste in the country, so the welfare of individual i is given by

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

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

Suppose that the n individuals in this economy can be categorized into 3 groups. Among them, group 1 consists of $m_1 < n$ individuals who own capital, referred to as capitalists. For simplicity, all the capitalists are assumed to have the same environmental preference, denoted by $\beta_C \in (0, \bar{\beta}]$, and each of them has an equal endowment of capital, $\bar{K}/m_1$. Group 2 consists of m_2 non-capitalists who share the same strong preference for environmental quality, referred to as environmentalists, with $\beta_E \geq \bar{\beta}$. In the model, environmentalists are assumed to be those who only care about local pollution and do not have global concerns – referred to as NIMBYs (not in my backyard). Finally, the remaining m_3 non-capitalists, referred to as workers, constitute Group 3 with the same moderate preference for environmental quality at $\beta_W \in [\beta_C, \beta_E]$, but whether β_W is greater than $\bar{\beta}$ or not remains unknown.

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

Suppose individuals with similar interests can overcome the free-riding problem (Olson, 1965), and are formed as organized lobby groups to further their interest by taking collective action to influence government policies. I adopt the structure of the two-stage common agency game developed by Bernheim and Whinston (1986) and later employed by Grossman and Helpman (1994) on endogenous trade policies. In the first stage of the game, each of the organized groups simultaneously and non-cooperatively offers to the incumbent government a campaign contribution contingent on the pollution tax selected by the government to correct for the externality. While a group that prefers low taxes will always make more political donations the lower the announced tax, a group that stands to gain in terms of its own welfare with respect to a higher tax will always increase its contributions. Within the context, the not-in-my-back-yard environmentalists will typically push for a higher environmental tax to avoid too much pollution in the country, while capitalists will only lobby for a lower tax if doing so increases their welfare. By definition, individuals in an unorganized group do not have enough stake in the policy outcome and thus make no campaign contributions. In the second stage of the game, the government takes the "announced contribution schedules" as given and chooses an environmental tax t on the manufacturing output to maximize a weighted sum of social welfare and its receipt of campaign contributions:

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

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

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

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

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

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

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

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

$$t - \mu = \eta'(Q), \tag{1.1}$$

and

$$(p_c(t) - t)F_L(\bar{K}, L) = 1, \tag{1.2}$$

where F_L denotes the marginal product of labor in manufacturing. Equation (1.1) says that at the optimal waste export level $\hat{Q}$, the marginal benefit must be equal to the marginal cost of exporting waste. As long as $t > \mu$, firms would want to export waste abroad. Equation (1.2) says that at the optimal labor allocation $\hat{L}$, the value of the marginal product of labor is equated to the wage rate. Given $\hat{Q}$ and $\hat{L}$, the maximized aggregate return to capital is

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

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

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

where M_i is the income of consumer i. Every consumer in the economy receives income from two sources: first, she supplies her endowment of labour inelastically to the competitive labour market and thus earns the wage income $w\bar{l}$; second, she receives $1/n$ of the government's net tax revenue $t(\hat{Y} - \hat{Q})$ as a lump sum transfer. However, a capitalist has one additional income source from her endowment of capital, which claims $\frac{\hat{\Pi}}{m_1}$. Therefore, the income of a representative non-capitalist, i.e., environmentalist or worker, is given by

$$M_j = \bar{l} + t(\hat{Y} - \hat{Q})/n, \tag{1.3}$$

while that of a representative capitalist is

$$M_k = \hat{\Pi}/m_1 + \bar{l} + t(\hat{Y} - \hat{Q})/n. \tag{1.4}$$

Utility maximization yields the first order condition:

$$u'(y_i) = p_c. \tag{1.5}$$

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

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

and the indirect utility function of consumer i is

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

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

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

where $\hat{Z} = \hat{Y} - \hat{Q}$ and M_i is given by equation (1.3) for a non-capitalist and equation (1.4) for a capitalist. Therefore, the gross welfare of each group can be expressed as

$$J_1(t) = m_1 \left[\hat{\Pi}(t)/m_1 + \bar{l} + t(\hat{Y}(t) - \hat{Q}(t))/n + CS(p_c(t)) \right] - m_1 \beta_C D(\hat{Y}(t) - \hat{Q}(t)),$$

$$J_2(t) = m_2 \left[\bar{l} + t(\hat{Y}(t) - \hat{Q}(t))/n + CS(p_c(t)) \right] - m_2 \beta_E D(\hat{Y}(t) - \hat{Q}(t)),$$

$$J_3(t) = m_3 \left[\bar{l} + t(\hat{Y}(t) - \hat{Q}(t))/n + CS(p_c(t)) \right] - m_3 \beta_W D(\hat{Y}(t) - \hat{Q}(t)).$$

and the aggregate social welfare is

$$J(t) = n\left[\bar{l} + t(\hat{Y}(t) - \hat{Q}(t))/n + CS(\hat{y}(t))\right] + \hat{\Pi}(t) - n\bar{\beta}D(\hat{Y}(t) - \hat{Q}(t)), \tag{1.6}$$

where by definition, $n\bar{\beta} = m_1\beta_C + m_2\beta_E + m_3\beta_W$.

Before we proceed to characterize the two-stage subgame perfect equilibrium, it will be useful to derive the socially optimal environmental tax so that we have a benchmark to compare to. Also, it will be helpful to compute the comparative statics of $\hat{L}, \hat{Y}, \hat{Q}, \hat{Z}, \hat{\Pi}$ with respect to t, which constitute a building block to analyze the effects of environmental lobbying on tax and by extension trade in waste. But first note that in equilibrium, the total consumption of the manufactured good must be equal to that sector's total output, i.e.,

$$n\hat{y} = \hat{Y} = F(\bar{K}, \hat{L}) \Longleftrightarrow \hat{y} = \frac{\hat{Y}}{n}. \tag{1.7}$$

1.2.1.1 Pigovian tax

Without any political considerations, a benevolent government only cares about the aggregate welfare level of its country and thus welfare maximization is the main force that drives environmental policy decisions. Maximizing (1.6) with respect to t yields the socially optimal environmental tax, i.e.,

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

Proof. See Appendix 1.6.1.1. □

That is, the socially optimal or Pigovian tax is equal to the social marginal cost of waste.

1.2.1.2 Comparative statics with respect to tax

The equilibrium demand for labour in the manufacturing sector, $\hat{L}$, is implicitly given by equation (1.2): $(p_c(t) - t)F_L(\bar{K}, L) = 1$. This, combined with equation (1.5): $u'(y_i) = p_c$ and equation (1.7): $\hat{y} = \frac{\hat{Y}}{n} = \frac{F(\bar{K},\hat{L})}{n}$, yields a unique equation that determines $\hat{L}$ as a function of t:

$$\left[u'\left(\frac{F(\bar{K}, \hat{L})}{n}\right) - t\right]F_L(\bar{K}, \hat{L}) - 1 = 0. \tag{1.8}$$

Applying the implicit function theorem to equation (1.8) yields

$$\frac{d\hat{L}}{dt} = \frac{F_L}{u''F_L^2/n + F_{LL}/F_L} < 0.$$

Then, it follows that

$$\frac{d\hat{Y}}{dt} = F_L\frac{d\hat{L}}{dt} = \frac{F_L^2}{u''F_L^2/n + F_{LL}/F_L} = \frac{1}{u''/n + F_{LL}/F_L^3} < 0,$$

with

$$\frac{dp_c}{dt} = \frac{u''}{n}\frac{d\hat{Y}}{dt} = \frac{u''F_L^2/n}{u''F_L^2/n + F_{LL}/F_L} < 0, \quad \frac{dp_c}{dt} - 1 = -\frac{F_{LL}}{F_L^3}\frac{d\hat{Y}}{dt} < 0.$$

The equilibrium waste exports, $\hat{Q}$, can be implicitly obtained from equation (1.1): $t - \mu = \eta'(Q)$ as a function of t. Totally differentiate (1.1) with respect to $\hat{Q}$ and t yields

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

Therefore, the equilibrium pollution level is $\hat{Z}(t) = \hat{Y}(t) - \hat{Q}(t)$ with $\frac{d\hat{Z}}{dt} = \frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt} < 0$. Finally, using the envelope theorem, we can get

$$\frac{d\hat{\Pi}}{dt} = \left[\frac{dp_c}{dt} - 1\right]\hat{Y} + \hat{Q} = \hat{Q} - \hat{Y}\frac{F_{LL}}{F_L^3}\frac{d\hat{Y}}{dt},$$

which can be rearranged as

$$\frac{dp_c}{dt} - 1 = \frac{\frac{d\hat{\Pi}}{dt} - \hat{Q}}{\hat{Y}} < 0. \tag{1.9}$$

A higher pollution tax increases firms' burden and would typically lead to lower aggregate industry profits or producer surplus. Thus, by construction,

$$\frac{d\hat{\Pi}}{dt} < 0 \Longleftrightarrow \hat{Q} < \hat{Y}\frac{F_{LL}}{F_L^3}\frac{d\hat{Y}}{dt}.$$

1.2.1.3 Political economy tax

In this paper, I only consider two organized lobby groups – capitalists and environmentalists, while workers are not organized.[9] I now investigate how the pressure exercised by an

[9] When all groups are organized, the political economy equilibrium tax is efficient and identical to the Pigovian tax, see e.g., Aidt (1998) or Cassing and Long (2021).

environmental and industry lobby group could result in a political economy equilibrium and characterize the government's optimal choice of environmental tax.

The incumbent governments action is the unit pollution tax and the lobby groups' actions are contribution schedules that map each tax policy into a contribution level. The political equilibrium thus consists of a set of feasible contribution functions $(\{\psi_h(t^{**})\}_{h\in\Lambda})$ and the environmental tax policy (t^{**}). Following Bernheim and Whinston (1986), I focus on the interior equilibrium contribution schedules that truthfully reflect the gains expected by the pressure groups such that $\psi_h(t) = J_h(t) - B_h$, where $B_h > 0$ is a constant.[10] Then, t^{**} must be the solution to the problem

$$\max_t \hat{G}(t) = (1+\delta)\Big[J_1(t) - B_1 + J_2(t) - B_2\Big] + \delta J_3(t).$$

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

$$\frac{\frac{d\hat{G}(t)}{dt}}{(\lambda_0+\delta)\frac{d\hat{Z}}{dt}} = \Omega \equiv \Big[t - n\bar{\beta}D'(\hat{Z})\Big] + \frac{1-\lambda_0}{\delta+\lambda_0}\Big\{(n\beta_W - n\bar{\beta})D'(\hat{Z}) + \frac{d\hat{\Pi}}{d\hat{Z}}\Big\} = 0, \qquad (1.10)$$

where

$$\lambda_0 = \frac{m_1+m_2}{n}, \quad \frac{d\hat{Z}}{dt} = \frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt} < 0, \quad \frac{d\hat{\Pi}}{d\hat{Z}} = \frac{d\hat{\Pi}/dt}{d\hat{Z}/dt} > 0.$$

Proof. See Appendix 1.6.1.2. □

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

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

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

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

Now, we are ready to compare the outcome of this political equilibrium with the benchmark outcome under a benevolent social planner. From equation (1.10), we can

[10] I do not derive the equilibrium condition here. For a detailed description of the common-agency game, please refer to Bernheim and Whinston (1986) and see Proposition 1 in Grossman and Helpman (1994) for the necessary and sufficient conditions of the subgame-perfect Nash equilibrium.

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

However, if instead $\beta_C \leq \beta_W < \bar{\beta} \leq \beta_E$ (i.e., the society has a disproportionally large number of environmentalists or environmentalists have an extremely high preference for a clean environment), then $(n\beta_W - n\bar{\beta})D'(\hat{Z}) < 0$ and we may have different cases where the political equilibrium tax is above, equal or less than the Pigovian level. Denote $A \equiv (n\beta_W - n\bar{\beta})D'(\hat{Z}) + \frac{d\hat{\Pi}}{d\hat{Z}}$, then we can rewrite A as

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

where the first term captures the positive effect of tax on social environmental valuations (i.e., savings from environmental damages), and the second term is the negative effect of tax on industry profits. If $D'(\hat{Z})$ is small enough, then $A < 0$ and thus $t^{**} < t^* = n\bar{\beta}D'(\hat{Z})$. The same intuition as earlier applies here. However, if $D'(\hat{Z})$ is large enough, then we may have a situation where the two effects are cancelled out or even the former effect dominates, i.e., $A \leq 0$. In this case, we would have $t^{**} \geq t^* = n\bar{\beta}D'(\hat{Z})$. This is because the significant environmental damage caused by waste plays an increasing role in both lobby groups' welfare calculations. From the capitalists' perspective, the loss from environmental damages caused by waste can be so severe as to dominate any profit gains due to a lower tax. As a result, capitalists will diminish their lobbying efforts for a lower tax. Meanwhile, in response to the significant environmental damages, environmentalists will lobby more aggressively for a higher tax. Consequently, the political tax may overshoot the Pigovian level. These findings can be summarized in Proposition 1:

Proposition 1. *If group 3 is not organized, when $\beta_W \geq \bar{\beta}$, or $\beta_W < \bar{\beta}$ but $D'(\hat{Z})$ is small enough, the political economy equilibrium tax on the externality is below the Pigovian one. However, when $\beta_W < \bar{\beta}$ and $D'(\hat{Z})$ is large enough, the political tax can be equal to or above the Pigovian level.*

It will prove helpful to demonstrate the model and the findings of the above proposition with some specific functional forms and numerical examples. I provide several examples in Appendix 1.6.2.1 for illustration.

1.2.1.4 The effects of environmental lobbying on tax and waste exports

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

Assume that the number of capitalists (m_1) and the total population (n) are fixed. As more workers (m_3) become environmentalists (m_2) and their associated environmental preference (β_W) also increases to β_E, it follows that the effect of strengthening environmental lobbying on tax is given by

$$\frac{dt}{dm_2} = \frac{\frac{1+\delta}{\delta+\lambda_0}\frac{1}{m_3}\left[m_3(\beta_E - \beta_W)D'(\hat{Z}) - \left(t - n\bar{\beta}D'(\hat{Z})\right)\right]}{\frac{d\Omega}{dt}}. \tag{1.11}$$

Proof. See Appendix 1.6.1.3. □

Since $\frac{d\Omega}{dt} > 0$, the sign of $\frac{dt}{dm_2}$ is determined by the two terms in the square bracket: $m_3(\beta_E - \beta_W)D'(\hat{Z}(t))$ and $\left(t - n\bar{\beta}D'(\hat{Z})\right)$. Note that $(\beta_E - \beta_W)$ measures how much environmental valuation increases when one worker becomes an environmentalist, so the first term $m_3(\beta_E - \beta_W)D'(\hat{Z}(t)) > 0$ captures the social marginal benefit of this environmental movement, whereas the second term $\left(t - n\bar{\beta}D'(\hat{Z})\right)$ captures the political distortion from the socially optimal level, therefore representing the social marginal loss from lobbying.

Suppose we are starting with a situation where $t < n\bar{\beta}D'(\hat{Z})$. This corresponds to the above-mentioned case where the capitalists have a dominating lobby power (i.e., when $\beta_W \geq \bar{\beta}$, or $\beta_W < \bar{\beta}$ but $D'(\hat{Z})$ is small enough), which creates a downward distortion of environmental policy that is inefficiently weak. Since $t - n\bar{\beta}D'(\hat{Z}) < 0$, then the numerator must be positive, so we have $\frac{dt}{dm_2} > 0$, and by extension, $\frac{d\hat{Q}}{dm_2} = \frac{d\hat{Q}}{dt}\frac{dt}{dm_2} > 0$. This result is highly intuitive. As more people become environmentally concerned and join the environmental lobbying while the number of capitalists is fixed, this translates into more power exercised by the environmental lobby group. As a result, the government will respond to this boosted political pressure by increasing the stringency of environmental policy. This ultimately pushes up the cost of disposing of waste domestically, thereby resulting in more waste being exported to other countries. This conclusion is similar to McAusland (2008), which demonstrates that when facing increased political pressure exercised by the organized interest groups, regulators have an incentive to increase regulation on pollution that is a by-product of consumption activities and thereby induce firms to export waste to lower environmental regulation locations. Eventually, when environmentalists are able to mobilize all the workers to join forces, the resulting equilibrium tax will equate to the social optimum.

This finding resembles the so-called "Green Paradox" (Jensen et al., 2015; Sinn, 2008; Van der Ploeg and Withagen, 2015), in which increased environmental stringency leads to accelerated fossil fuel extraction and therefore greater pollution. Similarly, within the waste trade context, a well-intended movement to strengthen environmental protection leads to increased domestic environmental stringency and more waste – often highly toxic– to be shipped to countries that are less equipped to deal with it, possibly exacerbating the environmental damages.

However, if $t > n\bar{\beta}D'(\hat{Z})$, this corresponds to the situation where the environmentalists lobby more aggressively while the capitalists diminish their lobbying efforts (i.e., when $\beta_W < \bar{\beta}$ and $D'(\hat{Z})$ is large enough), creating an upward distorted environmental policy that is inefficiently strict. Now both the terms $m_3(\beta_E - \beta_W)D'(\hat{Z}(t))$ and $t - n\bar{\beta}D'(\hat{Z})$ are positive. If the former exceeds the latter, then still we have $\frac{dt}{dm_2} > 0, \quad \frac{d\hat{Q}}{dm_2} = \frac{d\hat{Q}}{dt}\frac{dt}{dm_2} > 0$. However, if the former is less than the latter, i.e., $m_3(\bar{\beta}_E - \bar{\beta}_M)D'(\hat{Z}(t)) < \left(t - n\bar{\beta}D'(\hat{Z})\right)$, then we would have

$$\frac{dt}{dm_2} < 0, \quad \frac{d\hat{Q}}{dm_2} = \frac{d\hat{Q}}{dt}\frac{dt}{dm_2} < 0.$$

This is quite surprising as one would expect that strengthening environmental lobby groups should always lead to a higher tax. While this result may seem counterintuitive, the main intuition behind it is that we are starting with a situation where the tax is already set very high, meaning that the marginal benefit for any extra efforts to increase the environmental stringency would be very small, but the marginal loss of doing so could be significant. While environmentalists enjoy saving the country from suffering too much environmental damage caused by waste, they also derive utility from the consumption of manufacturing goods. When the extra savings from environmental damages cannot exceed their loss from the happiness of consumption, they would like to trade off the two and exchange some environmental protection for more consumption, which drives down the tax. As the number of environmental lobbyists increases, the desire for the tradeoff also increases, which further reduces the tax. As the pollution tax decreases, the cost of disposing of waste domestically goes down and thereby less waste will be exported to other countries. Eventually, when all workers become environmentalists, the equilibrium tax will equate to the socially optimum level. This result is similar to Aidt (1998), which demonstrates that the competitive political process and the fact that some lobby groups adjust their economic objectives to reflect environmental concerns will lead to the political internalization of environmental externalities. These results can be summarized in the following proposition:

Proposition 2. *In the political economy equilibrium, if the pollution tax is inefficiently weak, then strengthening green lobbies will lead to a higher tax and more waste to be exported, resulting in a "waste green paradox". However, if the pollution tax is inefficiently strict and the marginal benefit of the environmental movement is less than the marginal loss from lobbying, then strengthening environmental lobbying may result in a lower tax and less waste to be exported.*

Proposition 2 shows that the effects of environmental movement depend on the political equilibrium pollution tax relative to the efficient Pigovian level, which in turn crucially depends on the environmental lobbying strength and the degree of environmental damages caused by waste. In the following, I will present the waste demand side – a small open economy in the South that imports the waste from the North.

1.2.2 The South: waste demand

Consider a corresponding small open economy in the South with a very similar structure to that in the North. For notational convenience, the superscript argument, S, is omitted throughout this entire section, but it should be understood that all the variables are denoting the South to be distinguished from the North.[11] To focus on trade in waste, I assume that the manufactured good is non-traded and cannot be produced in the South.

The South also has two sectors: a clean sector and a waste-disposal sector. Both sectors use labor as the only inputs. The clean sector produces the same numeraire good as the North with constant returns to scale but is less productive. The competitive waste-disposal sector offers the North a "waste absorption" service at a constant price $\mu > 0$ per unit of waste imported, but incurs an increasing treatment cost at $C(I)$, where I is the

[11] For example, the number of population n should be interpreted as n^S, and the environmental preference β_i should be understood as β_i^S, etc.

amount of waste imported, with $C'(I) > 0$ and $C''(I) > 0$. Therefore, in the global equilibrium, the total waste exported from the North must be equal to the total waste imports from the South, i.e., $\sum_{i \in N} Q_i = \sum_{j \in S} I_j$. Suppose that the South is endowed with a fixed supply of labor $\bar{L}$ and labor is perfectly mobile across sectors, and that full employment prevails. Thus, labour becomes irrelevant to firms' problems, and in terms of the conventional trade model, North exports the numeraire good and imports the South's waste disposal service.

The economy is also populated by a large number of individuals n, each endowed with $\bar{l}$ units of labor, where $\bar{L} = n\bar{l}$. Each individual i derives utility from the consumption of the numeraire good x_i, but the imported waste itself or the waste treatment process causes environmental damages $D(I)$, so the welfare of individual i is given by

$$W_i(x_i, I) = U(x_i) - \beta_i D(I) = x_i - \beta_i D(I),$$

where for simplicity $U(x_i)$ is assumed to be linear in x_i, and $D(0) = 0, D(I) > 0, D''(I) > 0$, and β_i denotes individual i's preference for a clean environment. Denote $\bar{\beta} = \frac{1}{n} \sum_{i=1}^{n} \beta_i$, then it follows that the social marginal cost of waste is given by $\frac{d \sum_{i=1}^{n} W_i}{dI} = n\bar{\beta} D'(I)$.

Among the n individuals in the economy, $m_1 < n$ capitalists own the waste-disposal factories and for simplicity, each capitalist is assumed to own only one waste-disposal factory; m_2 environmentalists have strong preferences for environmental quality, with the remaining m_3 workers having moderate preferences for environmental quality. Let β_C, β_E and β_W denote the environmental preference for each capitalist, environmentalist and worker, respectively, with $\beta_C \leq \bar{\beta} \leq \beta_E$ and $\beta_W \in [\beta_C, \beta_E]$, but whether β_W is larger than $\bar{\beta}$ remains unknown. Suppose capitalists and environmentalists can overcome the free-riding problem and are formed as organized lobby groups to further their interests by taking collective actions to influence the government's policies. Within this context, the government imposes an ad valorem tariff rate τ on the imported waste to avoid the country from becoming a garbage dump and distributes all the tariff revenue to its citizens as a lump sum transfer. Following Grossman and Helpman (1994), I adopt the structure of a two-stage common agency game between the lobbies and the government. In the first stage, each of the organized lobby groups confronts the incumbent government with contribution schedules, $\psi_h(\tau)$, that are contingent on the governments choice of tariff rate on waste, while ordinary workers are not organized and do not take any actions. In the second stage, the government takes the announced contribution schedules as given and chooses τ to maximize a weighted sum of social welfare $J(\tau)$ and its receipt of campaign contributions:

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

where $\delta > 0$ is an exogenously given weight that the government places on the aggregate social welfare relative to total campaign contributions.

Taking as given the per unit waste disposal fee μ and the tariff rate τ on the imported waste, the waste-disposal firms must decide on how much waste to be imported, so firms solve the following profit maximization problem

$$\max_{I>0} \Pi = (1-\tau)\mu I - C(I).$$

The first order condition with respect to I yields

$$(1-\tau)\mu = C'(I), \tag{1.12}$$

which says that at the optimal waste import level $\hat{I}(\tau)$, the marginal benefit must be equal to the marginal cost of importing waste. The equilibrium waste demand, $\hat{I}$, can thus be implicitly expressed as a function of τ. Totally differentiate (1.12) with respect to $\hat{I}$ and τ yields $\frac{d\hat{I}}{d\tau} = -\frac{\mu}{C''(I)} < 0$. Given $\hat{I}(\tau)$, the maximized aggregate profit of waste-disposing firms is

$$\hat{\Pi}(\tau) = (1-\tau)\mu\hat{I}(\tau) - C(\hat{I}(\tau)).$$

Each consumer derives income from working at either sector and receives an equally distributed lump-sum government transfer of the tariff revenue, but a capitalist earns an extra income from the ownership of the waste-disposal factories. Therefore, the income of a representative capitalist is $M_k = \hat{\Pi}/m_1 + \bar{l} + \tau\mu\hat{I}/n$, and the income of a representative non-capitalist is $M_j = \bar{l} + \tau\mu\hat{I}/n$. Given the linearity of the utility function, the welfare of each group is thus

$$J_1(\tau) = m_1\left[\hat{\Pi}(\tau)/m_1 + \bar{l} + \tau\mu\hat{I}(\tau)/n\right] - m_1\beta_C D(\hat{I}(\tau)),$$

$$J_2(\tau) = m_2\left[\bar{l} + \tau\mu\hat{I}(\tau)/n\right] - m_2\beta_E D(\hat{I}(\tau)),$$

$$J_3(\tau) = m_3\left[\bar{l} + \tau\mu\hat{I}(\tau)/n\right] - m_3\beta_W D(\hat{I}(\tau)),$$

and social welfare is the sum of the three groups:

$$J(\tau) = \sum_{i=1}^{3} J_i(\tau) = \bar{L} + \tau\mu\hat{I}(\tau) + \hat{\Pi}(\tau) - n\bar{\beta}D(\hat{I}(\tau)),$$

where by definition, $n\bar{\beta} = m_1\beta_C + m_2\beta_E + m_3\beta_W$.

1.2.2.1 Socially optimal tariff rate

Without any political distortion, a benevolent government chooses the tariff rate to maximize the aggregate social welfare, i.e.,

$$\frac{dJ(\tau)}{d\tau} = \left(\mu\tau - n\bar{\beta}D'(\hat{I}(\tau))\right)\frac{d\hat{I}(\tau)}{d\tau} = 0 \Rightarrow \tau^* = \frac{n\bar{\beta}D'(\hat{I})}{\mu}$$

Proof. See Appendix 1.6.1.4. □

Note that μ is the unit waste disposal price the North has to pay to the South and $n\bar{\beta}D'(\hat{I})$ is the social marginal cost of waste. That is, the social optimal tariff rate is equal to the ratio of the marginal social cost of waste over the private marginal cost of waste.

1.2.2.2 Political economy tariff rate

In this section, I investigate how the pressure exercised by an organized environmental and industry lobby group could result in a political economy equilibrium and characterize the government's optimal choice of the tariff rate on waste. Following Bernheim and Whinston (1986), I focus on the interior equilibrium contribution schedules that truthfully reflect the gains expected by the pressure groups such that $\psi_h(\tau) = J_h(\tau) - B_h$, where $B_h > 0$ is a constant. Then, τ^{**} must be the solution to the problem

$$\max_{\tau} \hat{G}(\tau) = \delta J(\tau) + \Big[J_1(\tau) - B_1 + J_2(\tau) - B_2\Big].$$

Therefore, when both environmentalists and capitalists are organized, the equilibrium tariff rate τ^{**} is characterized by the following equation:

$$\frac{\frac{d\hat{G}(\tau)}{d\tau}}{(\lambda_0 + \delta)\frac{d\hat{I}}{d\tau}} = \Omega \equiv \Big[\mu\tau - n\bar{\beta}D'(\hat{I})\Big] + \frac{1-\lambda_0}{\delta+\lambda_0}\left[(n\beta_W - n\bar{\beta})D'(\hat{I}) + \frac{d\hat{\Pi}}{d\hat{I}}\right] = 0, \tag{1.13}$$

where

$$\lambda_0 = \frac{m_1 + m_2}{n}, \quad \frac{d\hat{\Pi}}{d\hat{I}} = \frac{\frac{d\hat{\Pi}(\tau)}{d\tau}}{\frac{d\hat{I}(\tau)}{d\tau}} = \frac{-\mu \hat{I}(\tau)}{\frac{d\hat{I}(\tau)}{d\tau}} > 0.$$

Proof. See Appendix 1.6.1.5. □

Note that for τ^{**} to be a maximum, we need to ensure that the second order condition of the government's maximization with respect to τ is negative, i.e.,

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

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

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

Up to now, equation (1.13) should look very familiar. Clearly, the politically chosen tariff rate is ambiguous relative to the socially optimal tariff rate. Following our earlier discussion on the tax in the North, the relationship between the political economy equilibrium tariff and the socially optimal one can be directly summarized in the following proposition.

Proposition 3. *If group 3 is not organized, when $\beta_W \geq \bar{\beta}$, or $\beta_W < \bar{\beta}$ but $D'(\hat{I})$ is small enough, the political economy equilibrium tariff rate on the imported externality is below the social optimal one. However, when $\beta_W < \bar{\beta}$ and $D'(\hat{I})$ is large enough, the political tariff rate can be equal to or above the social optimum.*

In the former case, because of the relatively lower valuations for environmental damages and the additional incentive to counter the negative impact of a higher tariff rate on profits that are missing in environmentalists' welfare calculation, the capitalists will launch a massive lobbying blitz for a lower tariff, which eventually dominates any countervailing efforts from environmentalists. In the latter case, the significant environmental damages caused by imported waste play a much bigger role in both groups' welfare considerations, inducing capitalists to diminish their lobbying efforts for a lower tariff, while triggering a more aggressive lobbying response by environmentalists for a higher tariff. The resulting tariff rate can thus be equal to or higher than the social optimum. I illustrate the above findings with some specific functional forms and numerical examples in Appendix 1.6.2.2.

1.2.2.3 The effects of environmental lobbying on tariff and waste imports

In this section, I analyze how the environmental movement might impact the import tariff and by extension firms' decision to import waste. Following our conclusion from the North, it is not hard to obtain the effects of environmental lobbying on the tariff as

$$\frac{d\tau}{dm_2} = \frac{\frac{1+\delta}{\delta+\lambda_0}\frac{1}{m_3}\left[m_3(\beta_E - \beta_W)D'(\hat{I}) - \left(\mu\tau - n\bar{\beta}D'(\hat{I})\right)\right]}{\frac{d\Omega}{d\tau}},$$

and we can observe the following:

Proposition 4. *In the political economy equilibrium, if the import tariff is inefficiently weak, then a strengthening of the environmental lobby group will lead to a higher tariff and result in less waste being imported. However, if the import tariff is inefficiently strict and the marginal benefit of the environmental movement is less than the marginal loss from lobbying, then strengthening environmental lobbying may result in a lower tariff and more waste to be imported.*

In the former case, as more people become environmentally concerned and join the environmental lobbying while the number of capitalists is fixed, this translates into more power exercised by the environmental lobby group. As a result, the government will respond to this boosted political pressure by increasing the tariff rate, which effectively deters more waste to be imported. In the latter case, we are starting with a situation where the tariff is already set very high, which means that the marginal benefit for any extra efforts to increase the tariff would be very small, but the marginal loss of doing so could be significant. When the extra savings from environmental damages cannot exceed their loss of income (or utility from consumption), environmentalists would like to sacrifice some environmental protection for more income, which pushes down the tariff rate. As the number of members increases, the desire for the tradeoff also increases, which further reduces the tariff. As the tariff decreases, more waste will be imported. Eventually, when all workers become environmentalists, the equilibrium tariff rate will be equal to the social optimum, leading to a political internalization of environmental externality (Aidt, 1998).

1.3 Data and descriptive statistics

The model presented above illuminates how the strength of environmental lobbies might affect policy stringency and corporate decisions to export/import waste. However, the theory does not yield unambiguous predictions without making any further assumptions.

Depending on the waste-induced environmental damages and heterogeneity of group environmental preferences, the effects of environmental lobbying on the North-to-South waste exports can be either positive or negative. To better understand the role played by environmental lobby groups, I empirically test the effects of environmental lobbying on the North-to-South waste trade. However, I face several empirical challenges in doing so: (i) measuring waste trade and environmental lobbying strength; (ii) identifying the causal effects of environmental lobbying on trade in waste.

1.3.1 Waste trade

The challenge in measuring waste trade arises partly from the question of what constitutes waste. Things can alternate during their lifespan from waste to treasure, from useless to useful, or move in the opposite direction. I share the same viewpoint as Moore (2011) that whether or not something is considered a waste depends on time and place more than any inherent characteristics of the object itself.

In this paper, I consider waste as all the waste products under the UN six-digit Harmonized System (HS) Codes for commodity classification. Specifically, I retrieve the information on waste exports between country pairs from the UN Comtrade database for the periods 1992-2019. The bilateral waste data can date back to 1962 from this database. However, the HS Codes for commodity classification were not uniformly adopted until 1992. Even though several countries retrospectively reported trade data from prior years using the 1992 HS codes, I believe many countries did not and this may yield inconsistencies in the description of the product traded and result in measurement errors. Thus, I choose to start with the year 1992.

An alternative source of waste trade data is the Basel Convention, whose goal was to reduce shipments of hazardous waste to countries that were unable to safely and adequately dispose of it. Under the rules of the Convention, member countries are required to self-report data on their shipments of hazardous waste to the Basel Convention Secretariat each year. This self-reported hazardous waste trade data has been used by Baggs (2009) to explore the role that differences in the size of the economy (measured by GDP), capital/labor ratios, and GDP per capita (a proxy for regulatory stringency) across countries play in determining bilateral trade in hazardous waste. But as Kellenberg (2012) has pointed out, including only hazardous waste defined under the classification of the Basel Convention may miss a large proportion of other waste categories that may seem harmless but pose severe environmental and health consequences when disposed of improperly. Also, as mentioned earlier, countries such as the US have not signed the Convention and are thus not obligated to report their waste shipments. In addition, countries may have an incentive to under-report the true extent of hazardous waste shipments, particularly when being shipped to low environmental regulation countries (Kellenberg, 2012).

Following Kellenberg (2012) and Kellenberg and Levinson (2014), I define waste exports as all six-digit HS categories where waste and/or scrap are the only categorization of a product in the UN Comtrade database. Upon searching the keywords “waste", “scrap", “slag", “residue", and “ash" as the primary descriptors of the product in the six-digit HS codes, I obtain the waste exports for a total of 87 categories, which can be found in Table 1.12 of Appendix 1.6.3. For each of the 87 waste products, there are two measures of trade between country pairs – the total weight (in kg) and the total value (in US dollars). I use the size of waste as the main observation suggested by the model, and then sum up the total weight of waste traded between country pairs across all 87 HS categories, yielding the aggregate waste exports between country pairs for each year. This comprises my original waste trade dataset of 196 countries for 28 years.

1.3.2 Environmental lobbying strength

The challenge in measuring the environmental lobbying strength arises largely because of the difficulties in collecting information on the active membership base and financial resources of various environmental lobby groups within a country. Often, data is not readily available for the budget and membership numbers of many environmental lobby groups, and attempting to collect this information for a cross-country time-series study is prohibitively difficult.

In this paper, I choose to use the number of environmental NGOs (ENGOs) as a proxy, as in Binder and Neumayer (2005) and Fredriksson et al. (2005). However, unlike the cross-country approach taken by Fredriksson et al. (2005) that focuses on a specific year and the panel study of Binder and Neumayer (2005) that focuses on a limited set of countries with a time dimension covering 1977-1988 for which environmental protectionism has not become pronounced, I use a comprehensive dataset that covers a large number of countries with more recent time periods that better capture the growing trend of global environmental awareness. More specifically, I derive information on the number of ENGOs in a given country from two independent sources – the World Directory of Environmental Organizations (*the Directory*) and the Encyclopedia of Associations: International Organizations (*the Encyclopedia*).[12] These two sources are believed to be the most comprehensive cross-national data sources available for ENGOs (Longhofer and Schofer, 2010).

The Directory, first released by the Sierra Club in 1973 and published regularly thereafter, provides basic information such as name, address, contact information and founding date on governmental and nongovernmental environmental organizations across the world (Longhofer and Schofer, 2010; Trzyna and Didion, 2013). Organizations listed in *the Directory* such as citizens environmental groups, environmentally oriented development organizations, and academic research centers involved in either environmental policy work or information dissemination, are then categorized as ENGOs. The measure from *the Encyclopedia* is obtained from the Gale Group's Associations Unlimited database, which contains detailed information on more than 30,000 domestic organizations worldwide (Longhofer et al., 2016). This measure documents all formal, private, noncommercial, self-governing, and voluntary organizations in each country over time, including development NGOs, human rights organizations, arts and recreational clubs, and so on (Schofer and Longhofer, 2011). Then Gale's keywords are used to identify groups that have an environmental focus, yielding another dataset of ENGOs. These two sources of ENGOs are then combined to reduce idiosyncratic source-level biases, filling in any missing information from either source and correcting for any mismatch between the two sources. This yields a final coverage of 213 countries from 1971 to 2011 on ENGOs.

For this analysis, I assume that this proxy measure captures the overall environmental lobbying strength in a country. However, there may be some concerns. ENGOs are heterogeneous in terms of their sizes, main focuses, and so on. Typically, ENGOs differ significantly in their environmental focus. Some care about waste issues very much while others focus on other emerging environmental problems such as climate change, biodiversity loss, and so on. Also, ENGOs differ in their compositions and objectives, which gives rise to different viewpoints on worldwide environmental issues. For example, Greenpeace has branches in many countries, which may lead to a coordinated effort to reduce global waste rather than caring about a single country's domestic waste issue. Unfortunately, I do not observe this information in the data, so I can not improve upon this proxy measure.

[12] I am deeply indebted to Professor Wesley Longhofer from Emory University for sharing his Environmental NGO data with me. For a more detailed description on the data construction and limitations, please refer to Longhofer and Schofer (2010), Schofer and Longhofer (2011) and Longhofer et al. (2016).

1.3.3 Control variables

Finally, the challenge I face in identifying the causal effects of environmental lobbying on the waste trade arises due to the potential for both reverse causality and omitted variable bias. The reverse causality issue is typically observed in estimating policy effects on international trade (Baier and Bergstrand, 2007; Yotov et al., 2016). As governments often alter trade policy in response to changes in environmental quality (Copeland, Shapiro and Taylor, 2021) and alter environmental policy in response to trade (Cherniwchan and Najjar, 2021), it is likely that increasing waste flows may incentivize governments to tighten environmental/trade policies, thereby reducing the need for environmental lobbies. However, it will be less of a concern here. As shown later in Figure 1.3, the number of ENGOs increases steadily over time and thus it is highly unlikely that ENGOs are endogenously determined by waste trade.

Another concern is the omitted variable bias. There may exist a set of time-varying country-specific characteristics and time-invariant bilateral trade characteristics that are all potentially correlated with both waste trade flows among country pairs and the probability that more people become environmentalists. I control for these possible factors, which include: (i) the industry lobbying strength and population; (ii) the traditional gravity variable – GDP that captures the scale effect – as larger countries typically generate larger volumes of waste and have more available disposal capacity, and thus more waste should be traded; (iii) geographic and cultural factors such as bilateral distance between country pairs, whether countries share a common border, a common official language, and have ever had colonial ties, to proxy trade costs; (iv) trade facilitation factors such as whether both countries are members of the WTO or in some regional trade agreements; (v) capital-labor ratios in Baggs (2009) that reflect the technological capabilities of the recycling sectors across countries; (vi) whether both countries ratified the Basel Convention (Kellenberg and Levinson, 2014), which is aimed at reducing hazardous waste trade to countries that were unable to safely and adequately recycle or dispose of it.

There is no direct measure for the countervailing effects of the industry lobby group within a country. Similar to Binder and Neumayer (2005), I choose to employ commercial energy use (kg of oil equivalent per capita) as a proxy. This data along with other country-specific characteristics including GDP, population and labour force are obtained from the World Bank's World Development Indicators Database, which covers 264 countries from 1960 to 2021. The capital stock data is sourced from the International Monetary Fund (IMF), which provides three types of capital stock – general government capital stock, private capital stock and public-private partnership capital stock – over the period of

1960-2019 for 170 countries.[13] I then derive the aggregate country-level capital stock by summing up these three types and divide it by the labour force to get the capital-labour ratio across countries.

Bilateral variables such as geographical distance between country pairs, and dummy variables indicating whether country pairs share a common border, a common official language, or have ever had colonial ties are directly obtained from the CEPII website, which consists of 224 unique bilateral country pairs.[14] Data on Basel Convention ratification status comes from the Basel Convention website, which includes 188 signatories with only Haiti and the USA as the two exceptions.[15] Data on WTO membership is directly taken from the WTO website, which covers information on 164 members and 25 observers.[16] Data on whether a bilateral country-pair was in one of the regional trade agreements was obtained from Prof. Mario Larch's website, which covers all multilateral and bilateral regional trade agreements (RTA) as notified to the World Trade Organization for the last 70 years from 1950 to 2019 between 280 country-pairs.[17] Then, three respective dummy variables are constructed to indicate whether both countries were ratified members of the Basel Convention, members of the WTO, and in some regional trade agreements in year t. The definition of all the variables used in this paper and their sources can be found in Table 1.14 of Appendix 1.6.3.

1.3.4 Waste trade trend and evolution of ENGOs

My final sample includes 122 countries that had at least some positive quantity of waste trade for the period from 1992 to 2011.[18] To identify a country's development status, I follow the IMF's definition and categorize a developed country based on its advanced economy while considering the nation a developing country if it possesses an emerging or

[13] See https://data.imf.org/?sk=1CE8A55F-CFA7-4BC0-BCE2-256EE65AC0E4.

[14] See the dist-cepii.dta data file, http://www.cepii.fr/anglaisgraph/bdd/distances.htm.

[15] See http://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/4499/Default.aspx.

[16] See https://www.wto.org/english/thewto_e/whatis_e/tif_e/org6_e.htm.

[17] See https://www.ewf.uni-bayreuth.de/en/research/RTA-data/index.html.

[18] These 122 countries comprise more than 92% of the total waste trade.

developing economy.[19] I end up with 35 developed countries and 87 developing countries in the sample, documented in Table 1.13 of Appendix 1.6.3.[20]

The complex annual data on waste volumes shipped in each direction between each pair of countries reveal a number of stark facts about international trade in waste. There are two types of exporters and importers (developed versus developing), yielding 4 different types of annual waste shipments. As described in Table 1.1, a total of 2.9 billion tonnes of waste were shipped between countries over the 20-year period from 1992 to 2011. More than half of this waste trade was among developed countries themselves, whereas developed to developing waste shipments constituted the second largest component with more than one-quarter of the trade volume. As for the shipments from developing countries (Columns 4 and 5), they only made up a small proportion of the total waste trade. In fact, international trade in waste has been growing so much that these cross-section differences in Table 1.1 may be obscured by the overall growth. Figure 1.1 plots the total annual waste exports between country pairs, which shows that the global waste trade has grown substantially from 1992 to 2011. Although waste trade among developed countries has been steadily increasing over the years, it is not hard to observe that much of the world growth should be attributed to the increasing shipments from developed to developing countries – the ones that are most concerning and the main focus of this paper.

Table 1.1: Waste shipments among country pairs

	All	Developed to Developed	Developed to Developing	Developing to Developed	Developing to Developing
Total (million tonnes)	2922.18	1,529.75	848.76	262.15	281.53
Annual average (tonnes)	44,212.55	100,873.52	48,431.26	16,712.59	15,889.25
	(335,885.19)	(456,040.49)	(459,515.06)	(127,250.20)	(124,249.84)
Observations	66,094	15,165	17,525	15,686	17,718

Notes: Based on 35 developed countries and 87 developing countries in the sample for the years 1992-2011. Standard deviation in parentheses.

[19] IMF takes several different factors into account when determining whether a nation is an advanced economy, an emerging market and developing economy, or a low-income developing country. The main three criteria are: (1) per capita income level, (2) export diversification – so oil exporters that have high per capita GDP would not make the advanced classification because around 70% of their exports are oil, and (3) degree of integration into the global financial system. For details, please see https://www.imf.org/external/pubs/ft/weo/faq.htm.

[20] In many other classifications, EU member countries such as Poland and Hungary will be typically considered as developed, but this is not the case according to the IMF standard. Nevertheless, I conduct several robustness checks with the inclusion of these two countries as developed countries and the regression results remain very robust.

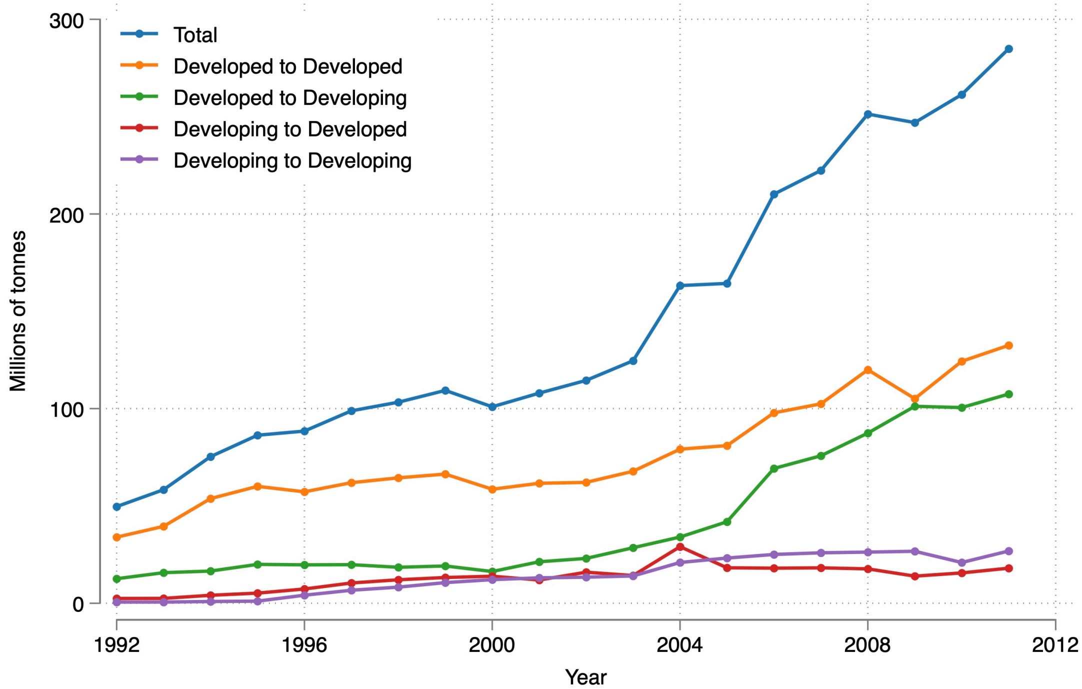


Figure 1.1: Total annual waste exports in million tonnes

These stylized facts have highlighted the increasing role of North-to-South shipments in the global waste trade. To get a better idea of where waste has been shipped, I follow Kellenberg (2012) and document in Table 1.2 the largest waste exporters and importers by aggregate volume from 1992 to 2011. Table 1.2a shows that the top 10 waste exporters make up more than 70% of all waste exported worldwide. Among them, 9 are developed countries with Russia, a developing country, being the only exception. Perhaps more surprisingly is a similar trend observed in Table 1.2b. With the exception of China and Turkey, all of the top 10 waste importers are also developed countries, which account for a total of 42.5% of global waste imported. Contrary to the common but somewhat misleading belief that developing countries are the main waste recipients, developed countries do import a large proportion of worldwide waste. This begs the question: where does the rest of the waste go and do developing countries play an important role in the waste trade? Table 1.2c answers this question by reporting the top 10 developing country waste importers, which shows that they collectively import more than 32% of global traded waste – a significant share.

A similar story emerges if we look at all of the countries in the sample. Table 1.3 presents the share of world GDP, world waste exports and imports, and the yearly average number of ENGOs for developed and developing countries, respectively. Whereas

Table 1.2: Largest waste exporters, importers and number of ENGOs

(a) Top 10 waste exporters

Ranking	Country	Exports (million tonnes)	World share (%)	Annual average ENGOs
1	Germany	438.52	15.01	40.95
2	United States	437.68	14.98	170.15
3	Japan	218.67	7.48	34.30
4	France	189.97	6.50	40.55
5	United Kingdom	164.47	5.63	182.90
6	Netherlands	161.68	5.53	36.95
7	Belgium	136.14	4.66	31.50
8	Russia	127.86	4.38	20.30
9	Canada	113.45	3.88	94.30
10	Hong Kong SAR	74.03	2.53	5.75
	Sum	2062.48	70.58	657.65

(b) Top 10 waste importers

Ranking	Country	Imports (million tonnes)	World share (%)	Annual average ENGOs
1	China	431.72	14.77	13.85
2	Turkey	208.66	7.14	11.70
3	Germany	182.03	6.23	40.95
4	Netherlands	177.94	6.09	36.95
5	South Korea	166.14	5.69	9.80
6	Italy	152.71	5.23	33.60
7	United States	150.07	5.14	170.15
8	France	142.51	4.88	40.55
9	Spain	137.39	4.70	24.65
10	Belgium	137.02	4.69	31.50
	Sum	1886.19	64.55	413.70

(c) Top 10 developing country waste importers

Ranking	Country	Imports (million tonnes)	World share (%)	Annual average ENGOs
1	China	431.72	14.77	13.85
2	Turkey	208.66	7.14	11.70
3	India	83.60	2.86	19.65
4	Indonesia	49.68	1.70	12.00
5	Mexico	43.77	1.50	19.75
6	Malaysia	40.75	1.39	12.10
7	Thailand	33.54	1.15	14.50
8	United Arab Emirates	23.74	0.81	4.55
9	Egypt	20.65	0.71	13.35
10	Vietnam	18.76	0.64	5.30
	Sum	954.87	32.68	126.75

Notes: The ranking is based on the aggregate waste trade volume from 1992 to 2011 for a total of 122 countries, including 35 developed and 87 developing countries.

developed countries produce 75% of the world's income (measured by GDP) and supply approximately 82% of world waste exports, developing countries only make up 18%

of global waste exports with around 25% of the world income share. That is, countries with a larger capacity to produce and consume also tend to supply more waste to international markets (Kellenberg, 2015). Indeed, both Baggs (2009) and Higashida and Managi (2014) have found positive and significant effects of GDP on bilateral trading pairs for waste. However, if we compare the income with import share, the evidence seems to confirm that developing countries import a disproportionately larger share of world waste (38.68%) relative to their income share (24.72%).

One possible explanation for this disparity could be the differences in terms of environmental lobbying strength (proxied by ENGOs) between developed and developing countries. A closer look at the last columns of Table 1.2 and Table 1.3 indicates that developed countries, in general, have a substantially higher number of ENGOs than developing countries. For example, the UK and US have the largest average number of ENGOs with 183 and 170 respectively, nearly 15 times more than the ones in Turkey, Indonesia and many other developing countries. Moreover, the average number of ENGOs in developed countries is nearly 4 times larger than that in developing countries. Therefore, one reason for developing countries to import a larger share of waste could be their lack of ENGOs who typically lobby aggressively for environmental protection. My analysis aims to explore whether strengthening ENGOs in those developing countries may result in less waste being imported.

Table 1.3: GDP, waste trade, and ENGOs by country status

Country status	Share of world GDP(%)	Share of world waste exports(%)	Share of world waste imports(%)	Annual average number of ENGOs
Developed	75.28	81.39	61.32	33.29
Developing	24.72	18.61	38.68	8.52

Notes: Based on 35 developed countries and 87 developing countries in the sample for the years 1992-2011.

Before I address this question, I explore further the evolution of ENGOs over time and across countries. Figure 1.2 plots the aggregate number of ENGOs over the 20-year period, which shows that there has been a steady increase of ENGOs for both developed and developing countries. This fact is consistent with the growing environmental awareness worldwide. Figure 1.3 describes the number of ENGOs for a selected sample of developed and developing countries over the period from 1992 to 2011. Whereas large differences exist between countries, most countries experience only a slight increase in the number of ENGOs over time. That is, there is much cross-country variation but little within-country variation in ENGOs.

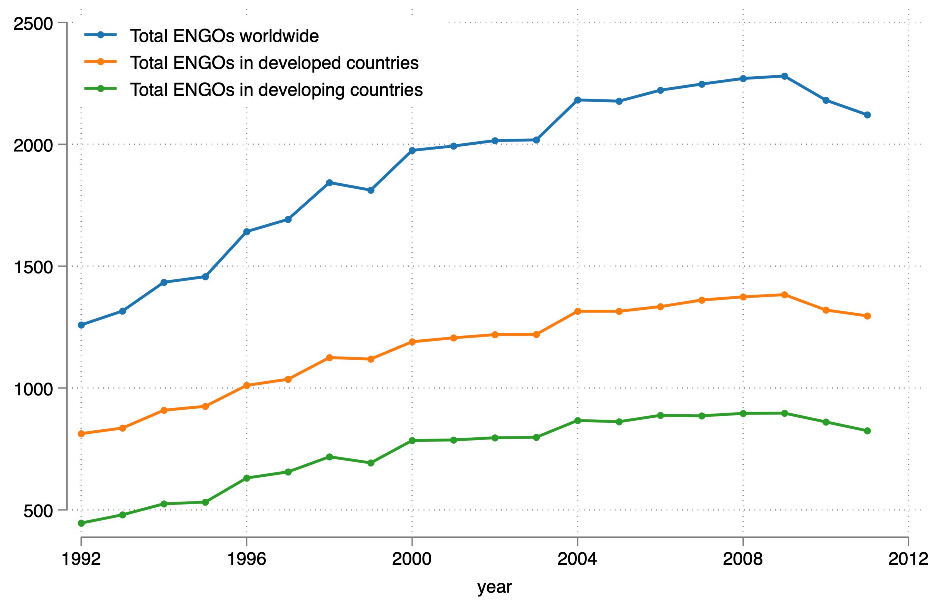


Figure 1.2: Annual total number of ENGOs from 1992 to 2011

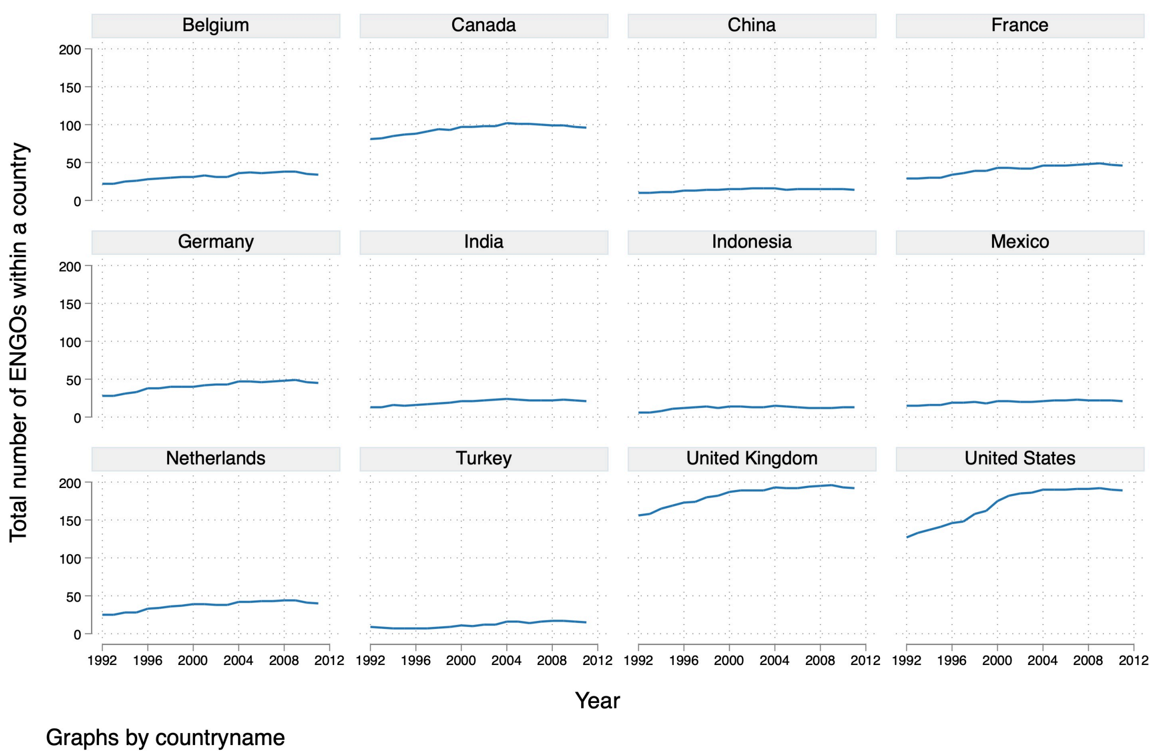


Figure 1.3: Number of ENGOs by country from 1992 to 2011

Finally, Table 1.4 summarizes the descriptive statistics for the main dependent variable of interest – North-to-South waste exports, and the main independent variables –

environmental lobbying strength proxied by ENGOs in developed and developing countries, respectively.[21] As Table 1.4 shows, there are 17,525 observed waste shipments from

Table 1.4: Summary Statistics

	Mean	S.D.	Min	Max
North-to-South waste exports (tonnes)	48,431.264	459,515.061	0.001	23698532.000
ENGO exporter	33.292	40.213	0.000	196.000
ENGO importer	8.516	6.289	0.000	29.000
Bilateral trade observations	17,525			

Notes: The first row shows summary statistics for the main dependent variable: the volume of North-to-South waste exports in tonnes between 1992 and 2011. The second and third rows describe summary statistics for ENGOs among the 35 developed and 87 developing countries between 1992 and 2011, respectively. Row four reports the number of positive bilateral waste trade observations in the sample.

developed countries to developing countries in my sample, among which an average of 48,431 tonnes are traded each year. However, bilateral country pairs differ substantially in terms of their waste trade volume, which ranges from 1 kg to 23.7 million tonnes. Moreover, there are substantial variations in the number of ENGOs for both exporters and importers. The average number of ENGOs in developed countries is 33.3 with a range from 0 to 196, while that in developing countries is nearly 4 times less (8.5), ranging from 0 to 29. In the following analysis, I exploit these variations to estimate the effects of environmental lobbying on the North-to-South waste trade.

1.4 Empirical strategies and results

Does strengthening environmental lobby groups in the North/South lead to less waste being shipped from developed to developing countries? The theoretical framework does not provide a clear answer. To provide some clarity on this question, I employ two empirical strategies to test the effects of environmental lobbying in this section. I discuss them in detail in what follows.

[21] For a full description of summary statistics of all variables, please refer to Table 1.15 in Appendix 1.6.3.

1.4.1 Gravity specification

In the first strategy, I explore both cross-country and within-country variations in ENGOs and implement the following gravity regression specifications:

$$\ln Y_{ijt} = \alpha + \beta_1 \ln \text{ENGO}_{it} + \beta_2 \ln \text{ENGO}_{jt} + \beta_3 \text{X}_{ijt} + \beta_t + e_{ijt},$$

where $\ln Y_{ijt}$ is the natural log of aggregate waste exports in tonnes from a developed country i to a developing country j in year t, ENGO_{it} and ENGO_{jt} are the main variables of interest – the strength of environmental lobby groups at country i and country j respectively in year t, $\boldsymbol{X}_{ijt}$ is a vector of control variables that include country-specific characteristics and bilateral characteristics as defined earlier, β_t is the year fixed effect to control for any global changes,[22] and ε_{ijt} is the unobserved error term.

Table 1.5 reports the main estimation results for the exporter side, importer side, and gravity specifications, respectively, using ordinary least squares (OLS) with robust standard errors clustered by country pairs.[23] While columns 1, 3 and 5 present results based on the simplest specifications with country-specific control variables, columns 2, 4 and 6 include additional bilateral control variables in the specifications. The coefficients on the main variables of interest – environmental lobbying strength, proxied by the number of ENGOs – are all negative and statistically significant for both exporter and importer in all the specifications. This suggests that strong environmental lobby groups in either developed or developing countries will result in less North-to-South waste exports. More specifically, a 10% increase in the number of ENGOs in developed countries will reduce waste exports by 3.52%, whereas a similar increase in developing countries can lower waste exports by 8.74%, according to the most preferred gravity specification – model 6. Recall that the average numbers of ENGOs in developed and developing countries are 33.3 and 8.5, respectively and the annual average waste shipments are 48,431 tonnes. These estimates thus imply that on average, an increase of ENGOs by 3.3 and 0.85 in developed and developing countries reduces annual North-to-South waste exports by 1,705 tonnes and 4,233 tonnes, respectively. This sums up to an aggregate amount by 118,760 tonnes [24] – a significant waste export reduction in volume.

[22] It would be ideal to include additional country fixed effects to capture and net out average differences across countries. But the inclusion of country fixed effects seems to take away much of the variation across countries – the main source of variation in the sample, causing most of the estimated coefficients to be either in unexpected signs or insignificant. Results are available from the author on request.

[23] A more detailed description of the results can be found in Appendix 1.6.4.

[24] $(1,705 + 4,233) * 20 = 118,760$ tonnes.

Table 1.5: North-to-South waste trade regression specifications

	Dependent variable: ln (North-to-South waste exports)					
	Exporter only		Importer only		Gravity	
Variables	(1)	(2)	(3)	(4)	(5)	(6)
ln (ENGO exporter)	-0.657***	-0.627***			-0.385**	-0.352***
	(0.179)	(0.168)			(0.155)	(0.133)
ln (ENGO importer)			-0.318**	-0.837***	-0.231*	-0.874***
			(0.131)	(0.124)	(0.128)	(0.117)
Exporter-specific Controls	X	X			X	X
Importer-specific Controls			X	X	X	X
Bilateral Controls		X		X		X
Observations	17512	17512	17322	17322	17309	17309
R^2	0.044	0.088	0.153	0.221	0.208	0.289

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. All regressions include a constant term and year fixed effects. Exporter and importer-specific controls include industry lobbying strength, population, GDP and capital-labour ratio. Bilateral controls include bilateral distance and dummy variables that indicate whether country pairs share a common border, common language, had colonial ties, are both members of WTO and Basel Convention, or in some regional trade agreements.

Despite our endeavour to include as many control variables as possible to account for the omitted variable bias, there may still exist some unobserved time-varying country-specific characteristics that might confound our results. For example, the time-varying country-specific multilateral resistance terms in Anderson and Van Wincoop (2003) and the firm-level heterogeneity in Helpman, Melitz and Rubinstein (2008) are found to be important factors in determining trade flows,[25] and may also be correlated with the strength of environmental lobbying, but both are theoretical constructs that can not be directly observed by the researcher. One possible approach to address this endogeneity concern is to use country-year fixed effects (i.e., exporter-year and importer-year fixed effects – β_{it} and β_{jt}). However, I would be unable to do so, because all the time-varying country-specific characteristics can be captured by β_{it} and β_{jt}, and as a result, the main variables of interest would drop out because they are collinear with the country-year fixed effects.

[25] Anderson and Van Wincoop (2003) show that bilateral trade flows depend on trade costs across all possible bilateral routes. Therefore, ignoring the fact that regions operate in a multilateral world and failing to account for this multilateral resistance will lead to overstating the importance of changes in trade barriers on bilateral trade flows (Behar and Nelson, 2014). Meanwhile, Helpman, Melitz and Rubinstein (2008) demonstrate that firms are heterogeneous within a country, meaning that not all firms are productive enough to cover the fixed costs of exporting. Therefore, in the case of high enough fixed costs, firms in a given country may find it unprofitable to export to a given destination, thereby resulting in zero trade between country pairs. Failing to account for this firm heterogeneity represents a country selection bias and thus misrepresents bilateral trade elasticities.

These endogenous concerns may bias the above estimates and lead one to question a causal interpretation of the coefficients. In order to provide further evidence of the effects of environmental lobbying on the North-to-South waste exports, I exploit an EU policy on waste shipments and use a triple-difference estimation strategy.

1.4.2 Triple-difference estimation strategy

The increasing transboundary waste trade has called for an urgent need to regulate waste shipments and their inherent risks. In accordance with the Basel Convention and OECD decision on the control of hazardous waste, the European Union (EU) approved a main legislative act called Waste Shipment Regulation (WSR) in 2006 to regulate transboundary movements of waste. One of the main objectives of the regulation is to ensure that waste exported outside the EU does not create adverse effects on the environment or public health in the countries of destination, by prohibiting the export of hazardous waste to developing countries that are typically unable to manage the waste in an environmentally sound manner.

The regulation is a formalization of the Basel Convention and the EU's commitment to the Ban Amendment on hazardous waste. Using this policy information in a quasi-natural experiment setting, I exploit plausibly exogenous variation created by waste exports restriction following the introduction of the WSR. The idea is that firms inside the EU market will be limited in their ability to ship their waste to developing countries due to the WSR, while firms in other non-EU developed countries should not be affected by this EU policy. Consequently, this regulation creates large cross-country or group discrepancies between EU developed countries and non-EU developed countries in terms of their aggregate waste exports to the developing world.

1.4.2.1 Difference-in-differences specification

Exploring differences in waste exports between EU developed countries (defined as the treatment group) and non-EU developed countries (defined as the control group), before and after the EU-WSR, I start with a simple difference-in-differences research design by implementing the following regression specification:

$$\ln Y_{ijt} = \alpha + \beta_1 * \text{Treatment}_i + \beta_2 * \text{Post}_t + \beta_3 * \text{Treatment}_i * \text{Post}_t + \varepsilon_{ijt},$$

where $\ln Y_{ijt}$ denotes the natural log of aggregate waste exports from a developed country i to a developing country j in year t. The dummy variable Treatment_i equals one if the country i belongs to an EU developed country, and equals zero otherwise. The dummy variable Post_t equals one if year t is equal to or greater than 2006,[26] and equals zero otherwise. ε_{ijt} is the unobserved error term.

I begin my analysis with a simple exercise by dividing the exporters into EU and non-EU groups and plotting the aggregate annual waste exports from each group to developing countries over the 20-year period. The purpose of doing so is to provide a simple test of my research design or check the underlying parallel trend assumption. That is, after controlling for observable differences, the trend of treatment and control groups' aggregate waste exports to developing countries should be similar to each other and thus differences in the volume of trade after the policy between the two groups are purely due to the implementation of the EU-WSR. So if WSR did, in fact, affect EU waste exports, then I should observe trade volume changes across these two groups after the regulation went into effect in 2006.

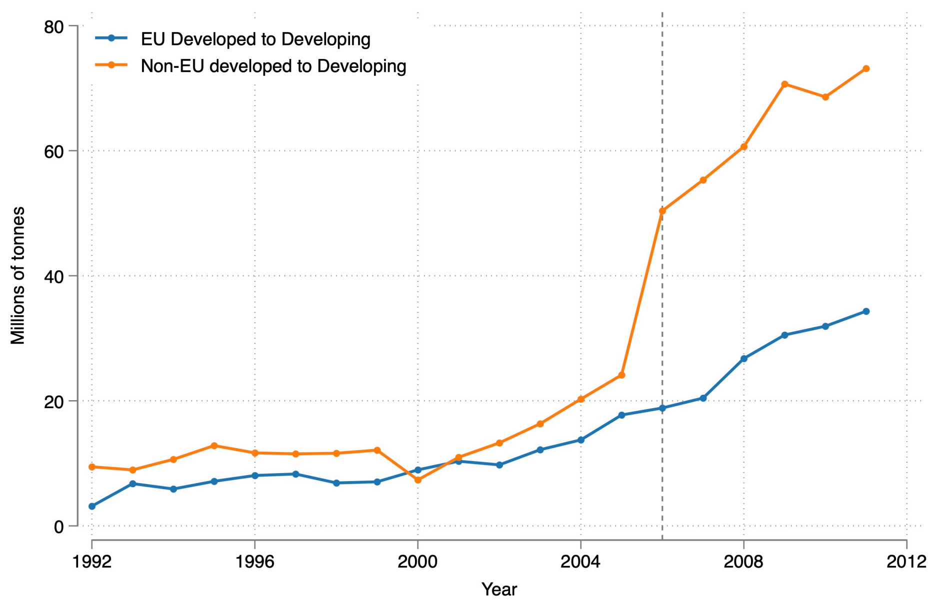


Figure 1.4: Total annual waste exports to developing countries

Figure 1.4 provides such suggestive evidence by illustrating the annual aggregate waste exports from EU developed and non-EU developed countries to the developing world from 1992 to 2011. While there were small level differences in the trade volumes between these two groups, the waste export trends followed a very similar pattern prior

[26]The EU-WSR was approved in 2006, but actually went into force in 2007. However, firms may have already known about this regulation earlier and anticipated its potential impacts on their waste disposal. Therefore, firms had already taken some actions such as building more waste disposal factories, increasing disposal capacities, and so on before 2007.

to 2006. However, after the implementation of WSR in 2006, the trends seem to diverge substantially. While the waste shipments from non-EU developed countries increased considerably, the increasing trend for EU developed countries remained relatively steady. One possible explanation for this post-policy difference may be that the EU waste regulation effectively deters more domestic firms from shipping their waste to the developing world, as it would be considered as a violation of the law. But as Bernard (2015) has pointed out, firms can undertake both legal and illegal waste shipments that take different forms to bypass the regulation, including transporting waste on the black market, mixing different types of waste, declaring hazardous waste as non-hazardous, or classifying waste as second-hand goods. Nonetheless, waste exports from EU developed countries do not present the same substantial increase trend as those non-EU ones.

However, it is possible that this markedly divergent trend is due to some other reasons rather than the EU-WSR. Though the regulation strictly bans the export of hazardous waste to developing countries, it does allow waste trade between developed countries themselves. Thus, one explanation for the nonparallel waste trend between EU and non-EU developed countries could be trade diversion. That is, EU developed countries may have shipped a large part of their waste to other non-EU developed countries, or simply there is more waste trade within the EU block. Figure 1.5 clarifies this concern by plotting

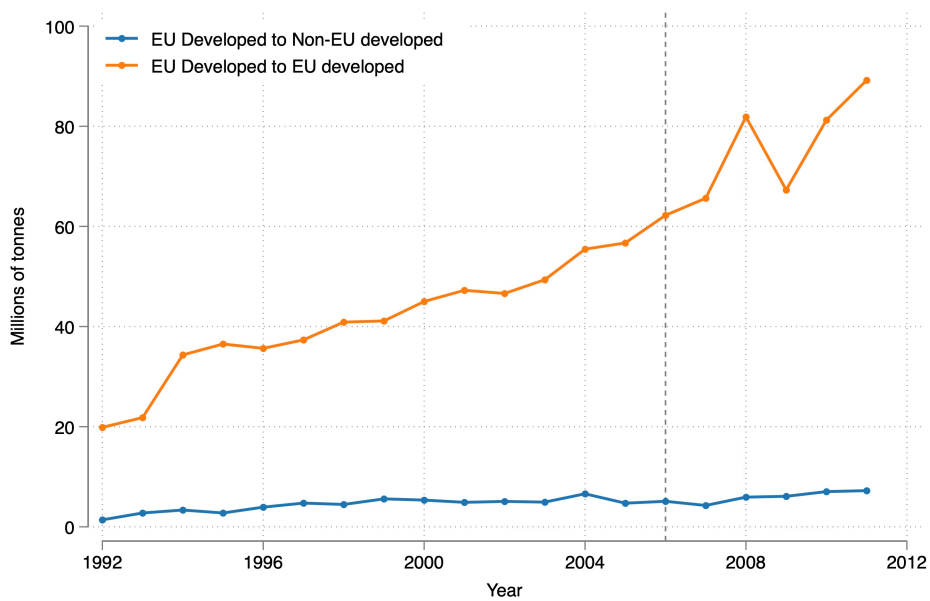


Figure 1.5: Total annual waste exports from EU developed countries

the total annual waste exports from EU developed countries to other non-EU developed countries and to themselves, respectively. Clearly, there was substantial within-EU trade after the implementation of the WSR, while the waste shipments from EU developed to non-EU developed countries remained relatively stable.[27] That is, in the absence of the WSR, waste exports from EU developed countries would have followed a similar trend to those from non-EU developed countries.

While these figures are suggestive of the policy effects, they do not fully exploit the variation in waste exports created by EU-WSR. As my next step, I present estimates of the average effects on waste export reduction in Table 1.6 using the above-outlined specification. Column 1 reports estimates from the simplest specification. In columns 2-4, I include year fixed effects, exporter fixed effects and importer fixed effects to capture and net out average differences across years, exporters and importers, respectively. Finally, column 5 includes both year and exporter fixed effects, and column 6 includes all of the three fixed effects. The coefficients on the double-difference estimator presented in Table 1.6 are all negative, indicating that EU developed countries decreased their waste exports to developing countries after the implementation of the WSR. More specifically, according to the estimate in column 6, the WSR reduced the waste exports of EU developed countries by 31.9%.[28]

Table 1.6: Simple difference-in-differences regression specifications

	Dependent variable: ln (North-to-South waste exports)					
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Treatment* Post	-0.192	-0.208	-0.187	-0.376**	-0.200	-0.384***
	(0.153)	(0.153)	(0.151)	(0.148)	(0.151)	(0.143)
Year FE		X			X	X
Exporter FE			X		X	X
Importer FE				X		X
Observations	17525	17525	17525	17525	17525	17525
R^2	0.010	0.013	0.113	0.255	0.115	0.401

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is from 2006 onwards.

[27] This evidence is further confirmed in the subsequent EU reports on the implementation of the Waste Shipment Regulation. Please refer to https://environment.ec.europa.eu/topics/waste-and-recycling/waste-shipments_en for more details.

[28] $(exp(-0.384) - 1) * 100\% = 31.9\%$.

1.4.2.2 Mechanism: the role of ENGOs

The results from the simple difference-in-differences specification lend confidence to my research design and provide evidence about the policy effects on waste export reduction by EU developed countries. I now turn to the main focus of the paper and identify the mechanism through which environmental lobbies can play a role in reducing the waste trade. That is, how much of the waste export reduction brought by EU-WSR can be explained by the variation in environmental lobbying strength? Do countries with more ENGOs tend to experience a larger effect?

To better answer these questions, I explore the differences in environmental lobbying strength (proxied by the number of ENGOs) across countries, in addition to the double differences discussed earlier, and thus use a triple-difference estimation strategy. I implement the following regression specification for the triple-difference estimation:

$$\begin{aligned}\ln Y_{ijt} = {} & \alpha + \beta_1 * \text{Treatment}_i + \beta_2 * \text{Post}_t + \beta_3 * \ln \text{ENGO}_{it} \\ & + \beta_4 * \text{Treatment}_i * \text{Post}_t + \beta_5 * \text{Treatment}_i * \ln \text{ENGO}_{it} + \beta_6 * \text{Post}_t * \ln \text{ENGO}_{it} \\ & + \beta_7 * \text{Treatment}_i * \text{Post}_t * \ln \text{ENGO}_{it} + \gamma \text{X}_{ijt} + \varepsilon_{ijt},\end{aligned}$$

where Y_{ijt} denotes the size of aggregate waste exports from a developed country i to a developing country j in year t. The dummy variable Treatment_i equals one if country i belongs to an EU developed country, and equals zero otherwise. The dummy variable Post_t equals one if year t is equal to or greater than 2006, and equals zero otherwise. As for ENGO_{it}, I use the variation in the number of ENGOs in 2005, which is prior to the policy implementation. X_{ijt} is a vector of control variables defined as earlier, and ε_{ijt} is the unobserved error term. β_7 is the triple-difference estimator – my main coefficient of interest. Identifying β_7 requires some assumptions. That is, countries with different baseline ENGOs react similarly to changes in unobservable differences between EU developed and non-EU developed countries.

It is possible that the number of ENGOs and waste exports are simultaneously determined. Thus, if I use the yearly number of ENGOs in the regression, the variable may be endogenous. To address this issue, I use the baseline variation in the number of ENGOs. Another concern is that the EU-WSR may be the result of stronger pressure from ENGOs. But the interaction term $(\text{Treatment}_i * \ln \text{ENGO}_{it})$ in the regression should capture any baseline differences in environmental lobbying strength between EU developed countries. Finally, there are some concerns that the EU waste export reduction was driven by some other waste policies than the WSR.[29] For example, the EU's directives on End of Life Vehicle (ELV) in 2000 and Waste Electrical and Electronic Equipment (WEEE) in 2000 (amended in 2006), may have helped reduce some waste production and improve waste reuse, possibly reducing the amount of waste being exported and thereby reducing the need for environmental lobbies. However, as shown in Figure 1.3, the number of ENGOs increases steadily over time and thus it is highly unlikely that ENGOs are endogenously determined by these policies. Nonetheless, I conduct a robustness check using the variation of ENGOs in 1999, but the results remain very similar.[30]

Table 1.7 reports the coefficient estimates from the triple-difference specification on the exporter side; a more detailed description of the results can be found in Appendix 1.6.5.1. While column 1 describes the estimates from the simplest specification, column 2 includes additional exporter-specific controls and column 3 adds extra bilateral control variables in the specifications. In columns 4-6, I include additional year fixed effects, exporter fixed effects and importer fixed effects to capture and net out average differences across years, exporters and importers, respectively. Finally, column 7 controls for all of these additional factors simultaneously.

Table 1.7: Triple-difference exporter side regression specifications

	Dependent variable: ln (North-to-South waste exports)						
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment* Post* ln (ENGO exporter)	-0.811***	-0.874***	-0.916***	-0.883***	-0.889***	-0.778***	-0.670***
	(0.152)	(0.158)	(0.156)	(0.157)	(0.158)	(0.152)	(0.154)
Exporter-specific Controls		X	X	X	X	X	X
Bilateral Controls			X	X	X	X	X
Year FE				X			X
Exporter FE					X		X
Importer FE						X	X
Observations	17525	17512	17512	17512	17512	17512	17512
R^2	0.015	0.046	0.083	0.093	0.158	0.413	0.483

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is equal to or greater than 2006. ENGO uses the number of ENGOs in 2005. Exporter-specific controls include industry lobbying strength, population, GDP and capital-labour ratio. Bilateral controls include bilateral distance and dummy variables that indicate whether countries share a common border, common language, had colonial ties, are both members of WTO and Basel Convention, or in some regional trade agreements.

[29] For a full list of all EU waste policies, please see https://www.municipalwasteeurope.eu/summary-current-eu-waste-legislation.

[30] Results are available from the author on request.

Throughout all the specifications, the coefficients on the triple-difference estimator are all negative and statistically significant at the 1% level. This means that the more ENGOs in 2005, the more pronounced is the decrease in waste exports triggered by the policy for the EU developed countries. More specifically, according to the estimate in column 7, EU developed countries with 10% more ENGOs in 2005 are estimated to decrease their waste exports by 6.7% more than their EU counterparts after the implementation of the WSR.

As shown earlier, the importer-specific factors can also affect the waste trade. I thus implement the triple-difference estimation with the gravity specification as a robustness check. The results from this analysis are reported in Table 1.8 with more details in Appendix 1.6.5.2. Column 1 again describes the estimates from the simplest specification, whereas column 2 includes additional exporter-specific and import-specific controls, and column 3 adds extra bilateral control variables in the specifications. In columns 4-5, I include additional year fixed effects, both exporter fixed effects and importer fixed effects to capture and net out average differences across years, and exporters and importers, respectively. Finally, column 6 includes all of these additional factors simultaneously. The triple-difference coefficient estimates presented in Table 1.8 prove to be quite robust – still negative and statistically significant at the 1% level, with only the magnitudes increasing slightly. Therefore, I can conclude that environmental lobby groups exert a statistically significant impact on North-to-South waste export reduction.

1.4.3 Robustness check with zero waste trade

In the previous sections, I have focused only on the positive waste trade and estimated the regressions by OLS, while leaving out a significant proportion of zero waste trade.[31] One clear drawback of using OLS is that it cannot take into account the information contained in the zero trade flows, since these observations are simply dropped out when transformed into a logarithmic form. This may constitute a selection bias because the sample is not drawn randomly from all trade flows, but only consists of those trade flows which are strictly positive. Several researchers (Eaton and Tamura, 1994; Helpman, Melitz and Rubinstein, 2008; Martin and Pham, 2020; Silva and Tenreyro, 2006) have proposed different approaches to address this zero trade issue.[32] I follow Silva and Tenreyro (2006) and employ the Poisson Pseudo Maximum Likelihood (PPML) estimation technique for a robustness check.

[31] In fact, there should be $35 \times 87 \times 20 = 60,900$ total observations, in which the zero trade makes up 71.2% of the total trade if counted.

[32] See Head and Mayer (2014) for a review.

Table 1.8: Triple-difference gravity regression specifications

	Dependent variable: ln (North-to-South waste exports)					
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment* Post* ln (ENGO exporter)	-0.811***	-0.952***	-0.936***	-0.898***	-0.700***	-0.704***
	(0.152)	(0.159)	(0.157)	(0.157)	(0.153)	(0.154)
Exporter-specific Controls		X	X	X	X	X
Importer-specific Controls		X	X	X	X	X
Bilateral Controls			X	X	X	X
Year FE				X		X
Exporter FE					X	X
Importer FE					X	X
Observations	17525	17309	17309	17309	17309	17309
R^2	0.015	0.213	0.290	0.296	0.489	0.490

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is equal to or greater than 2006. ENGO uses the number of ENGOs in 2005. Exporter and importer-specific controls include industry lobbying strength, population, GDP and capital-labour ratio. Bilateral controls include bilateral distance and dummy variables that indicate whether countries share a common border, common language, had colonial ties, are both members of WTO and Basel Convention, or in some regional trade agreements.

Similar to Table 1.5, Table 1.9 reports the main estimation results for the exporter side, importer side, and gravity specifications, respectively, but now estimated by PPML with the tonnes of North-to-South waste exports as the dependent variable. Though the coefficients for ENGO on the exporter side become statistically insignificant, the ones on the importer side remain quite robust – negative and statistically significant at 1% level in all specifications. This further validates my previous finding that strong environmental lobby groups in developing countries will result in less waste being shipped from North to South.

Table 1.9: North-to-South waste trade regression specifications using PPML

	Dependent variable: North-to-South waste exports					
	Exporter only		Importer only		Gravity	
Variables	(1)	(2)	(3)	(4)	(5)	(6)
ln (ENGO exporter)	-0.045	-0.056			-0.045	0.280
	(0.380)	(0.385)			(0.289)	(0.216)
ln (ENGO importer)			-0.899***	-0.892***	-0.899***	-1.135***
			(0.257)	(0.168)	(0.198)	(0.167)
Exporter-specific Controls	X	X			X	X
Importer-specific Controls			X	X	X	X
Bilateral Controls		X		X		X
Observations	60117	60117	59325	59325	58646	58646
Pseudo R^2	0.244	0.353	0.492	0.657	0.679	0.767

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. All regressions include a constant term and year fixed effects. Exporter and importer-specific controls include industry lobbying strength, population, GDP and capital-labour ratio. Bilateral controls include bilateral distance and dummy variables that indicate whether countries share a common border, common language, had colonial ties, are both members of WTO and Basel Convention, or in some regional trade agreements.

Two similar exercises are performed for the triple-difference estimations using PPML with the North-to-South waste exports in tonnes as the dependent variable. The results on the triple-difference estimator for the exporter-side specification and gravity specification are reported in Table 1.10 and Table 1.11, respectively. Though only very weak evidence is observed in the exporter side specifications from Table 1.10, the triple-difference coefficient estimates reported in Table 1.11 show that the results are highly robust – all negative and statistically significant at the 1% level, except for the second one at 5% level. This further confirms my previous claim that EU developed countries with more ENGOs tend to reduce their waste exports by more after the implementation of the regulation. These additional empirical exercises take into consideration the "missing" zero waste trade and provide robust evidence of my previous findings that strengthening ENGOs can reduce the international waste trade.

Table 1.10: Triple-difference exporter side regression specifications using PPML

Variables	Dependent variable: North-to-South waste exports						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment* Post* ln (ENGO exporter)	-0.522**	-0.327	-0.289	-0.311*	-0.206	-0.211	-0.259*
	(0.238)	(0.231)	(0.189)	(0.185)	(0.172)	(0.148)	(0.150)
Exporter-specific Controls		X	X	X	X	X	X
Bilateral Controls			X	X	X	X	X
Year FE				X			X
Exporter FE					X		X
Importer FE						X	X
Observations	60900	60291	60291	60291	60291	60291	60291
Pseudo R^2	0.190	0.256	0.369	0.377	0.440	0.851	0.902

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is equal to or greater than 2006. ENGO uses the number of ENGOs in 2005. Exporter-specific controls include industry lobbying strength, population, GDP and capital-labour ratio. Bilateral controls include bilateral distance and dummy variables that indicate whether countries share a common border, common language, had colonial ties, are both members of WTO and Basel Convention, or in some regional trade agreements.

1.5 Conclusion

In this paper, I develop a political economy model to investigate the role played by lobby groups on international trade in waste, an externality generated by production activities in a developed-country market that can be exported to a developing country for disposal but with a fee. The model assumes that groups have heterogeneous preferences for environmental quality and that the environmental and trade policy on the externality is endogenously determined by balancing the competing interests of an organized environmental and industry lobby group. I show that the politically chosen policy is ambiguous relative to the socially optimal level, depending on the heterogeneity of environmental attitudes and the degree of pollution damages from waste. Further, taking theory to data to provide some empirical clarity on the effects of environmental lobbying, I find compelling evidence that environmental lobby groups exert a statistically significant impact on North-to-South waste export reduction. Therefore, strengthening ENGOs can represent an important strategy to reduce the international waste trade. Thus, it may be worthwhile for international donor organizations to provide support for the development of ENGOs all over the world (Binder and Neumayer, 2005; Fredriksson et al., 2005).

Table 1.11: Triple-difference gravity regression specifications using PPML

	Dependent variable: North-to-South waste exports					
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment* Post* ln (ENGO exporter)	-0.522**	-0.336**	-0.405***	-0.422***	-0.335***	-0.371***
	(0.238)	(0.148)	(0.106)	(0.102)	(0.100)	(0.105)
Exporter-specific Controls		X	X	X	X	X
Importer-specific Controls		X	X	X	X	X
Bilateral Controls			X	X	X	X
Year FE				X		X
Exporter FE					X	X
Importer FE					X	X
Observations	60900	58792	58792	58792	58792	58792
Pseudo R^2	0.190	0.695	0.775	0.779	0.902	0.905

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is equal to or greater than 2006. ENGO uses the number of ENGOs in 2005. Exporter and importer-specific controls include industry lobbying strength, population, GDP and capital-labour ratio. Bilateral controls include bilateral distance and dummy variables that indicate whether countries share a common border, common language, had colonial ties, are both members of WTO and Basel Convention, or in some regional trade agreements.

The paper has some limitations. First, I have only explored the policy channels through which environmental lobby groups affect the waste trade. However, as demonstrated in Yu (2005), the amount of political contributions observed from environmental lobby groups is typically very small compared to industrial ones, and thus the success of environmental lobbying is largely due to their greater effectiveness in public persuasion and the growing public environmental awareness. In addition, as identified in Connelly et al. (2012), ENGOs can engage in many other activities to affect policymakers' perceived political support, such as producing scientific research and reports, organizing protests, staging public stunts, and so on. They can also use environmental litigation and courts to fulfil their goals (Bentata and Faure, 2015). Therefore, it would be interesting to extend the analysis to explore other possible mechanisms of environmental lobbying on the waste trade.

Second, I do not seek to test the relationship between the strength of environmental lobby groups and policy stringency, due to data availability and challenges. There is no explicit measurement of the environmental tax on waste, and attempting to collect this information for a cross-country time-series study is prohibitively difficult. Though tariff data on waste is largely available,[33] it turns out to be very poor and information on many waste categories is missing. Also, as argued by Gawande and Krishna (2003), the trade barriers used in practice are a complicated combination of tariff and nontariff barriers, and trade protection has been heavily dominated in recent decades by the use of nontariff barriers. Given the particular nature of waste, it is not difficult to imagine that most of the waste categories will be subject to nontariff barriers. Therefore, the use of available average or aggregate data to proxy for the country's overall ad valorem import tariff on waste will be unreliable.

Third, I have made the small open economy assumption and thus the price of waste is exogenously given. However, as noted in the data, China has played a significant role in the waste trade, and the Chinese waste ban in 2017 has undoubtedly affected the worldwide waste industry (Guo, Walls and Zheng, 2023). It would be worthwhile to investigate how the results will change when the price of waste is endogenously determined. Finally, I have assumed that environmentalists are those not-in-my-back-yard ones that only care about domestic environmental protection. A natural extension will be modelling the case when they also care about other countries' environments. These are all relevant and promising extensions for future research.

[33]The tariff data on waste can be directly obtained from the WTO Tariff Download Facility, which contains comprehensive information on Most-Favoured-Nation (MFN) applied and bound tariffs at the standard codes of the Harmonized System (HS) for all WTO members. This information is sourced from submissions made to the WTO Integrated Data Base (IDB) for applied tariffs and imports and from the Consolidated Tariff Schedules (CTS) database for the bound duties of all WTO members. See more at https://www.wto.org/english/tratop_e/tariffs_e/tariff_data_e.htm.

References

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

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

Anderson, James E, and Eric Van Wincoop. 2003. "Gravity with gravitas: A solution to the border puzzle." *American Economic Review*, 93(1): 170–192.

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

Baier, Scott L, and Jeffrey H Bergstrand. 2007. "Do free trade agreements actually increase members' international trade?" *Journal of International Economics*, 71(1): 72–95.

Behar, Alberto, and Benjamin D Nelson. 2014. "Trade flows, multilateral resistance, and firm heterogeneity." *The Review of Economics and Statistics*, 96(3): 538–549.

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

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

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

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

Cassing, James, and Thomas Kuhn. 2003. "Strategic environmental policies when waste products are tradable." *Review of International Economics*, 11(3): 495–511.

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

Cherniwchan, Jevan, and Nouri Najjar. 2021. "Free Trade and the Formation of Environmental Policy: Evidence from US Legislative Votes." Working Paper 21-11, Carleton University.

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

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

Copeland, Brian R, Joseph S Shapiro, and M. Scott Taylor. 2021. "Globalization and the Environment." National Bureau of Economic Research Working Paper 28797.

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

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

Eaton, Jonathan, and Akiko Tamura. 1994. "Bilateralism and regionalism in Japanese and US trade and direct foreign investment patterns." *Journal of the Japanese and International Economies*, 8(4): 478–510.

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

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

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

Gawande, Kishore, and Pravin Krishna. 2003. "The political economy of trade policy: Empirical approaches." *Handbook of International Trade*, 1: 139–152.

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

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

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

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

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

Head, Keith, and Thierry Mayer. 2014. "Gravity equations: Workhorse, toolkit, and cookbook." In *Handbook of International Economics*. Vol. 4, 131–195. Elsevier.

Helpman, Elhanan, Marc Melitz, and Yona Rubinstein. 2008. "Estimating trade flows: Trading partners and trading volumes." *The Quarterly Journal of Economics*, 123(2): 441–487.

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

Jensen, Svenn, Kristina Mohlin, Karen Pittel, and Thomas Sterner. 2015. "An introduction to the green paradox: the unintended consequences of climate policies." *Review of Environmental Economics and Policy*, 9(2): 246–265.

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

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

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

Kellenberg, Derek. 2015. "The economics of the international trade of waste." *Annual Review of Resource Economics*, 7(1): 109–125.

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

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

Longhofer, Wesley, Evan Schofer, Natasha Miric, and David John Frank. 2016. "NGOs, INGOs, and environmental policy reform, 1970–2010." *Social Forces*, 94(4): 1743–1768.

Martin, William, and Cong S Pham. 2020. "Estimating the gravity model when zero trade flows are frequent and economically determined." *Applied Economics*, 52(26): 2766–2779.

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

Moore, Sarah A. 2011. "Global garbage: waste, trash trading, and local garbage politics." *Global political ecology*, 133–144.

Olson, Mancur. 1965. "The logic of collective action Harvard University Press." *Cambridge, MA*.

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

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

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

Schofer, Evan, and Wesley Longhofer. 2011. "The structural sources of association." *American Journal of Sociology*, 117(2): 539–585.

Silva, JMC Santos, and Silvana Tenreyro. 2006. "The log of gravity." *The Review of Economics and Statistics*, 88(4): 641–658.

Sinn, Hans-Werner. 2008. "Public policies against global warming: a supply side approach." *International Tax and Public Finance*, 15(4): 360–394.

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

Trzyna, Thaddeus C, and Julie Didion. 2013. *World Directory of Environmental Organizations (6th ed.).* Routledge.

Van der Ploeg, Frederick, and Cees Withagen. 2015. "Global warming and the green paradox: A review of adverse effects of climate policies." *Review of Environmental Economics and Policy*, 9(2): 285–303.

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

Yotov, Yoto V, Roberta Piermartini, Mario Larch, et al. 2016. *An Advanced Guide to Trade Policy Analysis: The Structural Gravity Model.* WTO iLibrary.

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

1.6 Appendix

1.6.1 Proofs

1.6.1.1 FOC for socially optimal tax

Proof. Note that

$$\begin{aligned}\frac{dJ_1}{dt} &= \frac{d\hat{\Pi}}{dt} + \frac{m_1}{n}\left[\hat{Y} - \hat{Q} + t\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)\right] + m_1\frac{dCS(p_c)}{dp_c}\frac{dp_c}{dt} - m_1\beta_C D'(\hat{Z})\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)\\ &= \left[\frac{dp_c}{dt} - 1\right]\hat{Y} + \hat{Q} + \frac{m_1}{n}\left[\hat{Y} - \hat{Q} + t\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)\right] - m_1\frac{\hat{Y}}{n}\frac{dp_c}{dt} - m_1\beta_C D'(\hat{Z})\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right),\end{aligned}$$

$$\frac{dJ_2}{dt} = \frac{m_2}{n}\left[\hat{Y} - \hat{Q} + t\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)\right] - m_2\frac{\hat{Y}}{n}\frac{dp_c}{dt} - m_2\beta_E D'(\hat{Z})\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right),$$

$$\frac{dJ_3}{dt} = \frac{m_3}{n}\left[\hat{Y} - \hat{Q} + t\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)\right] - m_3\frac{\hat{Y}}{n}\frac{dp_c}{dt} - m_3\beta_W D'(\hat{Z})\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right),$$

and thus

$$\begin{aligned}\frac{dJ}{dt} &= \left[\frac{dp_c}{dt} - 1\right]\hat{Y} + \hat{Q} + \left[\hat{Y} - \hat{Q} + t\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)\right] - \hat{Y}\frac{dp_c}{dt} - n\bar{\beta}D'(\hat{Z})\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)\\ &= \left(t - n\bar{\beta}D'(\hat{Z})\right)\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right).\end{aligned}$$

□

1.6.1.2 FOC for political equilibrium tax

Proof. The first-order condition yields

$$\frac{d\hat{G}(t)}{dt} = (1+\delta)\left(\frac{dJ_1}{dt} + \frac{dJ_2}{dt}\right) + \delta\frac{dJ_3}{dt} = 0,$$

or

$$\frac{dJ_1}{dt} + \frac{dJ_2}{dt} + \delta\frac{dJ}{dt} = 0.$$

That is,

$$\left[\frac{dp_c}{dt} - 1\right]\hat{Y} + \hat{Q} + \frac{m_1 + m_2}{n}\left[\hat{Y} - \hat{Q} + t\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)\right] - \frac{m_1 + m_2}{n}\hat{Y}\frac{dp_c}{dt}$$

$$-(m_1\beta_C + m_2\beta_E)D'(\hat{Z})\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right) + \delta\left(t - n\bar{\beta}D'(\hat{Z})\right)\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right) = 0.$$

This equation reduces to

$$\frac{m_3}{n}\hat{Y}\left[\frac{dp_c}{dt} - 1\right] + \frac{m_3}{n}\hat{Q} + \left(\frac{m_1 + m_2}{n}t - (m_1\beta_C + m_2\beta_E)D'(\hat{Z})\right)\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)$$

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

Substitute with equation (1.9):

$$\frac{dp_c}{dt} - 1 = \frac{\frac{d\hat{\Pi}}{dt} - \hat{Q}}{\hat{Y}},$$

and use the result

$$m_1\beta_C + m_2\beta_E = n\bar{\beta} - m_3\beta_W = \frac{m_1 + m_2 + m_3}{n}n\bar{\beta} - m_3\beta_W = \frac{m_1 + m_2}{n}n\bar{\beta} - \frac{m_3}{n}(n\beta_W - n\bar{\beta}),$$

the equation becomes

$$\frac{m_3}{n}\frac{d\hat{\Pi}}{dt} + \left[\frac{m_1 + m_2}{n}t - \left(\frac{m_1 + m_2}{n}n\bar{\beta} - \frac{m_3}{n}(n\beta_W - n\bar{\beta})\right)D'(\hat{Z})\right]\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)$$

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

Define $\lambda_0 = \frac{m_1+m_2}{n}$ as the fraction of the population that belong to the organized group, then

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

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

Combine terms, we have

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

□

1.6.1.3 Effects of environmental movement

Proof. Given $n = m_1 + m_2 + m_3$, we must have

$$\frac{dm_1}{dm_2} = \frac{dn}{dm_2} = 0, \quad \frac{dm_3}{dm_2} = -1, \quad \frac{d\lambda_0}{dm_2} = \frac{1}{n},$$

$$\frac{d\frac{1-\lambda_0}{\delta+\lambda_0}}{dm_2} = \frac{-\frac{1}{n}(\delta+\lambda_0) - \frac{1}{n}(1-\lambda_0)}{(\delta+\lambda_0)^2} = \frac{-\frac{1}{n}(\delta+1)}{(\delta+\lambda_0)^2} < 0,$$

$$\frac{d\beta_C}{dm_2} = \frac{d\beta_W}{dm_2} = \frac{d\beta_E}{dm_2} = 0, \quad \frac{dn\bar{\beta}}{dm_2} = \frac{d(m_1\beta_C + m_2\beta_E + m_3\beta_W)}{dm_2} = \beta_E - \beta_M > 0.$$

Rewrite equation (1.10) as

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

then

$$\frac{dt}{dm_2} = (\beta_E - \beta_W)D'(\hat{Z}(t)) + n\bar{\beta}D''(\hat{Z}(t))\frac{d\hat{Z}}{dt}\frac{dt}{dm_2} + \frac{\frac{1}{n}(\delta+1)}{(\delta+\lambda_0)^2}\left[(n\beta_W - n\bar{\beta})D'(\hat{Z}(t)) + \frac{d\hat{\Pi}/dt}{d\hat{Z}/dt}\right]$$

$$-\frac{1-\lambda_0}{\delta+\lambda_0}\left[-(\beta_E-\beta_W)D'(\hat{Z}(t)) + (n\beta_W - n\bar{\beta})D''(\hat{Z}(t))\frac{d\hat{Z}}{dt}\frac{dt}{dm_2} + \frac{\frac{d^2\hat{\Pi}}{dt}\frac{dt}{dm_2}\frac{d\hat{Z}}{dt} - \frac{d\hat{\Pi}}{dt}\frac{dt}{dm_2}\frac{d^2\hat{Z}}{dt^2}}{(\frac{d\hat{Z}}{dt})^2}\right].$$

Combine terms on the right hand, we have

$$\frac{dt}{dm_2} = \frac{1+\delta}{\delta+\lambda_0}(\beta_E-\beta_W)D'(\hat{Z}(t)) + \frac{(1+\delta)n\bar{\beta} - (1-\lambda_0)n\beta_W}{\delta+\lambda_0}D''(\hat{Z}(t))\frac{d\hat{Z}}{dt}\frac{dt}{dm_2}$$

$$+\frac{\frac{1}{n}(\delta+1)}{(\delta+\lambda_0)^2}\left[(n\beta_W - n\bar{\beta})D'(\hat{Z}(t)) + \frac{d\hat{\Pi}/dt}{d\hat{Z}/dt}\right] - \frac{1-\lambda_0}{\delta+\lambda_0}\frac{\frac{d^2\hat{\Pi}}{dt}\frac{d\hat{Z}}{dt} - \frac{d\hat{\Pi}}{dt}\frac{d^2\hat{Z}}{dt^2}}{(\frac{d\hat{Z}}{dt})^2}\frac{dt}{dm_2}.$$

Now, combine the term dt/dm_2, then

$$\left[1 - \frac{(1+\delta)n\bar{\beta} - (1-\lambda_0)n\beta_W}{\delta+\lambda_0}D''(\hat{Z}(t))\frac{d\hat{Z}}{dt} + \frac{1-\lambda_0}{\delta+\lambda_0}\frac{\frac{d^2\hat{\Pi}}{dt}\frac{d\hat{Z}}{dt} - \frac{d\hat{\Pi}}{dt}\frac{d^2\hat{Z}}{dt^2}}{(\frac{d\hat{Z}}{dt})^2}\right]\frac{dt}{dm_2}$$

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

That is,

$$\frac{dt}{dm_2} = \frac{\frac{1+\delta}{\delta+\lambda_0}(\beta_E - \beta_W)D'(\hat{Z}(t)) + \frac{\frac{1}{n}(\delta+1)}{(\delta+\lambda_0)^2}\left[(n\beta_W - n\bar{\beta})D'(\hat{Z}(t)) + \frac{d\hat{\Pi}/dt}{d\hat{Z}/dt}\right]}{1 - \frac{(1+\delta)n\bar{\beta}-(1-\lambda_0)n\beta_W}{\delta+\lambda_0}D''(\hat{Z}(t))\frac{d\hat{Z}}{dt} + \frac{1-\lambda_0}{\delta+\lambda_0}\frac{\frac{d^2\hat{\Pi}}{dt}\frac{d\hat{Z}}{dt} - \frac{d\hat{\Pi}}{dt}\frac{d^2\hat{Z}}{dt^2}}{(\frac{d\hat{Z}}{dt})^2}}.$$

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

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

and the second term in the numerator can be rewritten from equation (1.10) as

$$\left[(n\beta_W - n\bar{\beta})D'(\hat{Z}) + \frac{d\hat{\Pi}}{d\hat{Z}}\right] = -\frac{\delta+\lambda_0}{1-\lambda_0}\left[t - n\bar{\beta}D'(\hat{Z})\right] = -\frac{n}{m_3}(\delta+\lambda_0)\left[t - n\bar{\beta}D'(\hat{Z})\right].$$

Therefore,

$$\frac{dt}{dm_2} = \frac{\frac{1+\delta}{\delta+\lambda_0}(\beta_E - \beta_W)D'(\hat{Z}) - \frac{1+\delta}{(\delta+\lambda_0)}\frac{1}{m_3}\left[t - n\bar{\beta}D'(\hat{Z})\right]}{\frac{d\Omega}{dt}},$$

or

$$\frac{dt}{dm_2} = \frac{\frac{1+\delta}{\delta+\lambda_0}\frac{1}{m_3}\left[m_3(\beta_E - \beta_W)D'(\hat{Z}) - \left(t - n\bar{\beta}D'(\hat{Z})\right)\right]}{\frac{d\Omega}{dt}}.$$

□

1.6.1.4 FOC for socially optimal tariff rate

Proof. Note that

$$\frac{dJ_1}{d\tau} = \frac{d\hat{\Pi}(\tau)}{d\tau} + \frac{m_1\mu}{n}\left(\hat{I}(\tau) + \tau\frac{d\hat{I}(\tau)}{d\tau}\right) - m_1\beta_C D'(\hat{I}(\tau))\frac{d\hat{I}(\tau)}{d\tau},$$

$$\frac{dJ_2}{d\tau} = \frac{m_2\mu}{n}\left(\hat{I}(\tau) + \tau\frac{d\hat{I}(\tau)}{d\tau}\right) - m_2\beta_E D'(\hat{I}(\tau))\frac{d\hat{I}(\tau)}{d\tau},$$

$$\frac{dJ_3}{d\tau} = \frac{m_3\mu}{n}\left(\hat{I}(\tau) + \tau\frac{d\hat{I}(\tau)}{d\tau}\right) - m_3\beta_W D'(\hat{I}(\tau))\frac{d\hat{I}(\tau)}{d\tau},$$

$$\frac{d\hat{\Pi}(\tau)}{d\tau} = -\mu\hat{I}(\tau) + \left[(1-\tau)\mu - C'(\hat{I}(\tau))\right]\frac{d\hat{I}(\tau)}{d\tau} = -\mu\hat{I}(\tau) < 0,$$

and thus

$$\frac{dJ}{d\tau} = \frac{d\hat{\Gamma}\mathrm{I}(\tau)}{d\tau} + \mu\left(\hat{I}(\tau) + \tau\frac{d\hat{I}(\tau)}{d\tau}\right) - n\bar{\beta}D'(\hat{I}(\tau))\frac{d\hat{I}(\tau)}{d\tau} = \left(\mu\tau - n\bar{\beta}D'(\hat{I}(\tau))\right)\frac{d\hat{I}(\tau)}{d\tau}.$$

□

1.6.1.5 FOC for political equilibrium tariff rate

Proof. The first-order condition yields

$$\frac{d\hat{G}(\tau)}{d\tau} = \frac{dJ_1}{d\tau} + \frac{dJ_2}{d\tau} + \delta\frac{dJ}{d\tau} = 0.$$

That is,

$$-\mu\hat{I}(\tau) + \frac{(m_1+m_2)\mu}{n}\left(\hat{I}(\tau) + \tau\frac{d\hat{I}(\tau)}{d\tau}\right) - (m_1\beta_C + m_2\beta_E)D'(\hat{I}(\tau))\frac{d\hat{I}(\tau)}{d\tau}$$

$$+\delta\left(\mu\tau - n\bar{\beta}D'(\hat{I}(\tau))\right)\frac{d\hat{I}(\tau)}{d\tau} = 0.$$

Use the result of

$$m_1\beta_C + m_2\beta_E = n\bar{\beta} - m_3\beta_W = \frac{m_1+m_2+m_3}{n}n\bar{\beta} - m_3\beta_W = \frac{m_1+m_2}{n}n\bar{\beta} - \frac{m_3}{n}(n\beta_W - n\bar{\beta}),$$

the equation reduces to

$$-\frac{m_3}{n}\mu\hat{I}(\tau) + \left[\frac{m_1+m_2}{n}\mu\tau - \left(\frac{m_1+m_2}{n}n\bar{\beta} - \frac{m_3}{n}(n\beta_W - n\bar{\beta})\right)D'(\hat{I}(\tau))\right]\frac{d\hat{I}(\tau)}{d\tau}$$

$$+\delta\left(\mu\tau - n\bar{\beta}D'(\hat{I}(\tau))\right)\frac{d\hat{I}(\tau)}{d\tau} = 0.$$

Define

$$\lambda_0 = \frac{m_1+m_2}{n}, \quad 1-\lambda_0 = \frac{m_3}{n},$$

then we have

$$-(1-\lambda_0)\mu\hat{I}(\tau) + \left[\lambda_0\left(\mu\tau - n\bar{\beta}D'(\hat{I}(\tau))\right) + (1-\lambda_0)(n\beta_W - n\bar{\beta})D'(\hat{I}(\tau))\right]\frac{d\hat{I}(\tau)}{d\tau}$$

$$+\delta\left(\mu\tau - n\bar{\beta}D'(\hat{I}(\tau))\right)\frac{d\hat{I}(\tau)}{d\tau} = 0.$$

Combine terms, then

$$\frac{d\hat{G}(\tau)}{d\tau} = (1-\lambda_0)\left[-\mu\hat{I}(\tau) + (n\beta_W - n\bar{\beta})D'(\hat{I}(\tau))\frac{d\hat{I}(\tau)}{d\tau}\right] + (\lambda_0+\delta)\left(\mu\tau - n\bar{\beta}D'(\hat{I}(\tau))\right)\frac{d\hat{I}(\tau)}{d\tau} = 0.$$

□

1.6.2 Examples

1.6.2.1 Examples for political equilibrium tax

Suppose the production function, utility function, cost function and damage function take the following forms respectively:

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

which will allow us to obtain an analytical solution. For simplicity, let $\bar{K} = 1$, then

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

and we have

$$u'(y) = A - y, \quad \eta'(Q) = Q, \quad D'(Z) = \gamma Z.$$

From equation (1.8):

$$\left[u'\left(\frac{F(\bar{K},\hat{L})}{n}\right) - t\right]F_L(\bar{K},\hat{L}) - 1 = 0,$$

we can obtain the optimal labour and thereby output in the manufacturing sector as

$$\hat{L}(t) = \left(\frac{n(A-t)}{n+2}\right)^2, \quad \hat{Y}(t) = 2\hat{L}^{\frac{1}{2}} = \frac{2n(A-t)}{n+2}.$$

From equation (1.1), the optimal exported waste can be expressed as

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

Therefore, the optimal pollution is given by

$$\hat{Z}(t) = \hat{Y}(t) - \hat{Q}(t) = \frac{2n(A-t)}{n+2} - t + \mu.$$

To ensure $\hat{Y}, \hat{Q}, \hat{Z} > 0$, we would need

$$\mu < t < \frac{2nA + \mu(n+2)}{3n+2} < A.$$

Clearly,

$$\frac{d\hat{Y}(t)}{dt} = -\frac{2n}{n+2} < 0, \quad \frac{d\hat{Q}(t)}{dt} = 1 > 0, \quad \frac{d\hat{Z}(t)}{dt} = -\frac{2n}{n+2} - 1 < 0,$$

Then, we have

$$\frac{d\hat{\Pi}}{dt} = \hat{Q} - \hat{Y}\frac{F_{LL}}{F_L^3}\frac{d\hat{Y}}{dt} = t - \mu - \frac{2n(A-t)}{n+2}(-\frac{1}{2})(-\frac{2n}{n+2}) = t - \mu - \frac{2n^2(A-t)}{(n+2)^2},$$

and

$$\frac{d\hat{\Pi}}{d\hat{Z}} = \frac{\frac{d\hat{\Pi}}{dt}}{\frac{d\hat{Z}}{dt}} = \frac{t - \mu - \frac{2n^2(A-t)}{(n+2)^2}}{-\frac{2n}{n+2} - 1} = \frac{2n^2(A-t) - (t-\mu)(n+2)^2}{(3n+2)(n+2)}$$

To ensure $\frac{d\hat{\Pi}}{dt} < 0$ or $\frac{d\hat{\Pi}}{d\hat{Z}} > 0$, we need

$$t < \frac{2n^2A + \mu(n+2)^2}{3n^2+4n+4}.$$

It can be easily verified that

$$\frac{2n^2A + \mu(n+2)^2}{3n^2+4n+4} < \frac{2nA + \mu(n+2)}{3n+2}.$$

Therefore, the resulting political equilibrium tax must satisfy the condition:

$$\mu < t < \frac{2n^2A + \mu(n+2)^2}{3n^2+4n+4}.$$

Finally, from equation (1.10), we have

$$t - n\bar{\beta}\gamma\hat{Z} + \frac{1-\lambda_0}{\delta+\lambda_0}\left[(n\beta_W - n\bar{\beta})\gamma\hat{Z} + \frac{d\hat{\Pi}}{d\hat{Z}}\right] = 0.$$

That is,

$$t + \gamma\frac{m_3\bar{\beta}_M - (\delta+1)n\bar{\beta}}{\delta + \frac{m_1+m_2}{n}}\left[\frac{2n(A-t)}{n+2} - t + \mu\right] + \frac{\frac{m_3}{n}}{\delta + \frac{m_1+m_2}{n}}\left[\frac{2n^2(A-t) - (t-\mu)(n+2)^2}{(3n+2)(n+2)}\right] = 0$$

For numerical illustrations, we use the following parameter values:

$$n = 10, \quad \mu = 2.5, \quad A = 5, \quad \bar{L} = 10, \quad m_1 = 3, \quad m_2 = 2, \quad m_3 = 5, \quad \delta = 0.5.$$

Thus,

$$\lambda_0 = \frac{m_1 + m_2}{n} = 0.5, \quad \frac{1 - \lambda_0}{\delta + \lambda_0} = \frac{0.5}{0.5 + 0.5} = 0.5$$

Example 1. Suppose the average environmental preference for each group is such that

$$\beta_C = 0.01 < \bar{\beta} = 0.2 < \beta_W = 0.25 < \beta_E = 0.36,$$

with

$$m_1\beta_C + m_2\beta_E + m_3\beta_W = 3 \times 0.01 + 2 \times 0.36 + 5 \times 0.25 = 2 = 10 \times 0.2 = n\bar{\beta}$$

and $\gamma = 3$, then the political economy equilibrium tax can be solved as

$$t^{**} = 3.7867 \in \left(\mu = 2.5, \frac{2n^2A + \mu(n+2)^2}{3n^2 + 4n + 4} = 3.9535\right).$$

Thus, we have

$$\hat{L}(t^{**}) = 1.0223, \quad \hat{Y}(t^{**}) = 2.0222, \quad \hat{Q}(t^{**}) = 1.2867, \quad \hat{Z}(t^{**}) = 0.7355,$$

and the Pigovian tax is

$$t^* = n\bar{\beta}\gamma\hat{Z} = 4.4130 > t^{**} = 3.7867.$$

Example 1 shows that when $\beta_W \geq \beta$, the political economy equilibrium tax on the externality is below the Pigovian level.

Example 2. Suppose the average environmental preference for each group is such that

$$\beta_C = 0.02 < \beta_W = 0.18 < \bar{\beta} = 0.2 < \beta_E = 0.52,$$

with

$$m_1\beta_C + m_2\beta_E + m_3\beta_W = 3 \times 0.02 + 2 \times 0.52 + 5 \times 0.18 = 2 = 10 \times 0.2 = n\bar{\beta}$$

and $\gamma = 1$, then the political economy equilibrium tax can be solved as

$$t^{**} = 3.4101 \in \left(\mu = 2.5, \frac{2n^2 A + \mu(n+2)^2}{3n^2 + 4n + 4} = 3.9535\right).$$

Thus, we have

$$\hat{L}(t^{**}) = 1.7554, \quad \hat{Y}(t^{**}) = 2.6498, \quad \hat{Q}(t^{**}) = 0.9101, \quad \hat{Z}(t^{**}) = 1.7398,$$

and the Pigovian tax is

$$t^* = n\bar{\beta}\gamma\hat{Z} = 3.4795 > t^{**} = 3.4101.$$

Example 2 shows that when $\beta_W < \bar{\beta}$ but $D'(\hat{Z})$ is small enough (i.e., $\gamma = 1$), the political economy equilibrium tax on the externality is below the Pigovian level.

Example 3. We retain the same average environmental preference for each group as in Example 2:

$$\beta_C = 0.02 < \beta_W = 0.18 < \bar{\beta} = 0.2 < \beta_E = 0.52,$$

but now $\gamma = 5$, then the political economy equilibrium tax is

$$t^{**} = 3.9219 \in \left(\mu = 2.5, \frac{2n^2 A + \mu(n+2)^2}{3n^2 + 4n + 4} = 3.9535\right).$$

Thus, we have

$$\hat{L}(t^{**}) = 0.8071, \quad \hat{Y}(t^{**}) = 1.7968, \quad \hat{Q}(t^{**}) = 1.4219, \quad \hat{Z}(t^{**}) = 0.3749,$$

and the Pigovian tax is

$$t^* = n\bar{\beta}\gamma\hat{Z} = 3.7486 < t^{**} = 3.9219.$$

Example 3 shows that when $\beta_W < \bar{\beta}$ and $D'(\hat{Z})$ is large enough (i.e., $\gamma = 5$), the political economy equilibrium tax on the externality is above Pigovian level.

1.6.2.2 Examples for political economy tariff rate

Suppose the cost function and damage function both take the quadratic forms:

$$C(I) = \frac{1}{2}I^2, \quad D(I) = \frac{\alpha}{2}I^2,$$

which will allow us to obtain an analytical solution. Then, we have

$$C'(I) = I, \quad D'(I) = \alpha I.$$

From equation (1.12), we can obtain the optimal imported waste as

$$\hat{I}(\tau) = (1-\tau)\mu,$$

and thus

$$\frac{d\hat{I}}{d\tau} = -\mu, \quad \frac{d\hat{\Pi}}{d\tau} = -\mu\hat{I}, \quad \frac{d\hat{\Pi}}{d\hat{I}} = \frac{\frac{d\hat{\Pi}(\tau)}{d\tau}}{\frac{d\hat{I}(\tau)}{d\tau}} = \hat{I}.$$

Therefore, equation (1.13) becomes

$$\left[\mu\tau - n\bar{\beta}\alpha\hat{I}\right] + \frac{1-\lambda_0}{\delta+\lambda_0}\left[(n\beta_W - n\bar{\beta})\alpha\hat{I} + \hat{I}\right] = 0.$$

For numerical illustrations, we retain some of the same parameter values used in the North:

$$n = 10, \quad \mu = 2.5, \quad m_1 = 3, \quad m_2 = 2, \quad m_3 = 5, \quad \delta = 0.5.$$

Thus,

$$\lambda_0 = \frac{m_1 + m_2}{n} = 0.5, \quad \frac{1-\lambda_0}{\delta+\lambda_0} = \frac{0.5}{0.5+0.5} = 0.5$$

Example 4. Suppose the average environmental preference for each group is such that

$$\beta_C = 0.01 < \bar{\beta} = 0.2 < \beta_W = 0.25 < \beta_E = 0.36,$$

and $\alpha = 3$, then the political economy equilibrium tariff rate can be solved as

$$\tau^{**} = 0.8261 \in [0, 1].$$

Thus, the optimal imported waste is

$$\hat{I} = 0.4348,$$

and the social optimal tariff rate is

$$\tau^* = \frac{n\bar{\beta}\alpha\hat{I}}{\mu} = 1.0435 > \tau^{**} = 0.8261.$$

Example 4 shows that when $\beta_W \geq \bar{\beta}$, the political economy equilibrium tariff rate on the imported externality is below the socially optimal one.

Example 5. Suppose the average environmental preference for each group is such that

$$\beta_C = 0.02 < \beta_W = 0.18 < \bar{\beta} = 0.2 < \beta_E = 0.52,$$

and $\alpha = 1$, then the political economy equilibrium tariff rate can be solved as

$$\tau^{**} = 0.6154 \in [0, 1].$$

Thus, the optimal imported waste is

$$\hat{I} = 0.9615,$$

and the social optimal tariff rate is

$$\tau^* = \frac{n\bar{\beta}\alpha\hat{I}}{\mu} = 0.7692 > \tau^{**} = 0.6154.$$

Example 5 shows that when $\beta_W < \bar{\beta}$ but $D'(\hat{I})$ is small enough (i.e., $\alpha = 1$), the political economy equilibrium tariff rate on the imported externality is below the socially optimal one.

Example 6. We retain the same average environmental preference for each group as in Example 5:

$$\beta_C = 0.02 < \beta_W = 0.18 < \bar{\beta} = 0.2 < \beta_E = 0.52,$$

but now $\alpha = 5$, then the political economy equilibrium tariff rate is

$$\tau^{**} = 0.9091 \in [0, 1].$$

Thus, the optimal imported waste is

$$\hat{I} = 0.2273,$$

and the social optimal tariff rate is

$$\tau^* = \frac{n\bar{\beta}\alpha\hat{I}}{\mu} = 0.9091 = \tau^{**}.$$

Example 6 shows that when $\beta_W < \bar{\beta}$ and $D'(\hat{I})$ is large enough (i.e., $\alpha = 5$), the political economy equilibrium tariff rate on the imported externality is identical to the socially optimal one.

1.6.3 Additional tables for data

Table 1.12: 87 categories of internationally traded waste by HS code

HS Code	Commodity Description
180200	Cocoa; shells, husks, skins and other cocoa waste
230320	Beet-pulp, bagasse and other waste of sugar manufacture; whether or not in the form of pellets
230330	Brewing or distilling dregs and waste; whether or not in the form of pellets
230800	Vegetable materials and vegetable waste, vegetable residues and by-products; whether or not in the form of pellets, of a kind used in animal feeding, not elsewhere specified or included
251720	Macadam of slag, dross or similar industrial waste; whether or not incorporating the materials in item no. 2517.10
252530	Mica; waste
261800	Slag, granulated (slag sand); from the manufacture or iron or steel
261900	Slag, dross; (other than granulated slag), scalings and other waste from the manufacture of iron or steel
262011	Slag, ash and residues; (not from the manufacture of iron or steel), containing mainly zinc, hard zinc spelter
262019	Slag, ash and residues; (not from the manufacture of iron or steel), containing mainly zinc, other than hard zinc spelter
262021	Slag, ash and residues; (not from the manufacture of iron or steel), containing mainly lead; leaded gasoline sludges and leaded anti-knock compound sludges
262029	Slag, ash and residues; (not from the manufacture of iron or steel), containing mainly lead; excluding leaded gasoline sludges and leaded anti-knock compound sludges
262020	Ash and residues; (not from the manufacture of iron or steel), containing mainly lead
262030	Slag, ash and residues; (not from the manufacture of iron or steel), containing mainly copper
262040	Slag, ash and residues; (not from the manufacture of iron or steel), containing mainly aluminium
262050	Ash and residues; (not from the manufacture of iron or steel), containing mainly vanadium

(To be continued)

HS Code	Commodity Description
262060	Slag, ash and residues; (not from the manufacture of iron or steel), containing arsenic, mercury, thallium or their mixtures, of a kind used for the extraction of arsenic or those metals or for the manufacture of their chemical compounds
262091	Slag, ash and residues; (not from the manufacture of iron or steel), containing antimony, beryllium, cadmium, chromium or their mixtures
262099	Slag, ash and residues; (not from the manufacture of iron or steel), containing mainly metals or their compounds, n.e.c. in heading no. 2620
262100	Slag and ash nes, including seaweed ash (kelp)
262110	Slag and ash; ash and residues from the incineration of municipal waste
262190	Slag and ash n.e.c. in chapter 26; including seaweed ash (kelp) but excluding ash and residues from the incineration of municipal waste
300680	Pharmaceutical goods; waste pharmaceuticals
300692	Pharmaceutical goods; waste pharmaceuticals
382510	Residual products of the chemical or allied industries, not elsewhere specified or included; municipal waste
382520	Residual products of the chemical or allied industries, not elsewhere specified or included; sewage sludge
382530	Residual products of the chemical or allied industries, not elsewhere specified or included; clinical waste
382541	Residual products of the chemical or allied industries, not elsewhere specified or included; halogenated waste organic solvents
382549	Residual products of the chemical or allied industries, not elsewhere specified or included; waste organic solvents, other than halogenated
382550	Residual products of chemical or allied industries, not elsewhere specified or included; wastes of metal pickling liquors, hydraulic fluids, brake fluids and anti-freeze fluids
382561	Residual products of the chemical or allied industries, not elsewhere specified or included; (other than sewage sludge, municipal waste or waste covered in 27.10); other wastes n.e.c. in 3825; those mainly containing organic constituents
382569	Residual products of the chemical or allied industries, not elsewhere specified or included; (other than sewage sludge, municipal waste or waste covered by 27.10); other wastes n.e.c. in 3825; except those mainly containing organic constituents
391510	Ethylene polymers; waste, parings and scrap
391520	Styrene polymers; waste, parings and scrap
391530	Vinyl chloride polymers; waste, parings and scrap
391590	Plastics n.e.c. in heading no. 3915; waste, parings and scrap
400400	Rubber; waste, parings and scrap of rubber (other than hard rubber) and powders and granules obtained therefrom

(To be continued)

HS Code	Commodity Description
411520	Leather; parings and other waste, of leather or composition leather; not suitable for the manufacture of leather articles; leather dust, powder and flour
450190	Cork; waste cork, crushed, granulated or ground cork
470710	Paper or paperboard; waste and scrap, of unbleached kraft paper or paperboard or corrugated paper or paperboard
470720	Paper or paperboard; waste and scrap, paper or paperboard made mainly of bleached chemical pulp, not coloured in the mass
470730	Paper or paperboard; waste and scrap, paper or paperboard made mainly of mechanical pulp (e.g. newspapers, journals and similar printed matter)
470790	Paper or paperboard; waste and scrap, of paper or paperboard n.e.c. in heading no. 4707 and of unsorted waste and scrap
500300	Silk waste (including cocoons unsuitable for reeling, yarn waste and garnetted stock)
510320	Wool and hair; waste of wool or of fine animal hair, including yarn waste, but excluding garnetted stock and noils of wool or of fine animal hair
520210	Cotton; yarn waste (including thread waste)
520291	Cotton; garnetted stock waste
520299	Cotton; waste other than garnetted stock and yarn (including thread) waste
530130	Flax; tow and waste, including yarn waste and garnetted stock
550510	Fibres; waste (including noils, yarn waste and garnetted stock), of synthetic fibres
550520	Fibres; waste (including noils, yarn waste and garnetted stock), of artificial fibres
700100	Glass; cullet and other waste and scrap of glass, glass in the mass
711230	Waste and scrap of precious metal or of metal clad with precious metal; ash containing precious metal or precious metal compounds
711291	Waste and scrap of precious metals; of gold, including metal clad with gold but excluding sweepings containing other precious metals
711292	Waste and scrap of precious metals; of platinum, including metal clad with platinum but excluding sweepings containing other precious metals
711299	Waste and scrap of precious metals; waste and scrap of precious metals including metal clad with precious metals, other than that of gold and platinum and excluding ash which contains precious metal or precious metal compounds
720410	Ferrous waste and scrap; of cast iron
720421	Ferrous waste and scrap; of stainless steel
720429	Ferrous waste and scrap; of alloy steel (excluding stainless)
720430	Ferrous waste and scrap; of tinned iron or steel
720441	Ferrous waste and scrap; turnings, shavings, chips, milling waste, sawdust, fillings, trimmings and stampings, whether or not in bundles
720449	Ferrous waste and scrap; n.e.c. in heading no. 7204
740400	Copper; waste and scrap
750300	Nickel; waste and scrap

(To be continued)

HS Code	Commodity Description
760200	Aluminium; waste and scrap
780200	Lead; waste and scrap
790200	Zinc; waste and scrap
800200	Tin; waste and scrap
810197	Tungsten (wolfram); waste and scrap
810297	Molybdenum; waste and scrap
810330	Tantalum; waste and scrap
810420	Magnesium; waste and scrap
810530	Cobalt; waste and scrap
810730	Cadmium; waste and scrap
810830	Titanium; waste and scrap
810930	Zirconium; waste and scrap
811020	Antimony; waste and scrap
811213	Beryllium; waste and scrap
811222	Chromium; waste and scrap
811252	Thallium; waste and scrap
854810	Waste and scrap of primary cells, primary batteries and electric accumulators; spent primary cells, spent primary batteries and spent electric accumulators

Table 1.13: Country list

35 developed countries				
Australia	Austria	Belgium	Canada	Cyprus
Czechia	Denmark	Estonia	Finland	France
Hong Kong SAR, China	Germany	Greece	Iceland	Ireland
Israel	Italy	Japan	Latvia	Lithuania
Luxembourg	Malta	Netherlands	New Zealand	Norway
Portugal	Singapore	Slovakia	Slovenia	South Korea
Spain	Sweden	Switzerland	United Kingdom	United States
87 developing countries				
Albania	Algeria	Argentina	Armenia	Azerbaijan
Bahrain	Bangladesh	Belarus	Benin	Bolivia
Bosnia and Herzegovina	Botswana	Brazil	Bulgaria	Cambodia
Cameroon	Chile	China	Colombia	Congo
Costa Rica	Croatia	Côte dIvoire	Dominican Republic	Ecuador
Egypt	El Salvador	Ethiopia	Gabon	Georgia
Ghana	Guatemala	Haiti	Honduras	Hungary
India	Indonesia	Iran	Jamaica	Jordan
Kazakhstan	Kenya	Kuwait	Kyrgyzstan	Lebanon
Malaysia	Mauritius	Mexico	Moldova	Mongolia
Morocco	Mozambique	Namibia	Nepal	Nicaragua
Nigeria	North Macedonia	Oman	Pakistan	Panama
Paraguay	Peru	Philippines	Poland	Qatar
Romania	Russia	Saudi Arabia	Senegal	South Africa
Sri Lanka	Sudan	Syria	Tanzania	Thailand
Togo	Trinidad and Tobago	Tunisia	Turkey	Ukraine
United Arab Emirates	Uruguay	Venezuela	Vietnam	Yemen
Zambia	Zimbabwe			

Notes: There is no commonly agreed-upon definition of what constitutes a developed and developing country in the literature. IMF's definition is used to identify a country's status, in which an advanced economy is categorized as a developed country while a nation is designated as a developing country if it possesses an emerging or developing economy. IMF takes several different factors into account when determining whether a nation is an advanced economy, an emerging market and developing economy, or a low-income developing economy. The main three criteria are: (1) per capita income level, (2) export diversification – so oil exporters that have high per capita GDP would not make the advanced classification because around 70% of their exports are oil, and (3) degree of integration into the global financial system. For details, please refer to https://www.imf.org/external/pubs/ft/weo/faq.htm.

Table 1.14: Definition of variables and data source

Variable	Definition	Source
Waste trade	Aggregate waste exports in tonnes between bilateral country pairs	UN Comtrade database
ENGO	Environmental lobbying strength, proxied by the total number of ENGOs	World Directory of Environmental Organizations; Encyclopedia of Associations: International Organizations
Industry	Industry lobbying strength, proxied by the commercial energy use (kg of oil equivalent per capita)	World Bank's World Development Indicators(WDI) database
GDP	Gross domestic product in billion dollars	WDI
Population	Population in millions	WDI
Capital/labour	Capital per worker in dollars	WDI; International Monetary Fund (IMF)
Distance	Bilateral distance between country pairs in km	Centre d'Études Prospectives et d'Informations Internationales (CEPII)
Common border	Dummy variable indicating whether both countries share a common border	CEPII
Common language	Dummy variable indicating whether both countries share a common language	CEPII
Colonial ties	Dummy variable indicating whether both countries had colonial ties	CEPII
Basel	Dummy variable indicating whether both countries had ratified the Basel Convention	Basel Convention website
WTO	Dummy variable indicating whether both countries had joined the WTO	WTO website
RTA	Dummy variable indicating whether both countries were in regional trade agreements	Prof. Mario Larch's website

Table 1.15: Descriptive statistics for North-to-South waste trade

	Obs.	Mean	S.D.	Min	Max
North-to-South waste exports	17,525	48,431.264	459,515.061	0.001	23698532.000
ENGO exporter	60,761	33.292	40.213	0.000	196.000
ENGO importer	60,761	8.516	6.289	0.000	29.000
Industry exporter	60,761	4,313.295	2,154.642	1,546.682	18,157.598
Industry importer	60,551	1,743.814	2,793.187	122.727	22,120.430
GDP exporter	60,152	894.863	2,060.840	2.709	15,542.600
GDP importer	60,271	117.990	381.699	0.652	7,551.500
Population exporter	60,761	27.210	52.266	0.261	311.557
Population importer	60,656	55.414	177.876	0.495	1,344.130
Capital/labour exporter	60,761	162,247.940	68,528.565	25,831.807	408,884.688
Capital/labour importer	60,656	51,887.886	66,419.309	0.000	647,583.312
Distance	60,761	7,122.088	3,982.239	111.093	19,747.404
Common border	60,761	0.009	0.093	0.000	1.000
Common language	60,761	0.084	0.278	0.000	1.000
Colonial ties	60,761	0.024	0.152	0.000	1.000
WTO	60,761	0.650	0.477	0.000	1.000
RTA	60,761	0.139	0.346	0.000	1.000
Basel	60,761	0.737	0.440	0.000	1.000

Notes: The table shows summary statistics for all the variables in the sample. For a detailed description of how each variable is defined and sourced, please refer to Table 1.14.

1.6.4 Additional gravity specification results

Table 1.16: Exporter side only waste regression specifications

	Dependent variable: ln (North-to-South waste exports)						
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln (ENGO exporter)	0.240**	0.002	-0.453***	-0.328*	-0.657***	-0.660***	-0.627***
	(0.109)	(0.124)	(0.158)	(0.172)	(0.179)	(0.168)	(0.168)
ln (Industry exporter)		1.198***	1.211***	1.470***	1.433***	1.546***	1.688***
		(0.266)	(0.265)	(0.284)	(0.282)	(0.275)	(0.272)
ln (Population exporter)			0.430***	1.042***	-0.516	-0.745**	-0.642*
			(0.086)	(0.212)	(0.342)	(0.334)	(0.330)
ln (GDP exporter)				-0.627***	1.026***	1.303***	1.228***
				(0.210)	(0.359)	(0.348)	(0.346)
ln (Capital/labour exporter)					-2.347***	-2.319***	-2.372***
					(0.429)	(0.431)	(0.428)
ln (Distance)						-0.329***	-0.389***
						(0.106)	(0.120)
Common border						3.194***	3.194***
						(0.679)	(0.657)
Common language						0.114	0.051
						(0.313)	(0.309)
Colonial ties						0.336	0.313
						(0.447)	(0.432)
WTO							1.146***
							(0.153)
RTA							0.236
							(0.194)
Basel							0.472**
							(0.214)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17525	17525	17525	17512	17512	17512	17512
R^2	0.007	0.017	0.030	0.033	0.044	0.073	0.088

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. The variables *ENGO*, *Industry*, *Population*, *GDP* and *Capital/labour* represent the environmental lobbying strength (proxied by the total number of ENGOs), industry lobbying strength (proxied by the commercial energy use, kg of oil equivalent per capita), population (in millions), gross domestic product (in billion dollars), and capital per worker (in dollars), respectively. The variable *Distance* represents the bilateral distance between country pairs in km, and *Common border*, *Common language* , *Colonial ties*, *WTO*, *RTA* and *Basel* are dummy variables indicating whether both countries share a common border, a common language, had colonial ties, had joined the WTO, were in some regional trade agreements, and had ratified the Basel Convention, respectively.

Table 1.17: Importer side only waste regression specifications

	Dependent variable: ln (North-to-South waste exports)						
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln (ENGO importer)	1.215***	1.200***	-0.068	-0.320**	-0.318**	-0.608***	-0.837***
	(0.102)	(0.102)	(0.125)	(0.130)	(0.131)	(0.123)	(0.124)
ln (Industry importer)		-0.139*	0.331***	-0.256*	-0.312**	-0.577***	-0.312**
		(0.079)	(0.082)	(0.139)	(0.143)	(0.141)	(0.136)
ln (Population importer)			0.910***	0.369***	0.531***	0.456***	0.748***
			(0.063)	(0.119)	(0.148)	(0.143)	(0.133)
ln (GDP importer)				0.689***	0.519***	0.730***	0.571***
				(0.130)	(0.157)	(0.153)	(0.144)
ln (Capital/labour importer)					0.252*	0.278**	0.320***
					(0.135)	(0.127)	(0.114)
ln (Distance)						-0.528***	-0.668***
						(0.102)	(0.109)
Common border						2.542***	2.307***
						(0.611)	(0.546)
Common language						0.422*	0.187
						(0.249)	(0.234)
Colonial ties						0.531	0.751**
						(0.378)	(0.356)
WTO							1.457***
							(0.163)
RTA							0.303*
							(0.181)
Basel							-1.617***
							(0.201)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17437	17417	17417	17332	17322	17322	17322
R^2	0.051	0.052	0.142	0.151	0.153	0.188	0.221

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. The variables *ENGO*, *Industry*, *Population*, *GDP* and *Capital/labour* represent the environmental lobbying strength (proxied by the total number of ENGOs), industry lobbying strength (proxied by the commercial energy use, kg of oil equivalent per capita), population (in millions), gross domestic product (in billion dollars), and capital per worker (in dollars), respectively. The variable *Distance* represents the bilateral distance between country pairs in km, and *Common border*, *Common language* , *Colonial ties*, *WTO*, *RTA* and *Basel* are dummy variables indicating whether both countries share a common border, a common language, had colonial ties, had joined the WTO, were in some regional trade agreements, and had ratified the Basel Convention, respectively.

Table 1.18: Gravity waste regression specifications

	Dependent variable: ln (North-to-South waste exports)						
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln (ENGO exporter)	0.365***	0.112	-0.270**	-0.150	-0.385**	-0.373***	-0.352***
	(0.106)	(0.120)	(0.136)	(0.146)	(0.155)	(0.137)	(0.133)
ln (ENGO importer)	1.272***	1.273***	0.001	-0.257**	-0.231*	-0.631***	-0.874***
	(0.105)	(0.103)	(0.122)	(0.127)	(0.128)	(0.114)	(0.117)
ln (Industry exporter)		1.248***	1.134***	1.385***	1.375***	1.709***	1.723***
		(0.257)	(0.231)	(0.247)	(0.246)	(0.228)	(0.221)
ln (Industry importer)		-0.117	0.434***	-0.161	-0.231*	-0.589***	-0.297**
		(0.077)	(0.079)	(0.136)	(0.138)	(0.132)	(0.129)
ln (Population exporter)			0.574***	1.163***	0.083	-0.282	-0.211
			(0.075)	(0.198)	(0.306)	(0.289)	(0.283)
ln (Population importer)			0.984***	0.447***	0.634***	0.548***	0.849***
			(0.060)	(0.115)	(0.137)	(0.125)	(0.124)
ln (GDP exporter)				-0.608***	0.538*	1.006***	0.922***
				(0.197)	(0.319)	(0.297)	(0.292)
ln (GDP importer)				0.681***	0.465***	0.795***	0.566***
				(0.127)	(0.146)	(0.135)	(0.132)
ln (Capital/labour exporter)					-1.648***	-1.895***	-1.857***
					(0.381)	(0.370)	(0.365)
ln (Capital/labour importer)					0.313***	0.323***	0.338***
					(0.120)	(0.104)	(0.101)
ln (Distance)						-0.995***	-1.144***
						(0.099)	(0.111)
Common border						2.156***	2.055***
						(0.594)	(0.559)
Common language						0.404*	0.265
						(0.227)	(0.221)
Colonial ties						0.611*	0.685**
						(0.358)	(0.339)
WTO							1.577***
							(0.161)
RTA							0.027
							(0.179)
Basel							-0.234
							(0.166)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17437	17417	17417	17319	17309	17309	17309
R^2	0.058	0.070	0.189	0.202	0.208	0.271	0.289

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. The variables *ENGO*, *Industry*, *Population*, *GDP* and *Capital/labour* represent the environmental lobbying strength (proxied by the total number of ENGOs), industry lobbying strength (proxied by the commercial energy use, kg of oil equivalent per capita), population (in millions), gross domestic product (in billion dollars), and capital per worker (in dollars), respectively. The variable *Distance* represents the bilateral distance between country pairs in km, and *Common border*, *Common language* , *Colonial ties*, *WTO*, *RTA* and *Basel* are dummy variables indicating whether both countries share a common border, a common language, had colonial ties, had joined the WTO, were in some regional trade agreements, and had ratified the Basel Convention, respectively.

1.6.5 Additional triple-difference estimation results

1.6.5.1 Exporter side specification

Table 1.19: Triple-difference exporter side regression specifications

	Dependent variable: ln (North-to-South waste exports)						
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment	-2.356***	-2.431***	-1.788**	-2.832***	-2.149**	-2.586***	-2.817***
	(0.805)	(0.799)	(0.827)	(0.866)	(0.868)	(0.835)	(0.833)
Post	-1.379***	-1.461***	-1.586***	-1.241***	-1.793***	-1.825***	-1.888***
	(0.364)	(0.359)	(0.363)	(0.374)	(0.391)	(0.383)	(0.377)
ln (ENGO exporter)	-0.013	-0.233	-0.639***	-0.611***	-0.931***	-0.895***	-0.841***
	(0.142)	(0.155)	(0.175)	(0.174)	(0.176)	(0.164)	(0.163)
Treatment* Post	2.802***	2.805***	3.161***	3.395***	3.076***	3.284***	3.280***
	(0.575)	(0.573)	(0.583)	(0.586)	(0.597)	(0.595)	(0.591)
Treatment* ln (ENGO exporter)	0.443**	0.539**	0.420*	0.689***	0.620***	0.698***	0.744***
	(0.215)	(0.213)	(0.219)	(0.229)	(0.230)	(0.224)	(0.223)
Post* ln (ENGO exporter)	0.468***	0.487***	0.515***	0.513***	0.542***	0.540***	0.535***
	(0.090)	(0.090)	(0.090)	(0.091)	(0.094)	(0.093)	(0.091)
Treatment* Post* ln (ENGO exporter)	-0.811***	-0.799***	-0.885***	-0.928***	-0.874***	-0.927***	-0.916***
	(0.152)	(0.153)	(0.155)	(0.155)	(0.158)	(0.158)	(0.156)
ln (Industry exporter)		0.948***	1.053***	1.447***	1.671***	1.715***	1.718***
		(0.285)	(0.285)	(0.303)	(0.299)	(0.289)	(0.284)
ln (Population exporter)			0.413***	1.143***	-0.090	-0.152	0.052
			(0.088)	(0.191)	(0.241)	(0.234)	(0.239)
ln (GDP exporter)				-0.754***	0.598**	0.691***	0.462*
				(0.185)	(0.245)	(0.236)	(0.242)
ln (Capital/labour exporter)					-2.156***	-1.925***	-1.771***
					(0.349)	(0.352)	(0.350)
ln (Distance)						-0.331***	-0.346***
						(0.108)	(0.121)
Common border						3.263***	3.237***
						(0.671)	(0.652)
Common language						0.053	-0.036
						(0.311)	(0.310)
Colonial ties						0.216	0.229
						(0.453)	(0.445)
WTO							0.762***
							(0.129)
RTA							0.219
							(0.192)
Basel							-0.098
							(0.183)
Observations	17525	17525	17525	17512	17512	17512	17512
R^2	0.015	0.020	0.031	0.037	0.046	0.075	0.083

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is equal to or greater than 2006. ENGO uses the number of ENGOs in 2005. The variables *Industry*, *Population*, *GDP* and *Capital/labour* represent the industry lobbying strength (proxied by the commercial energy use, kg of oil equivalent per capita), population (in millions), gross domestic product (in billion dollars), and capital per worker (in dollars), respectively. The variable *Distance* represents the bilateral distance between country pairs in km, and *Common border*, *Common language* , *Colonial ties*, *WTO*, *RTA* and *Basel* are dummy variables indicating whether both countries share a common border, common language, had colonial ties, had joined the WTO, were in some regional trade agreements, and had ratified the Basel Convention, respectively.

Table 1.20: Triple-difference exporter side regression specifications with year FE

	Dependent variable: ln (North-to-South waste exports)						
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment	-2.310***	-2.376***	-1.742**	-2.980***	-1.785*	-2.159**	-1.999**
	(0.804)	(0.798)	(0.826)	(0.890)	(0.918)	(0.886)	(0.879)
ln (ENGO exporter)	-0.016	-0.248	-0.650***	-0.610***	-1.000***	-0.974***	-0.931***
	(0.141)	(0.154)	(0.174)	(0.175)	(0.182)	(0.170)	(0.168)
Treatment* Post	2.745***	2.735***	3.092***	3.414***	2.880***	3.065***	3.067***
	(0.572)	(0.571)	(0.580)	(0.586)	(0.601)	(0.598)	(0.593)
Treatment* ln (ENGO exporter)	0.434**	0.532**	0.415*	0.731***	0.549**	0.615***	0.557**
	(0.214)	(0.213)	(0.219)	(0.235)	(0.239)	(0.232)	(0.231)
Post* ln (ENGO exporter)	0.470***	0.491***	0.519***	0.513***	0.552***	0.551***	0.585***
	(0.090)	(0.090)	(0.090)	(0.091)	(0.096)	(0.094)	(0.093)
Treatment* Post* ln (ENGO exporter)	-0.800***	-0.784***	-0.870***	-0.934***	-0.833***	-0.882***	-0.883***
	(0.152)	(0.152)	(0.154)	(0.155)	(0.158)	(0.158)	(0.157)
ln (Industry exporter)		0.994***	1.096***	1.514***	1.699***	1.748***	1.841***
		(0.289)	(0.288)	(0.306)	(0.300)	(0.289)	(0.286)
ln (Population exporter)			0.410***	1.250***	-0.419	-0.534	-0.442
			(0.088)	(0.219)	(0.356)	(0.346)	(0.339)
ln (GDP exporter)				-0.865***	0.945**	1.094***	1.028***
				(0.218)	(0.375)	(0.363)	(0.358)
ln (Capital/labour exporter)					-2.484***	-2.307***	-2.328***
					(0.442)	(0.443)	(0.437)
ln (Distance)						-0.336***	-0.423***
						(0.108)	(0.122)
Common border						3.256***	3.210***
						(0.668)	(0.649)
Common language						0.066	-0.018
						(0.309)	(0.306)
Colonial ties						0.250	0.270
						(0.451)	(0.437)
WTO							1.178***
							(0.153)
RTA							0.151
							(0.192)
Basel							0.425**
							(0.210)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17525	17525	17525	17512	17512	17512	17512
R^2	0.017	0.023	0.034	0.040	0.050	0.079	0.093

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is equal to or greater than 2006. ENGO uses the number of ENGOs in 2005. The variables *Industry*, *Population*, *GDP* and *Capital/labour* represent the industry lobbying strength (proxied by the commercial energy use, kg of oil equivalent per capita), population (in millions), gross domestic product (in billion dollars), and capital per worker (in dollars), respectively. The variable *Distance* represents the bilateral distance between country pairs in km, and *Common border*, *Common language* , *Colonial ties*, *WTO*, *RTA* and *Basel* are dummy variables indicating whether both countries share a common border, common language, had colonial ties, had joined the WTO, were in some regional trade agreements, and had ratified the Basel Convention, respectively.

Table 1.21: Triple-difference exporter side regression specifications with exporter FE

	Dependent variable: ln (North-to-South waste exports)						
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Post	-1.538***	-1.587***	-1.320***	-1.316***	-1.315***	-1.219***	-0.973***
	(0.361)	(0.363)	(0.364)	(0.364)	(0.363)	(0.356)	(0.353)
ln (ENGO exporter)	0.516	-0.303	0.432	3.935**	3.927**	5.678***	5.687***
	(0.325)	(0.415)	(0.518)	(1.718)	(1.727)	(1.695)	(1.054)
Treatment* Post	2.701***	2.623***	2.336***	2.323***	2.332***	2.437***	2.834***
	(0.576)	(0.575)	(0.571)	(0.584)	(0.596)	(0.588)	(0.591)
Treatment* ln (ENGO exporter)	-0.220	-0.034	0.245	-0.357*	-0.352	-0.604***	-1.975***
	(0.174)	(0.203)	(0.240)	(0.210)	(0.215)	(0.214)	(0.319)
Post* ln (ENGO exporter)	0.516***	0.529***	0.505***	0.504***	0.504***	0.475***	0.457***
	(0.091)	(0.091)	(0.090)	(0.091)	(0.091)	(0.089)	(0.088)
Treatment* Post* ln (ENGO exporter)	-0.785***	-0.759***	-0.709***	-0.707***	-0.710***	-0.744***	-0.889***
	(0.154)	(0.154)	(0.152)	(0.155)	(0.159)	(0.157)	(0.158)
ln (Industry exporter)		0.506	0.609	0.595	0.613	0.409	-0.399
		(0.434)	(0.437)	(0.457)	(0.463)	(0.459)	(0.480)
ln (Population exporter)			-1.905**	-2.052**	-2.058**	-3.121***	-4.705***
			(0.849)	(1.028)	(1.022)	(1.004)	(1.037)
ln (GDP exporter)				0.028	0.036	0.192	-0.239
				(0.169)	(0.176)	(0.173)	(0.178)
ln (Capital/labour exporter)					-0.058	0.350	-0.258
					(0.488)	(0.479)	(0.495)
ln (Distance)						-0.460***	-0.435***
						(0.109)	(0.119)
Common border						2.846***	2.831***
						(0.697)	(0.657)
Common language						-0.048	-0.088
						(0.300)	(0.296)
Colonial ties						0.597	0.634
						(0.460)	(0.444)
WTO							0.807***
							(0.123)
RTA							0.413**
							(0.178)
Basel							0.659***
							(0.131)
Exporter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17525	17525	17525	17512	17512	17512	17512
R^2	0.115	0.115	0.116	0.116	0.116	0.145	0.158

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is equal to or greater than 2006. ENGO uses the number of ENGOs in 2005. The variables *Industry*, *Population*, *GDP* and *Capital/labour* represent the industry lobbying strength (proxied by the commercial energy use, kg of oil equivalent per capita), population (in millions), gross domestic product (in billion dollars), and capital per worker (in dollars), respectively. The variable *Distance* represents the bilateral distance between country pairs in km, and *Common border*, *Common language* , *Colonial ties*, *WTO*, *RTA* and *Basel* are dummy variables indicating whether both countries share a common border, common language, had colonial ties, had joined the WTO, were in some regional trade agreements, and had ratified the Basel Convention, respectively.

Table 1.22: Triple-difference exporter side regression specifications with importer FE

	Dependent variable: ln (North-to-South waste exports)						
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment	-2.659***	-2.791***	-1.732***	-2.539***	-2.029***	-1.833***	-2.147***
	(0.648)	(0.626)	(0.631)	(0.642)	(0.653)	(0.566)	(0.562)
Post	-1.169***	-1.276***	-1.479***	-1.213***	-1.629***	-1.449***	-1.318***
	(0.374)	(0.368)	(0.369)	(0.372)	(0.386)	(0.391)	(0.383)
ln (ENGO exporter)	0.368***	0.093	-0.586***	-0.565***	-0.808***	-0.532***	-0.635***
	(0.116)	(0.125)	(0.135)	(0.134)	(0.140)	(0.124)	(0.122)
Treatment* Post	2.252***	2.263***	2.872***	3.071***	2.839***	2.774***	2.504***
	(0.578)	(0.576)	(0.583)	(0.582)	(0.593)	(0.597)	(0.584)
Treatment* ln (ENGO exporter)	0.627***	0.755***	0.567***	0.775***	0.723***	0.626***	0.751***
	(0.169)	(0.167)	(0.167)	(0.170)	(0.173)	(0.147)	(0.148)
Post* ln (ENGO exporter)	0.466***	0.492***	0.541***	0.539***	0.562***	0.536***	0.507***
	(0.091)	(0.090)	(0.090)	(0.089)	(0.093)	(0.094)	(0.092)
Treatment* Post* ln (ENGO exporter)	-0.702***	-0.689***	-0.838***	-0.876***	-0.837***	-0.852***	-0.778***
	(0.151)	(0.151)	(0.152)	(0.152)	(0.154)	(0.155)	(0.152)
ln (Industry exporter)		1.170***	1.362***	1.675***	1.848***	2.176***	2.141***
		(0.236)	(0.224)	(0.238)	(0.240)	(0.214)	(0.212)
ln (Population exporter)			0.717***	1.283***	0.353*	0.239	0.084
			(0.065)	(0.164)	(0.199)	(0.184)	(0.189)
ln (GDP exporter)				-0.587***	0.432**	0.620***	0.724***
				(0.158)	(0.198)	(0.181)	(0.187)
ln (Capital/labour exporter)					-1.636***	-1.611***	-1.698***
					(0.289)	(0.274)	(0.276)
ln (Distance)						-1.804***	-1.803***
						(0.132)	(0.134)
Common border						2.030***	1.970***
						(0.497)	(0.491)
Common language						0.370*	0.353*
						(0.200)	(0.198)
Colonial ties						0.444	0.480*
						(0.283)	(0.281)
WTO							0.300***
							(0.103)
RTA							-0.065
							(0.182)
Basel							-0.859***
							(0.121)
Importer FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17525	17525	17525	17512	17512	17512	17512
R^2	0.281	0.289	0.321	0.325	0.331	0.409	0.413

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is equal to or greater than 2006. ENGO uses the number of ENGOs in 2005. The variables *Industry*, *Population*, *GDP* and *Capital/labour* represent the industry lobbying strength (proxied by the commercial energy use, kg of oil equivalent per capita), population (in millions), gross domestic product (in billion dollars), and capital per worker (in dollars), respectively. The variable *Distance* represents the bilateral distance between country pairs in km, and *Common border*, *Common language* , *Colonial ties*, *WTO*, *RTA* and *Basel* are dummy variables indicating whether both countries share a common border, common language, had colonial ties, had joined the WTO, were in some regional trade agreements, and had ratified the Basel Convention, respectively.

Table 1.23: Triple-difference exporter side regression specifications with all FE

	Dependent variable: ln (North-to-South waste exports)						
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln (ENGO exporter)	1.449***	-0.599*	-0.756	0.194	0.138	2.034	1.254
	(0.203)	(0.308)	(0.660)	(2.142)	(2.135)	(2.100)	(1.261)
Treatment* Post	2.356***	2.033***	2.081***	2.302***	2.275***	2.246***	2.097***
	(0.565)	(0.556)	(0.560)	(0.572)	(0.582)	(0.579)	(0.575)
Treatment* ln (ENGO exporter)	-0.126	0.389***	0.333*	0.573***	0.565***	0.241	-0.554***
	(0.098)	(0.132)	(0.171)	(0.171)	(0.172)	(0.167)	(0.149)
Post* ln (ENGO exporter)	0.519***	0.570***	0.577***	0.571***	0.570***	0.500***	0.469***
	(0.085)	(0.086)	(0.086)	(0.086)	(0.086)	(0.086)	(0.086)
Treatment* Post* ln (ENGO exporter)	-0.743***	-0.640***	-0.647***	-0.702***	-0.692***	-0.719***	-0.670***
	(0.150)	(0.148)	(0.148)	(0.151)	(0.155)	(0.155)	(0.154)
ln (Industry exporter)		1.933***	1.971***	2.157***	2.101***	1.960***	1.983***
		(0.497)	(0.504)	(0.514)	(0.515)	(0.510)	(0.508)
ln (Population exporter)			0.412	0.485	0.548	-0.425	-0.424
			(1.165)	(1.199)	(1.189)	(1.169)	(1.163)
ln (GDP exporter)				-0.366	-0.397	-0.285	-0.328
				(0.280)	(0.282)	(0.276)	(0.273)
ln (Capital/labour exporter)					0.198	0.650	0.672
					(0.519)	(0.511)	(0.508)
ln (Distance)						-1.953***	-1.933***
						(0.117)	(0.124)
Common border						1.533***	1.530***
						(0.534)	(0.532)
Common language						0.156	0.158
						(0.195)	(0.194)
Colonial ties						0.956***	0.959***
						(0.286)	(0.287)
WTO							0.340**
							(0.141)
RTA							0.124
							(0.162)
Basel							-0.444***
							(0.115)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exporter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17525	17525	17525	17512	17512	17512	17512
R^2	0.403	0.404	0.404	0.405	0.405	0.482	0.483

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is equal to or greater than 2006. ENGO uses the number of ENGOs in 2005. The variables *Industry*, *Population*, *GDP* and *Capital/labour* represent the industry lobbying strength (proxied by the commercial energy use, kg of oil equivalent per capita), population (in millions), gross domestic product (in billion dollars), and capital per worker (in dollars), respectively. The variable *Distance* represents the bilateral distance between country pairs in km, and *Common border*, *Common language* , *Colonial ties*, *WTO*, *RTA* and *Basel* are dummy variables indicating whether both countries share a common border, common language, had colonial ties, had joined the WTO, were in some regional trade agreements, and had ratified the Basel Convention, respectively.

1.6.5.2 Gravity specification

Table 1.24: Triple-difference gravity regression specifications

	Dependent variable: ln (North-to-South waste exports)							
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	-2.356***	-2.867***	-2.869***	-1.659**	-2.900***	-2.324***	-2.822***	-3.341***
	(0.805)	(0.786)	(0.774)	(0.733)	(0.747)	(0.760)	(0.687)	(0.669)
Post	-1.379***	-1.450***	-1.517***	-1.799***	-1.915***	-2.198***	-2.333***	-2.280***
	(0.364)	(0.374)	(0.368)	(0.375)	(0.392)	(0.400)	(0.395)	(0.383)
ln (ENGO exporter)	-0.013	0.079	-0.146	-0.528***	-0.517***	-0.775***	-0.676***	-0.739***
	(0.142)	(0.139)	(0.151)	(0.158)	(0.157)	(0.161)	(0.138)	(0.132)
Treatment* Post	2.802***	2.988***	2.973***	3.349***	3.654***	3.389***	3.553***	3.323***
	(0.575)	(0.586)	(0.584)	(0.591)	(0.598)	(0.608)	(0.615)	(0.598)
Treatment* ln (ENGO exporter)	0.443**	0.573***	0.655***	0.476**	0.807***	0.741***	0.816***	0.978***
	(0.215)	(0.207)	(0.205)	(0.193)	(0.196)	(0.199)	(0.182)	(0.179)
Post* ln (ENGO exporter)	0.468***	0.433***	0.453***	0.532***	0.543***	0.575***	0.570***	0.558***
	(0.090)	(0.092)	(0.091)	(0.091)	(0.092)	(0.094)	(0.094)	(0.091)
Treatment* Post* ln (ENGO exporter)	-0.811***	-0.859***	-0.842***	-0.927***	-0.997***	-0.952***	-1.009***	-0.936***
	(0.152)	(0.155)	(0.155)	(0.155)	(0.157)	(0.159)	(0.162)	(0.157)
ln (ENGO importer)		1.189***	1.183***	-0.065	-0.297**	-0.293**	-0.676***	-0.866***
		(0.100)	(0.099)	(0.113)	(0.120)	(0.120)	(0.108)	(0.114)
ln (Industry exporter)			0.972***	1.194***	1.650***	1.823***	2.024***	2.032***
			(0.280)	(0.253)	(0.275)	(0.274)	(0.249)	(0.241)
ln (Industry importer)			-0.119	0.442***	-0.178	-0.243*	-0.589***	-0.402***
			(0.076)	(0.079)	(0.133)	(0.137)	(0.131)	(0.128)
ln (Population exporter)				0.585***	1.394***	0.406*	0.324	0.383*
				(0.077)	(0.185)	(0.236)	(0.219)	(0.218)
ln (Population importer)				1.003***	0.433***	0.690***	0.622***	0.846***
				(0.059)	(0.111)	(0.131)	(0.121)	(0.119)
ln (GDP exporter)					-0.840***	0.243	0.393*	0.282
					(0.178)	(0.237)	(0.219)	(0.216)
ln (GDP importer)					0.710***	0.429***	0.728***	0.583***
					(0.121)	(0.139)	(0.129)	(0.126)
ln (Capital/labour exporter)						-1.672***	-1.548***	-1.502***
						(0.331)	(0.313)	(0.308)
ln (Capital/labour importer)						0.370***	0.393***	0.439***
						(0.121)	(0.105)	(0.102)
ln (Distance)							-0.981***	-1.119***
							(0.101)	(0.112)
Common border							2.295***	2.153***
							(0.590)	(0.561)
Common language							0.396*	0.247
							(0.229)	(0.221)
Colonial ties							0.408	0.466
							(0.363)	(0.346)
WTO								1.255***
								(0.133)
RTA								-0.072
								(0.175)
Basel								-0.813***
								(0.154)
Observations	17525	17437	17417	17417	17319	17309	17309	17309
R^2	0.015	0.062	0.068	0.190	0.206	0.213	0.274	0.290

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is equal to or greater than 2006. ENGO uses the number of ENGOs in 2005. The variables *Industry*, *Population*, *GDP* and *Capital/labour* represent the industry lobbying strength (proxied by the commercial energy use, kg of oil equivalent per capita), population (in millions), gross domestic product (in billion dollars), and capital per worker (in dollars), respectively. The variable *Distance* represents the bilateral distance between country pairs in km, and *Common border*, *Common language* , *Colonial ties*, *WTO*, *RTA* and *Basel* are dummy variables indicating whether both countries share a common border, common language, had colonial ties, had joined the WTO, were in some regional trade agreements, and had ratified the Basel Convention, respectively.

Table 1.25: Triple-difference gravity regression specifications with year FE

	Dependent variable: ln (North-to-South waste exports)							
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment	-2.310***	-2.789***	-2.811***	-1.635**	-2.857***	-1.907**	-2.278***	-2.576***
	(0.804)	(0.779)	(0.767)	(0.730)	(0.759)	(0.794)	(0.720)	(0.705)
ln (ENGO exporter)	-0.016	0.074	-0.179	-0.545***	-0.527***	-0.859***	-0.782***	-0.829***
	(0.141)	(0.137)	(0.148)	(0.157)	(0.157)	(0.165)	(0.144)	(0.137)
Treatment* Post	2.745***	2.871***	2.850***	3.282***	3.608***	3.181***	3.305***	3.104***
	(0.572)	(0.582)	(0.580)	(0.588)	(0.595)	(0.609)	(0.618)	(0.602)
Treatment* ln (ENGO exporter)	0.434**	0.559***	0.655***	0.475**	0.800***	0.660***	0.708***	0.804***
	(0.214)	(0.205)	(0.203)	(0.192)	(0.199)	(0.205)	(0.187)	(0.185)
Post* ln (ENGO exporter)	0.470***	0.443***	0.466***	0.537***	0.547***	0.585***	0.582***	0.594***
	(0.090)	(0.092)	(0.091)	(0.091)	(0.092)	(0.096)	(0.096)	(0.093)
Treatment* Post* ln (ENGO exporter)	-0.800***	-0.836***	-0.816***	-0.912***	-0.988***	-0.909***	-0.958***	-0.898***
	(0.152)	(0.154)	(0.154)	(0.154)	(0.156)	(0.159)	(0.162)	(0.157)
ln (ENGO importer)		1.284***	1.288***	0.009	-0.246*	-0.233*	-0.628***	-0.849***
		(0.104)	(0.104)	(0.121)	(0.126)	(0.126)	(0.112)	(0.115)
ln (Industry exporter)			1.085***	1.247***	1.668***	1.838***	2.038***	2.103***
			(0.283)	(0.256)	(0.277)	(0.275)	(0.250)	(0.242)
ln (Industry importer)			-0.095	0.443***	-0.166	-0.244*	-0.601***	-0.336***
			(0.076)	(0.079)	(0.136)	(0.137)	(0.131)	(0.129)
ln (Population exporter)				0.582***	1.373***	-0.000	-0.204	-0.136
				(0.077)	(0.208)	(0.324)	(0.302)	(0.295)
ln (Population importer)				0.985***	0.431***	0.627***	0.537***	0.816***
				(0.060)	(0.115)	(0.139)	(0.126)	(0.124)
ln (GDP exporter)					-0.819***	0.672**	0.954***	0.864***
					(0.205)	(0.337)	(0.313)	(0.307)
ln (GDP importer)					0.697***	0.481***	0.809***	0.607***
					(0.127)	(0.147)	(0.135)	(0.132)
ln (Capital/labour exporter)						-2.072***	-2.084***	-2.067***
						(0.403)	(0.384)	(0.377)
ln (Capital/labour importer)						0.322***	0.332***	0.357***
						(0.123)	(0.106)	(0.102)
ln (Distance)							-0.989***	-1.176***
							(0.100)	(0.113)
Common border							2.252***	2.110***
							(0.586)	(0.554)
Common language							0.422*	0.272
							(0.228)	(0.220)
Colonial ties							0.441	0.497
							(0.361)	(0.340)
WTO								1.599***
								(0.161)
RTA								-0.116
								(0.176)
Basel								-0.429**
								(0.173)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17525	17437	17417	17417	17319	17309	17309	17309
R^2	0.017	0.070	0.077	0.193	0.208	0.216	0.277	0.296

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is equal to or greater than 2006. ENGO uses the number of ENGOs in 2005. The variables *Industry*, *Population*, *GDP* and *Capital/labour* represent the industry lobbying strength (proxied by the commercial energy use, kg of oil equivalent per capita), population (in millions), gross domestic product (in billion dollars), and capital per worker (in dollars), respectively. The variable *Distance* represents the bilateral distance between country pairs in km, and *Common border*, *Common language* , *Colonial ties*, *WTO*, *RTA* and *Basel* are dummy variables indicating whether both countries share a common border, common language, had colonial ties, had joined the WTO, were in some regional trade agreements, and had ratified the Basel Convention, respectively.

Table 1.26: Triple-difference gravity regression specifications with country FE

	Dependent variable: ln (North-to-South waste exports)							
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post	-1.277***	-1.188***	-1.547***	-1.561***	-1.597***	-1.645***	-1.321***	-1.271***
	(0.344)	(0.347)	(0.339)	(0.344)	(0.347)	(0.345)	(0.341)	(0.340)
ln (ENGO exporter)	1.442***	1.455***	-0.399	-0.505	3.046	2.251	4.066**	1.859*
	(0.202)	(0.203)	(0.289)	(0.523)	(2.487)	(1.932)	(1.878)	(1.101)
Treatment* Post	2.358***	2.339***	2.167***	2.181***	2.299***	2.333***	2.319***	2.156***
	(0.566)	(0.570)	(0.553)	(0.553)	(0.567)	(0.579)	(0.577)	(0.573)
Treatment* ln (ENGO exporter)	-0.124	-0.119	0.321**	0.293	0.189	0.011	-0.381**	-0.512
	(0.098)	(0.098)	(0.127)	(0.191)	(0.209)	(0.173)	(0.154)	(0.321)
Post* ln (ENGO exporter)	0.521***	0.500***	0.551***	0.554***	0.547***	0.560***	0.493***	0.465***
	(0.085)	(0.086)	(0.084)	(0.084)	(0.084)	(0.084)	(0.084)	(0.084)
Treatment* Post* ln (ENGO exporter)	-0.744***	-0.741***	-0.677***	-0.678***	-0.712***	-0.726***	-0.755***	-0.700***
	(0.150)	(0.151)	(0.147)	(0.146)	(0.149)	(0.154)	(0.153)	(0.153)
ln (ENGO importer)		-0.030	-0.288***	-0.291**	-0.264**	-0.250**	-0.260**	-0.148
		(0.106)	(0.111)	(0.119)	(0.124)	(0.125)	(0.127)	(0.134)
ln (Industry exporter)			1.427***	1.455***	1.602***	1.520***	1.452***	1.596***
			(0.431)	(0.436)	(0.446)	(0.445)	(0.439)	(0.446)
ln (Industry importer)			1.431***	1.410***	1.255***	0.827***	0.941***	0.920***
			(0.251)	(0.257)	(0.282)	(0.291)	(0.290)	(0.287)
ln (Population exporter)				0.232	0.077	-0.469	-1.371	-1.191
				(1.040)	(1.138)	(1.104)	(1.076)	(1.068)
ln (Population importer)				-0.099	-0.320	0.367	0.466	0.511
				(0.337)	(0.367)	(0.386)	(0.384)	(0.387)
ln (GDP exporter)					-0.264	-0.203	-0.082	-0.103
					(0.197)	(0.195)	(0.191)	(0.192)
ln (GDP importer)					0.283**	0.115	0.110	0.146
					(0.129)	(0.130)	(0.130)	(0.130)
ln (Capital/labour exporter)						-0.133	0.312	0.407
						(0.481)	(0.470)	(0.465)
ln (Capital/labour importer)						0.919***	1.073***	1.070***
						(0.206)	(0.207)	(0.208)
ln (Distance)							-1.989***	-1.974***
							(0.118)	(0.125)
Common border							1.519***	1.516***
							(0.537)	(0.535)
Common language							0.154	0.155
							(0.194)	(0.193)
Colonial ties							0.987***	0.988***
							(0.284)	(0.284)
WTO								0.104
								(0.103)
RTA								0.090
								(0.164)
Basel								-0.478***
								(0.108)
Exporter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17525	17437	17417	17417	17319	17309	17309	17309
R^2	0.402	0.402	0.406	0.406	0.407	0.409	0.488	0.489

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is equal to or greater than 2006. ENGO uses the number of ENGOs in 2005. The variables *Industry*, *Population*, *GDP* and *Capital/labour* represent the industry lobbying strength (proxied by the commercial energy use, kg of oil equivalent per capita), population (in millions), gross domestic product (in billion dollars), and capital per worker (in dollars), respectively. The variable *Distance* represents the bilateral distance between country pairs in km, and *Common border*, *Common language* , *Colonial ties*, *WTO*, *RTA* and *Basel* are dummy variables indicating whether both countries share a common border, common language, had colonial ties, had joined the WTO, were in some regional trade agreements, and had ratified the Basel Convention, respectively.

Table 1.27: Triple-difference gravity regression specifications with all FE

	Dependent variable: ln (North-to-South waste exports)							
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ln (ENGO exporter)	1.449***	1.464***	-0.574*	-0.734	0.319	0.779	2.686	1.679
	(0.203)	(0.204)	(0.307)	(0.660)	(2.164)	(2.101)	(2.060)	(1.240)
Treatment* Post	2.356***	2.347***	2.057***	2.100***	2.321***	2.370***	2.373***	2.214***
	(0.565)	(0.568)	(0.550)	(0.555)	(0.571)	(0.580)	(0.579)	(0.576)
Treatment* ln (ENGO exporter)	-0.126	-0.121	0.385***	0.325*	0.568***	0.524***	0.194	-0.425
	(0.098)	(0.098)	(0.132)	(0.172)	(0.170)	(0.168)	(0.163)	(0.351)
Post* ln (ENGO exporter)	0.519***	0.501***	0.561***	0.567***	0.559***	0.577***	0.506***	0.472***
	(0.085)	(0.086)	(0.085)	(0.085)	(0.085)	(0.085)	(0.085)	(0.085)
Treatment* Post* ln (ENGO exporter)	-0.743***	-0.742***	-0.645***	-0.651***	-0.708***	-0.719***	-0.754***	-0.704***
	(0.150)	(0.151)	(0.146)	(0.146)	(0.150)	(0.154)	(0.154)	(0.154)
ln (ENGO importer)		-0.194	-0.182	-0.187	-0.146	-0.077	-0.117	-0.075
		(0.145)	(0.146)	(0.150)	(0.151)	(0.152)	(0.154)	(0.154)
ln (Industry exporter)			1.877***	1.914***	2.119***	2.022***	1.875***	1.894***
			(0.488)	(0.495)	(0.506)	(0.502)	(0.493)	(0.493)
ln (Industry importer)			1.396***	1.378***	1.279***	0.849***	0.950***	0.909***
			(0.269)	(0.282)	(0.289)	(0.293)	(0.291)	(0.289)
ln (Population exporter)				0.433	0.479	0.240	-0.723	-0.809
				(1.167)	(1.215)	(1.171)	(1.149)	(1.143)
ln (Population importer)				-0.067	-0.219	0.610	0.683	0.634
				(0.387)	(0.395)	(0.423)	(0.422)	(0.421)
ln (GDP exporter)					-0.400	-0.398	-0.291	-0.314
					(0.279)	(0.277)	(0.270)	(0.268)
ln (GDP importer)					0.193	0.027	0.012	0.036
					(0.155)	(0.152)	(0.152)	(0.151)
ln (Capital/labour exporter)						0.088	0.529	0.578
						(0.499)	(0.488)	(0.484)
ln (Capital/labour importer)						0.997***	1.151***	1.124***
						(0.211)	(0.212)	(0.212)
ln (Distance)							-1.989***	-1.972***
							(0.118)	(0.125)
Common border							1.511***	1.510***
							(0.537)	(0.535)
Common language							0.153	0.155
							(0.194)	(0.193)
Colonial ties							0.987***	0.988***
							(0.284)	(0.284)
WTO								0.111
								(0.135)
RTA								0.096
								(0.164)
Basel								-0.455***
								(0.118)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Exporter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Importer FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17525	17437	17417	17417	17319	17309	17309	17309
R^2	0.403	0.404	0.407	0.407	0.409	0.410	0.489	0.490

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered at country pairs are in parentheses. Treatment equals one if the country belongs to an EU developed country. Post equals one if the year is equal to or greater than 2006. ENGO uses the number of ENGOs in 2005. The variables *Industry*, *Population*, *GDP* and *Capital/labour* represent the industry lobbying strength (proxied by the commercial energy use, kg of oil equivalent per capita), population (in millions), gross domestic product (in billion dollars), and capital per worker (in dollars), respectively. The variable *Distance* represents the bilateral distance between country pairs in km, and *Common border*, *Common language* , *Colonial ties*, *WTO*, *RTA* and *Basel* are dummy variables indicating whether both countries share a common border, common language, had colonial ties, had joined the WTO, were in some regional trade agreements, and had ratified the Basel Convention, respectively.

In the previous chapter, I showed how the presence of lobby groups could lead to market distortions in the international waste market, resulting in excessive waste trade and worsening environmental degradation in the South. But the good news is that strengthening environmental lobbying can help reduce the growing transboundary waste shipments and potentially prevent further deterioration of the environment in developing countries. This result thus highlights the important role environmental lobby groups can play in shaping governments' waste policies and influencing firms' waste trade decisions. It will be worthwhile for international donor organizations to promote the development of environmental NGOs globally and foster greater collaboration and dialogue between civil society, governments, and the private sector to create a more sustainable and responsible waste market that benefits both the environment and local communities.

While political lobbying is only one source of inefficiency in resource markets, the following chapter looks at another type of market distortion. Specifically, I examine the effects of imperfect competition linked to the presence of cross-ownership in the nonrenewable resource sector. When firms hold ownership stakes in their rivals, they tend to compete less aggressively with each other, as one firm's profit gains may come at the loss of their competitors in which they have shareholdings. As a result, these cross-ownership activities create market distortions, giving rise to market power of those cross-owners and thus affecting firms' strategic resource use. In the following, I investigate the effects of this type of ownership structure on market outcomes and its implications for competition policy.

Chapter 2

On the Profitability of Cross-ownership in Cournot Nonrenewable Resource Oligopolies: Stock Size Matters

2.1 Introduction

Nonrenewable resource industries have experienced intense and widely documented cross-ownership activities mainly through partial acquisitions and joint ventures.[1] As noted by Kumar (2012) and Benchekroun, Breton and Chaudhuri (2019), the volume of mergers and acquisitions has been historically and consistently much higher in the exhaustible sector than others. Many joint ventures exist in the nonrenewable resource sector, as firms often jointly own and/or develop a mine. For instance, in the global oil and gas industry, the top six multinational oil companies, i.e., ExxonMobile, British Petroleum (BP), Royal Dutch Shell, Chervon, Total and Eni, are more closely interconnected with each other than would be expected.[2] According to a report by Water Street Partners based on the source from Rystad Energy,[3] intriguingly large amounts of supermajor-to-supermajor joint-ventures exist in the production stage, let alone other stages such as exploration, refining, distributing and retailing. We seek to understand the incentives of rival firms to participate in cross-ownership and the levels of cross-shareholdings that will be profitable in nonrenewable resource industries. This will require investigating

[1] When firms form a joint venture, it is usually majority-owned and operated by one firm and minority-held by the others. This translates into mutual shareholdings of one firm in another.

[2] Other notable examples include: BP holds a 19.75% stake in the Russian oil giant Rosneft; the Mexican state-owned petroleum company Pemex holds a 9.3% stake in the Spanish oil giant Repsol; China's state-owned Sinopec holds a 30% stake in Petrogal Brasil, and 40% in Repsol YPF Brasil, respectively.

[3] See https://www.waterstreetpartners.net/blog/the-web-of-partnerships-between-bp-chevron-eni-exxonmobil-shell-

how ownership links between any rival firms may affect the use of a nonrenewable resource and whether increased cross-ownership will give rise to increased market power.

To better understand the role played by resource constraints, we start by examining the profitability of cross-ownership in a static game since it has not been addressed even in this benchmark framework.[4] Specifically, we consider a k-symmetric cross-ownership structure in an n-firm Cournot homogeneous-product model where a subset of $k \leq n$ firms engage in rival cross-shareholdings and each firm has an equal silent financial interest in the other firms, while the remaining $n-k$ firms stay independent. By examining the profitability of cross-ownership, we show that for any levels of non-controlling minority shareholdings, a k-symmetric cross-ownership is never profitable if the number of participating firms is below some lower threshold, but always profitable when the number of participating firms is above some upper threshold. When the number of participating firms is between these thresholds, the profitability of cross-ownership depends on the value of stakes that each firm involved in cross-ownership holds in the other firms. Cross-ownership is then profitable only when the stakes are below a certain threshold. This result seems surprising as one would naturally think it should be always profitable for firms to participate in cross-ownership due to a less intensified competition. We thus define this result as a cross-ownership paradox, analogous to the merger paradox. In general, firms have no incentive to engage in cross-shareholdings if less than 50% of the firms in the industry participate. However, beyond that participation ratio, for example, with $n = 10$ and $k = 6$, cross-ownership is profitable provided that each of the 6 firms holds no more than 6.5% of the shares of any other firm; with $n = 9$ and $k = 6$, cross-ownership is profitable provided that each of the 6 firms holds no more than 12.5% of the shares of any other firm; and with $n = 8$ and $k = 6$, cross-ownership is profitable provided that each of the 6 firms holds less than 17.6% of the shares of any other firm. Moreover, cross-ownership is always profitable for any non-controlling minority shareholdings if more than 80% of the firms participate. Thus a k-symmetric cross-ownership is more likely to be profitable with lower levels of shareholdings for a lower participation ratio. The main intuition behind the result can be explained by cross-ownership theory and oligopoly theory. When a firm acquires a partial ownership stake in a rival, it has an incentive to

[4] Viewing cross-ownership as "partial mergers", previous studies have focused mainly on the potential anticompetitive effects induced by cross-ownership, i.e., unilateral effects (Bresnahan and Salop, 1986; Brito et al., 2018; Brito, Cabral and Vasconcelos, 2014; Brito, Ribeiro and Vasconcelos, 2014; Dietzenbacher, Smid and Volkerink, 2000; Farrell and Shapiro, 1990; Flath, 1991, 1992; O'Brien and Salop, 2000; Reynolds and Snapp, 1986) and coordinated effects (Brito, Ribeiro and Vasconcelos, 2018; Gilo, Moshe and Spiegel, 2006; Malueg, 1992), and have thus proposed various modified measurement indexes—the Herfindahl-Hirschman Index and the Gross Upward Price Pressure Index—to account for it. However, none have addressed the issue of profitability of cross-shareholdings.

compete less aggressively and thus unilaterally reduce its output. A larger shareholding by the firms that engage in the symmetric cross-ownership will induce them to further reduce output, triggering a more aggressive response by the outsiders in terms of strategic substitutes in Cournot competition. The increase in both the number and output of the outsiders more than offsets the benefit the cross-owners can receive from their reduction of output, thereby reducing the profitability of cross-ownership.

We show that the conclusions reached in the static benchmark above may not be extendable to the case of nonrenewable resource oligopolies. The output of each resource extracting firm, i.e., their cumulative extraction over time, is constrained by their limited initial resource stocks. As a result, current extraction and production affect the availability of reserves for future extraction and production (Hotelling, 1931). To capture the specificity of the nonrenewable resource sector, we use a dynamic game model in which firms compete *à* la Cournot while each firm faces a resource stock constraint. We use a continuous time framework with an endogenous time horizon. Following much of the existing literature on oligopoly models of nonrenewable resource markets (Benchekroun, Halsema and Withagen, 2009, 2010; Benchekroun, Breton and Chaudhuri, 2019; Lewis and Schmalensee, 1980; Loury, 1986; Salant, 1976), we adopt the open-loop strategies by which firms commit to a fixed time path of extraction. We acknowledge that open-loop Nash equilibrium (OLNE) is only time-consistent but not necessarily subgame perfect.[5] If firms have all the information about its own and competitors' stocks at any future dates, they would be able to adjust their production at each instant of time, i.e., use closed-loop or Markov strategies. However, there are several reasons to justify the use of OLNE as noted in Benchekroun, van der Meijden and Withagen (2019). The first justification is the analytical tractability, as one has to resort to numerical methods to characterize a closed-loop equilibrium, but such methods suffer from the curse of dimensionality. The second is the prevalence of long-term contracts in nonrenewable resource markets so that actual extraction rates do not only depend on the actual resource stocks but also from the pre-committed supplies. Finally, requiring information on the vector of stocks at each moment can be quite unrealistic given the difficulty to gather that information. We then characterize an open-loop Nash-Cournot cross-ownership equilibrium (OL-NCOE) of the game and investigate the profitability of a k-symmetric cross-ownership in this context. We find that a k-symmetric cross-ownership can be profitable even when the participation ratio is below the lower threshold and is always profitable when above the lower threshold, provided that the initial resource stock owned by each firm is small enough. Moreover, the profitability increases in levels of cross-ownership when resource stock

[5]See Chapter 4 in Dockner et al. (2000) for more details.

owned by each firm is small. This result sharply contrasts with the static model in which lower levels of cross-ownership seem more profitable. Unlike the static model in which outsiders respond to any increased shareholdings between cross-owners by aggressively increasing output and mitigating the cross-ownership participants' gain in market power, the limited resource stocks restrict the outsiders in their response. Consequently, when the stock is sufficiently small, a higher level of cross-ownership will generate a higher profitability.

In addition, a k-symmetric cross-ownership results in a slower extraction rate for the industry and induces the outsiders to exhaust their stocks earlier than the cross-ownership participants at any resource stock level. These findings indicate that the degree of concentration in supply will increase over time, and a group of cross-owners will eventually supply the resource before exhaustion. This result resembles the 'oil'igopoly theory (Loury, 1986; Polasky, 1992), which predicts that small firms will exhaust their stocks before large firms do, leading possibly to eventual monopolization of the market. The increased concentration over time induced by cross-ownership confers market power on those cross-owners. As such, the cross-ownership participants can raise prices more than in other industries without stock constraint, which provides an additional incentive to look at the exhaustible sector differently.

Our paper also contrasts cross-ownership with horizontal mergers. One of the seminal works in the literature is arguably the paper by Salant, Switzer and Reynolds (1983), who show that the seemingly profitable mergers between competing firms in the same industry can be unprofitable, which is known as the merger paradox. More specifically, when firms compete à la Cournot in an oligopolistic industry with linear demand and constant marginal cost of production, horizontal mergers are not profitable unless at least 80% of the industry participates in the merger. Since cross-ownership is often referred to as "partial mergers", one may wonder why firms do not engage in a full merger in the first place, as a merger totally eliminates the previous rivalry and can pool resources more efficiently. Foros, Kind and Shaffer (2011) answer this question by showing that in a spatial Salop 3-firm Bertrand model with differentiated products, the profitability of a partial cross-ownership that gives the acquirer corporate control over all pricing decisions could be much higher than that of a full merger because a partial ownership arrangement can greatly lessen competition when the firms' choices are strategic complements. Stühmeier (2016) extends their 3-firm setting with four or more firms, only to find that firms prefer a merger to a partial acquisition, because both neighbors to the entity respond differently to the acquisition. Thus he concludes that whether partial acquisition is preferable to a merger is sensitive to the intensity of competition in the market. However, these papers only consider Bertrand competition whereas there are numerous industries in which firms compete in a way that is more consistent with Cournot competition. Using models with price competition to investigate quantity competition would often end up with unreliable results and give misleading policy implications. Our paper thus provides a possible explanation as to why cross-ownership is preferable to a full merger in terms of Cournot competition. For example, as indicated earlier, when $k = 6$ and $n = 10$, cross-ownership is profitable provided that each of the 6 firms holds no more than 6.5% of the non-controlling minority shares of any other firm, while a horizontal merger of 6 firms is unprofitable.

This result also bears some practical considerations from a company's corporate strategy point of view. Not only is participating in cross-ownership more profitable than a horizontal merger, but—more importantly—it constitutes a "smart" way to avoid the possible legal challenges. While horizontal mergers are subject to substantial antitrust scrutiny and are often opposed by antitrust authorities, non-controlling minority shareholdings are either granted a de facto exemption from antitrust liability or have gone unchallenged by antitrust agencies (Gilo, 2000; Gilo, Moshe and Spiegel, 2006). Indeed, Nain and Wang (2018) document that fewer than 1% of the minority acquisitions are challenged by the Federal Trade Commission (FTC) or the Department of Justice (DOJ), and even fewer are blocked outright. Antitrust authorities of the European Union (EU) do not even have competence to investigate such cases.[6] As noted by Jovanovic and Wey (2014), in many merger cases, the acquiring firm often proposes a passive cross-ownership in the target firm before a full merger. This two-step covert takeover strategy has two central benefits: first, it evades merger scrutiny when antitrust authorities often give the green light to non-controlling minority shareholdings; second, it achieves the eventual goal of a full acquisition on the basis of increasing consumer surplus approved by antitrust authorities. Therefore, firms may view cross-ownership as a more attractive corporate strategy, further explaining why firms want to engage in cross-shareholdings. Our analysis thus suggests that competition authorities should adapt their current lenient approach towards minority shareholdings to a stricter regulation.

In the absence of any possible efficiency gains, passive cross-shareholdings result in a welfare loss, and thus competition authorities should rule against them in accordance

[6] It should be noted that "Articles 101 and/or 102 TFEU may apply to passive minority shareholdings in situations where there is evidence of an anticompetitive agreement or concerted practice among the investigated firms or the firms that are engaged in the acquisition of non-controlling stakes and/or one or more firms have a dominant position" (Fotis and Zevgolis, 2016). But European Commission also acknowledged its limited ability to use these Articles to intervene against minority shareholdings in the 2013 Consultation Paper and therefore does not cover all types of anti-competitive minority interests.

with a total surplus criterion.[7] However, when competition authorities need to make the tradeoffs between the possible efficiency gains and the welfare loss brought by cross-ownership, they should be cautious when ruling in the nonrenewable resource sector. As when the resource stock owned by each firm is small enough, cross-ownership results in a relatively smaller welfare loss than in a static Cournot oligopoly. This is because a group of cross-owners will monopolize the market after the outsiders deplete their resource stocks. As such, they can substantially raise the price, which slows down resource extraction and extends the date of exhaustion. As the resource becomes increasingly scarce, the extended periods of the use of the resource partially offset the negative effect of the higher price on social welfare.

The remainder of the paper is structured as follows. Section 2 presents first a static model used as a benchmark and then the dynamic model of a nonrenewable resource industry. Section 3 analyzes the profitability of cross-ownership. Section 4 provides a welfare analysis. Section 5 conducts a comparative static analysis. Finally, Section 6 concludes with the summary of our findings.

2.2 The model and preliminary analysis

2.2.1 The static model

We consider an n-firm oligopolistic industry where firms compete *à* la Cournot. Demand is linear and given by $p = a - b\sum_{j=1}^{n} q_j = a - bQ$, where p is the market price and q_j is the output produced by firm j. Marginal costs are constant and identical across all firms, denoted by c with $a > c$. Assume that a subset of k firms ($2 \leq k \leq n$) engage in rival cross-shareholdings[8] and each firm has an equal silent financial interest in the other firms, while the remaining $n - k$ firms stay independent. Denote the set of firms as $J = \{1, 2, \cdots, n\}$, indexed by j, and use the subsets $I = \{1, 2, \cdots, k\}$, indexed by i and $O = \{k+1, \cdots, n\}$, indexed by o, referring, respectively, to the insiders and the outsiders

[7] We have assumed absence of efficiency gains throughout the paper to highlight the market power effect of cross-ownership.

[8] In an industry characterized by rival cross-shareholdings, the aggregate profits of a firm j include not only the stream of profits generated by the firm from its own operations, but also a share in its competitors' aggregate profits due to its direct and indirect ownership stakes in these firms (Flath, 1992; Gilo, Moshe and Spiegel, 2006). The aggregate profits can be interpreted as the accounting profits or the taxable profits of firm j. For example, say, if the corporate tax rate is 20%, then firm j must pay the government a tax amount of $0.2\Pi_j$.

to the cross-ownership. Then firm j's problem can be expressed as

$$\max_{q_j \geq 0} \Pi_j = \pi_j + v \sum_{i \neq j} \Pi_i = (p-c)q_j + v \sum_{i \neq j} \Pi_i$$

where $\pi_j = (p-c)q_j$ denotes firm j's operating profit and $v \geq 0$ represents firm j's fractional shareholdings in firm i for any $i \neq j$. Let $\boldsymbol{\Pi}$ and $\boldsymbol{q}$ denote the $n1$ vectors of aggregate profits and outputs, respectively, and $\boldsymbol{D}$ denote the nn cross-shareholding matrix, then the aggregate profit functions can be expressed in matrix form as

$$\boldsymbol{\Pi} = (p-c)\boldsymbol{q} + \boldsymbol{D\Pi}.$$

Under the k-symmetric cross-ownership structure, $\boldsymbol{D} = \begin{bmatrix} \boldsymbol{A}_{kk} & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{0}_{n-k} \end{bmatrix}$, where $\boldsymbol{A}_{kk}$ is a $k \times k$ matrix with element 0 in the diagonal and v off-diagonal. This set of n equations implicitly defines the aggregate profit for each firm. Then $\boldsymbol{I} - \boldsymbol{D} = \begin{bmatrix} \boldsymbol{B}_{kk} & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{I}_{n-k} \end{bmatrix}$, where $\boldsymbol{B}_{kk}$ is a $k \times k$ matrix with element 1 in the diagonal and $-v$ off-diagonal, and $\boldsymbol{I}_{n-k}$ denote the $(n-k) \times (n-k)$ identity matrix. We make the following assumption:

Assumption 1. *Each firm seeks to maximize the value of its aggregate profits, but controls only its own production q_j, with rival shareholdings $v < \frac{1}{k-1}$, i.e., firms only have a silent financial interest or non-controlling minority stake in the rivals.*

Similar restriction can be found in Gilo, Moshe and Spiegel (2006) where the weight given to rivals' profits is bounded from above by $1/(n-1)$ when $k = n$. Assumption 1 guarantees that the aggregate stake of rivals in each cross-ownership participant, $(k-1)v$, is less than 1.[9] Under Assumption 1, matrix $(\boldsymbol{I} - \boldsymbol{D})$ is invertible,[10] which implies that it

[9]We don't allow v to be equal to $1/(k-1)$. The reason is that from the firm' corporate governance perspective, it makes little sense if each of the other $k-1$ firms holds a $1/(k-1)$ share of the k-th firm while the k-th firm can still make its own independent decision. It should also be noted that the k-firm merger outcome can be achieved with k-symmetric cross-ownership when $v = 1/(k-1)$, as if firms are maximizing the industry profits in that case.

[10]This follows from the properties of "Dominant Diagonal Matrices" (see, e.g.,Takayama (1985), Mathematical Economics, Cambridge University Press, page 381). According to Theorem 4.C.1 of that book, if an $n \times n$ matrix A has a dominant diagonal, then A^{-1} exists, where an $n \times n$ matrix A is said to have a dominant diagonal if there exists positive numbers $d_1, d_2, \cdots, d_n$ such that, for each j, we have

$$d_j|a_{jj}| > \sum_{i \neq j} d_i |a_{ij}|.$$

Clearly the matrix $\boldsymbol{I} - \boldsymbol{D} = A$ has a dominant diagonal because $a_{jj} = 1$ and $\sum_{i \neq j} a_{ij} < 1$.

is possible to solve for the aggregate profit functions:

$$\mathbf{\Pi} = (\boldsymbol{I} - \boldsymbol{D})^{-1}(p-c)\boldsymbol{q} = \begin{bmatrix} \boldsymbol{B}_{kk}^{-1} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{I}_{n-k} \end{bmatrix} (a-c-bQ)\boldsymbol{q},$$ [11]

where $\boldsymbol{B}_{kk}^{-1}$ is given by the following matrix

$$\Omega \equiv \frac{1}{f(v)} \begin{bmatrix} 1-(k-2)v & v & \cdots & v \\ v & 1-(k-2)v & \cdots & v \\ \vdots & \vdots & \ddots & \vdots \\ v & v & \cdots & 1-(k-2)v \end{bmatrix}$$

with $f(v) = (1+v)\big(1-(k-1)v\big) > 0$. The aggregate profit function of firm $i \in I$ is

$$\Pi_i = \frac{a-c-bQ_{-i}-bq_i}{f(v)} \left[\big(1-(k-2)v\big)q_i + v \sum_{k \in I \setminus i} q_k \right],$$

while for firm $o \in O$, the aggregate profit function is

$$\Pi_o = (a - bQ_{-o} - bq_o - c)q_o$$

where $Q_{-j} = Q - q_j$. Firm j takes other firms' production Q_{-j} as given and chooses q_j to maximize its aggregate profit. The first order conditions are

$$\Big(1-(k-2)v\Big)\Big(a-c-bQ_{-i}-bq_i\Big) - b\left[\big(1-(k-2)v\big)q_i + v\sum_{k\in I\setminus i} q_k\right] = 0 \tag{2.1}$$

$$a - c - 2bq_o - bQ_{-o} = 0 \tag{2.2}$$

[11]Note that by the theory of partitioned matrices, if $\boldsymbol{B}_{kk}^{-1}$ exists, then

$$(\boldsymbol{I}-\boldsymbol{D})^{-1} = \begin{bmatrix} \boldsymbol{B}_{kk}^{-1} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{I}_{n-k} \end{bmatrix}.$$

To see this is true, observe that

$$\begin{bmatrix} \boldsymbol{B}_{kk} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{I}_{n-k} \end{bmatrix} \begin{bmatrix} \boldsymbol{B}_{kk}^{-1} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{I}_{n-k} \end{bmatrix} = \begin{bmatrix} \boldsymbol{B}_{kk}\boldsymbol{B}_{kk}^{-1} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{I}_{n-k} \end{bmatrix} = \boldsymbol{I}$$

Exploiting symmetry, the interior solution[12] yields the static Cournot equilibrium outputs:

$$q_i^v = \frac{(2-k)v+1}{(k+n+1-k^2)v+n+1}\frac{a-c}{b}, \quad q_o^v = \frac{1+v}{(k+n+1-k^2)v+n+1}\frac{a-c}{b}.$$

Thus, the equilibrium industry output is

$$Q_v = kq_i^v + (n-k)q_o^v = \frac{(-k^2+n+k)v+n}{(k+n+1-k^2)v+n+1}\frac{a-c}{b}.$$

Then, the equilibrium operating profit for a typical firm i is

$$\pi_i^v = (a-c-bQ_v)q_i^v = \frac{(1+v)\big(1-(k-2)v\big)}{\big((k+n+1-k^2)v+n+1\big)^2}\frac{(a-c)^2}{b}$$

and for a typical firm o is

$$\pi_o^v = (a-c-bQ_v)q_o^v = \frac{(1+v)^2}{\big((k+n+1-k^2)v+n+1\big)^2}\frac{(a-c)^2}{b}$$

2.2.2 The case of a nonrenewable resource industry: A dynamic model

The above model, however, cannot apply directly to the exhaustible resource sector, as the specificity of a nonrenewable resource (i.e., current extraction goes at the cost of future extraction) makes it inherently a dynamic problem. We consider an exhaustible resource industry involving n firms with the same initial stock endowments $S_{0j} = S$ and the same marginal cost of production c. Firms are oligopolists in the resource market where they compete *à* la Cournot. Let $q_j(t) \geq 0$ denote the extraction rate at time t for firm j. Demand for resource is stationary and linear with a choke price $a > c$, so that the inverse demand at time $t \geq 0$ for the extracted resource is given by $p(t) = a - bQ(t) = a - b\sum_{j=1}^{n} q_j(t)$. In an industry characterized by symmetric rival cross-shareholdings, the aggregate profits of firm j at time t is as follows:

$$\Pi_j(t) = \pi_j(t) + v\sum_{i\neq j}\Pi_i(t) = (p(t)-c)q_j(t) + v\sum_{i\neq j}\Pi_i(t)$$

[12]Note that the denominator is positive because we have imposed the restriction that $v < 1/(k-1)$.

$$(k+n+1-k^2)v+n+1 = n+1+(n+1)v-k(k-1)v \geq 1+(n+1)v+n-k > 0$$

Each firm j takes the supply paths of all other firms as given and maximizes the discounted sum of the aggregate profits, which consists of its operating profit and the share of profits obtained through ownership interests in other firms, subject to its resource constraint:

$$\max_{q_j(t)\geq 0} \int_0^\infty e^{-rt}\left[(a-bQ(t)-c)q_j(t)+\sum_{i\neq j} v_{ji}\Pi_i(t)\right]dt$$

$$s.t. \quad \int_0^\infty q_j(t)dt \leq S_{0j}$$

We consider the k-symmetric cross-ownership structure as in the static model and make a similar assumption:

Assumption 2. *Each firm j seeks to maximize the discounted sum of the value of its aggregate profits, including returns on any shares held in rivals, but controls only its own production $q_j(t)$ with $v < \frac{1}{k-1}$ for all i, k, i.e., firms only have a silent financial interest or non-controlling minority stake in the rivals.*

Under Assumption 2, it is possible to solve for the aggregate profit equation at each time t, and thus the problem of all firms can be reformulated as

$$\max_{\boldsymbol{q}(t)\geq 0} \int_0^\infty e^{-rt}\left(\begin{bmatrix}\boldsymbol{B}_{kk}^{-1} & \mathbf{0}\\ \mathbf{0} & \boldsymbol{I}_{n-k}\end{bmatrix}(a-c-bQ(t))\boldsymbol{q}(t)\right)dt$$

$$s.t. \quad \int_0^\infty \boldsymbol{q}(t)dt \leq \boldsymbol{S_0}(t)dt$$

where $\boldsymbol{S_0} = [S_{01}, S_{02}, \cdots, S_{0n}]'$. Let's write $Q(t) = q_j(t) + Q_{-j}(t)$. Then for a typical firm $i \in I$,

$$\max_{q_i(t)\geq 0} \int_0^\infty e^{-rt}\left[\frac{1}{1-(k-2)v-(k-1)v^2}\left((1-(k-2)v)q_i + v\sum_{k\in I\setminus i} q_k\right)\left(a-c-bQ_{-i}-bq_i\right)\right]dt$$

$$s.t. \quad \int_0^\infty q_i(t)dt \leq S_{0i}$$

while for a typical firm $o \in O$,

$$\max_{q_o(t)\geq 0} \int_0^\infty e^{-rt}\left[(a-bQ_{-o}-bq_o-c)q_o\right]dt$$

$$s.t. \quad \int_0^\infty q_o(t)dt \leq S_{0o}$$

We characterize an open-loop Nash-Cournot cross-ownership equilibrium (OL-NCOE) of this game. More precisely,

Definition 1 (Open-loop Nash-Cournot Cross-ownership Equilibrium (OL-NCOE))**.** *An n-tuple vector of extraction paths $\boldsymbol{q} = (q_1, q_2, \cdots, q_k, q_{k+1}, \cdots, q_n)$ with $q(t) \geq 0$ for all $t \geq 0$ is an open-loop Nash-Cournot cross-ownership equilibrium if*

(i) every extraction path is admissible and satisfies the corresponding resource constraint,

(ii) for all $i \in I$,

$$\int_0^\infty e^{-rt}\left[\frac{1}{1-(k-2)v-(k-1)v^2}\left((1-(k-2)v)q_i + v\sum_{k\in I\setminus i} q_k\right)\left(a-c-bQ_{-i}-bq_i\right)\right]dt$$
$$\geq \int_0^\infty e^{-rt}\left[\frac{1}{1-(k-2)v-(k-1)v^2}\left((1-(k-2)v)q_l + v\sum_{k\in I\setminus l} q_k\right)\left(a-c-bQ_{-i}-bq_l\right)\right]dt$$

for all q_l satisfying the resource constraint, and

(iii) for all $o \in O$,

$$\int_0^\infty e^{-rt}\Big[(a-bQ_{-o}-bq_o-c)q_o\Big]dt$$
$$\geq \int_0^\infty e^{-rt}\Big[(a-bQ_{-o}-bq_m-c)q_m\Big]dt$$

for all q_m satisfying the resource constraint.

We now proceed to characterize an OL-NCOE of the above-defined game. Let T_i and T_o denote the time at which firm $i \in I$ and firm $o \in O$ deplete their stocks, and denote by q_i and q_o the extraction paths of firm $i \in I$ and firm $o \in O$, respectively. Then,

Proposition 5. *Assume that the initial stocks of all firms are equal, i.e., $S_{0j} = S$, then the n-tuple vector $\boldsymbol{q}^{eq}$ where $q_j^{eq} = q_i$ when $j = 1, 2, \cdots, k$ and $q_j^{eq} = q_o$ when $j = k+1, \cdots, n$ constitutes* *an OL-NCOE.*

$$q_i(t) = \begin{cases} \dfrac{\big(1-(k-2)v\big)(a-c)\Big[1+k+\big(1-k(k-2)\big)v-\big((k+n+1-k^2)v+n+1\big)e^{r(t-T_i)}+(n-k)(1+v)e^{r(t-T_o)}\Big]}{\Big[(k+n+1-k^2)v+n+1\Big]\Big[1+k+\big(1-k(k-2)\big)v\Big]b} & \textit{for } 0 \le t \le T_o \\ \dfrac{(1-(k-2)v)(a-c)}{\Big[1+k+\big(1-k(k-2)\big)v\Big]b}\Big[1-e^{r(t-T_i)}\Big] & \textit{for } T_o \le t \le T_i \\ 0 & \textit{for } t \ge T_i \end{cases} \tag{2.3}$$

$$q_o(t) = \begin{cases} \dfrac{(a-c)(1+v)}{\Big[(k+n+1-k^2)v+n+1\Big]b}\Big[1-e^{r(t-T_o)}\Big] & \textit{for } 0 \le t \le T_o \\ 0 & \textit{for } t \ge T_o \end{cases} \tag{2.4}$$

where T_i and T_o are the unique solutions to

$$\int_0^{T_i} q_i(t)dt = S, \quad \int_0^{T_o} q_o(t)dt = S \tag{2.5}$$

Proof. See the Appendix. □

Proposition 1 shows that given an initial resource stock S, all firms will exhaust their stocks in finite time. Moreover, it can be shown that $T_i > T_o$ for all S and $0 < v < \frac{1}{k-1}$, i.e., the outsiders will deplete their stocks earlier than the insiders. This is in line with cross-ownership theory where, when a firm acquires a partial ownership stake in a rival, it has an incentive to compete less aggressively and thus unilaterally reduce its output, as one firm's gain may come at the loss of the other firms in which it has financial interests. This is also consistent with standard oligopoly theory where, for strategic substitutes, a reduction in cross-owners' outputs will result in an expansion of the outsider firms. As a result, each of the outsider firms tends to extract from its resource stock faster than each of the insider firms. Using the parameter values $a = 1, b = 1, c = 0$ and $r = 0.1$, Figure 2.1 plots the stock exhaustion dates (T_i, T_o) as a function of the initial resource stock S, of a typical insider firm $i \in I$ that engages in cross-ownership, and an outsider firm $o \in O$ that remains independent, respectively, for $k = 6, n = 9, v = 0.05$. Simulations using any combinations of k, n with $v < \frac{1}{k-1}$ and various values for the parameters a, b, c and r show that this result is qualitatively robust: a k-symmetric cross-ownership induces the outsiders to exhaust their stocks earlier than the cross-ownership participants for any resource stock level.

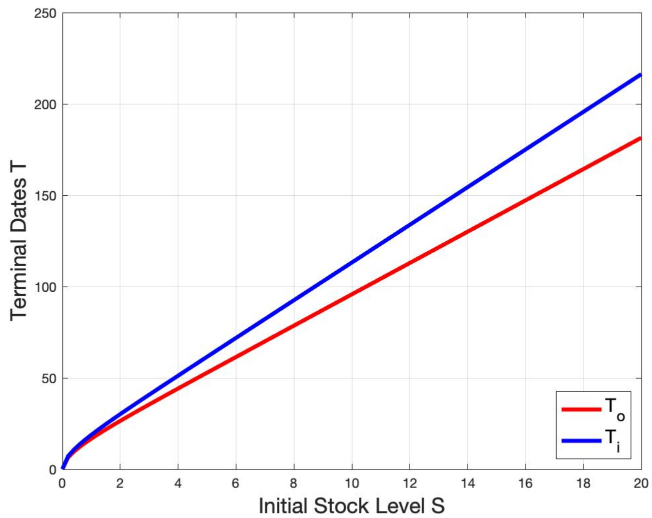
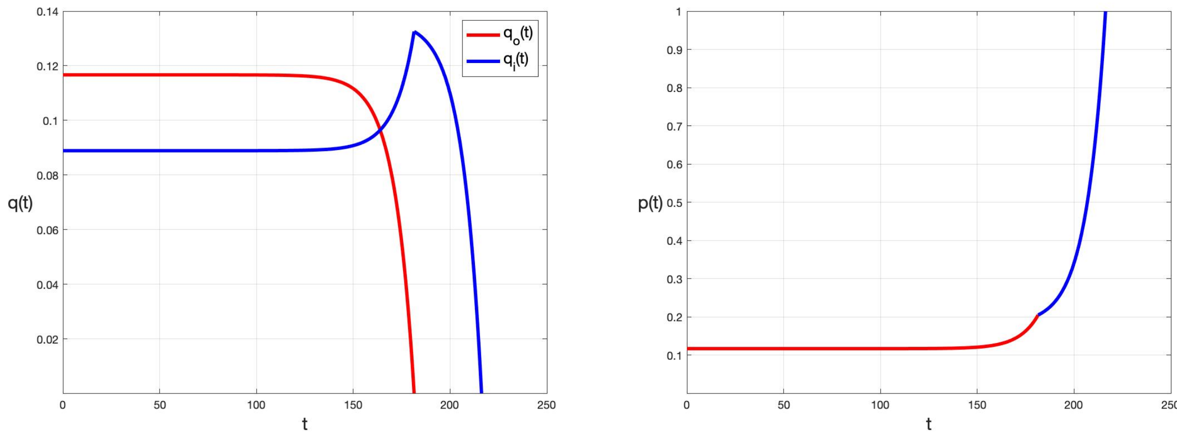


Figure 2.1: Terminal dates as a function of initial stock

The equilibrium extraction path then consists of two phases: phase I from date 0 to T_o, and phase II from T_o to T_i. During phase I, the extraction of all the n firms is positive until T_o, where the extraction and the stock of firms $o \in O$ vanish. During phase II, only firms $i \in I$ still own a positive stock, until T_i where the extraction and the stock of these remaining firms vanish. To illustrate these results, we use the same parameter values as in Figure 2.1 and plot in Figure 2.2 the equilibrium extraction paths of a typical insider firm $i \in I$ and an outsider firm $o \in O$ as well as the equilibrium price path for $n = 9, k = 6, v = 0.05$ and $S = 20$. As shown in Figure 2.2a, the outsiders start with a higher exploitation rate than the cross-owners, but as more resource gets depleted, the outsiders gradually decrease their production while the insiders steadily increase their output. When the outsiders exhaust their resource stocks, the resource is supplied only by the group of cross-owners. The degree of concentration in supply increases over time. These findings are in line with the 'oil'igopoly theory (Loury, 1986; Polasky, 1992), which predicts that small firms will exhaust their stocks before large firms do, leading to the eventual monopolization of the market. The increased concentration over time induced by cross-ownership confers market power on those cross-owners. As a consequence, the cross-ownership participants can raise prices substantially higher than in other industries without stock constraint as shown in Figure 2.2b, thus providing an additional incentive to view the exhaustible sector differently. With the remaining stocks, the insiders gradually decrease their production until total depletion of the resource.



(a) The OL-NCOE extraction path

(b) The OL-NCOE price path

Figure 2.2: The open-loop Nash-Cournot cross-ownership equilibrium (OL-NCOE)

2.3 Profitability of cross-ownership

In this section, we exploit the characterization of both the static Cournot equilibrium and the OL-NCOE in the above-defined game to investigate the profitability of the k-symmetric cross-ownership in the industry. We define the profitability of cross-ownership in the static case as the difference between the equilibrium operating profits with and without cross-ownership, and in the dynamic case as the difference between the equilibrium discounted sum of operating profits with and without cross-ownership.[13] We first focus on the static case for a generic industry and formally define our findings that cross-ownership is profitable only when it involves a relatively large number of firms as the *cross-ownership paradox*, analogous to the *merger paradox* which refers to the seminal result in oligopoly theory that a horizontal merger is profitable only when it involves a relatively large number of firms (Salant, Switzer and Reynolds, 1983). We then compare cross-ownership with horizontal merger and provide some explanations as to why firms want to engage in cross-shareholdings instead of a full merger. Next, we move to focus on the exhaustible sector. Specifically, we numerically examine the profitability under different cross-ownership structures and show that a k-symmetric cross-ownership can be profitable even when the participation ratio $\frac{k}{n}$ is less than or equal to $\frac{k}{2k-1}$ and is always

[13]Here we use the operating profits (π_j) instead of the aggregate profits or accounting profits (Π_j) to compare with the case of a standard Cournot model. This is the usual distinction we make about the economic profits and accounting profits.

profitable when the participation ratio $\frac{k}{n}$ is greater than $\frac{k}{2k-1}$, provided that the resource stock owned by each firm is small enough for any levels of cross-ownership.

2.3.1 Profitability: the static case

The equilibrium operating profit for a typical firm i that participates in cross-ownership is given by

$$\pi_i^v(k,n,v) = (a - bQ_v - c)q_i^v = \frac{(1+v)\big(1-(k-2)v\big)}{\big((k+n+1-k^2)v+n+1\big)^2}\frac{(a-c)^2}{b},$$

while that for a typical firm in the standard Cournot model without cross-ownership is

$$\pi_c = \pi_i^v(k,n,0) = \frac{1}{(n+1)^2}\frac{(a-c)^2}{b}$$

A k-symmetric cross-ownership is profitable if

$$G(k,n,v) = \pi_i^v(k,n,v) - \pi_i^v(k,n,0) > 0$$

We summarize in Proposition 2 the profitability of a $k-$symmetric cross-ownership in the static case:

Proposition 6. *For any $2 \leq k \leq n$ and $0 < v < \frac{1}{k-1}$, the profitability of a k-symmetric cross-ownership for Cournot competitors depends on the following scenarios:*

1. *If $\frac{k}{n} \leq \frac{k}{2k-1}$, then $G < 0$ for all $v \in (0, \frac{1}{k-1})$;*
2. *If $\frac{k}{2k-1} < \frac{k}{n} < \gamma(k) \equiv \frac{k}{k+\sqrt{k-1}}$, then $G > 0$ for $v < \bar{v}$ and $G < 0$ for $v \in (\bar{v}, \frac{1}{k-1})$, where $G(\bar{v}) = 0$ and $\bar{v} \equiv -\frac{(n+1)(2k-n-1)}{(n+1)(2k-n-1)-k^2(k-1)}$;*
3. *If $\frac{k}{n} > \gamma(k) \equiv \frac{k}{k+\sqrt{k-1}}$, then $G > 0$ for all $v \in (0, \frac{1}{k-1})$.*

Proof. See the Appendix. □

This result seems surprising as one would naturally think it should be always profitable for firms to participate in cross-ownership due to a less intensified competition. We thus define this result as a cross-ownership paradox, analogous to the merger paradox. A closer look at the lower threshold participation ratio $\left(\frac{k}{2k-1}\right)$ indicates that firms can never profit from cross-shareholdings if less than half of the firms in the industry participate. This 50-percent benchmark has also been addressed in Levin (1990)'s analysis of horizontal mergers under quite general conditions. However, our threshold includes ratios beyond only 50 percent, and crucially depends on both k and n. For example, when $k = 2$ and $n = 3$ (or $k/n = 66.7\%$), $k = 3$ and $n = 5$ (or $k/n = 60\%$), $k = 4$ and $n = 7$ (or $k/n = 57.1\%$), firms will also find any levels of cross-shareholdings unprofitable. A similar examination at the upper threshold $\left(\frac{k}{k+\sqrt{k}-1}\right)$ demonstrates that the profitability of cross-ownership is always positive if the number of firms involved in cross-ownership is significant enough. In particular, we can show that this upper threshold is at least 80% ($\frac{k}{k+\sqrt{k}-1} = 80\%$ when $k = 4$, but for any other $k \geq 2$, $\frac{k}{k+\sqrt{k}-1} > 80\%$). The threshold of 80% coincides with the famous threshold determined in Salant, Switzer and Reynolds (1983) for the case of horizontal mergers, where they show that a merger needs to involve at least 80% of the firms to be profitable. Finally, the second part of the cross-ownership paradox posits a large range of cross-shareholdings for which a k-symmetric cross-ownership can be profitable when the participation ratio is in between the lower threshold ($\frac{k}{2k-1}$) and upper threshold ($\frac{k}{k+\sqrt{k}-1}$).

We illustrate the findings of the above proposition with several numerical examples below where we fix the number of insiders at $k = 6$ and vary the number of firms in the industry from $n = 7, 8, 9, 10$ to 11, respectively. These examples will serve as benchmarks when analyzing the profitability of cross-ownership in the case of a nonrenewable resource industry. The lower and upper threshold participation ratios with $k = 6$ are respectively

$$\frac{k}{2k-1} = 0.5455 \quad \text{and} \quad \gamma(k) = \frac{k}{k+\sqrt{k}-1} = 0.8054.$$

Example 7. First, consider $n = 7$. Since

$$\frac{k}{n} = \frac{6}{7} = 0.8571 > \gamma(k) = 0.8054,$$

we have

$$G > 0, \forall\, v \in (0, \frac{1}{k-1}).$$

Example 1 shows that with $n = 7$ and $k = 6$, cross-ownership is always profitable for any admissible $v \in (0, \frac{1}{k-1})$.

Example 8. Consider $n = 8$, then

$$\frac{k}{2k-1} = 0.5455 < \frac{k}{n} = \frac{6}{8} = 0.75 < \gamma(k) = 0.8054$$

Thus $G > 0$ if and only if

$$v \leq \bar{v} \equiv -\frac{(n+1)(2k-n-1)}{(n+1)(2k-n-1)-k^2(k-1)} = 0.176$$

Example 2 shows that with $n = 8$ and $k = 6$, cross-ownership is profitable provided that each of the 6 firms holds no more than 17.6% of the shares of any other firm.

Example 9. Consider $n = 9$, then

$$\frac{k}{2k-1} = 0.5455 < \frac{k}{n} = \frac{6}{9} = 0.6667 < \gamma(k) = 0.8054$$

Thus $G > 0$ if and only if

$$v \leq \bar{v} \equiv -\frac{(n+1)(2k-n-1)}{(n+1)(2k-n-1)-k^2(k-1)} = 0.125$$

Example 3 shows that with $n = 9$ and $k = 6$, cross-ownership is profitable provided that each of the 6 firms holds no more than 12.5% of the shares of any other firm.

Example 10. Consider $n = 10$, then

$$\frac{k}{2k-1} = 0.5455 < \frac{k}{n} = \frac{6}{10} = 0.6 < \gamma(k) = 0.8054$$

Thus $G > 0$ if and only if

$$v \leq \bar{v} \equiv -\frac{(n+1)(2k-n-1)}{(n+1)(2k-n-1)-k^2(k-1)} = 0.065$$

Example 4 shows that with $n = 10$ and $k = 6$, cross-ownership is profitable provided that each of the 6 firms holds no more than 6.5% of the shares of any other firm.

Example 11. Finally, consider $n = 11$. Since

$$\frac{k}{n} = \frac{6}{11} = 0.5455 = \frac{k}{2k-1}$$

we have

$$G < 0, \forall\, v \in (0, \frac{1}{k-1}).$$

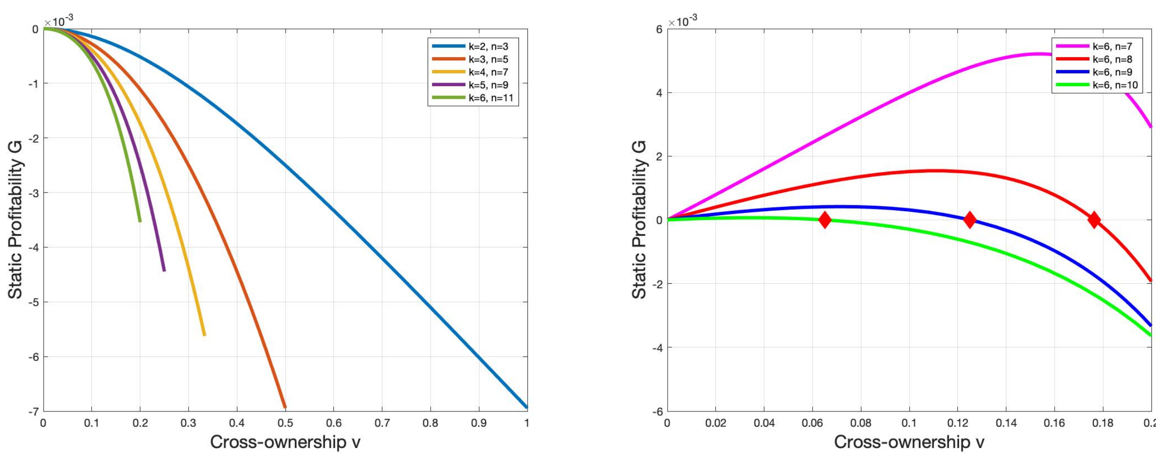
Example 5 shows that with $n = 11$ and $k = 6$, cross-ownership is never profitable for any admissible $v \in (0, \frac{1}{k-1})$. To visualize these results, we also plot the static profitability G as a function of the level of cross-ownership v for different k and n in Figure 2.3. Specially, we have different combinations of k and n that satisfy $\frac{k}{n} \leq \frac{k}{2k-1}$ in Figure 2.3a and $\frac{k}{n} > \frac{k}{2k-1}$ in Figure 2.3b with $k = 6$ and $n = 7, 8, 9$ and 10, respectively. Clearly, these figures have validated our results.

The above numerical and graphic illustrations help clarify the intuition behind the "cross-ownership paradox". The profitability of cross-ownership depends on three competing forces. First, by partially internalizing previous rivalry, each of the cross-ownership participants reduces its quantity and thereby increases its profit. Second, given that firms' quantities are strategic substitutes, the outsider firms react by increasing their output, which reduces the profitability of cross-ownership. Third, a larger ownership stakes between cross-owners will lead to a greater output reduction, but this induces the outsiders to respond more aggressively, thereby reducing the profitability of cross-ownership. So for a cross-ownership to be profitable, either the number of cross-ownership participants must be significant enough (i.e., the first effect dominates the latter two effects) or the number of cross-ownership participants is moderate but the shareholding is not too large (i.e., the first effect and third effect dominates the second effect).

An immediate result that follows Proposition 2 is the set of admissible levels of shareholdings on profitability, which we summarize as below:

Corollary 1. When $\frac{k}{n} > \frac{k}{2k-1}$, the set of admissible levels of shareholdings for which a k-symmetric cross-ownership is profitable decreases with the participation ratio k/n.

Proof. See the Appendix. □



(a) $\frac{k}{n} \leq \frac{k}{2k-1}$

(b) $\frac{k}{n} > \frac{k}{2k-1}$

Figure 2.3: Static profitability as a function of cross-ownership

Indeed, throughout Example 1-4 and Figure 2.3b, we can observe that a k-symmetric cross-ownership is more likely to be profitable with lower levels of shareholdings for a lower participation ratio. The intuition behind this result is that a larger shareholding by the firms that engage in the symmetric cross-ownership will induce them to reduce output by more, but this triggers a more aggressive response by the outsiders in terms of strategic substitutes in Cournot competition. The increase in both the number and the output of the outsiders more than offsets the benefit the cross-owners can receive from their reduction of output, thereby reducing the profitability of cross-ownership. This result has shed light on the differences between cross-ownership and horizontal mergers, possibly explaining why firms may prefer to participate in cross-ownership than in a horizontal merger. For example, when $n = 10$ and $k = 6$, the profitability of a k-symmetric cross-ownership is positive provided that each of the 6 firms holds no more than 6.5% of the non-controlling minority shares of any other firm, while that of a horizontal merger of 6 firms is negative.

These findings also raise some practical considerations from a company's corporate strategy viewpoint. Not only is it more profitable to participate in cross-ownership than a horizontal merger, more importantly, it constitutes a "smart" way to avoid the possible legal challenges. In the US, partial cross-ownership arrangements are most often examined under Section 7 of the Clayton Act.[14] While Section 7 of the Clayton Act covers the acquisition of "any part" of the stock of another company, it also "shall not apply to persons purchasing such stock solely for investment" (Scott Morton and Hovenkamp, 2017). The ambiguity in the statutory language has left courts struggling to access the antitrust risk of those partial stock acquisitions, and thus provides very little guidance for antitrust practitioners to set forth any clear guidelines or parameters as to what the "safe" shareholdings are (O'Brien and Salop, 2000). As a result, antitrust authorities have adopted a lenient approach toward passive investments. As a matter of fact, Nain and Wang (2018) document that fewer than 1% of the minority acquisitions are challenged by FTC or DOJ, and even fewer are blocked. In the EU and most other jurisdictions, however, antitrust authorities have no competence to investigate such cases. As noted by Jovanovic and Wey (2014), in many merger cases, the acquiring firm often proposes to take a passive partial ownership stake in the target firm prior to a full merger. They show that antitrust

[14] Acquisitions of voting securities can be also challenged under Section 1 of the Sherman Act, which prohibits contracts, combinations, or conspiracies in restraint of trade, but a plaintiff challenging an acquisition under Section 1 carries the burden of proving an actual anticompetitive effect through a restraint of trade, as well as concerted action (O'Brien and Salop, 2000). The Hart-Scott-Rodino (HSR) Act is also being used to evaluate certain transactions above a certain dollar threshold – including minority acquisitions – in the premerger notification program, but it specifically exempts from reporting requirements acquisitions solely for purposes of investment when the securities acquired or held do not exceed 10% of the outstanding voting securities of the issuer. See more at https://www.ftc.gov/enforcement/premerger-notification-program.

authorities, which do not account for passive partial ownership acquisitions, create incentives among firms to engage in "sneaky takeovers", which proceed in two steps. First, the acquiring firm abstains from proposing a full acquisition, as this would harm consumers. Rather, it strategically acquires a passive partial ownership, which often goes unnoticed or unchallenged by the antitrust authorities. Second, the acquiring firm proposes a full takeover, which can then be viewed as consumer surplus increasing and accepted by the antitrust authorities. The consumer surplus increases because passive partial ownership reduces the necessary minimal synergy level that leaves consumer surplus unchanged by a merger, thus relaxing the synergy requirement for a merger to increase consumer surplus (Jovanovic and Wey, 2014). As a result, a larger set of such synergies would be supported by antitrust authorities. However, if the antitrust authorities evaluated the whole process, they would find that it is actually detrimental to consumers. Because this two-step strategy perfectly evades scrutiny, it can eventually achieve the goal of a full merger without any legal challenges, which further explains why firms may want to engage in cross-shareholdings. Viewing cross-ownership as a more attractive corporate strategy, firms disproportionately adopt it without any legal accountability, ultimately to the detriment of consumers. Competition authorities should thus reform their current lenient approach by subjecting minority shareholdings to a stricter scrutiny.

2.3.2 Profitability in the case of a nonrenewable resource industry

We can now compute the value function of each firm $i \in I$ that engages in rival cross-shareholdings, which constitute a building block to analyze the profitability of cross-ownership in a nonrenewable resource industry. The equilibrium discounted sum of operating profits with a k-symmetric cross-ownership for a typical firm is given by:

$$\begin{aligned} V_S &= \int_0^{T_o} e^{-rt} \left[(a - b \sum_{j=1}^{n} q_j - c) q_i \right] dt + \int_{T_o}^{T_i} e^{-rt} \left[(a - b \sum_{j=1}^{n} q_j - c) q_i \right] dt \\ &= \int_0^{T_o} e^{-rt} \left[(a - bkq_i - b(n-k)q_o - c) q_i \right] dt + \int_{T_o}^{T_i} e^{-rt} \left[(a - bkq_i - c) q_i \right] dt \end{aligned}$$

where the equilibrium extraction paths for each phase are given by (2.3) and (2.4) and the exhaustion dates are solutions to (2.5). It will be useful to explicitly write down the equilibrium discounted sum of operating profits as a function of (k, n, v, S), but the expression is too cumbersome to report here. Instead we choose to numerically examine the profitability of the k-symmetric cross-ownership under two groups of participation ratios: $\frac{k}{n} \leq \frac{k}{2k-1}$ and $\frac{k}{n} > \frac{k}{2k-1}$. The equilibrium discounted sum of profits without cross-ownership for an individual firm is given by:

$$V_C = \int_0^{T_C} e^{-rt} \Big[(a - bnq_C - c) q_C \Big] dt$$

where

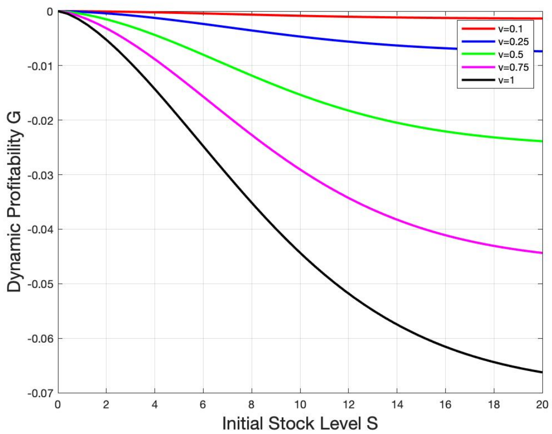
$$q_C(t) = \frac{a-c}{b(n+1)} \left[1 - e^{r(t-T_C)} \right], \quad \frac{a-c}{b(n+1)} \left(T_C - \frac{1}{r} + \frac{e^{-rT_C}}{r} \right) = S$$

Then a k-symmetric cross-ownership is profitable when

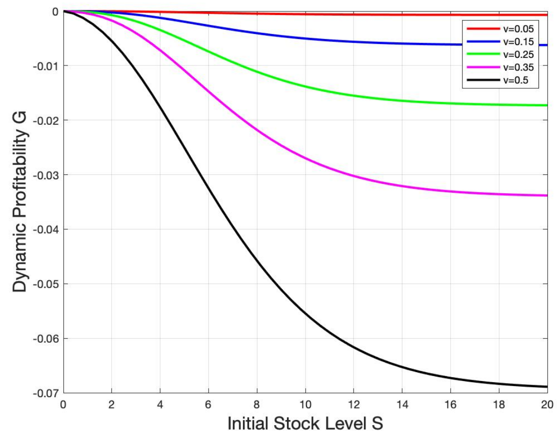
$$G(k, n, v, S) = V_S - V_C > 0$$

We use the same parameter values as in Figure 2.1 and illustrate in Figure 2.4 the gains resulting from a k-symmetric cross-ownership as a function of initial stock S for different levels of shareholdings when the participation ratio $\frac{k}{n} \leq \frac{k}{2k-1}$. While Figure 2.4a and 2.4b show that it is never profitable for firms to participate in cross-ownership for any levels of initial resource stock, Figure 2.4c and 2.4d indicate that the profitability of cross-ownership can be positive for any $v \in (0, \frac{1}{k-1})$ when the initial stock owned by each firm is small enough. Simulations using many other combinations of k and n (i.e., for all $k = \frac{1}{2}n$ and $k \geq 6$; for all $k = \frac{1}{2}(n+1)$ and $n \geq 7$) satisfying $\frac{k}{n} \leq \frac{k}{2k-1}$ also show such findings. These similar findings mean that the previous static results do not necessarily carry over to our dynamic model.

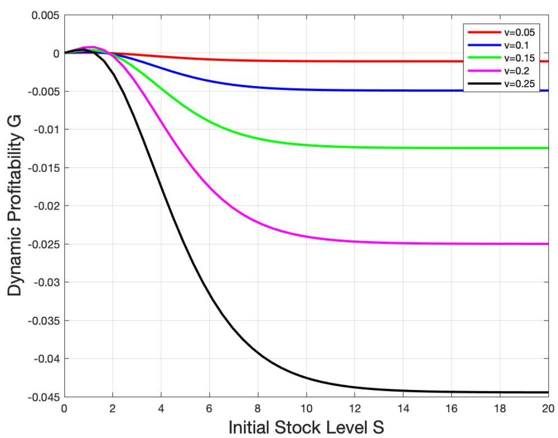
We now move to check whether this result holds when the participation ratio $\frac{k}{n} > \frac{k}{2k-1}$. Specifically, Figure 2.5 illustrates the profitability resulting from a k-symmetric cross-ownership as a function of initial stock S when $k = 6$ and $n = 7, 8, 9$ and 10 respectively, using the same parameter values as in Figure 2.1. As a comparison, we refer back to Figure 2.3b, which illustrates the profitability as a function of cross-ownership v in the static case. With $n = 7$ and $k = 6$, cross-ownership is always profitable for any $v \in (0, \frac{1}{k-1})$ in the static model. The same holds true in the dynamic model for all resource stock levels. With $n = 8$ and $k = 6$, where the k-symmetric cross-ownership in the static model is not profitable if each of the 6 firms holds more than 17.6% of the shares of any other firm, it can be profitable in the dynamic model for any levels of cross-shareholdings $v \in (0, \frac{1}{k-1})$ as long as the stock of the firms is small. Moreover, compared to the static case where the k-symmetric cross-ownership for which $k = 6$ and $n = 9$ is not profitable when $v > 12.5\%$, it can be profitable for any $v \in (0, \frac{1}{k-1})$ as long as the stock of the firms is small. In addition, whereas in the static case profitability with $k = 6$ and $n = 10$ is negative for $v > 6.5\%$, in the dynamic case it is always positive for any $v \in (0, \frac{1}{k-1})$ provided that the



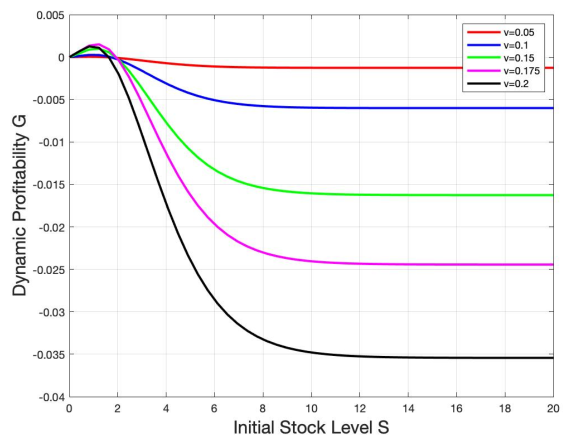
(a) $k = 2, n = 3$



(b) $k = 3, n = 5$



(c) $k = 5, n = 9$



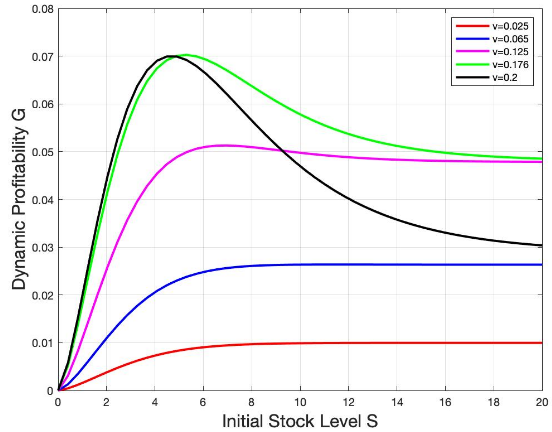
(d) $k = 6, n = 11$

Figure 2.4: Profitability as a function of initial stock when $\frac{k}{n} \leq \frac{k}{2k-1}$

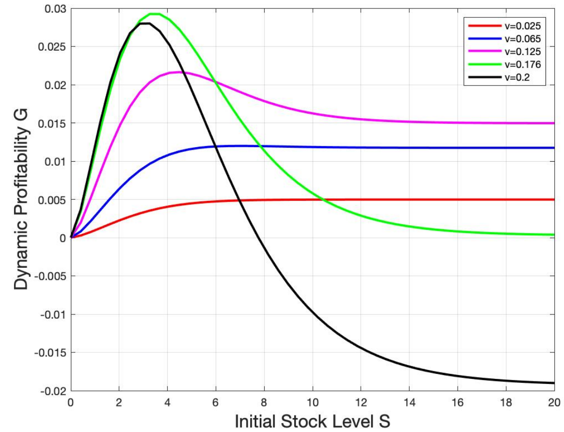
stock of the firms is small enough. We also observe that the profitability of a k-symmetric cross-ownership increases in v for all $v \in (0, \frac{1}{k-1})$ when the stock is small enough, but this increase in v does not hold if the initial stock is large. Simulations using a wide range of values of k and n satisfying $\frac{k}{n} > \frac{k}{2k-1}$ suggest that these findings are quite robust.

Clearly, some of the results from the cross-ownership paradox do not carry over to the case of nonrenewable resource industries. We therefore summarize these findings in Result 1, which is robust to different combinations of k and n and changes in parameter values.

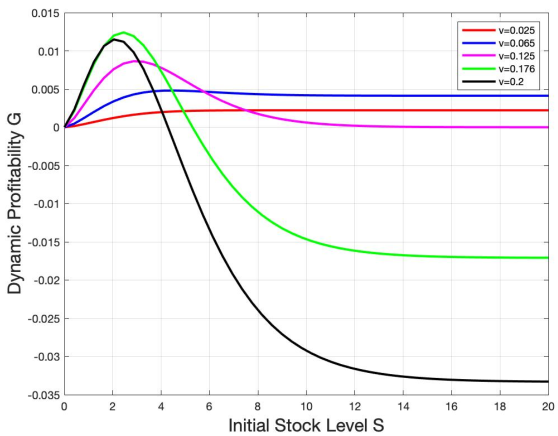
Result 1. *The profitability of a k-symmetric cross-ownership can be positive even when the participation ratio $\frac{k}{n} \leq \frac{k}{2k-1}$ and is always positive when the participation ratio $\frac{k}{n} > \frac{k}{2k-1}$, provided*



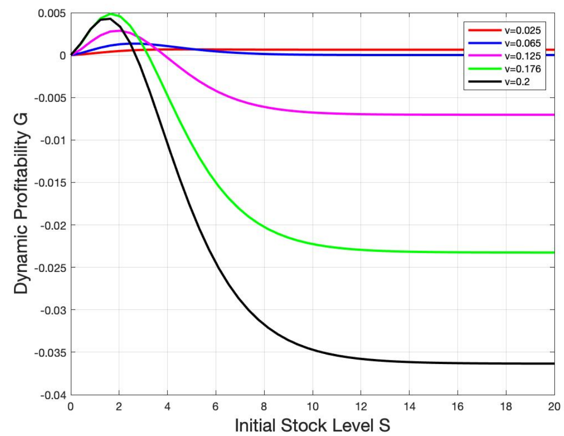
(a) $k = 6, n = 7$



(b) $k = 6, n = 8$



(c) $k = 6, n = 9$



(d) $k = 6, n = 10$

Figure 2.5: Profitability as a function of initial stock when $\frac{k}{n} > \frac{k}{2k-1}$

that the initial resource stock owned by each firm is small enough. Moreover, the profitability of k-symmetric cross-ownership increases in $v \in (0, \frac{1}{k-1})$ *for S positive and sufficiently small.*

Result 1 sharply contrast with the case of a standard Cournot model with cross-ownership but without resource stock constraints. In our earlier static settings, with linear demand and constant marginal cost, a k-symmetric cross-ownership can be profitable even if only 60% of the firms in the industry participate provided that the cross-shareholdings are small enough. However, in the presence of stock constraints, there exists a range of stock levels for which any levels of cross-ownership can be profitable —the higher the shareholdings, the higher the profitability. Unlike in the static Cournot model with cross-ownership, where outsiders respond to any increased shareholdings between cross-owners by aggressively increasing output and mitigating the cross-ownership participants' gain in market power, here the outsiders are restricted in their response due to their resource constraints. As a result, when the stock levels are sufficiently small, a larger level of cross-ownership will ensure a higher profitability. Within our context, the $n-k$ outsiders exhaust their stocks earlier than the cross-ownership participants, resulting in greater induced market power by cross-ownership than in the static model. A similar result can be found in Benchekroun, Breton and Chaudhuri (2019), who find that a merger is always profitable provided that the resource stock owned by each firm is small enough. The fact that the profitability of a k-symmetric cross-ownership is mostly positive when resource stock owned by each firm is small thus provides an explanation as to why there is so much cross-ownership in the exhaustible sector.

2.4 Welfare analysis

Antitrust authorities may be concerned by profitable cross-ownership if it is detrimental to welfare. In this section, we first examine the welfare implications in the static case of the k-symmetric cross-ownership using the total surplus criterion, i.e., the sum of consumer surplus and producer surplus or industry profits, where industry profits are defined as the combined sum of the operating profits of the cross-ownership participants (belonging to the subset I of insiders), $k\pi_i^v$, and of the firms outside the cross-ownership (belonging to the subset O of outsiders), $(n-k)\pi_o^v$.[15] Subsequently, we compare the results obtained in the dynamic model (for a nonrenewable resource industry) with that in the static model. Finally, we provide some policy implications from our analysis.

The change in total surplus induced by the k-symmetric cross-ownership is given by:

$$\Delta TS = W_v - W_c = \frac{b}{2}Q_v^2 - \frac{b}{2}Q_c^2 + +k\pi_i^v + (n-k)\pi_o^v - n\pi_c$$

where Q_v and Q_c are the equilibrium industry output with and without cross-ownership, respectively. After substitution, it yields

$$\Delta TS(k,n,v) = \frac{\left[v\Big(k(k-1) - 2(n+1)\Big) - 2(n+1)\right]kv(k-1)}{\Big((k+n+1-k^2)v + n + 1\Big)^2 (n+1)^2}\left[\frac{(a-c)^2}{2b}\right]$$

[15]We thank an anonymous reviewer for suggesting the conduct of welfare analysis using the total surplus criterion to be more in line with the existing literature. In a previous version, we focused on consumer surplus only.

Proposition 7. *For any $2 \leq k \leq n$ and $v \in (0, \frac{1}{k-1})$, a k-symmetric cross-ownership is never welfare-improving when evaluated in accordance with a total surplus criterion.*

Proof. See the Appendix. □

This result is quite intuitive. When firms engage in rival cross-shareholdings, they will compete less aggressively with each other and thus unilaterally reduce their outputs, since any gains from the acquirers' own activities may be offset by a negative impact on the acquirers' share of the targets' profits. Although the outsiders expand their outputs as a response, the reduction in the outputs brought by cross-ownership more than offsets the increase. As a result, the industry output decreases and market price increases, thus increasing industry profits[16] but decreasing consumer surplus. However, the overall reduction from consumer surplus dominates the increase in industry profits, thereby resulting in a welfare loss.

We now turn to the welfare analysis in a nonrenewable industry. The consumer surplus generated by the exploitation of the nonrenewable resource under the k-symmetric cross-ownership structure is

$$\begin{aligned} CS_S &= \int_0^{T_i} e^{-rt} \left[\frac{b}{2} (\sum_{j=1}^{n} q_j)^2 \right] dt \\ &= \int_0^{T_o} e^{-rt} \left[\frac{b}{2} (kq_i + (n-k)q_o)^2 \right] dt + \int_{T_o}^{T_i} e^{-rt} \left[\frac{b}{2} (kq_i)^2 \right] dt, \end{aligned}$$

while the industry profits are

$$\begin{aligned} PS_S &= \int_0^{T_i} e^{-rt} \left[(a - b\sum_{j=1}^{n} q_j - c)(kq_i + (n-k)q_o) \right] dt \\ &= \int_0^{T_o} e^{-rt} \left[(a - bkq_i - b(n-k)q_o - c)(kq_i + (n-k)q_o) \right] dt + \int_{T_o}^{T_i} e^{-rt} \left[(a - bkq_i - c)kq_i \right] dt, \end{aligned}$$

where the equilibrium extraction paths for each phase are given by (2.3) and (2.4) and the exhaustion dates are solutions to (2.5). Thus, the welfare under the k-symmetric cross-

[16] Industry profits surge because of an increase in profits from both insiders and outsiders. The outsiders increase its profits as both market price and quantity increase. While the change in insiders' profits may seem ambiguous as market price increases but its output decreases, the insiders' profits actually increase otherwise they wouldn't have engaged in cross-shareholdings at the first place.

ownership structure in a nonrenewable resource industry is given by

$$\begin{aligned}W_S &= CS_S + PS_S \\ &= \int_0^{T_o} e^{-rt}\left[\frac{b}{2}(kq_i + (n-k)q_o)^2 + (a - bkq_i - b(n-k)q_o - c)(kq_i + (n-k)q_o)\right]dt \\ &+ \int_{T_o}^{T_i} e^{-rt}\left[\frac{b}{2}(kq_i)^2 + (a - bkq_i - c)kq_i\right]dt.\end{aligned}$$

The total surplus generated by the exploitation of the nonrenewable resource under the standard Cournot model without cross-ownership is given by

$$W_C = \int_0^{T_C} e^{-rt}\left[\frac{b}{2}(nq_C)^2 + n(a - bnq_C - c)q_C\right]dt,$$

where

$$q_C(t) = \frac{a-c}{b(n+1)}\left[1 - e^{r(t-T_C)}\right], \quad \frac{a-c}{b(n+1)}\left(T_C - \frac{1}{r} + \frac{e^{-rT_C}}{r}\right) = S.$$

The competition authority determines the total surplus change induced by the k-symmetric cross-ownership in a nonrenewable resource industry:

$$W(k, n, v, S) = W_S - W_C$$

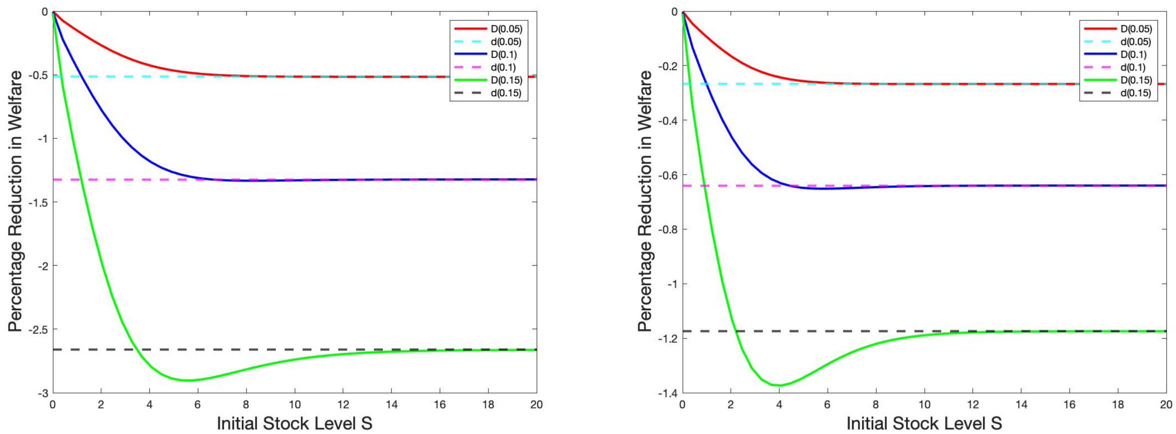
It will be useful to explicitly express W as a function of (k, n, v, S). Its expression is too cumbersome to report here. Instead, we choose to numerically examine the percentage welfare change of the k-symmetric cross-ownership in the dynamic case defined as

$$D(v) = \frac{W_S - W_C}{W_C},$$

and directly compare it with the static percentage welfare change defined as

$$d(v) = \frac{W_v - W_c}{W_c}.$$

When S is large enough, i.e., the resource is abundant, the dynamic percentage welfare change will asymptotically converge to the static result. Using the same parameter values as in Figure 2.1, we illustrate in Figure 2.6 the percentage welfare change resulting from a k-symmetric cross-ownership as a function of initial stock S for different levels of cross-ownership under participation ratios $\frac{k}{n} = \frac{6}{8}$ and $\frac{k}{n} = \frac{6}{10}$. The dashed and solid line denote the percentage welfare loss in the static and dynamic cases, respectively. Figure 2.6



(a) $k = 6$ and $n = 8$ **(b)** $k = 6$ and $n = 10$

Figure 2.6: Percentage welfare change as a function of initial stock

indicates that a k-symmetric cross-ownership is never welfare-improving for all S based on a total surplus criterion. Simulations using a wide range of values of k and n with $v < \frac{1}{k-1}$ and of the parameters a, b, c and r show that this result is qualitatively robust. We also observe the following:

Result 2. *When the initial resource stock owned by each firm is small enough, the percentage welfare loss in the case of a nonrenewable resource oligopoly resulting from a k-symmetric cross-ownership is smaller than that in the static case.*

This result seems surprising, as one would expect the exact opposite: the welfare loss is larger in the dynamic case. This is because when resource stock owned by each firm is small enough, a k-symmetric cross-ownership induces the outsiders to exhaust their resource stocks before the cross-ownership participants. Consequently, a group of cross-owners will eventually monopolize the market, and thus the price can be raised higher than in a static model, resulting in more welfare loss. While result 2 may seem counterintuitive, the main intuition behind it is that although the cross-owners can raise the price higher, it also extends the duration of the resource that can be used. As the resource becomes increasingly scarce, its extended periods of use partially offset the negative effect of the higher price on the consumer surplus. Therefore, the loss in consumer surplus is relatively smaller in the dynamic case than the static case when S is small enough.[17] As a result, the smaller loss in consumer surplus due to increased scarcity and the increased

[17] In addition to the scarcity effect, the risk of future trade disruption may also favor a more conservationist extraction path at the cost of higher price, as emphasized in Hillman and Long (1983).

profits due to higher price will lead to a smaller welfare loss in the case of a nonrenewable resource oligopoly than that in the static case.

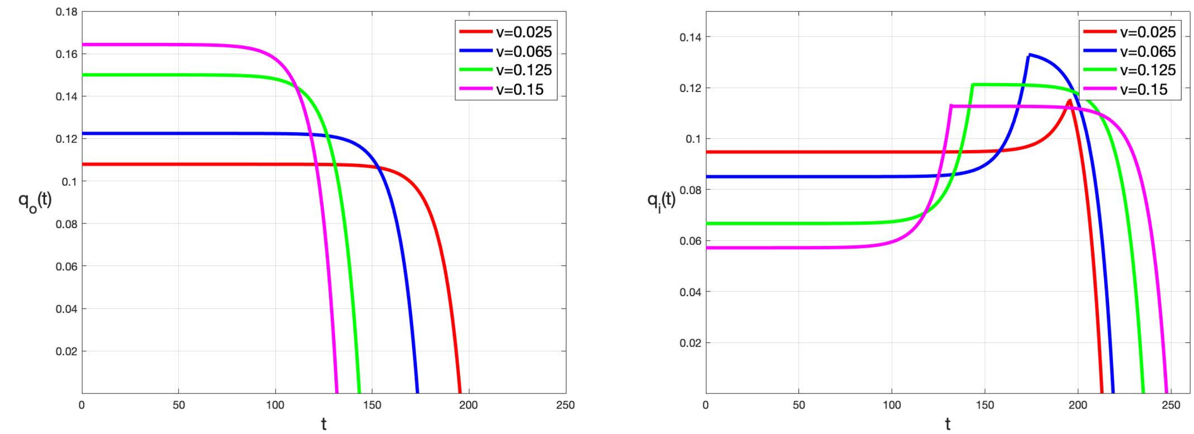
In the absence of any potential efficiency gains, our results thus suggest that passive minority cross-shareholdings should be blocked by competition authorities according to a total surplus standard. However, cross-ownership is generally believed to bring efficiency gains. For example, partial cross-ownership "offers a means for providing and compensating capital to risky ventures, for solidifying buyer-seller relationships, for funding and exploiting joint R&D activities, and for appropriating the returns to technology transfer" (Reynolds and Snapp, 1986). From a financial perspective, partial cross-ownership can "help to reduce holdup costs, mitigate financing constraints, and facilitate greater innovation and relation-specific investment", thus improving in operating efficiency (Nain and Wang, 2018).[18] Thus, when competition authorities make the tradeoffs between the possible efficiency gains and the welfare loss brought by cross-ownership, they should be cautious when ruling in the nonrenewable resource sector. As when the resource stock owned by each firm is small enough, cross-ownership may turn out to be relatively less detrimental to society.

2.5 Comparative static analysis

In this section, we examine how a change in v, k and n impacts the exploitation rates (q_i and q_o), discounted consumer surplus (CS_S), discounted industry profits (PS_S) and ultimately discounted welfare (W_S) in a nonrenewable industry. [19] The results are illustrated by numerical simulations.

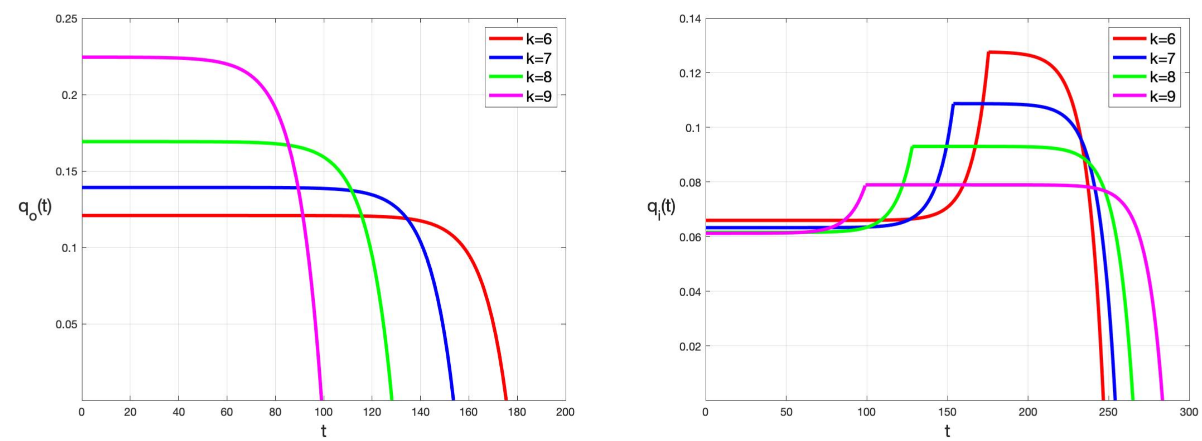
[18]It should be noted that these possible efficiency gains are also one of the reasons why firms want to participate in cross-ownership.

[19]We thank an anonymous reviewer for suggesting conducting this analysis.



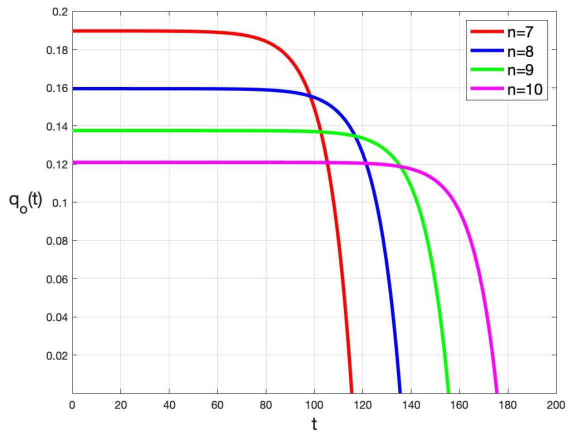
(a) Extraction path of firm $o \in O$ **(b)** Extraction path of firm $i \in I$

Figure 2.7: Comparative statics of exploitation rates with respect to v

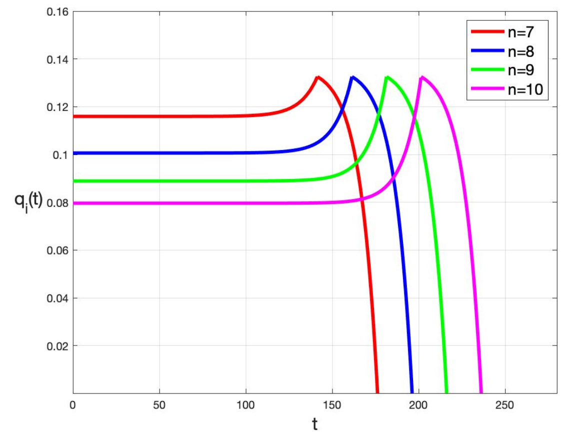


(a) Extraction path of firm $o \in O$ **(b)** Extraction path of firm $i \in I$

Figure 2.8: Comparative statics of exploitation rates with respect to k



(a) Extraction path of firm $o \in O$



(b) Extraction path of firm $i \in I$

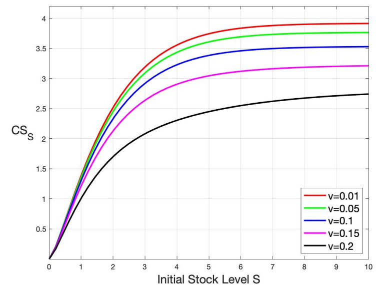
Figure 2.9: Comparative statics of exploitation rates with respect to n

We first conduct the comparative statics of exploitation rates (q_i and q_o) with respect to v, k and n, respectively. Using the parameter values $a = b = 1, c = 0, r = 0.1$ and $S = 20$, we plot the equilibrium extraction paths of a typical insider firm $i \in I$ and an outsider firm $o \in O$ for different levels of cross-ownership v when fixing $k = 6, n = 9$ in Figure 2.7, for different number of cross-ownership participants k when fixing $v = 0.1$ and $n = 10$ in Figure 2.8, and for different number of industry players n when fixing $k = 6$ and $v = 0.1$ in Figure 2.9. We observe the following result:

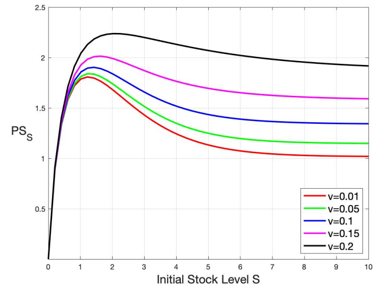
Result 3. *Ceteris paribus, an increase in v or k and a decrease in n will accelerate the speed at which the outsiders deplete their resource but delay the exhaustion of the cross-owners.*

This is intuitive. An increased cross-ownership either in levels (v) or ratios (k/n) results in a weaker competition between insiders, but this induces the outsiders to compete more aggressively. Each outsider starts with a higher exploitation rate and speeds up their resource exhaustion, while the insiders slow down their extraction due to their ownership stakes in rival firms and enjoy the cross-ownership conferred market power after the outsiders deplete their stocks, thereby delaying their resource exhaustion to a later date.

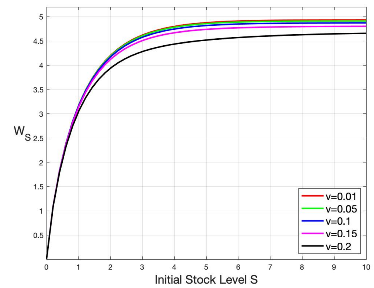
Using the parameter values $a = b = 1, c = 0$ and $r = 0.1$, we plot the discounted sum of consumer surplus, industry profits as well as welfare as a function of initial stock S for different v when fixing $k = 6$ and $n = 8$ in Figure 2.10, for different k when fixing $v = 0.1$ and $n = 10$ in Figure 2.11, and for different n when fixing $k = 6$ and $v = 0.1$ in Figure 2.12, respectively. From these figures, we observe the following result:



(a) CS as a function of initial stock

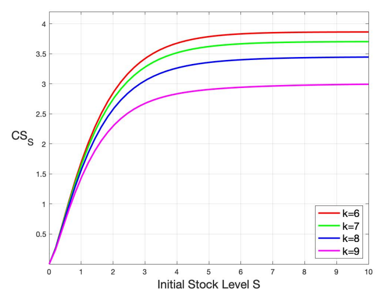


(b) PS as a function of S

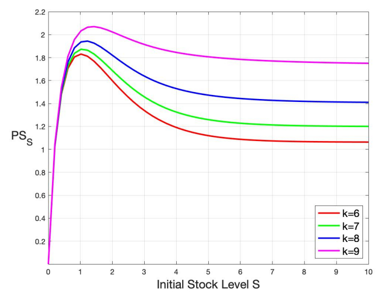


(c) Welfare as a function of S

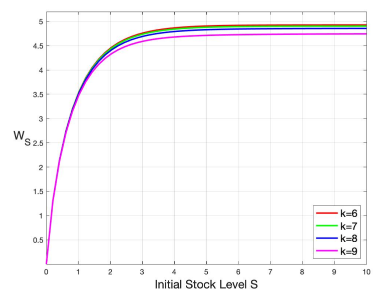
Figure 2.10: Comparative statics of CS_S, PS_S and W_S with respect to v



(a) CS as a function of S

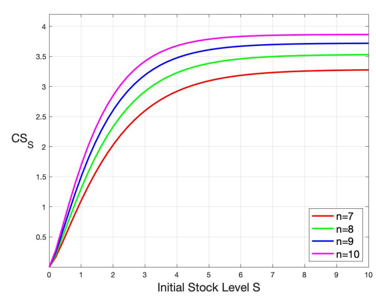


(b) PS as a function of S

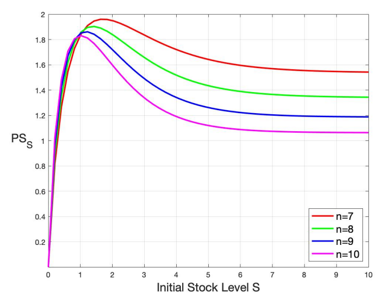


(c) Welfare as a function of S

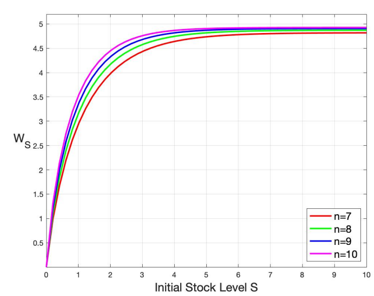
Figure 2.11: Comparative statics of CS_S, PS_S and W_S with respect to k



(a) CS as a function of S



(b) PS as a function of S



(c) Welfare as a function of S

Figure 2.12: Comparative statics of CS_S, PS_S and W_S with respect to n

Result 4. *Ceteris paribus, an increase in v or k results in a decrease in consumer surplus, an increase in industry profits and ultimately a decrease in social welfare for all levels of resource stock S.*

Result 5. *Ceteris paribus, a decrease in n will lead to a reduction in both consumer surplus and social welfare for all levels of initial resource stock S but a rise in industry profits when S is large. However, for S positive and small enough, a decrease in n will result in less industry profits.*

Indeed, for any S, an increase in v or k will lead to a larger output reduction from the insiders. Even though the outsiders respond aggressively by expanding their outputs, the reduction from the cross-owners more than offsets the increase from the outsiders. As a result, the industry output decreases and market price increases. This brings down consumer surplus but increases industry profits. However, the overall reduction from consumer surplus always dominates the increase in industry profits, thereby resulting in a welfare loss.

The same intuition illustrated earlier (equivalently when k increases) applies for the effect of a decrease of n on consumer surplus, industry profits when S is large enough and social welfare. However, when the initial resource stock owned by each firm is small enough, as the number of players in the industry decreases, outsiders will be restricted in their response to the increased cross-ownership because they have a limited resource stock. The scarcity effect then overcomes the competition effect. Since the total industry resource stock is also reduced because of a reduction in n, total industry profits decrease.

2.6 Conclusion

We have shown that for a nonrenewable resource industry, the profitability of a k-symmetric cross-ownership can be positive for any participation ratios, provided that the initial resource stock owned by each firm is small enough. This outcome occurs because when the cross-owners reduce their output due to their ownership stakes in the rival firms, the outsiders are limited in their response in terms of increased output due to their finite resource stocks. Consequently, the cross-ownership participants may raise prices more than in other industries without stock constraint. These findings are in sharp contrast with those obtained in cases where resource constraints are absent. Indeed, we have shown in the static case that for any levels of non-controlling minority shareholdings, a k-symmetric cross-ownership is never profitable if the participation ratio is below some lower threshold, but always profitable when the participation ratio is above some upper threshold, while there exists a large range of shareholdings for which it can be profitable when the participation ratio is in between the lower and upper thresholds. We define the result that cross-ownership may be unprofitable as a cross-ownership paradox, analogous to the merger paradox. Our analysis shows that with symmetric firms, the cross-ownership paradox applies in nonrenewable industries only when the stock is large enough.

Our paper also highlights that cross-ownership can be preferable to a full merger in terms of Cournot competition. Not only is it more profitable to participate in the cross-ownership than a horizontal merger, more importantly, it constitutes a shrewd strategy to avoid the possible legal challenges. Thus competition authorities should adapt their current lenient approach towards minority shareholdings to a stricter scrutiny. Our analysis also shows that cross-ownership may turn out to be relatively less detrimental to consumers in a nonrenewable resource industry than other industries where resource constraints are absent. Thus, antitrust authorities should consider adapting its guidelines and conduct a specific examination when dealing with industries where inter-temporal constraints play an important role. These include, for example, industries where a common property renewable resource is exploited (Colombo and Labrecciosa, 2018), or where stock pollutants are generated (Arguedas, Cabo and Martín-Herrán, 2020; De Frutos and Martín-Herrán, 2019), or where the buildup of capital is a strategic decision (Feichtinger et al., 2005; Huisman and Kort, 2015; López and Vives, 2019), or where firms compete under price stickiness (Colombo and Labrecciosa, 2021; Esfahani, 2019).

References

Arguedas, Carmen, Francisco Cabo, and Guiomar Martín-Herrán. 2020. "Enforcing regulatory standards in stock pollution problems." *Journal of Environmental Economics and Management*, 100: 102297.

Benchekroun, Hassan, Alex Halsema, and Cees Withagen. 2009. "On nonrenewable resource oligopolies: The asymmetric case." *Journal of Economic Dynamics and Control*, 33(11): 1867–1879.

Benchekroun, Hassan, Alex Halsema, and Cees Withagen. 2010. "When additional resource stocks reduce welfare." *Journal of Environmental Economics and Management*, 59(1): 109–114.

Benchekroun, Hassan, Gerard van der Meijden, and Cees Withagen. 2019. "An oligopoly-fringe non-renewable resource game in the presence of a renewable substitute." *Journal of Economic Dynamics and Control*, 105: 1–20.

Benchekroun, Hassan, Michèle Breton, and Amrita Ray Chaudhuri. 2019. "Mergers in nonrenewable resource oligopolies and environmental policies." *European Economic Review*, 111: 35–52.

Bresnahan, Timothy F, and Steven C Salop. 1986. "Quantifying the competitive effects of production joint ventures." *International Journal of Industrial Organization*, 4(2): 155–175.

Brito, Duarte, António Osório, Ricardo Ribeiro, and Helder Vasconcelos. 2018. "Unilateral effects screens for partial horizontal acquisitions: The generalized HHI and GUPPI." *International Journal of Industrial Organization*, 59: 127–189.

Brito, Duarte, Luís Cabral, and Helder Vasconcelos. 2014. "Divesting ownership in a rival." *International Journal of Industrial Organization*, 34: 9–24.

Brito, Duarte, Ricardo Ribeiro, and Helder Vasconcelos. 2014. "Measuring unilateral effects in partial horizontal acquisitions." *International Journal of Industrial Organization*, 33: 22–36.

Brito, Duarte, Ricardo Ribeiro, and Helder Vasconcelos. 2018. "Quantifying the coordinated effects of partial horizontal acquisitions." *European Economic Review*, 110: 108–149.

Colombo, Luca, and Paola Labrecciosa. 2018. "Consumer surplus-enhancing cooperation in a natural resource oligopoly." *Journal of Environmental Economics and Management*, 92: 185–193.

Colombo, Luca, and Paola Labrecciosa. 2021. "A stochastic differential game of duopolistic competition with sticky prices." *Journal of Economic Dynamics and Control*, 122: 104030.

De Frutos, Javier, and Guiomar Martín-Herrán. 2019. "Spatial effects and strategic behavior in a multiregional transboundary pollution dynamic game." *Journal of Environmental Economics and Management*, 97: 182–207.

Dietzenbacher, Erik, Bert Smid, and Bjørn Volkerink. 2000. "Horizontal integration in the Dutch financial sector." *International Journal of Industrial Organization*, 18(8): 1223–1242.

Dockner, Engelbert J, Steffen Jorgensen, Ngo Van Long, and Gerhard Sorger. 2000. *Differential games in economics and management science.* Cambridge University Press.

Esfahani, Hamideh. 2019. "Profitability of horizontal mergers in the presence of price stickiness." *European Journal of Operational Research*, 279(3): 941–950.

Farrell, Joseph, and Carl Shapiro. 1990. "Asset ownership and market structure in oligopoly." *The RAND Journal of Economics*, 275–292.

Feichtinger, Gustav, Richard F Hartl, Peter M Kort, and Vladimir M Veliov. 2005. "Environmental policy, the Porter hypothesis and the composition of capital: Effects of learning and technological progress." *Journal of Environmental Economics and Management*, 50(2): 434–446.

Flath, David. 1991. "When is it rational for firms to acquire silent interests in rivals?" *International Journal of Industrial Organization*, 9(4): 573–583.

Flath, David. 1992. "Horizontal shareholding interlocks." *Managerial and Decision Economics*, 13(1): 75–77.

Foros, Øystein, Hans Jarle Kind, and Greg Shaffer. 2011. "Mergers and partial ownership." *European Economic Review*, 55(7): 916–926.

Fotis, Panagiotis, and Nikolaos Zevgolis. 2016. *The competitive effects of minority shareholdings: legal and economic issues.* Bloomsbury Publishing.

Gilo, David. 2000. "The anticompetitive effect of passive investment." *Michigan Law Review*, 99(1): 1–47.

Gilo, David, Yossi Moshe, and Yossi Spiegel. 2006. "Partial cross ownership and tacit collusion." *The RAND Journal of Economics*, 37(1): 81–99.

Hillman, Arye L, and Ngo Van Long. 1983. "Pricing and depletion of an exhaustible resource when there is anticipation of trade disruption." *The Quarterly Journal of Economics*, 98(2): 215–233.

Hotelling, Harold. 1931. "The economics of exhaustible resources." *Journal of Political Economy*, 39(2): 137–175.

Huisman, Kuno JM, and Peter M Kort. 2015. "Strategic capacity investment under uncertainty." *The RAND Journal of Economics*, 46(2): 376–408.

Jovanovic, Dragan, and Christian Wey. 2014. "Passive partial ownership, sneaky takeovers, and merger control." *Economics Letters*, 125(1): 32–35.

Kumar, B Rajesh. 2012. *Mega Mergers and Acquisitions.* Springer.

Levin, Dan. 1990. "Horizontal mergers: The 50-percent benchmark." *American Economic Review*, 80(5): 1238–1245.

Lewis, Tracy R, and Richard Schmalensee. 1980. "On oligopolistic markets for nonrenewable natural resources." *The Quarterly Journal of Economics*, 95(3): 475–491.

López, Ángel L, and Xavier Vives. 2019. "Overlapping ownership, R&D spillovers, and antitrust policy." *Journal of Political Economy*, 127(5): 2394–2437.

Loury, Glenn C. 1986. "A theory of'oil'igopoly: Cournot equilibrium in exhaustible resource markets with fixed supplies." *International Economic Review*, 285–301.

Malueg, David A. 1992. "Collusive behavior and partial ownership of rivals." *International Journal of Industrial Organization*, 10(1): 27–34.

Nain, Amrita, and Yan Wang. 2018. "The product market impact of minority stake acquisitions." *Management Science*, 64(2): 825–844.

O'Brien, Daniel P, and Steven C Salop. 2000. "Competitive effects of partial ownership: financial interest and corporate control." *Antitrust Law Journal*, 67(3): 559–614.

Polasky, Stephen. 1992. "Do oil producers act as Oiligopolists?" *Journal of Environmental Economics and Management*, 23(3): 216–247.

Reynolds, Robert J, and Bruce R Snapp. 1986. "The competitive effects of partial equity interests and joint ventures." *International Journal of Industrial Organization*, 4(2): 141–153.

Salant, Stephen W. 1976. "Exhaustible resources and industrial structure: A Nash-Cournot approach to the world oil market." *Journal of Political Economy*, 84(5): 1079–1093.

Salant, Stephen W, Sheldon Switzer, and Robert J Reynolds. 1983. "Losses from horizontal merger: the effects of an exogenous change in industry structure on Cournot-Nash equilibrium." *The Quarterly Journal of Economics*, 98(2): 185–199.

Scott Morton, Fiona, and Herbert Hovenkamp. 2017. "Horizontal shareholding and antitrust policy." *Yale Law Journal*, 127: 2026.

Stühmeier, Torben. 2016. "Competition and corporate control in partial ownership acquisitions." *Journal of Industry, Competition and Trade*, 16(3): 297–308.

Takayama, Akira. 1985. *Mathematical economics.* Cambridge University Press.

2.7 Appendix

Proof of Proposition 1:

Proof. We characterize the OL-NCOE by using optimal control theory. The current value Hamiltonian associated with the problem of a typical firm $i \in I$ is given by

$$H_i(q_i, Q_{-i}, \lambda_i, t) = \frac{1}{1-(k-2)v-(k-1)v^2}\Bigg((1-(k-2)v)q_i + v\sum_{k\in I\setminus i} q_k\Bigg)\Big(a-c-bQ_{-i}-bq_i\Big) - \lambda_i q_i,$$

while that for a typical firm $o \in O$ is

$$H_o(q_o, Q_{-o}, \lambda_o, t) = (a - bQ_{-o} - bq_o - c)q_o - \lambda_o q_o$$

Exploiting symmetry, the maximum principle yields the interior solution

$$\Big(1-(k-2)v\Big)(a-c) - \Big[1+k+\Big(1-k(k-2)\Big)v\Big]bq_i - \Big(1-(k-2)v\Big)(n-k)bq_o = \lambda_i\Big(1-(k-2)v-(k-1)v^2\Big) \tag{2.6}$$

$$a - c - (n-k+1)bq_o - bkq_i = \lambda_o \tag{2.7}$$

for $i = 1, 2, \cdots, k$ and $o = k+1, \cdots, n$, with

$$\frac{d\lambda_i}{dt} = r\lambda_i \tag{2.8}$$

$$\frac{d\lambda_o}{dt} = r\lambda_o \tag{2.9}$$

Solving for (q_i, q_o) from (2.6) and (2.7), then we get

$$q_i(t) = \frac{\Big(1-(k-2)v\Big)(a-c) - \Big(1-(k-2)v-(k-1)v^2\Big)(n-k+1)\lambda_i + \Big(1-(k-2)v\Big)(n-k)\lambda_o}{\Big((k+n+1-k^2)v+n+1\Big)b} \tag{2.10}$$

$$q_o(t) = \frac{(1+v)(a-c) + \Big(1-(k-2)v-(k-1)v^2\Big)k\lambda_i - \Big[1+k+\Big(1-k(k-2)\Big)v\Big]\lambda_o}{\Big((k+n+1-k^2)v+n+1\Big)b} \tag{2.11}$$

During the second phase where only firms $i \in I$ extract a positive quantity, the maximum principle yields

$$\Big(1-(k-2)v\Big)(a-c) - \Big[1+k+\Big(1-k(k-2)\Big)v\Big]bq_i = \lambda_i\Big(1-(k-2)v-(k-1)v^2\Big) \tag{2.12}$$

with

$$\frac{d\lambda_i}{dt} = r\lambda_i \tag{2.13}$$

Solving for q_i from (2.12), we obtain

$$q_i(t) = \frac{\Big(1-(k-2)v\Big)(a-c) - \Big(1-(k-2)v-(k-1)v^2\Big)\lambda_i}{\Big[1+k+\Big(1-k(k-2)\Big)v\Big]b} \tag{2.14}$$

The terminal dates T_i and T_o are endogenous and determined by

$$H_i(q_i(T_i), q_{-i}(T_i), \lambda_i(T_i), T_i) = 0$$

for $i \in I$ and

$$H_o(q_o(T_o), q_{-o}(T_o), \lambda_o(T_o), T_o) = 0$$

for $o \in O$. These terminal conditions along with the maximum principle imply that

$$q_i(T_i) = 0, \quad q_o(T_o) = 0 \tag{2.15}$$

From (2.8),(2.9) and (2.13) and continuity of the costate variable λ_i at T_o, we have

$$\lambda_i = \lambda_{i0}e^{rt} \quad \forall\, t \in [0, T_i] \tag{2.16}$$

$$\lambda_o = \lambda_{o0}e^{rt} \quad \forall\, t \in [0, T_o] \tag{2.17}$$

where λ_{i0} and λ_{o0} are determined using conditions (2.15) along with (2.14) and (2.11). From (2.14), we have

$$q_i(T_i) = \frac{\Big(1-(k-2)v\Big)(a-c) - \Big(1-(k-2)v-(k-1)v^2\Big)\lambda_{i0}e^{rT_i}}{\Big[1+k+\Big(1-k(k-2)\Big)v\Big]b} = 0,$$

that is,

$$\lambda_{i0} = (a-c)\Big(1-(k-2)v\Big)\Big(1-(k-2)v-(k-1)v^2\Big)^{-1} e^{-rT_i}$$

and

$$\lambda_i = \lambda_{i0}e^{rt} = (a-c)\Big(1-(k-2)v\Big)\Big(1-(k-2)v-(k-1)v^2\Big)^{-1} e^{r(t-T_i)} \tag{2.18}$$

From (2.11), we have

$$q_o(T_o) = \frac{(1+v)(a-c)+\Big(1-(k-2)v-(k-1)v^2\Big)k\lambda_i(T_o)-\Big[1+k+\Big(1-k(k-2)\Big)v\Big]\lambda_o(T_o)}{\Big((k+n+1-k^2)v+n+1\Big)b} = 0,$$

that is,

$$\lambda_{o0} = \frac{a-c}{1+k+\Big(1-k(k-2)\Big)v}\Big[(1+v)e^{-rT_o}+k\Big(1-(k-2)v\Big)e^{-rT_i}\Big]$$

and

$$\lambda_o = \lambda_{o0}e^{rt} = \frac{a-c}{1+k+\Big(1-k(k-2)\Big)v}\Big[(1+v)e^{r(t-T_o)}+k\Big(1-(k-2)v\Big)e^{r(t-T_i)}\Big] \tag{2.19}$$

Substituting (2.18) and (2.19) into (2.10), (2.11) and (2.14) yields the Phase I ($0 \leq t \leq T_o$) and Phase II ($T_o \leq t \leq T_i$) equilibrium supply paths of all the firms as presented in (2.3) and (2.4). These equilibrium paths are determined as functions of the terminal times T_i and T_o, which are determined from the resource constraint conditions, i.e.,(2.5). It can be shown that such a non-linear system in (T_i, T_o) admits a unique solution, with $T_i \geq T_o$. A full proof is provided in the following.

The terminal dates T_i and T_o are determined from the resource constraint conditions. More specifically,

$$\int_0^{T_o} \frac{(1-(k-2)v)(a-c)\cdot A}{((k+n+1-k^2)v+n+1)[1+k+(1-k(k-2))v]b}dt + \int_{T_o}^{T_i} \frac{(1-(k-2)v)(a-c)\cdot B}{[1+k+(1-k(k-2))v]b}dt = S_{0i} \tag{2.20}$$

where

$$A = \left[1+k+\Big(1-k(k-2)\Big)v-\Big((k+n+1-k^2)v+n+1\Big)e^{r(t-T_i)}+(n-k)(1+v)e^{r(t-T_o)}\right]$$

$$B = \left[1-e^{r(t-T_i)}\right]$$

and

$$\int_0^{T_o} \frac{(a-c)(1+v)}{\Big((k+n+1-k^2)v+n+1\Big)b}\left[1-e^{r(t-T_o)}\right]dt = S_{0o} \tag{2.21}$$

From (2.20), we have

$$\frac{(1-(k-2)v)}{[1+k+(1-k(k-2))v]}\left[\Big((k+n+1-k^2)v+n+1\Big)(e^{-rT_i}+rT_i-1)-(n-k)(1+v)(e^{-rT_o}+rT_o-1)\right]$$

$$= \frac{\Big((k+n+1-k^2)v+n+1\Big)brS_{0i}}{(a-c)}$$

From (2.21), we have

$$(1+v)(e^{-rT_o}+rT_o-1) = \frac{\Big((k+n+1-k^2)v+n+1\Big)brS_{0o}}{(a-c)}$$

Same resource endowments $S_{0i} = S_{0o} = S$ yields

$$\frac{(1-(k-2)v)}{[1+k+(1-k(k-2))v]}\left[\Big((k+n+1-k^2)v+n+1\Big)(e^{-rT_i}+rT_i-1)-(n-k)(1+v)(e^{-rT_o}+rT_o-1)\right]$$

$$= (1+v)(e^{-rT_o}+rT_o-1)$$

or

$$(1-(k-2)v)\Big((k+n+1-k^2)v+n+1\Big)(e^{-rT_i}+rT_i-1) = (1+v)\Big((1-n(k-2))v+n+1\Big)(e^{-rT_o}+rT_o-1)$$

Note that

$$
\begin{aligned}
&(1-(k-2)v)\Big((k+n+1-k^2)v+n+1\Big)-(1+v)\Big((1-n(k-2))v+n+1\Big)\\
=&-v(k-1)\big(k+v+2kv-k^2v+1\big)\\
=&-v(k-1)\Big(k\big(1-(k-2)v\big)+v+1\Big)<0 \quad \forall\, v\in(0,\frac{1}{k-1})
\end{aligned}
$$

Thus,

$$
(1-(k-2)v)\Big((k+n+1-k^2)v+n+1\Big)<(1+v)\Big((1-n(k-2))v+n+1\Big).
$$

Then we must have

$$
f(T_i)=e^{-rT_i}+rT_i-1>f(T_o)=e^{-rT_o}+rT_o-1 \quad \text{for } T_i>T_o
$$

In other words, we need to show that $f(T)=e^{-rT}+rT-1$ is an increasing function. Indeed,

$$
f'(T)=-re^{-rT}+r=r(1-e^{-rT})>0
$$

Thus we have finished our proof.

□

Proof of Proposition 2:

Proof. The profitability function G can be simplified as

$$
G(k,n,v)=\frac{\Big[(n+1)(v+1)(2k-n-1)-k^2v(k-1)\Big]v(k-1)}{\Big((k+n+1-k^2)v+n+1\Big)^2(n+1)^2}\left[\frac{(a-c)^2}{b}\right]
$$

For any $v>0$ and $2\le k\le n$, the function G has the same sign as the function H, where

$$
H(k,n,v)=(n+1)(v+1)(2k-n-1)-k^2v(k-1)
$$

This function is linear in v, indeed

$$
H(k,n,v)=(n+1)(2k-n-1)+\Big((n+1)(2k-n-1)-k^2(k-1)\Big)v,
$$

which can be rewritten as

$$H(k,n,v) = H(k,n,0) + \Big(H(k,n,0) - k^2(k-1)\Big)v.$$

Clearly, when $H(k,n,0) \le 0$, i.e. $2k - n - 1 \le 0$ or $k \le \dfrac{1+n}{2}$, we have $H(k,n,v) < 0$ and therefore $G < 0$. Thus, a necessary condition for cross-ownership to be profitable is that $k > \dfrac{1+n}{2}$.

We now show that $H(k,n,v)$ is a strictly decreasing function of v. Its slope is given by

$$\begin{aligned}\frac{\partial H(k,n,v)}{\partial v} &= H(k,n,0) - k^2(k-1)\\ &= (n+1)(2k-n-1) - k^2(k-1)\\ &= (2k-2)n - n^2 + \Big(2k - k^2(k-1) - 1\Big)\\ &\equiv F(k,n)\end{aligned}$$

Therefore, $F(k,n)$ is a quadratic inverted U-shaped function of n that we shall show is strictly decreasing in n for all $n \ge k$ and is negative for $n = k$, and thus negative for all $n \ge k$. Indeed

$$\frac{\partial F(k,n)}{\partial n} = 2k - 2 - 2n < 0 \quad \forall\, n \ge k$$

and at $n = k$,

$$F(k,k) = (k+1)(2k-k-1) - k^2(k-1) = -(k^2-k-1)(k-1) < 0$$

thus $F(k,n) < 0, \forall\, n \ge k$. So when $k > \frac{1+n}{2}$, for

$$H(k,n,v) = H(k,n,0) + \underbrace{\Big(H(k,n,0) - k^2(k-1)\Big)}_{=F(k,n)<0} v > 0,$$

we need

$$v < \bar{v} \equiv -\frac{H(k,n,0)}{H(k,n,0) - k^2(k-1)},$$

where $\bar{v}$ is the threshold shareholding such that $H(k,n,\bar{v}) = 0$ or $G(\bar{v}) = 0$. To sum up, $H(k,n,v)$ is a strictly decreasing linear function of v, and when $k > \frac{1+n}{2}$, we have $H(k,n,v) > 0$ or $G > 0$ if and only if $v < \bar{v} \equiv -\frac{H(k,n,0)}{(H(k,n,0)-k^2(k-1))}$.

We now determine when $\bar{v}$ is less than the upper bound of shareholdings $\frac{1}{k-1}$ by finding the sign of $H\left(k, n, \frac{1}{k-1}\right)$:

$$H\left(k, n, \frac{1}{k-1}\right) = (n+1)(2k-n-1) + \Big((n+1)(2k-n-1) - k^2(k-1)\Big)\frac{1}{k-1}$$
$$= \frac{1}{k-1}\Big(k(n+1)(2k-n-1) - k^2(k-1)\Big)$$
$$= \frac{1}{k-1}\Big(2k^2n + 2k^2 - kn^2 - 2kn - k - k^3 + k^2\Big)$$

or

$$(k-1)H\left(k, n, \frac{1}{k-1}\right) = -kn^2 + \left(2k^2 - 2k\right)n + \left(3k^2 - k^3 - k\right).$$

This $(k-1)H\left(k, n, \frac{1}{k-1}\right)$ function is a quadratic inverted U-shaped function of n and has two real roots n_1 and n_2 with

$$n_2 = k + \sqrt{k} - 1 > n_1 = k - \sqrt{k} - 1$$

and thus, it is strictly positive for $n \in (n_1, n_2)$ and negative for $n > n_2$. Since $n_1 < k < n_2$, by directly evaluating the sign of $(k-1)H\left(k, n, \frac{1}{k-1}\right)$ at $n = k$, we must have $(k-1)H\left(k, k, \frac{1}{k-1}\right) > 0$.

Therefore, for $n \in [k, n_2)$, we have $H\left(k, n, \frac{1}{k-1}\right) > 0 = H(k, n, \bar{v})$ and thus $\bar{v} > \frac{1}{k-1}$; for $n > n_2$, we have $H\left(k, n, \frac{1}{k-1}\right) < 0 = H(k, n, \bar{v})$ and thus $\bar{v} < \frac{1}{k-1}$, so there exists some $v \in (\bar{v}, \frac{1}{k-1})$ for which $G < 0$. To sum up:

1. For $k \leq \frac{1+n}{2}$, we have $G < 0$;
2. For $k > \frac{1+n}{2}$, there exists $\bar{v} \equiv -\frac{H(k,n,0)}{(H(k,n,0)-k^2(k-1))} > 0$ such that we have $G > 0$ if and only if $v < \bar{v}$, where

$$H(k, n, v) = (n+1)(2k-n-1) + \big((n+1)(2k-n-1) - k^2(k-1)\big)v.$$

Moreover, for $n \in [k, n_2)$, we have $\bar{v} > \frac{1}{k-1}$, therefore $G > 0$ for all admissible $v < \frac{1}{k-1}$. When $n > n_2$, then $G > 0$ for $v < \bar{v}$ and $G < 0$ for $v \in \left(\bar{v}, \frac{1}{k-1}\right)$, where $n_2 \equiv k + \sqrt{k} - 1$.

Note that the condition $k > \frac{1+n}{2}$ can be expressed as $\frac{k}{n} > \frac{k}{2k-1}$, and $n > n_2$ is equivalent to $\frac{k}{n} < \gamma(k) \equiv \frac{k}{k+\sqrt{k}-1}$, so we can draw the following conclusion: For any $2 \leq k \leq n$ and $0 < v < \frac{1}{k-1}$, the profitability of a k-symmetric cross-ownership for Cournot competitors depends on the following scenarios:

1. If $\frac{k}{n} \leq \frac{k}{2k-1}$, then $G < 0$ for all $v \in (0, \frac{1}{k-1})$;
2. If $\frac{k}{2k-1} < \frac{k}{n} < \gamma(k) \equiv \frac{k}{k+\sqrt{k-1}}$, then $G > 0$ for $v < \bar{v}$ and $G < 0$ for $v \in (\bar{v}, \frac{1}{k-1})$;
3. If $\frac{k}{n} > \gamma(k) \equiv \frac{k}{k+\sqrt{k-1}}$, then $G > 0$ for all $v \in (0, \frac{1}{k-1})$.

□

Proof of Corollary 1:

Proof. We focus on the case where $\frac{k}{n} > \frac{k}{2k-1}$ and show that $\bar{v} = -\frac{(n+1)(2k-n-1)}{(n+1)(2k-n-1)-k^2(k-1)}$ is strictly increasing in $y \equiv \frac{k}{n}$. We can rewrite $\bar{v}$ as

$$\bar{v} = -\frac{1}{\left(1 + \frac{k^2(k-1)}{(n+1)(n+1-2k)}\right)} = -\frac{1}{\left(1 + \frac{k^2(k-1)}{\left(\frac{k}{y}+1\right)\left(\frac{k}{y}+1-2k\right)}\right)}$$

Direct computation of $\frac{\partial \bar{v}}{\partial y}$ gives

$$\frac{\partial \bar{v}}{\partial y} = 2k^3 y(k-1) \frac{k(1-y)+y}{\left((k^3-k^2-2k+1)y^2 + 2k(1-k)y + k^2\right)^2} > 0.$$

□

Proof of Proposition 3:

Proof. The welfare change resulting from the k-symmetric cross-ownership is

$$\Delta TS(k,n,v) = \frac{\left[v\left(k(k-1)-2(n+1)\right) - 2(n+1)\right]kv(k-1)}{\left((k+n+1-k^2)v+n+1\right)^2 (n+1)^2}\left[\frac{(a-c)^2}{2b}\right]$$

For any $v > 0$ and $2 \leq k \leq n$, the function ΔTS has the same sign as the function Γ, where

$$\Gamma(k,n,v) = \left(k(k-1)-2(n+1)\right)v - 2(n+1)$$

which is linear in v. Note that

$$\Gamma(k,n,0) = -2(n+1) < 0$$

and

$$\Gamma(k,n,\frac{1}{k-1}) = \frac{1}{k-1}\Big(k(k-1) - 2(n+1)\Big) - 2(n+1)$$
$$= k - 2n - 2 - \frac{2(n+1)}{k-1} < 0$$

Thus,

$$\Gamma(k,n,v) < 0 \Longleftrightarrow \Delta TS(k,n,v) < 0, \forall\ v \in (0, \frac{1}{k-1})$$

□

Discussion and Conclusion

This thesis investigates the impact of resource market imperfections on firm behaviour, market competition, and the environment. Specifically, the research focuses on two distinct market distortions: lobby groups in the international waste market and cross-ownership in the nonrenewable resource sector.

The first chapter of my thesis examines whether strengthening the lobbying power of green lobbies can reduce the North-to-South waste trade. From the theoretical perspective, I find that the effect of environmental lobbying on waste trade is ambiguous. Depending on the existing policy stringency relative to the socially optimal one and how environmentalists perceive the tradeoff between the savings from environmental damages versus the utility from consumption, the effects of green lobbying on waste trade can be either positive or negative. However, I find compelling empirical evidence that environmental lobby groups exert a statistically significant impact on the North-to-South waste export by reducing it. My results thus highlight the important role of green lobbies in the North-to-South waste trade and identify environmental lobbying as an effective way to curb the growing waste shipments. This suggests that it will be worthwhile for international donor organizations to provide support for the development of environmental NGOs all over the world.

One limitation of my study is that my empirical results do not allow me to claim that the waste export reduction is purely from this policy channel of lobbying. For example, the reduction may come from other forms of political influence exerted by environmental lobby groups such as public persuasion, environmental litigation, and so on. Also, it may be possible that environmental lobbying would lead to technological improvements in waste recycling and disposal and thus result in less waste being exported. Further work is needed to understand the mechanisms through which environmental lobbies have played a role in reducing the waste trade and to what extent the reduction can be explained by political lobbying through its effects on government policy decisions.

The second chapter of my thesis investigates how cross-ownership affects the strategic nonrenewable resource use and its implications for competition policy. I show that the profitability of a symmetric cross-ownership among a subset of firms can be positive for any participation ratios, provided that the initial stock owned by each firm is small enough in a nonrenewable resource industry. This finding is in sharp contrast with the static case where the profitability of cross-ownership depends on three countervailing effects. One is the positive effect on cross-owners' profits due to the partial elimination of previous rivalry; the second is the negative effect of non-participants' production expansion in terms of strategic substitutability; and the last one is how aggressively outsiders will respond depending on the levels of shareholdings. This particular outcome occurs because resource scarcity plays an important role in shaping firms' decisions to compete. When the cross-owners reduce their output due to their ownership stakes in the rival firms, the outsiders are limited in their response in terms of increased output due to their finite resource stocks. I also demonstrate that cross-ownership can lead to less welfare loss in a nonrenewable resource industry than in other industries where resource constraints are absent. These findings thus highlight the unique feature of the nonrenewable resource industry and suggest that antitrust authorities should perform a specific examination when dealing with industries where inter-temporal constraints play an important role.

So far, I have focused mostly on cross-ownership while another contemporary phenomenon is the increasing ownership concentration of public firms among a small group of the largest institutional investors, i.e., common ownership. My research plan for the near future is to address: (i) how common ownership affects the use of a nonrenewable resource and how it differs from other industries; (ii) the impact of common ownership on corporate socially responsible firms and its implications for climate change. In addition, several extensions can be done along this line of research and are under investigation. The first one is on the modelling choice of whether firms can commit to a fixed time path of extraction. If firms can observe their competitors' stocks at any future dates, they would like to adjust their production at each instant of time, i.e., use closed-loop or Markov strategies, instead of committing to the open-loop strategies adopted in the paper. This alternate assumption where commitment is not feasible and firms use closed-loop strategies seems more realistic and can better capture the complex strategic interaction between players and the intertemporal nature of the problem each player faces. The second direction is to introduce product differentiation and investigate the profitability of cross-ownership in a differentiated product oligopoly. Indeed, firms seldom sell exactly the same products and there always exist different varieties of similar products in the market. For example, in the global oil market, there are different types of oil, including Brent, West Texas Intermediate, Western Canadian Select, Dubai Fateh, Murban, Urals, etc. So, in an oligopolistic market with differentiated products, is it more profitable for a firm to engage in cross-ownership with another firm that produces a similar product or a highly differentiated one? And if so, by a smaller or larger shareholding? All of these questions remain to be answered and represent a promising line for future research.

In conclusion, my thesis reveals the complex interactions between market imperfections, firm behaviour, and environmental outcomes. By examining the role of environmental lobby groups in international waste trade and the effects of cross-ownership on firms' strategic resource use, this thesis sheds light on the complexities of these issues and contributes to our understanding of how these market imperfections influence firms' decision-making and market dynamics, and their implications for the environment and competition policy. The thesis thus highlights the importance and need for a comprehensive understanding of market imperfections and their implications for environmental challenges.

The research findings presented in this thesis may also have implications for policy-makers, practitioners, and stakeholders involved in waste management, resource extraction, and environmental governance. Further research is needed in this area and can contribute to the development of more effective policies and strategies to address these market imperfections and promote more sustainable solutions in climate change mitigation and natural resources sound exploitation.