Regulation in a Global Economy: Models of Environmental and Social Dumping

By

Jean-François Godin

An essay submitted to the Department of Economics in partial fulfillment of the requirements for the degree of Master of Arts

Queen's University

Kingston, Ontario, Canada

August 2014

Abstract

In this paper, a strategic model of trade is developed to analyze the effect of environmental and social regulations set by a country on the demand in the world market for a good produced within that country. A three-country model is used where homogeneous firms in two of the countries compete in a Cournot setting to sell a good in the third country. Using a two-stage game where governments choose their policy in the first stage and the firms choose their quantity in the second stage, optimal policies and social welfare are derived both in the case where governments maximize welfare in their own country (non-collusive case) and in the case where a social planner maximizes welfare in both country (collusive case). A special emphasis is placed on a parameter capturing the level of environmental and social awareness in the world market. I show that, under certain assumptions, an increase in this parameter allows to bridge the gap between the collusive and the non-collusive outcome in government policies for the case of environmental regulation. For the case of social regulation, an increase in the parameter will only cause convergence between the collusive and the non-collusive outcome if the strategic effect is large enough and it will cause divergence between the two cases if the strategic effect is too small. I then discuss the impacts this has on the incentives for governments to collaborate on regulations and how governments can attempt to achieve and maintain the collusive outcome.

Acknowledgments

I would first like to thank my family for all their support throughout my academic career. In particular, I would like to thank my parents for encouraging my thirst for knowledge and for fueling the fire of my curiosity at an early age. I am also grateful to all the professors I have had a chance to learn from over the years and specially to the faculty members here at Queen's University. Furthermore, I would like to thank my supervisor Dr. Beverly Lapham whose guidance and advice were very precious to me as I was writing this paper. In terms of financial support, I was privileged to receive help from Queen's University and the Social Sciences and Humanities Research Council (SSHRC). Finally, some very kind words for my fellow classmates, many of whom have become great friends during the school year. The spirit of camaraderie and collaboration we enjoyed together allowed the creation of an environment suitable for learning and made the process very enjoyable.

Contents

1 Introduction

In this paper, the trade-offs faced by a nation when choosing environmental and social regulations are analyzed through the lens of strategic interactions in a framework of imperfect competition. In particular, the demand for a good consumed outside the country where it is produced is allowed to depend on the strictness of the regulations in the producing country. Governments of the producing countries therefore have to consider this relationship when they determine the optimal level of regulation to maximize the welfare of their citizens, which will in turn affect the incentives for a strategy of environmental and social dumping.

Dumping by a country is defined as "exporting a product at a price lower than the price it normally charges on its own home market" by the World Trade Organization (WTO). The WTO allows countries to take anti-dumping measures to protect their domestic industries. To avoid these so called anti-dumping duties, some developing nations have adopted strategies of environmental and social dumping. Instead of charging a lower price for the product in the foreign market relative to the domestic market, the government establishes lower regulations for the domestic market relative to the foreign market and therefore gives its industries a competitive edge in the form of lower production costs.

Weak regulations for a country relative to another can take many forms such as lower or no minimum wage, lower safety standards to protect workers, lower taxes or standards on emissions of pollutants and lower requirements to protect the ecosystem around a plant. The strength of regulations in a country will depend on the preferences, the history and the economic situation in that country and thus weak regulations are not per se a bad thing. The potential for an environmental or social dumping strategy can arise due to the difference in those factors across countries.

Individuals typically derive utility from environmental quality and good working conditions inside their own country. With increasing linkages within the global economy, the last few decades have seen concerns over environmental and social issues in other nations becoming more important for economic agents. Damages from global pollutants like carbon dioxide are not contained within a country's border and products are often produced by workers in a country thousands of kilometers away from where they are consumed.

As consumers, governments and firms in developed nations become more sensitive to environmental and social regulations of their less developed trading partners, the optimal policies for the governments of the latter countries will change. In particular, the practices of social and environmental dumping may not yield the anticipated benefits and costs for developing nations.

This paper focuses on the effects of environmental and social awareness by consumers in the world market on the incentives for environmental and social dumping. A special emphasis is placed on the impact this has on the benefits of collusion between two governments looking to improve welfare in their respective countries.

The rest of the paper is organized as follows: Section 2 gives a brief literature review on strategic trade policy in the context of environmental and social regulations and an argument as to why social responsibility and environmental protection of one country can be included in the preferences of another country. This is followed by a presentation of the model in Section 3. In Section 4, the model is solved for different applications using specific functional forms. Finally, a discussion of the trade-offs and their policy implications is presented in Section 5 and Section 6 concludes the paper.

2 Literature Review

2.1 Strategic Trade Policy

The origin of the strategic trade literature can be traced back to the early 1980's. Brander and Spencer were pioneers in the field publishing a number of papers on the subject. In their chapter of the *The New Palgrave Dictionary of Eco-*

nomics, they define strategic trade policy as "trade policy that affects the outcome of strategic interactions between firms in an actual or potential international oligopoly." In other words, strategic trade policy is concerned with government policies in the presence of imperfect competition and how it can potentially shift the profits of an industry toward domestic firms, often at the expense of foreign firms. This is in contrast with previous international trade literature focusing mainly on perfect competition.

Brander (1981) first used an oligopolistic model to explain intra-industry trade, a very popular subject at the time as theory was trying to catch up to the empirical observation that intra-industry trade was a prevalent form of trade. [1] While this paper focused on explaining intra-industry trade and not optimal government policy, it served as a base for future work in the field of strategic trade policy. Brander and Spencer (1981) then proceeded to include a policy instrument, a tariff, in a Stackelberg entry deterrence model inspired by Dixit (1979) to illustrate the profit-shifting motives a government could have in an imperfect competition setting. In doing so, Brander and Spencer (1981) formalized the idea that a government policy that would typically decrease welfare under perfect competition could in fact increase welfare under imperfect competition by shifting monopoly rents to a domestic firm.

The so called "three-country model" is quite common in the strategic trade literature. It consists of two producing countries competing to sell a product in a third country which can also be considered to be the world market. A further assumption often used in the three-country models is that consumers of the two producing countries own the capital and the welfare in these countries can thus be considered to be the profits of the firms. Spencer and Brander (1983) developed such a model in a three-stage game with an R&D decision by the firms. Governments also had an R&D subsidy available to them as a policy tool to replace an export subsidy. Brander and Spencer (1985) continued along the lines of the three-

[1] See chapter 6 from *International economics* by T.A. Pugel (15^{th} ed.) for evidence of this.

country model with a paper where the government acts as a Stackelberg leader to a firm in its country. The model features a firm in each country competing in a Cournot game while the governments compete in a Nash Equilibrium game in export subsidy yielding a positive optimal export subsidy. Initial assumptions are critical in this class of model as demonstrated by Eaton and Grossman (1986). Their paper shows that by replacing Cournot competition between the firms by Bertrand competition, the optimal policy goes from a subsidy to a tax.

While all the previously discussed models focused on a single industry, Dixit (1986) considered multiple industries and showed that imperfect competition can be reconciled with the optimality of free trade (no subsidy) under certain conditions, mainly similar demand and cost structures across industries. Amongst other noteworthy contribution to the literature, let us note two models of reciprocal dumping. Brander and Krugman (1983) showed that under free entry and Cournot competition, reciprocal dumping is welfare enhancing for the countries engaging in the practice. This conclusion is not very robust to assumptions as Friberg and Ganslandt (2008) showed that adding product differentiation to such a setting leads to a reduction of total surplus if reciprocal dumping occurs.

2.2 Environmental Dumping

Let us now turn our attention to environmental policies in the context of strategic trade. In his chapter from "Conflicts and Cooperation in Managing Environmental Resources", Alistair Ulph studied in 1992 the optimal policy instrument by a government that wants to regulate pollution in the context of a three-country model. A one-shot Cournot game yielded indifference between a standard and a tax in terms of total surplus, but for both a Stackelberg game and a two-stage Cournot game, an emission standard was Pareto-superior to an emission tax. In the same vein, Lapan and Sikdar (2011) showed that an emission standard was preferred to a tax to avoid a race to the bottom under free trade and the presence of a transboundary pollutant. Ulph (1996) provided another advantage of emission standards over emission taxes as they reduce the incentive for strategic over-investment by firms.[2] On the other hand, his paper showed that welfare need not be higher under a standard relative to a tax if the producing country is a significant consumer of the polluting good. Feenstra, Kort and de Zeeuw (2001) added another caveat to Ulph's conclusion on investment by introducing open-loop investment strategies. Under taxes in their model, there is a substitution between capital and the polluting input. This tends to reduce investment and thus reduces the incentive for over-investment.

Potentially the first finding of an optimal environmental dumping policy was made by Barret (1994). He argued there are incentives for governments to impose environmental regulations where marginal cost of abatement is less than the marginal damage from pollution under Cournot competition and one firm per country. In what is a very common theme in this field, the result is not very robust as it goes away for more than one firm per country or for Bertrand competition. Environmental dumping was also showed to be a welfare enhancing practice by Walz and Wellisch (1997) as the loss from sub-optimal environmental policies was more than compensated by the gains from increasing exports in their model. Interestingly enough, they discussed how this finding could be extrapolated to social regulation which is also a form of regulation considered in this paper. Ulph (1996) showed using a three country model with Cournot competition that when producers behave strategically in terms of their investment decisions, it may reduce the incentive of governments to engage in environmental dumping, while not completely eliminating it.

Environmental dumping does not always have to be the optimal outcome. In a model of monopolistic competition, Pfluger (2001) argued that when the importance of emissions in production is big relative to transport costs and markup, the emission tax may be set too high by the government rather than too low. Greaker (2003) followed along this path by putting forward a model in favor of the Porter

[2] Ulph published 2 articles in 1996, both of which are cited in this paper.

hypothesis. The Porter hypothesis was introduced by Porter and Linde (1995) and stipulates that strict environmental regulations may be beneficial to producers in a country by increasing their competitiveness through innovation. Greaker's work formalized this idea in a strategic trade model and showed that as long as emissions are an inferior input, strict environmental policies can be desirable as they increase competitiveness for a country's industries.

2.3 A Rationale for the Environmental and Social Awareness Parameter

The primary focus of this paper is to analyze strategic policy choices for a country when the demand for the good it produces is affected by the policy choice it makes. The first question one might ask is why should a consumer's decision to buy a good in one country be affected by the production environment in another country? While it may not be obvious at first glance why such a relationship should exist, the presence of fair trade products and big marketing efforts to label products as green seem to point toward some demand by consumers for products that have been produced in an environmentally friendly and socially responsible manner.

Let us first look at social regulations. In the wake of recent tragedies such as the collapse of a garment factory in Bangladesh (2013) and fires in Pakistani garment factories (2012) killing hundreds of workers, there has been much talk about the working conditions in developing countries. Although public indignation over terrible events such as these does not necessarily translate into market choices, the literature suggests that some consumers do take social factors into consideration when making a purchase. With survey data, Didier and Lucie (2008) using a willingness to pay approach and Lotade and Loureiroa (2005) using a survival analysis both found consumers were willing to pay a premium for fair trade and ethical goods.

Surveys are a good way to have an initial idea on how economic agents feel regarding a particular issue, but economists generally favor evidence from real market transactions (the revealed preference approach). Field experiments can be a good way to verify survey results and it allows to check whether consumers do in fact demand socially responsible products. Hainmueller, Hiscox, and Sequeira (2011) and Hiscox and Smyth (2009) did just that in the markets for coffee and clothing, respectively. Both studies confirmed an increase in demand for products when a social label was attached to them, even as price increased. With globalization showing no signs of slowing down and the advent of social medias allowing more information on the working conditions in less-developed nations to make its way to the people ultimately consuming what these countries produce, consumer demand for goods produced in a socially responsible environment is likely not on the verge of disappearing.

An even stronger case can be made for the demand dependence on environmental regulations as some pollutants are global in nature and the damages they cause are thus not limited to the jurisdiction in which production occurs. Emissions of greenhouse gases like carbon dioxide contributing to global warming and chemicals such as chlorofluorocarbon (CFC) depleting the ozone layer have effects that can be felt around the globe. Considering the direct link between the purchase of the good and the consequences from its purchase, we expect consumers to take environmental regulations into account in their decision process.

Brouwer, Brander and Beukering (2008) have showed that consumers do have a willingness to pay to offset their carbon emissions from air travel. By extrapolating their results to the global market, air travelers are found to be willing to contribute billions of dollars towards climate change mitigation activities. In terms of purchase decisions, Ek and Söderholm (2008) demonstrated that consumers in Sweden were willing to pay a premium for green energy and have attributed the findings to norm-motivated behavior and social pressures that can be incorporated in the utility function. Roe et al. (2001) also found using both a survey and a hedonic analysis of price premiums that U.S consumers were willing to pay more for cleaner electricity. A recent publication by Statistics Canada indicated that Canadian consumers also had a desire for ethical consumption. Twenty-seven percent of Canadians were found to have already boycotted a product for ethical considerations (encompassing both environmental and social factors).

The 2008 financial crisis had both a positive and negative impact on the fight against climate change. While an economic slowdown implies less production and thus less emission of greenhouse gases, concrete actions to face the problems have been delayed as the international community focused its attention to boost anemic economic growth. As the developed countries slowly emerge from the crisis and the time line for action on the climate front becomes more pressing, it is plausible the issue will take increased precedence in the public debate going forward. It is also plausible to believe that as that happens; the public will be more sensible to environmental concerns when buying goods.

2.4 Contribution to the Literature

This paper distinguishes itself from the existing literature in two ways. First, social dumping is considered as well as environmental dumping. In doing so, we introduce social regulations as a policy tool governments can use to regulate the working conditions within their country. More importantly, a new parameter is added to the demand function in the context of a three-country model. This new parameter is linked to the policy tool used by the governments in the producing countries and embodies the environmental and social awareness of the consumers in the world market. Emphasis will be put on the impact this parameter has on equilibrium outcomes and on how it affects the trade-offs faced by the firms and the governments. This will lead to interesting results as the newly added parameter can play a role in bridging the gap between the collusive and the non-collusive outcome for the governments' policy decision.

3 The Model

3.1 Description of the Environment and Structure of the Game

There are two countries, country 1 (referred to as domestic) and country 2 (referred to as foreign). Each country has one firm and they produce substitutable goods with homogeneous cost structures. Good 1 is associated with country 1 and good 2 is associated with country 2. They compete in a Cournot environment and sell their product in a third country (the world market). The governments of the two producing countries have access to a policy instrument, τ_1 for country 1 and τ_2 for country 2, to regulate emissions of a pollutant for the environmental dumping case or to regulate working conditions of workers in the social dumping case.

Governments in each country maximize social welfare assuming firms will react optimally to a given policy. Firms then maximize profits taking the policy instrument of the government as given. Thus, we have a two-stage game where the government acts as a Stackelberg leader in the first stage and firms engage in a Cournot competition game in the second stage.[3]

Consumers in the third country have a certain degree of environmental and social consciousness. The policy instrument of the government is therefore included in the demand function for the two goods. Preferences in the world market are captured by the following inverse demand functions:

$$p_1(q_1, q_2, \tau_1) = a - q_1 - q_2 + b\tau_1$$

$$p_2(q_1, q_2, \tau_2) = a - q_1 - q_2 + b\tau_2$$

$$a > 0, -1 < b < 1$$

The demand for good 1 is decreasing in p_1 and increasing in p_2 such that the goods are substitutes. In fact, since the parameter in front of both q_1 and q_2 are

[3]This is a similar setting to Brander and Spencer (1985).

set to one, the goods are homogeneous. The parameter b represents the level of environmental or social consciousness for consumers in the world market and will be the focus of the analysis.

I will start by considering a very general cost function for the two countries. After deriving some basic results, restrictions will be imposed on the cost structure to model an emission tax, an emission standard and social regulations. To maximize profits, firms choose quantity and another choice variable x. x can represent the level of abatement for example in the case of an emission tax. The cost function for both countries will consist of different interactions between the policy instrument of the government, firm quantity, and x. Thus, we can specify the following general cost functions for the two countries:

$$C_1(q_1, x_1, \tau_1) = cq_1 + dq_1^2 + e\tau_1 + f\tau_1^2 + gq_1\tau_1 + hx_1 + kx_1^2 + lx_1\tau_1$$

$$C_2(q_2, x_2, \tau_2) = cq_2 + dq_2^2 + e\tau_2 + f\tau_2^2 + gq_2\tau_2 + hx_2 + kx_2^2 + lx_2\tau_2$$

$$a > c, c > 0, d \geq 0$$

For the Cournot game, both firms maximize profits, π, by choosing their quantity and x. After taking first order conditions and solving the system of resulting best response functions, an optimal quantity q^* and an optimal choice variable x^* are obtained for each country as a function of τ_1 and τ_2 . In turn, q^* and x^* can be used to obtain p^* and C^*.

Both governments then maximize social welfare in their country with respect to their policy instrument from which we obtain the optimal level of policy instrument. The social welfare function in each country consists of the profits of the firm since citizens of the country are assumed to own the capital used by the firms. There is also a term to capture the impact of the policy instrument on the welfare of the citizens through a different mechanism other than profits. For instance, this could represent damages to the environment caused by the emission of a pollutant in the case of environmental dumping. This other term labeled y

can depend on the policy instrument, quantity and the other choice variable. The general social welfare function for each country therefore takes the following form:

$$\begin{aligned} W_1(\tau_1,\tau_2) &= \pi_1^*(\tau_1,\tau_2) + my_1(\tau_1, q_1^*(\tau_1,\tau_2), x_1^*(\tau_1,\tau_2)) \\ &= p_1^*(q_1^*(\tau_1,\tau_2), q_2^*(\tau_1,\tau_2),\tau_1)q_1^*(\tau_1,\tau_2) - C_1^*(q_1^*(\tau_1,\tau_2), x_1^*(\tau_1,\tau_2),\tau_1) \\ &\qquad + my_1(\tau_1, q_1^*(\tau_1,\tau_2), x_1^*(\tau_1,\tau_2)) \end{aligned}$$

$$\begin{aligned} W_2(\tau_1,\tau_2) &= \pi_2^*(\tau_1,\tau_2) + my_2(\tau_2, q_2^*(\tau_1,\tau_2), x_2^*(\tau_1,\tau_2)) \\ &= p_2^*(q_1^*(\tau_1,\tau_2), q_2^*(\tau_1,\tau_2),\tau_2)q_2^*(\tau_1,\tau_2) - C_2^*(q_2^*(\tau_1,\tau_2), x_2^*(\tau_1,\tau_2),\tau_2) \\ &\qquad + my_2(\tau_2, q_2^*(\tau_1,\tau_2), x_2^*(\tau_1,\tau_2)) \end{aligned}$$

I will examine both the non-collusive case and the collusive case. In the non-collusive case, the government maximizes social welfare with respect to its policy instrument taking into account that the other government is doing the same. The result is a Nash Equilibrium in policies, τ_1^*, τ_2^*.

In the collusive case, a social planner maximizes joint welfare of both countries with respect to the policy instrument in each country. The surplus from this outcome is divided between the countries through Nash bargaining. How to achieve this outcome (and the legality of such schemes) will be discussed in a latter section. This results in the collusive solution, τ_1^c, τ_2^c.

3.2 Model Analysis

Throughout the analysis of the model, I will focus on the problems of the government and the firm in country 1. By symmetry all the results derived extend to the second country.

3.2.1 The Second Stage

The Stackelberg game is solved by starting in the second stage and moving our way back to the first stage. Under Cournot competition, the firm in country 1 faces the following problem:

$$
\begin{aligned}
Max_{q_1,x_1} \qquad \Pi_1(q_1,q_2,x_1,\tau_1) &= (a-q_1-q_2+b\tau_1)q_1 \\
&\quad -(cq_1+dq_1^2+e\tau_1+f\tau_1^2+gq_1\tau_1+hx_1+kx_1^2+lx_1\tau_1)
\end{aligned}
$$

Taking first order conditions yields the following best response functions:

$$
q_1 = \frac{a-q_2+(b-g)\tau_1-c}{2(1+d)}
$$

$$
x_1 = \frac{-h-l\tau_1}{2k}
$$

It is easy to check that $k \geq 0$ (along with $d > -1$ which is always true under the restrictions imposed on the cost function) is a sufficient condition to ensure the second order conditions yield a maximum.

Also, we can see from the best response functions that the strategies are strategic substitutes, that is $\frac{\partial q_1}{\partial q_2} < 0$ and $\frac{\partial q_2}{\partial q_1} < 0$. Fudenberg and Tirole (1991) showed that for a Cournot duopoly game, $\frac{\partial q_1}{\partial q_2} < 1$ and $\frac{\partial q_2}{\partial q_1} < 1$ is a sufficient condition to ensure the stability of the Nash equilibrium.

Novshek (1985) established conditions for the existence of the Nash equilibrium. Existence of the Nash equilibrium requires the inverse demand function to cross the quantity axis at a finite value and to be strictly decreasing for quantities below that cut point, strategies to be strategic substitutes and cost functions to be both non-decreasing in quantity and lower semi-continuous. The conditions are respected under the restrictions imposed to the demand function, cost function and parameters in all applications of Section 4.

The conditions for the uniqueness of the Nash equilibrium are stricter. Gaudet and Salant (1991) showed that in addition to Novshek's conditions, each firm's cost function must be twice differentiable and strictly increasing and the slope of the marginal cost function must be strictly bounded above the slope of the demand function. Again, the conditions are respected under the restrictions imposed to the demand function, cost function and parameters in all applications of Section 4. [4]

Putting the first order conditions for the two firms together and solving the system gives us the following equilibrium values:

$$q_1^* = \frac{2\tau_1(b-g)(d+1) - \tau_2(b-g) + (a-c)(2d+1)}{4d^2+8d+3}$$

$$x_1^* = \frac{-h - l\tau_1}{2k}$$

Proposition 1. *An increase in τ_2 will cause the domestic firm to decrease quantity in equilibrium if $b > g$ and to increase quantity if $b < g$.*

Proof. $\frac{\partial q_1^*}{\partial \tau_2} = \frac{g-b}{4d^2+8d+3}$ and we know that $d \geq 0$. □

Proposition 2. *An increase in τ_1 will cause the domestic firm to increase quantity in equilibrium if $b > g$ and to decrease quantity if $b < g$.*

Proof. $\frac{\partial q_1^*}{\partial \tau_1} = \frac{2(b-g)(d+1))}{4d^2+8d+3}$ and we know that $d \geq 0$.

□

The first two propositions illustrate the trade-off between the "demand effect", the "strategic effect" and the "cost effect". If b is really large, there is a lot of "bonus demand" to be gained by a firm when its government increases the strictness of its policy instrument. Thus, when b is large the demand effect will be dominant and the domestic firm will increase quantity when its government increases the strictness of its policy instrument. The reverse is true for the policy instrument of the foreign governments since the quantities are strategic substitutes. On the other hand, if b is small, the cost effect and the strategic effect will be dominant. The cost effect simply represents the extra cost of producing more

[4]The discussion on Cournot competition in *The New Palgrave Dictionary of Economics* (2^{nd} ed.) has more information on stability, existence and uniqueness of the Nash equilibrium.

for the firm as the value of the policy instrument increases. The strategic effect captures how the policy instrument can be used as a tool for the firms to reduce quantity (and thus increase price) and capture a bigger share of the monopoly rents.

Proposition 3. *An increase in the parameter b causes an increase in the equilibrium quantities if the Nash equilibrium in policy instruments is characterized by symmetric policies.*

Proof. $\frac{\partial q_1^*}{\partial b} = \frac{2\tau 1(d+1)-\tau 2}{4d^2+8d+3}$ and we know that $d \geq 0$. □

Proposition 3 emphasizes the demand effect discussed above. As the level of environmental or social awareness increases, there is more bonus demand to be gained which pushes firms to produce more of their good.

3.2.2 The First Stage

Moving back to the first stage, the welfare maximizing problem of the government in country 1 is as follows in the non-collusive case:

$$\begin{aligned} Max_{\tau_1} \qquad W_1(\tau_1,\tau_2) = {} & p_1^*(q_1^*(\tau_1,\tau_2), q_2^*(\tau_1,\tau_2),\tau_1)q_1^*(\tau_1,\tau_2) \\ & - C_1^*(q_1^*(\tau_1,\tau_2), x_1^*(\tau_1,\tau_2),\tau_1) + my_1(\tau_1, q_1^*(\tau_1,\tau_2), x_1^*(\tau_1,\tau_2)) \end{aligned}$$

This problem yields the following best response function: [5]

$$\tau_1 = \frac{-[m\frac{\partial y_1}{\partial \tau_1} - \frac{\tau_2(b-g)^2}{2(2d+1)} - \frac{(b-g)[2(a-c)+\tau_2(b-g)]}{(2d+3)^2} + \frac{(b-g)[4(a-c)+\tau_2(b-g)]}{2(2d+3)}]}{\frac{(b-g)^2}{4d+2} - \frac{(b-g)^2}{(2d+3)^2} + \frac{3(b-g)^2}{4d+6} + \frac{l^2-4fk}{2k}}$$

The condition for a stable Nash equilibrium is derived in Appendix A along with the second order condition to ensure we have a maximum. All the examples considered in the next section satisfy both these conditions.

[5] Since the parameter e and the parameter h will not be needed in any of the three examples that follow, they have been set to 0 for the rest of the model analysis in order to obtain simpler solutions. Furthermore, the software MATLAB was used for this optimization problem and it will be used throughout the rest of the paper for optimization and mathematical simplifications.

Solving the system of best response functions to obtain the non-collusive Nash equilibrium in policy yields the optimal policy instruments for country 1 and country 2, τ_1^* and τ_2^*. From, τ_1^* and τ_2^* we can backtrack and obtain W_1^* and W_2^*.

In the collusive case, the social planner maximizes joint welfare with respect to the policy instrument in each country such that there will be two (symmetric) first order conditions. The first order condition with respect to the policy instrument in country 1 is:

$$\frac{\tau_1 l^2 + 2km(\frac{\partial y_1}{\partial \tau_1} + \frac{\partial y_2}{\partial \tau_1} - 4fk\tau_1)}{2k} + \frac{(b-g)[2(a-c)+(b-g)(\tau_1+\tau_2)]}{2d+3} - \frac{2(b-g)[2(a-c)+(b-g)(\tau_1+\tau_2)]}{(2d+3)^2} + \frac{(b-g)^2(\tau_1-\tau_2)}{2d+1} = 0$$

The second order conditions for policy instruments leading to a maximum in welfare are presented in Appendix A and once again all the applications in section 4 satisfy these conditions.

Solving the system of first order conditions yields the collusive outcome, τ_1^c and τ_2^c. From this, we can go back and get W_1^c and W_2^c.

Given the number of parameters, the solutions for the policy instrument and welfare are too complex to analyze for the general specification under the collusive and non-collusive case. Thus, we will turn to a series of specific applications for further analysis.

4 Applications Using Specific Functional Forms

Three cases will be considered: an emission standard, an emission tax and a social standard. The specifications chosen for the functional forms of the model are based on the work of Ulph (1996) for the emission tax and the emission standard. The units are chosen such that $E_1 = q_1 - \alpha_1$ where E is emissions of the pollutant and α is the level of abatement chosen by the firm. Thus, as α increases, the emissions of the pollutant for a given quantity will decrease. α is analogous to x

in the general specification. A higher level of abatement increases cost for a firm, but also reduces damages from pollution.

Just like in the previous section, the goods are substitutes and the inverse demand is linear in the quantity of both goods as well as in the strictness of the policy instrument. It makes sense to think the costs of abatement or the costs of satisfying a certain level of social regulations will be low at the beginning, but will increase quite rapidly as the regulations become stricter. Thus, they are allowed to vary with a quadratic term. The parameter in front of the costs of abatement will be fixed at $\frac{1}{2}$ for simplicity. Costs of abatement are therefore specified by $\frac{1}{2}\alpha^2$.

4.1 Emission Standard

Let us first consider an emission standard and denote ϵ to be the policy instrument. The demand for good 1 is given by: $p_1 = a - q_1 - q_2 + b\epsilon_1$

$$-1 < b \leq 0$$

As the emission standard becomes stricter (ϵ decreases) in a country, the demand for that country's good increases. We can also notice that as b goes toward -1 (the absolute value of b increases), individuals in the world market are more environmentally conscious.

Costs are given by: $C_1 = cq_1 + \frac{1}{2}\alpha^2 = cq_1 + \frac{1}{2}(q_1 - \epsilon_1)^2$

The welfare function takes the form: $W_1 = p_1 q_1 - C_1 + m\epsilon_1^2$

$$m < 0$$

Relating this to the general specification from section 3, we can notice the following:

The abatement (α) is analogous to the choice variable (x), but it does not enter in the firm's maximization problem since the level of abatement is fixed by the standard imposed by the government.

The term y in the welfare function is used to model the damages incurred in the producing country by the emissions of the pollutant. Damages are assumed to increase at an increasing rate with the emission of the pollutant and so we set $y = \epsilon^2$. Also, since we are modeling damages, we have the restriction $m < 0$.

The following parameters have also been fixed to a particular value:

$$d = .5,\ e = 0,\ f = .5,\ g = -1,\ h = 0,\ k = 0,\ l = 0$$

The value of the parameters allows us to model an emission standard. Costs are increasing with quantity as well as with abatement squared. Since emissions are specified as $E_1 = q_1 - \alpha_1$, abatement is simply $\alpha_1 = q_1 - E_1$. Under the emission standard, we also know that $E_1 = \epsilon_1$. This pins down parameters d, f and g.

The firm's profit maximization problem is:

$$Max_{q_1} \qquad \Pi_1 = q_1(a - q_1 - q_2 + b\epsilon_1) - cq_1 - \frac{1}{2}(q_1 - \epsilon_1)^2$$

From which we obtain a best response function:

$$q_1 = \frac{a - c + (b+1)\epsilon_1 - q_2}{3}$$

After solving the system of best response functions, the Nash equilibrium quantity for country 1 is:

$$q_1^* = \frac{2(a-c) + (b+1)(3\epsilon_1 - \epsilon_2)}{8}$$

Relating to propositions 1 and 2 from the general case, we have $b > g$. As ϵ_1 goes up (ϵ_2 goes down), equilibrium quantity increases (decreases). Thus, a stricter emission standard by the domestic country decreases the quantity produced by its firm. The cost and strategic effects always dominate the demand effect and a stricter policy instrument allows firms to collude to reduce cost and capture a bigger share of the monopoly rents. Let us also note that, everything else held constant, equilibrium quantity decreases as b goes towards -1 (environmental consciousness increases).

Moving back to the first stage, the government's problem for the non-collusive case is:

$$Max_{\epsilon_1} \qquad W_1 = p_1^* q_1^* - C_1^* + m\epsilon_1^2$$

By taking a first order condition, we get the following best response function for country 1:

$$\epsilon_1 = \frac{9(b+1)[-2(a-c) + \epsilon_2(b+1)]}{27b^2 + 54b + 128m - 37}$$

And solving the system of best response functions yields the following optimal policy for country 1 in the non-collusive case:

$$\epsilon_1^* = \frac{-9(a-c)(b+1)}{9b^2 + 18b + 64m - 23}$$

When maximizing joint welfare in the collusive case, the solution for the optimal policy in country 1 is:

$$\epsilon_1^c = \frac{-3(a-c)(b+1)}{3b^2 + 6b + 32m - 13}$$

Proposition 4. *A decrease in the parameter b (representing an increase in environmental consciousness) causes a decrease in the optimal emission standard (a stricter environmental policy) for the non-collusive case.*

Proof. $\frac{\partial \epsilon_1^*}{\partial b} = \frac{9(a-c)(9b^2+18b-64m+41)}{(9b^2+18b+64m-23)^2} > 0$ since $-1 < b \leq 0$, $a - c > 0$, $m < 0$. Thus, a decrease in b decreases ϵ_1^*. □

Proposition 5. *A decrease in the parameter b (representing an increase in environmental consciousness) causes a decrease in the optimal emission standard (a stricter environmental policy) for the collusive case.*

Proof. $\frac{\partial \epsilon_1^c}{\partial b} = \frac{3(a-c)(3b^2+6b-32m+19)}{(3b^2+6b+32m-13)^2} > 0$ since $-1 < b \leq 0$, $a-c > 0$, $m < 0$. Thus, a decrease in b decreases ϵ_1^c. □

Propositions 4 and 5 illustrate the demand effect. As environmental consciousness increases, governments will adopt a stricter environmental policy to allow their firm to capture a bigger share of the demand.

Proposition 6. *The optimal emission standard is always larger in the non-collusive case than in the collusive case. The environmental policy is therefore stricter in the collusive case than in the non-collusive case.*

Proof. $\epsilon_1^* - \epsilon_1^c = \frac{-48(2m-1)(a-c)(b+1)}{(3b^2+6b+32m-13)(9b^2+18b+64m-23)} > 0$ under $-1 < b \leq 0$, $a-c > 0$, $m < 0$. □

This is a consequence of the strategic effect. In the non-collusive case, governments wish to have a stronger emission standard to temper the damages from pollution in their country, but a stricter emission standard will increase its firm cost relative to the foreign firm. The collusive case allows government to agree to a stricter standard where they can reduce damages from pollution while maintaining demand for their product.

Proposition 7. *The optimal emission standard in the non-collusive case and the collusive case converge as b decreases (environmental consciousness increases) .*

Proof. Propositions 4 and 5 give us the partial derivative of the optimal emission standard with respect to b in both cases. From proposition 6, we know that ϵ_1^* is always larger than ϵ_1^c. Thus, we need to show that the partial derivative of the optimal emission standard with respect to b in the non-collusive case is larger than in the collusive case:

$$\frac{\partial \epsilon_1^*}{\partial b} - \frac{\partial \epsilon_1^c}{\partial b} = \frac{9(a-c)(9b^2+18b-64m+41)}{(9b^2+18b+64m-23)^2} - \frac{3(a-c)(3b^2+6b-32m+19)}{(3b^2+6b+32m-13)^2}$$

$$= [48(a-c)(2m-1)] \left[\frac{81b^4+324b^3+480b^2m+246b^2+960bm-156b-2048m^2+2528m-671}{(3b^2+6b+32m-13)^2(9b^2+18b+64m-23)^2}\right]$$

$$= [48(a-c)(2m-1)] \left[\frac{(480b^2+960b+2528)m-2048m^2+81b^4+324b^3+246b^2-156b-671}{(3b^2+6b+32m-13)^2(9b^2+18b+64m-23)^2}\right] > 0$$

under $-1 < b \leq 0$, $a-c > 0$, $m < 0$. □

When b is close to 0, the demand effect is almost inexistent. Thus, the strategic effect from proposition 6 dominates. As environmental consciousness increases, the demand effect picks up and gives an incentive for governments to set a stronger emission standard, and more so for the non-collusive case. In fact, b softens competition and allows governments to collude more easily and it can be viewed as a substitute to an agreement to collude.

We now have all the required values to obtain welfare under both the collusive case and the non-collusive case:

$$W_1^* = \frac{3(2m-1)(a-c)^2(27b^2+54b+128m-37)}{2(9b^2+18b+64m-23)^2}$$

$$W_1^c = \frac{3(2m-1)(a-c)^2}{2(3b^2+6b+32m-13)}$$

Proposition 8. *A decrease in the parameter b (increase in environmental con-*

sciousness) causes a decrease in the optimal welfare for the non-collusive case.

Proof. $\frac{\partial W_1^*}{\partial b} = \frac{-27(a-c)^2(b+1)(2m-1)(27b^2+54b+64m-5)}{(9b^2+18b+64m-23)^3} > 0$ since $-1 < b \leq 0$, $a-c > 0$, $m < 0$. □

Proposition 9. *A decrease in the parameter b (increase in environmental consciousness) causes a decrease in the optimal welfare for the collusive case.*

Proof. $\frac{\partial W_1^c}{\partial b} = \frac{-9(a-c)^2(b+1)(2m-1)}{(3b^2+6b+32m-13)^2} > 0$ since $-1 < b \leq 0$, $a-c > 0$, $m < 0$. □

Propositions 8 and 9 are simply due to the formulation of demand. As $|b|$ increases, consumers "penalize" polluting firms to a larger degree and the profits of the firms decrease.

Proposition 10. *Optimal welfare is always larger in the collusive case than in the non-collusive case when considering the emission standard as the policy instrument.*

Proof. $W_1^c - W_1^* = \frac{-72(a-c)^2(b+1)^2(2m-1)^2}{(3b^2+6b+32m-13)(9b^2+18b+64m-23)^2} > 0$ under $-1 < b \leq 0$, $a-c > 0$, $m < 0$ □

This result was expected. By collaborating and maximizing joint welfare instead of maximizing individual welfare at the expense of the other country, governments can make their country better off and attain a higher level of welfare.

Proposition 11. *Optimal welfare in the non-collusive case and the collusive case converge as b decreases (environmental consciousness increases) when considering the emission standard as the policy instrument.*

Proof. From propositions 8 and 9 we have the partial derivative of the optimal welfare with respect to b in both cases. From proposition 10, we know that W_1^c is always larger than W_1^*. Thus, we need to show that the partial derivative of the optimal welfare with respect to b in the collusive case is larger than in the non-collusive case.

$$\frac{\partial W_1^c}{\partial b} - \frac{\partial W_1^*}{\partial b} = \frac{-9(a-c)^2(b+1)(2m-1)}{(3b^2+6b+32m-13)^2} + \frac{27(a-c)^2(b+1)(2m-1)(27b^2+54b+64m-5)}{(9b^2+18b+64m-23)^3}$$

$$= [288(b+1)(2m-1)^2(a-c)^2] \left[\frac{(27b^4+108b^3+144b^2m+90b^2+288bm-36b-1024m^2+1168m-301)}{(3b^2+6b+32m-13)^2(9b^2+18b+64m-23)^3}\right]$$

$$= [288(b+1)(2m-1)^2(a-c)^2] \left[\frac{27b^4+108b^3+90b^2-36b-301-1024m^2+m(288b+144b^2+1168)}{(3b^2+6b+32m-13)^2(9b^2+18b+64m-23)^3}\right] > 0$$

under $-1 < b \leq 0$, $a-c > 0$, $m < 0$ □

Proposition 11 follows from proposition 7 and has the same intuition behind it. Since firms and countries are assumed to be symmetric and the emission standard converges between the two cases, so must welfare.

The following graphs illustrate propositions 4 to 11 (for $a = 10$, $c = 1$, $m = -.5$):

Figure 1: Optimal regulation with an emission standard

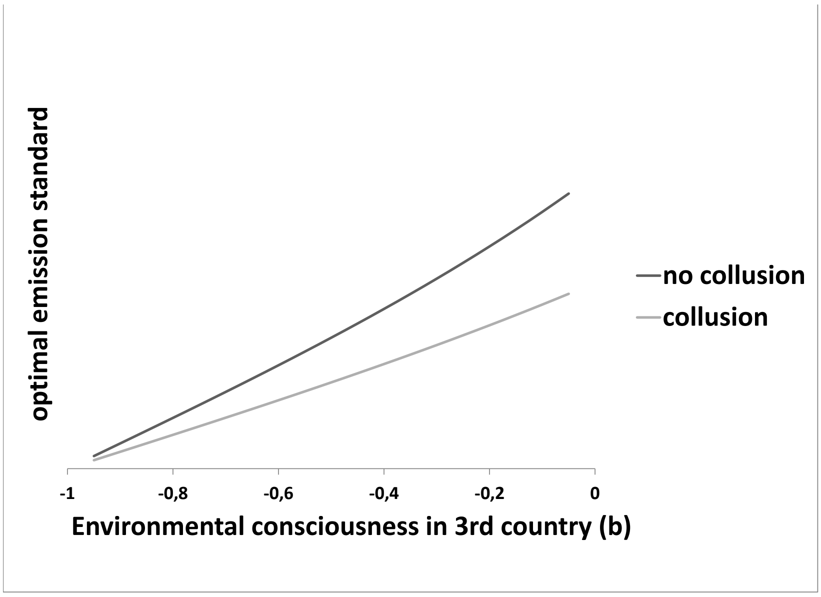
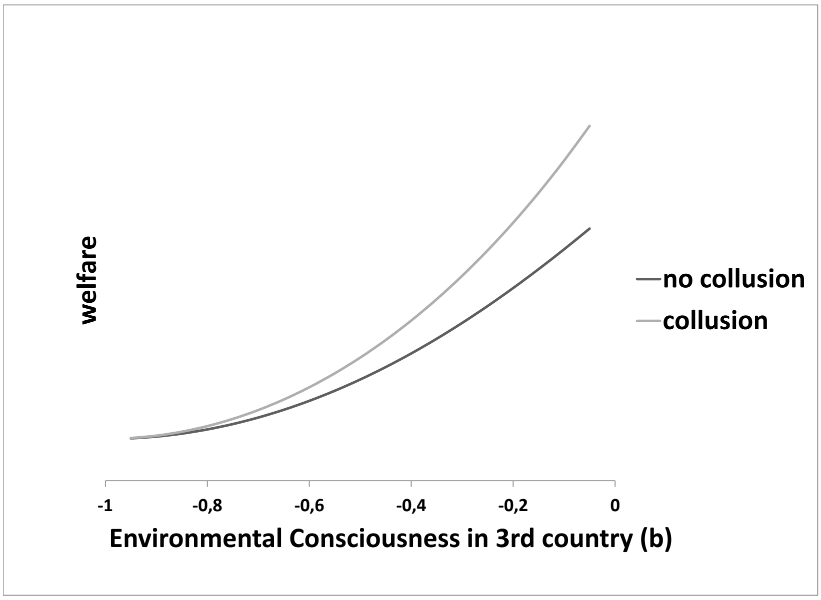


Figure 2: Welfare with an emission standard



4.2 Emission Tax

Let us now consider an emission tax and denote the tax rate t to be the policy instrument.

The demand for good 1 is given by: $p_1 = a - q_1 - q_2 + bt_1$

$$0 \leq b < 1$$

Consumers in the world market demand more of a good if it is produced in a country with a higher emission tax.

Since there is a tax on emissions, the firm must pay $t_1(q_1 - \alpha_1)$ to the government.

Costs are thus given by $C_1 = cq_1 + \frac{1}{2}\alpha_1^2 + t_1(q_1 - \alpha_1)$

The welfare function is specified as: $W_1 = p_1 q_1 - C_1 + t_1(q_1 - \alpha_1) - .5(q_1 - \alpha_1)^2$

The welfare function includes government revenues as well as damages from the pollutant. Given how emissions were defined, we have $y = (q_1 - \alpha_1)^2$ representing damages and the same restriction as for the emission standard case, $m < 0$ (m has been set to -.5).

This time, the firm does have control over its level of abatement and the maximization problem will therefore involve the choice of quantity as well as abatement.

Relative to the notation in section 3, the following parameters have been fixed:

$$d = 0,\ e = 0,\ f = 0,\ g = 1,\ h = 0,\ k = .5,\ l = -1,\ m = -.5$$

The value of the parameters allows us to model an emission tax. Costs are increasing with quantity as well as with abatement squared. There is also a cost associated with the emission tax. This pins down the value of the parameters g, k and l.

The firm's profit maximization problem in country 1 is:

$$Max_{q_1,\alpha_1} \qquad \Pi_1 = q_1(a - q_1 - q_2 + bt_1) - cq_1 - \frac{1}{2}\alpha_1^2 - t_1(q_1 - \alpha_1)$$

From this, we get the firm's best response functions:

$$q_1 = \frac{a - c - q_2 + (b-1)t_1}{2}$$

$$\alpha_1 = t_1$$

The second best response function simply represents the common condition in environmental economics that marginal abatement cost should equal the marginal benefits from abatement (tax savings from abatement).

Putting the best response functions of the two countries together, we obtain the following optimal quantity:

$$q_1^* = \frac{a - c + (b-1)(2t_1 - t_2)}{3}$$

Relating to propositions 1 and 2 from the general case, we have $b < g$. As t_1 goes up (t_2 goes down), equilibrium quantity decreases (increases). Thus, a stricter emission tax by the domestic country decreases the quantity produced by its firm. The cost and strategic effects always dominate the demand effect and a stricter policy instrument allows firms to collude to reduce cost and capture a bigger share of the monopoly rents. Let us also note that, everything else held constant, equilibrium quantity increases as b goes towards 1 (environmental consciousness increases).

Turning our attention to the government's problem:

$$Max_{t_1} \qquad W_1 = p_1^* q_1^* - C_1^* + t_1(q_1^* - t_1) - .5(q_1^* - t_1)^2$$

Taking the first order condition, we obtain the best response function:

$$t_1 = \frac{-(b+2)(a-c-t_2(b-1))}{2b^2+8b-19}$$

And putting the two best response functions together, we get the non-collusive Nash equilibrium in policy which is characterized by:

$$t_1^* = \frac{-(a-c)(b+2)}{b^2+7b-17}$$

In the collusive case, maximizing joint welfare yields:

$$t_1^c = \frac{-(a-c)(b+5)}{b^2+10b-29}$$

Proposition 12. *An increase in the parameter b causes an increase in the optimal tax for the non-collusive case.*

Proof. $\frac{\partial t_1^*}{\partial b} = \frac{(a-c)(b^2+4b+31)}{(b^2+7b-17)^2} > 0$ since $0 \leq b < 1$, $a - c > 0$. □

Proposition 13. *An increase in the parameter b causes an increase in the optimal tax for the collusive case.*

Proof. $\frac{\partial t_1^c}{\partial b} = \frac{(a-c)(b^2+10b+79)}{(b^2+10b-29)^2} > 0$ since $0 \leq b < 1$, $a - c > 0$. □

Again, propositions 12 and 13 depict the demand effect.

Proposition 14. *The optimal tax is always larger in the collusive case than in the non-collusive case.*

Proof. $t_1^c - t_1^* = \frac{-27(a-c)(b-1)}{(b^2+7b-17)(b^2+10b-29)} > 0$ under $0 \leq b < 1$, $a - c > 0$. □

Proposition 14 embodies the strategic effect.

Proposition 15. *The optimal tax in the non-collusive case and the collusive case converge as b increases.*

Proof. From propositions 12 and 13 we have the partial derivative of the optimal tax with respect to b in both cases. From proposition 14, we know that t_1^c is always larger than t_1^*. Thus, we need to show that the partial derivative of the optimal tax with respect to b in the non-collusive case is larger than in the collusive case. $\frac{\partial t_1^*}{\partial b} - \frac{\partial t_1^c}{\partial b} = \frac{81(a-c)(-b^4-10b^3+9b^2+16b+40)}{(b^2+7b-17)^2(b^2+10b-29)^2} > 0$ under $0 \leq b < 1$, $a - c > 0$. □

The intuition behind propositions 14 and 15 is similar to the one behind propositions 6 and 7 in the emission standard case.

We can now obtain welfare for the collusive and the non-collusive case:

$$W_1^* = \frac{-3(a-c)^2(2b^2+8b-19)}{2(b^2+7b-17)^2}$$

$$W_1^c = \frac{-3(a-c)^2}{b^2+10b-29}$$

Proposition 16. *An increase in the parameter b causes an increase in the optimal welfare for the non-collusive case when considering an emission tax as the policy instrument.*

Proof. $\frac{\partial W_1^*}{\partial b} = \frac{3(a-c)^2(2b^3+12b^2+24b-65)}{(b^2+7b-17)^3} > 0$ since $0 \leq b < 1$, $a - c > 0$. □

Proposition 17. *An increase in the parameter b causes an increase in the optimal welfare for the non-collusive case when considering an emission tax as the policy instrument.*

Proof. $\frac{\partial W_1^c}{\partial b} = \frac{3(a-c)^2(2b+10)}{(b^2+10b-29)^2} > 0$ since $0 \leq b < 1$, $a - c > 0$. □

In contrast with the emission standard, the parameter b enters demand as a bonus and not a penalty. This is why welfare increases with b for the emission tax, while it decreases for the emission standard.

Proposition 18. *Optimal welfare is always larger in the collusive case than in the non-collusive case when considering the emission tax as the policy instrument.*

Proof. $W_1^c - W_1^* = \frac{-81(a-c)^2(b-1)^2}{2(b^2+7b-17)^2(b^2+10b-29)} > 0$ under $0 \leq b < 1$, $a - c > 0$. □

Proposition 19. *Optimal welfare in the non-collusive case and the collusive case converge as b increases when considering the emission tax as the policy instrument.*

Proof. From proposition 16 and 17 we have the partial derivative of the optimal welfare in both cases. From proposition 18, we know that W_1^c is always larger than W_1^*. Thus, we need to show that the partial derivative of the optimal welfare with respect to b in the non-collusive case is larger than in the collusive case. $\frac{\partial W_1^*}{\partial b} - \frac{\partial W_1^c}{\partial b} = \frac{-81(a-c)^2(b-1)(2b^4+19b^3-33b^2+55b-205)}{(b^2+7b-17)^3(b^2+10b-29)^2} > 0$ under $0 \leq b < 1$, $a - c > 0$. □

Just like with the emission standard, we have a convergence in the policy instrument as b increases. Thus, we once again observe a convergence in welfare.

The following graphs illustrate propositions 12 to 19 (for $a = 10$, $c = 1$):

Figure 3: Optimal regulation with an emission tax

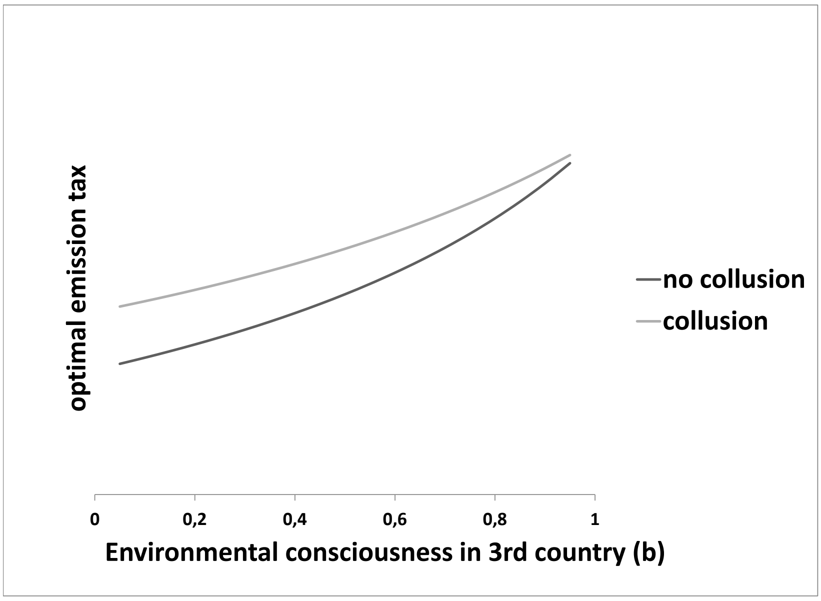
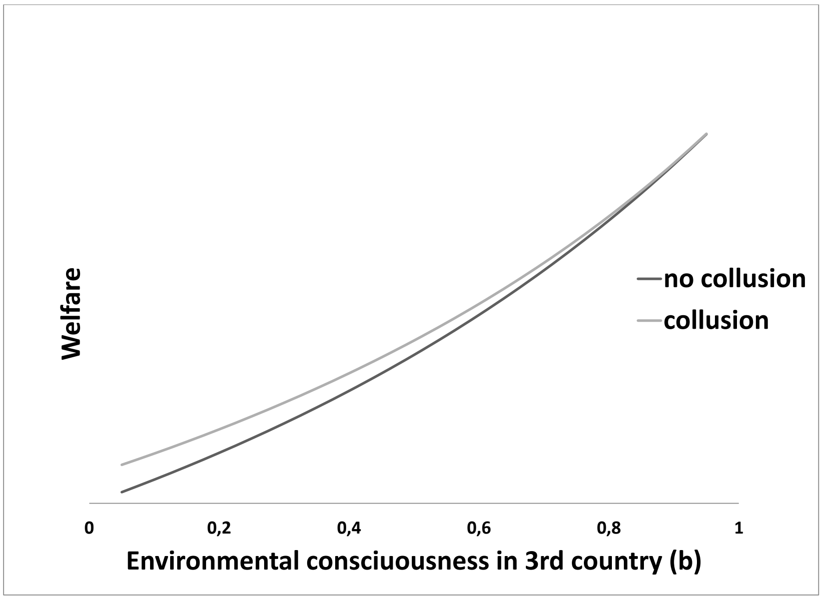


Figure 4: Welfare with an emission tax



4.3 Social Regulations

Finally, let us consider social regulations.

The demand for good 1 is given by: $p_1 = a - q_1 - q_2 + bw_1$

$$0 \leq b < 1$$

where w_1 represents regulations imposed by the government in country 1 to improve the social conditions of workers in its country. In reality, social regulations can take many forms such as a minimum wage, safety standards or restrictions on termination of employment. For the sake of simplicity, we will bundle all these regulations in one policy instrument and so we can think of an increase in w as an increase in the regulations protecting the workers.

The cost function is specified as follows: $C_1 = cq_1 + gq_1w_1 + w_1^2$

g will be restricted between 0 (inclusively) and 1 as it is sufficient to ensure a stable solution in the non-collusive policy setting game (see Appendix A).

There are no damages to the environment this time ($y = 0$) and so the welfare function simply consists of the profits of the firm:

$$W_1 = p_1 q_1 - C_1$$

In contrast with the general case in section 3, there is no choice variable other than quantity.

The following parameters have also been fixed:

$$d = 0,\ e = 0,\ f = 1,\ h = 0,\ k = 0,\ l = 0$$

The value of the parameters allows us to model a social standard. Costs are increasing with quantity as well as with social regulations squared. We also allow for an interaction between quantity and social regulations to model the demand, cost and strategic effect.

The firm's profit maximization problem is:

$$Max_{q_1} \qquad \Pi_1 = q_1(a - q_1 - q_2 + bw_1) - cq_1 - gq_1w_1 - w_1^2$$

Solving for the best response function yields:

$$q_1 = \frac{a - c - q_2 + (b - g)w_1}{2}$$

The Nash equilibrium in quantity for country 1 yields:

$$q_1^* = \frac{a - c + (b - g)(2w_1 - w_2)}{3}$$

The effect of w_1 and w_2 on quantity depends on the relationship between b and g as illustrated in propositions 1 and 2. From proposition 3, we know that an increase in b will cause quantity to increase.

In the first stage, the government's problem is:

$$Max_{w_1} \qquad W_1 = p_1^* q_1^* - C_1^*$$

Taking a first order condition to get the best response function for country 1 gives us:

$$w_1 = \frac{2(b-g)[(a-c)-(b-g)w_2]}{-4(b-g)^2+9}$$

We can solve the system of best response functions to get the following Nash equilibrium in policies for the non-collusive case:

$$w_1^* = \frac{2(a-c)(b-g)}{-2(b-g)^2+9}$$

Proposition 20. *An increase in the parameter b causes an increase in the optimal social standard for the non-collusive case.*

Proof. $\frac{\partial w_1^*}{\partial b} = \frac{2(a-c)(2(b-g)^2+9)}{(-2(b-g)^2+9)^2} > 0$ since $a-c>0$. □

For the collusive case, the solution for the social standard of country 1 is:

$$w_1^c = \frac{(a-c)(b-g)}{-(b-g)^2+9}$$

Proposition 21. *An increase in the parameter b causes an increase in the optimal social standard for the collusive case.*

Proof. $\frac{\partial w_1^c}{\partial b} = \frac{(a-c)}{2}[\frac{1}{(b-g+3)^2} + \frac{1}{(g-b+3)^2}] > 0$ since $a-c>0$. □

Propositions 20 and 21 are analogous to propositions 4, 5, 12 and 13. They illustrate the demand effect.

Proposition 22. *The optimal social standard is smaller in the collusive case than in the non-collusive case if $b > g$ and it is bigger in the collusive case than in the non-collusive case if $b < g$.*

Proof. $w_1^c - w_1^* = \frac{-9(a-c)(b-g)}{(-(b-g)^2+9)(-2(b-g)^2+9)} < 0$ under $0 \leq g < b < 1$, $a - c > 0$.

$w_1^c - w_1* = \frac{-9(a-c)(b-g)}{(-(b-g)^2+9)(-2(b-g)^2+9)} > 0$ under $0 \leq b < g < 1$, $a - c > 0$. □

Since there are no damages in the social standard case, as opposed to the environmental regulation cases, the difference in policy instrument between the collusive and the non-collusive case boils down to the demand and the strategic effect. If $b > g$, the demand effect dominates. Governments set their standard too high in the non-collusive case to capture the relatively large increase in demand from a high standard. They could cooperate to lower standards, reduce their firm's costs and still benefit from a large demand.

If $b < g$, the strategic effect dominates. In the non-collusive outcome, governments set low standards to reduce their firm's costs as there is little extra demand to be gained. However, governments could do better by setting a stronger standard. Proposition 2 tells us that under $b < g$, a higher policy instrument reduces equilibrium quantity for the domestic firm. Thus, by having a stronger standard, governments can reduce quantity which causes price to increase. This leads to increased profits for firms and the collusive outcome allows them to do just that.

Proposition 23. *The optimal social standard in the non-collusive case and the collusive case diverge as b increases if* $b > g$.

Proof. From propositions 20 and 21 we have the partial derivative of the optimal social standard with respect to b in both cases. From proposition 22, we know that w_1^c is always smaller than w_1^* if $b > g$. Thus, we need to show that the partial derivative of the optimal standard with respect to b in the non-collusive case is larger than in the collusive case.

$$\frac{\partial w_1^*}{\partial b} - \frac{\partial w_1^c}{\partial b} = \frac{2(a-c)(2(b-g)^2+9)}{(-2(b-g)^2+9)^2} - \frac{(a-c)}{2}[\frac{1}{(b-g+3)^2} + \frac{1}{(g-b+3)^2}]$$

$$= \frac{27(a-c)(-2b^4+8b^3g-12b^2g^2+9b^2+8bg^3-18bg-2g^4+9g^2+27)}{(b-g+3)^2(g-b+3)^2(-2(b-g)^2+9)^2}$$

$$= \frac{27(a-c)[(b-g)^2(-2(b-g)^2+9)+27)]}{(b-g+3)^2(g-b+3)^2(-2(b-g)^2+9)^2} > 0$$

since $a - c > 0$. □

A larger b has a greater incentive to increase the policy instrument in the non-collusive case than in the collusive case when $b > g$ since the demand effect dominates. We also know that when $b > g$, the non-collusive optimal social standard is larger than the collusive standard. Thus, we observe divergence as b increases.

We can also notice that if $b < g$, the optimal standard is negative. In that case, the demand effect is too small to overcome the increase in cost caused by the standard. Emphasis will therefore be on the case where $b > g$ in the derivation of propositions, graphical illustrations and policy discussions.

Finally, we can obtain welfare for the two cases:

$$W_1^* = \frac{(a-c)^2[-4(b-g)^2+9]}{(-2(b-g)^2+9)^2}$$

$$W_1^c = \frac{(a-c)^2}{-(b-g)^2+9}$$

Proposition 24. *An increase in the parameter b causes a decrease in optimal welfare for the non-collusive case when considering the social standard if $b > g$ and an increase in optimal welfare if $b < g$.*

Proof. $\frac{\partial W_1^*}{\partial b} = \frac{-16(a-c)^2(b-g)^3}{(-2(b-g)^2+9)^3} > 0$ under $0 \leq b < g < 1$, $a - c > 0$.

$\frac{\partial W_1^*}{\partial b} = \frac{-16(a-c)^2(b-g)^3}{(-2(b-g)^2+9)^3} < 0$ under $0 \leq g < b < 1$, $a - c > 0$. □

In the non-collusive case, an increase in b causes governments to compete too strongly on regulation to allow their firm to get access to a larger share of demand when $b > g$. The result is an increase in the firm's cost and lower welfare.

Proposition 25. *An increase in the parameter b causes an increase in optimal* *welfare for the collusive case when considering the social standard if $b > g$ and a decrease in optimal welfare if $b < g$.*

Proof. $\frac{\partial W_1^c}{\partial b} = \frac{2(a-c)^2(b-g)}{(b-g+3)^2(g-b+3)^2} > 0$ under $0 \leq g < b < 1$, $a - c > 0$.

$\frac{\partial W_1^c}{\partial b} = \frac{2(a-c)^2(b-g)}{(b-g+3)^2(g-b+3)^2} < 0$ under $0 \leq b < g < 1$, $a - c > 0$. □

In the collusive case, an increase in b does not cause as big an increase in regulation as in the non-collusive case to capture bonus demand when $b > g$. Governments balance the increase in cost from their policy with the added bonus in demand. This results in increasing profits for the firms.

Proposition 26. *Optimal welfare is always larger in the collusive case than in the non-collusive case when considering the social standard as the policy instrument.*

Proof. $W_1^c - W_1^* = \frac{9(a-c)^2(b-g)^2}{((b-g)^2+9)(-2(b-g)^2+9)^2} > 0.$ □

Proposition 27. *Optimal welfare in the non-collusive case and the collusive case diverge as b increases when considering the social standard as the policy instrument if $b > g$ and they converge if $b < g$.*

Proof. Proposition 27 follows from propositions 24, 25 and 26. We know that under $b > g$, welfare in the non-collusive case decreases as b increases, but it increases as b increases in the collusive case. We also know that welfare is always higher in the collusive case than in the non-collusive case. Thus, the gap between non-collusive welfare and collusive welfare must increase as b increases when $b > g$. The same logic can be used to explain why the gap between non-collusive welfare and collusive welfare shrinks as b increases when $b < g$. □

Proposition 27 follows from proposition 23 and the symmetry of the problem.

The following graphs illustrate propositions 20 to 27, focusing on the case where $b > g$ (for $a = 10$, $c = 1$ and $g = 0$):

Figure 5: Optimal regulation with a social standard

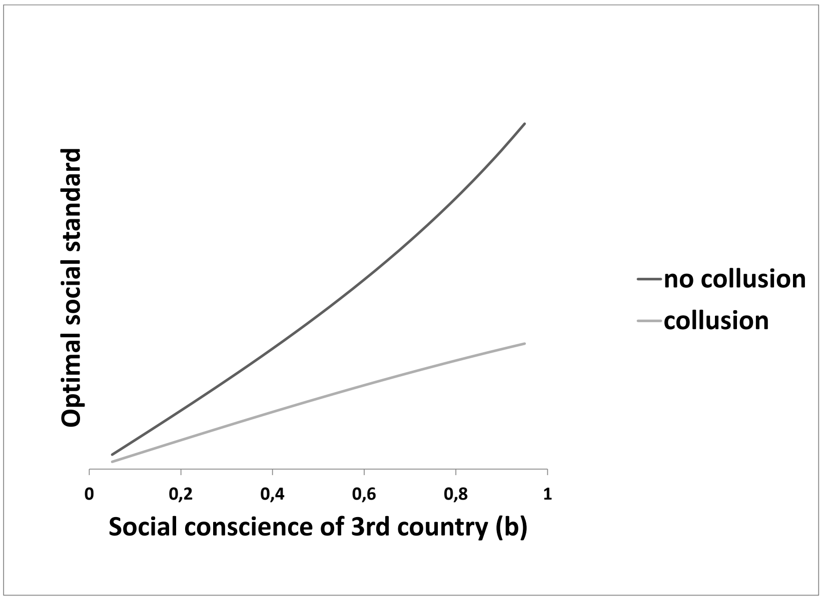
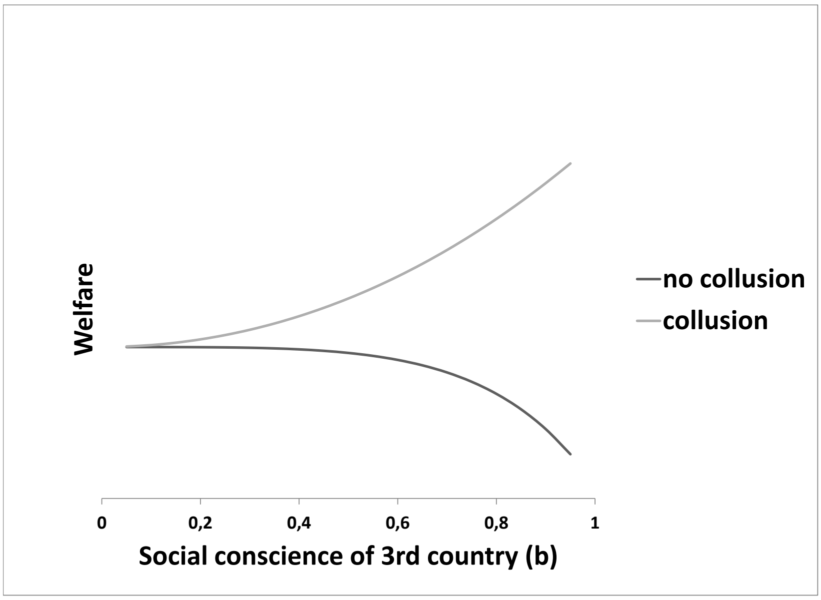


Figure 6: Welfare with a social standard



5 Discussion

5.1 Policy Implications

The general model from Section 3 introduced the demand effect and the strategic effect, as well as their impact on the firm's problem. In a model of imperfect competition, strategy becomes important for the government when choosing its optimal policy instrument to maximize the welfare of its citizens. The governments must consider how the firms will react to a certain policy, given the firms are also acting in a strategic manner. Unfortunately, no clear results can be derived from the government's problem under the very general cost specification, only restrictions on parameters for the specific cases can be obtained. We must therefore go one step further and model different situations of environmental and social regulations.

The models with specific functional forms presented in this paper showcase one of the main features observed in the strategic trade literature which is the non-robustness of the results and their sensitivity to the initial assumptions of the model. In both the case of the emission tax and the emission standard, the optimal policy instrument chosen in the collusive case is stricter relative to the non-collusive case. We observe the opposite for the social standard. In all the cases considered, the optimal policy instrument becomes more severe as $|b|$ (social or environmental consciousness) gets larger, whether we consider the colluding or the non-colluding case. This has implications for the governing bodies outside of the two producing countries. For example, the government of a country in the world market could be worried about a global pollutant, such as carbon dioxide, emitted in the production of a good consumed by its citizens. By informing its inhabitants about the effects of climate change and raising their awareness towards the issue (attempting to increase $|b|$), this government could affect the policy chosen by the governments of the producing countries without interfering directly in their internal affairs or entering in negotiation with them.

The parameter b also holds the key to bridge the gap between the non-collusive outcome and the social planner's optimum in the case of environmental regulations. This can be viewed as a shift in the relative strength of the strategic effect and the demand effect. When $|b|$ is very low, governments choose a policy instrument that is not strict enough in the Nash Equilibrium relative to what could be achieve under cooperation. This is a classical example of a prisoner's dilemma. Both countries would have a better outcome under cooperation, but since they each have an incentive to deviate from the cooperative outcome, the final result is an equilibrium where welfare is lower for both countries (the non-collusive Nash equilibrium). In other words, the strategic effect dominates the demand effect. Both governments would like to take advantage of the "bonus demand" from a strict policy instrument in the case of the tax (or have a strict policy instrument to avoid the "penalty" in demand in the emission standard case), but strategic considerations force them to an equilibrium that is not socially optimal. As $|b|$ increases, the demand effect becomes larger relative to the strategic effect and thus we see convergence between the Nash equilibrium and the collusive outcome.

We can therefore think of b as a substitute to an agreement between countries to collude on their policy instrument. Assuming there are costs in negotiating and implementing such an agreement on policy instruments, countries will weight these costs against the benefits of an increase in welfare from collusion. As $|b|$ gets larger, the difference in welfare between the Nash equilibrium and the social optimum becomes smaller and thus the likelihood of an agreement becomes smaller.

The story is different in the case of social dumping. Since there are no damages from emissions in the welfare function, when $b = 0$ there are no distinctions between the Nash equilibrium and the social planner's optimum. [6] The optimal policy instrument is no social standard at all. As b gets larger, the wedge between the two gets progressively larger. In contrast with environmental case, the strategic considerations drive the countries to set a standard that is too high relative to

[6] This is true in the cases depicted on the graphs. To be more general, there are no distinctions between the Nash equilibrium and the social planner's optimum when $b = g$.

the social planner's solution. The two countries are competing too intensively to capture the bonus demand from a high social standard. In doing so, they increase their firm's cost and don't achieve the level of welfare they could achieve under cooperation. This problem only gets larger as b increases.

b is no longer a substitute to an agreement to collude for the two nations as in the environmental case. The likelihood of an agreement for cooperation on social standards increases as social consciousness increases since the difference in welfare becomes larger between the non-colluding outcome and the colluding outcome. The following table contrasts the conclusions between the environmental dumping model and social dumping model:

Figure 7: Incentives for governments to collude

	Environmental Regulations		**Social Regulations**	
	Large environmental awareness	**Small environmental awareness**	**Large social Awareness**	**Small social Awareness**
Difference in welfare between the Nash equilibrium and the social optimum	**Small**	**Large**	**Large**	**Small**
Difference in strictness of the policy instrument between the Nash equilibrium and the social optimum	**Small**	**Large**	**Large**	**Small**
The incentives for an agreement to collude on policy instruments	**Small**	**Large**	**Large**	**Small**

The conclusions also have implications for social and environmental activists outside the two producing countries. To push an agenda of higher regulations, they should promote collaboration and cooperation between countries in setting their environmental policies. On the other hand, they should encourage competition in the setting of social regulations.

In terms of comparing welfare across the policy instruments, it is not such a useful exercise given how the parameter b was introduced in the demand function (as a bonus for the emission tax and a penalty in the emission standard). We do observe higher welfare from the emission standard relative to the emission tax when $b = 0$ in the non-collusive case which is line with the literature as discussed in Section 2.

5.2 A Note on the Feasibility of an Agreement to Collude

As opposed to collusion between firms, collusion between countries in setting regulations is not illegal. This is in part why the distinction between the collusive outcome and the non-collusive outcome in policy setting by the governments was given much attention in this paper while there was no mention of the collusive outcome in quantity setting for the firms. Collusion between countries to set higher regulations is even encouraged, specially in the environmental context. [7] The models presented in this paper suggest collusion between countries in setting higher environmental regulations is beneficial for both parties partaking in the venture. An agreement to collude could take the form of a bilateral treaty to engage in higher environmental regulations and would likely be welcomed on the international stage. The treaty could therefore succeed in taking countries from the Nash equilibrium to the social optimum and "solve" the Prisoner's dilemma problem.

On the other hand, the social model suggests that an agreement to set higher social standards relative to the Nash equilibrium would decrease welfare, not in-

[7]For example, The Montreal Protocol on substances that deplete the ozone layer and the Kyoto Protocol for greenhouse gases emissions.

crease it. It is hard to imagine countries entering in negotiation for an accord that would be detrimental to both parties. To the contrary, nations have incentives to negotiate to lower their social standard. It is unlikely that such an agreement would be welcomed by much enthusiasm from the international community. The agreement would likely be kept secret. Obviously, the temptation to break a secret agreement is far greater than it would be if the agreement was made public.

Three solutions are available to make such a bargain viable. First, if the game is repeated an infinite number of time (or at least lasts for an unknown length), then a trigger strategy cooperative Nash equilibrium is possible. An example of such a strategy is the grim strategy where each player cooperates as long as the other player does the same, but commits to behave in a non-cooperative way for the rest of the game if the other player defects. According to the Folk Theorem, the cooperative outcome can be maintained and is an equilibrium to the game as long as the discount rate is low enough for both countries.[8] It seems plausible that both the unknown length and low discount rate conditions could be satisfied in this case. A second solution is to make a commitment that non-cooperative behavior will be punished by some other mechanism, such that payoffs of the game are altered and cooperation becomes the Nash equilibrium. For example, the threat of impeding trade could be used if the two countries are trading partner. Ideally, such a threat would have to not be too detrimental to the country making it as credibility could then become an issue. Finally, the problem can be resolved if one country can take the leadership and transform the simultaneous game into a sequential one. This tends to be possible when one party is more powerful than the other one, which is not the case under the symmetry assumption of this model. [9]

[8]Chapter 12 of *Microeconomic Theory* by A. Mas-Colell has a formal definition of the Folk Theorem.

[9]See chapter 11 from *Games of Strategy* (3^{rd} ed.) by A. Dixit for more details on solving the prisoner's dilemma.

6 Concluding remarks

This paper outlined the different incentives for collusion in environmental and social regulations for countries competing in a Cournot setting when the demand for the good it produces is dependent on the regulations chosen. It was found that the non-collusive outcome and the collusive outcome in environmental regulations converge as environmental consciousness increases in the world market and that an agreement to collude would involve stronger environmental regulations for the producing countries. The opposite was found for social regulations as higher social consciousness led to a divergence in the two cases and that an agreement to collude would involve weaker social regulations.

To obtain these results, models with specific functional forms were used and numerous considerations were excluded from the model. Transportation costs were ignored, but under the symmetry of the model it would be easy to include them in the cost function and obtain the same results. Transboundary pollution was only included in the preferences of consumers, but not in the damages considered by the governments when maximizing welfare in their country. This not only simplified the problem, but also allowed to highlight the contrast between the collusive and non-collusive case as the collusive case is concerned with maximizing joint welfare which includes damages in both countries.

It was also assumed there was a single producer per country and only two countries competing for demand in the world market. The single producer per country assumption shifted the focus from strategic behavior within a country to strategic interactions between countries in policy instruments, a key area to the negotiation of treaties and agreements on social and environmental regulations. As for the assumption of two countries competing for demand in the world market, the results likely generalize to many countries with one firm competing in the world market under the Cournot specification made. As mentioned earlier, excluding domestic consumers from the welfare of producing countries is a common feature of this class of model and can be reconciled with economic theory by stipulating that the consumers own the capital used by the firms. Another limitation of the model is the restriction to the analysis of homogeneous goods. This assumption was relaxed in a numerical analysis of the three models with specific functional forms. [10] By considering heterogeneous goods, the magnitude of the gap between the collusive and the non-collusive case was reduced for every values of b, but the results from all the main propositions except for one remained the same.

There was also no consideration of other forms of competition, such as Bertrand competition. It is a common aspect of strategic trade models that Bertrand competition turns all the results upside down as introduced by Eaton and Grossman (1986). In this case, the units were chosen specifically to cater to a Cournot setting and a Bertrand analysis is not relevant for the models with specific functional forms, although it could be incorporated in the general specification from Section 3. In an argument similar to Greaker (2003), I propose that Cournot competition is best adapted to this model relative to Bertrand competition. Prices can be changed a lot easier than the governments can put forward a plan to apply and monitor new regulations. Prices can also be changed faster than firms can adapt to new regulations in terms of abatement technologies or investing to meet the new social standards. According to Kreps and Scheinkman (1983), in a situation where such a timing issue is present, Bertrand competition will yield a Cournot outcome which undermines the usefulness of a Bertrand analysis.

In terms of future research, it would be really interesting to see if the conclusions change in a model where both social and environmental regulations are included at the same time. Another potential extension would be to move away from the symmetry imposed by this model and consider heterogeneity between countries. For example, different cost functions between the two firms could model the case when one country has better technology than the other one and the analysis of such a case could differ from what is obtained in this paper. Finally, an empirical analysis could be performed. While it may prove difficult to do so, try-

[10] This is illustrated in Appendix B.

ing to capture the effect of environmental and social consciousness in the world market on policy instruments chosen by governments, as well as how they change over time, could be insightful.

7 Bibliography

References

[1] Barrett, S. 1994. "Strategic Environmental Policy and International Trade," *Journal of Public Economics*, 54(3): 325-338.

[2] Brander, James A. 1981. "Intra-Industry Trade in Identical Commodities," *Journal of International Economics*, 11(1): 1-14.

[3] Brander, James A., and Barbara J. Spencer. 1981. "Tariffs and the Extraction of Foreign Monopoly Rents under Potential Entry," *The Canadian Journal of Economics*, 14(3): 371-389.

[4] Brander, James A., and Barbara J. Spencer. 1985. "Export Subsidies and International Market Share Rivalry," *Journal of International Economics*, 18(1-2): 83-100.

[5] Brander, James A., and Paul Krugman. 1983. "A Reciprocal Dumping Model of International Trade," *Journal of International Economics*, 15(3-4): 313-321.

[6] Brouwer, R., L. Brander, and P. Beukering. 2008. "A Convenient Truth: Air Travel Passengers' Willingness to Pay to Offset Their CO2 Emissions," *Climatic Change*, 90(3): 299-313.

[7] Didier, Tagbata, and Sirieix Lucie. 2008. "Measuring Consumer's Willingness to Pay for Organic and Fair Trade Products," *International Journal of Consumer Studies*, 32(5): 479-490.

[8] Dixit, Avinash K. 1979. "A Model of Duopoly Suggesting a Theory of Entry Barriers," *The Bell Journal of Economics*, 10(1): 20-32.

[9] Dixit, Avinash K. 2009. *Games of Strategy*, 3rd ed. New York: W. W. Norton and Co.

[10] Dixit, Avinash K., and Gene M. Grossman. 1986. "Targeted Export Promotion with Several Oligopolistic Industries," *Journal of International Economics*, 21(3-4): 233-249.

[11] Durlauf, Steven N., and Lawrence E. Blume. 2008. *The New Palgrave Dictionary of Economics*, 2nd ed. Basingstoke: Nature Publishing Group.

[12] Eaton, Jonathan, and Gene M. Grossman. 1986. "Optimal Trade and Industrial Policy under Oligopoly," *The Quarterly Journal of Economics*, 101(2): 383-406.

[13] Ek, Kristina, and Patrik Söderholm. 2008. "Norms and Economic Motivation in the Swedish Green Electricity Market," *Ecological Economics*, 68(1-2): 169-182.

[14] Feenstra, Talitha, Peter M. Kort, and Aart de Zeeuw. 2001. "Environmental Policy Instruments in an International Duopoly with Feedback Investment Strategies," *Journal of Economic Dynamics and Control*, 25(10): 1665-1687.

[15] Friberg, Richard, and Mattias Ganslandt. 2008. "Reciprocal Dumping with Product Differentiation," *Review of International Economics*, 16(5): 942-954.

[16] Fudenberg, D., and J. Tirole. 1991. *Game Theory*, Cambridge, MA: MIT Press.

[17] Gaudet, G., and S. Salant. 1991. "Uniqueness of Cournot equilibrium: new results from old methods," *Review of Economic Studies*, 58: 399-404.

[18] Greaker, Mads. 2003. "Strategic Environmental Policy; Eco-Dumping or a Green Strategy?" *Journal of Environmental Economics and Management*, 45(3): 692-707.

[19] Hainmueller, Jens., Michael J. Hiscox, and Sandra Sequeira. 2011. "Consumer demand for the fair trade label: evidence from a field experiment," *MIT Political Science Department Research Paper*, No. 2011-9B.

[20] Hiscox, Michael J., and Nicholas F.B. Smyth. 2009. "Is There Consumer Demand for Improved Labor Standards? Evidence from Field Experiments in Social Labeling," *Department of Government, Harvard University.*

[21] Kreps, David M., and Jose A. Scheinkman. 1983. "Quantity Precommitment and Bertrand Competition Yield Cournot Outcomes," *The Bell Journal of Economics*, 14(2): 326-337.

[22] Lapan, Harvey E., and Shiva Sikdar. 2011. "Strategic Environmental Policy under Free Trade with Transboundary Pollution," *Review of Development Economics*, 15(1): 1-18.

[23] Lotade, Justin., and Maria L. Loureiroa. 2005. "Do Fair Trade and Eco-Labels in Coffee Wake up the Consumer Conscience?" *Ecological Economics*, 53: 129-138.

[24] Mas-Colell, Andreu. 1995. *Microeconomic Theory*, New York: Oxford University Press.

[25] Novshek, W. 1985. "On the existence of Cournot equilibrium," *Review of Economic Studies*, 52: 85-98.

[26] Pfluger, Michael. 2001. "Ecological Dumping under Monopolistic Competition," *Scandinavian Journal of Economics*, 103(4): 689-706.

[27] Porter, Michael E., and Claas van der Linde. 1995. "Toward a New Conception of the Environment-Competitiveness Relationship," *The Journal of Economic Perspectives*, 9(4): 97-118.

[28] Pugel, T. A. 2012. *International economics*, 15th ed. New York: McGraw-Hill.

[29] Roe, Brian et al. 2008. "US Consumers' Willingness to Pay for Green Electricity," *Energy Policy*, 29(11): 917-925.

[30] Spencer, Barbara J., and James A. Brander. 1983. "International R&D Rivalry and Industrial Strategy," *The Review of Economic Studies*, 50(4): 707-722.

[31] Turcotte, Martin. 2010. "Ethical Consumption," *Canadian Social Trends, Statistics Canada*.

[32] Ulph, Alistair. 1992. "The Choice of Environmental Policy Instruments and Strategic International Trade," *Conflicts and Cooperation in Managing Environmental Resources*, Springer Berlin Heidelberg. 111-132.

[33] Ulph, Alistair. 1996. "Environmental Policy and International Trade When Governments and Producers Act Strategically," *Journal of Environmental Economics and Management*, 30(3): 265-281.

[34] Ulph, Alistair. 1996. "Environmental Policy Instruments and Imperfectly Competitive International Trade," *Environmental and Resource Economics*, 7(4): 333-355.

[35] Walz, Uwe, and Dietmar Wellisch. 1997. "Is Free Trade in the Interest of Exporting Countries When There Is Ecological Dumping?" *Journal of Public Economics*, 66(2): 275-291.

[36] World Trade Organisation. 2014. "Understanding The WTO: The Agreements." wto.org.

8 Appendix A: Proofs of Stability and S.O.C for the Government's Problem

Stability of the Nash Equilibrium in policy (non-collusive case):

For a Nash equilibrium to be stable in a symmetric two-player game, it is sufficient that the partial derivative of the best response function of one player with respect to the choice variable of the other player is smaller than 1. In this case we have:

$$\frac{\partial BRF_1}{\partial \tau_2} = \frac{-m\frac{\partial \frac{\partial y_1}{\partial \tau_1}}{\partial \tau_2} + \frac{(b-g)^2}{2(2d+1)} + \frac{(b-g)^2}{(2d+3)^2} - \frac{(b-g)^2}{2(2d+3)}}{\frac{(b-g)^2}{4d+2} - \frac{(b-g)^2}{(2d+3)^2} + \frac{3(b-g)^2}{4d+6} + \frac{l^2-4fk}{2k}} < 1$$

Let us check that the condition is satisfied for every case considered in Section 4.

For the emission standard, we have $d = .5$, $\frac{\partial \frac{\partial y_1}{\partial \tau_1}}{\partial \tau_2} = 0$, $g = -1$, $f = .5$, $k = 0$, $l = 0$

The condition simplifies to:

$$\frac{\frac{(b+1)^2}{4} + \frac{(b+1)^2}{16} - \frac{(b+1)^2}{8}}{\frac{(b+1)^2}{4} - \frac{(b+1)^2}{16} + \frac{3(b+1)^2}{8} - 1} < 1$$

$$\frac{(b+1)^2(\frac{3}{16})}{(b+1)^2(\frac{9}{16}) - 1} < 1$$

Since $-1 < b \leq 0$, it is easy to see that the numerator will always be positive and the denominator will always be negative. The condition is thus satisfied. $\square$

For the emission tax, we have $d = 0$, $g = 1$, $f = 0$, $k = .5$, $l = -1$, $m = -.5$ and:

$$\frac{\partial \frac{\partial y_1}{\partial \tau_1}}{\partial \tau_2} = \frac{\partial}{\partial \tau_2}[2(q_1^* - t_1)(2(\frac{b-1}{3}) - 1)] = \frac{-4(b-1)^2}{9} + \frac{2(b-1)}{3}$$

And thus the conditions simplifies to:

$$\frac{\frac{2(b-1)^2}{9} - \frac{(b-1)}{3} + \frac{(b-1)^2}{2} + \frac{(b-1)^2}{9} - \frac{(b-1)^2}{6}}{\frac{(b-1)^2}{2} - \frac{(b-1)^2}{9} + \frac{3(b-1)^2}{6} + 1} < 1$$

$$\frac{(b-1)^2(\frac{2}{3}) - \frac{(b-1)}{3}}{(b-1)^2(\frac{8}{9}) + 1} < 1$$

Since $0 \leq b < 1$, the numerator is never larger than 1 and the denominator is always bigger than 1. The condition is always satisfied. □

For the social standard, we have $d = 0$, $f = 1$, $k = 0$, $l = 0$, $m = 0$, $0 \leq g < 1$

The condition simplifies to:

$$\frac{\frac{(b-g)^2}{2} + \frac{(b-g)^2}{9} - \frac{(b-g)^2}{6}}{\frac{(b-g)^2}{2} - \frac{(b-g)^2}{9} + \frac{3(b-g)^2}{6} - 2} < 1$$

$$\frac{(b-g)^2(\frac{4}{9})}{(b-g)^2(\frac{8}{9}) - 2} < 1$$

Since $0 \leq b < 1$, the numerator will always be positive and the denominator will always be negative as long as $0 \leq g < 1$. □

<u>Second-order condition for the non-collusive case:</u>

The second order condition for a welfare maximizing policy in the non-colluding case is that the second derivative of the welfare function with respect to a government's own policy instrument is smaller than zero. For country 1 we get:

$$\frac{\partial^2 W_1}{\partial \tau_1^2} = \frac{8(b-g)^2(d+1)^2}{(2d+1)(2d+3)^2} + \frac{l^2 - 4fk + 2km\frac{\partial^2 y_1}{\partial \tau_1^2}}{2k} < 0$$

Checking for the three cases:

For the emission standard, $d = .5$, $\frac{\partial^2 y_1}{\partial \tau_1^2} = 2$, $g = -1$, $f = .5$, $k = 0$, $l = 0$, $m < 0$

Replacing in the condition for a maximum, we obtain:

$$\frac{8(b+1)^2(1.5)^2}{32} - 1 + 2m < 0$$

$$\frac{9(b+1)^2}{16} - 1 + 2m < 0$$

Since $-1 < b \leq 0$ and $m < 0$, it is clear that the condition is always satisfied. □

For the emission tax, we have $d = 0$, $g = 1$, $f = 0$, $k = .5$, $l = -1$, $m = -.5$ and:

$$\frac{\partial^2 y_1}{\partial \tau_1^2} = \frac{\partial}{\partial \tau_1}[2(q_1^* - t_1)(2(\frac{b-1}{3}) - 1)] = \frac{8(b-1)^2}{9} - \frac{8b}{3} + \frac{14}{3}$$

Replacing in the condition for a maximum, we obtain:

$$\frac{8(b-1)^2}{9} + 1 - .5[\frac{8(b-1)^2}{9} - \frac{8b}{3} + \frac{14}{3}] < 0$$

$$\frac{8(b-1)^2}{9} + 1 - \frac{7}{3} + \frac{4b}{3} - \frac{4(b-1)^2}{9} < 0$$

$$\frac{4(b-1)^2}{9} + \frac{4(b-1)}{3} < 0$$

Since $0 \leq b < 1$, the condition is always satisfied. □

For the social standard, we have $d = 0$, $f = 1$, $k = 0$, $l = 0$, $m = 0$, $0 \leq g < 1$

Replacing in the condition for a maximum, we obtain:

$$\frac{8(b-g)^2}{9} - 2 < 0$$

Since $0 \leq b < 1$, this is always true as long as $0 \leq g < 1$. $\square$

Second-order conditions for the collusive case:

In order to get a maximum in the collusive case, we need to check the first two principle minors of the Hessian matrix. In other words we need the following two conditions to be satisfied:

$$\frac{\partial^2 W_{tot}}{\partial \tau_1^2} < 0$$

$$\frac{\partial^2 W_{tot}}{\partial \tau_1^2}\frac{\partial^2 W_{tot}}{\partial \tau_2^2} - \left(\frac{\partial^2 W_{tot}}{\partial \tau_1 \partial \tau_2}\right)^2 > 0$$

where $W_{tot} = W_1 + W_2$

From the general specification we have:

$$\frac{\partial^2 W_{tot}}{\partial \tau_1^2} = \frac{2(b-g)^2(4d^2+8d+5)}{(2d+1)(2d+3)^2} + \frac{l^2 - 4fk + 2km(\frac{\partial^2 y_1}{\partial \tau_1^2} + \frac{\partial^2 y_2}{\partial \tau_1^2})}{2k}$$

$$\frac{\partial^2 W_{tot}}{\partial \tau_1 \partial \tau_2} = (b-g)^2[\frac{-1}{2d+1} + \frac{1}{2d+3} - \frac{2}{(2d+3)^2}] + m[\frac{\partial^2 y_1}{\partial \tau_1 \partial \tau_2} + \frac{\partial^2 y_2}{\partial \tau_1 \partial \tau_2}]$$

Using previous calculations, we obtain the following results for the three cases.

Emission standard:

$$\frac{\partial^2 W_{tot}}{\partial \tau_1^2} = \frac{\partial^2 W_{tot}}{\partial \tau_2^2} = \frac{20(b+1)^2}{32} - 1 + 2m = (b+1)^2(\frac{5}{8}) - 1 + 2m < 0$$

$$\frac{\partial^2 W_{tot}}{\partial \tau_1 \partial \tau_2} = (b+1)^2[\frac{-1}{2} + \frac{1}{4} - \frac{1}{8}] = (b+1)^2(\frac{-3}{8})$$

As long as $-1 < b \leq 0$ and $m < 0$, both $\frac{\partial^2 W_{tot}}{\partial \tau_1^2} < 0$ and $\frac{\partial^2 W_{tot}}{\partial \tau_1^2}\frac{\partial^2 W_{tot}}{\partial \tau_2^2} - (\frac{\partial^2 W_{tot}}{\partial \tau_1 \partial \tau_2})^2 > 0$ will be satisfied. □

Emission tax:

$$\frac{\partial^2 y_1}{\partial \tau_1^2} = \frac{8(b-1)^2}{9} - \frac{8b}{3} + \frac{14}{3}$$

$$\frac{\partial^2 y_2}{\partial \tau_1^2} = \frac{2(b-1)^2}{9}$$

Thus,

$$\frac{\partial^2 W_{tot}}{\partial \tau_1^2} = \frac{\partial^2 W_{tot}}{\partial \tau_2^2} = (b-1)^2\frac{10}{9} + 1 + (-.5)[\frac{10(b-1)^2}{9} - \frac{8b}{3} + \frac{14}{3}]$$
$$= \frac{5(b-1)^2}{9} + \frac{4b}{3} - \frac{4}{3} < 0$$

$$\frac{\partial^2 W_{tot}}{\partial \tau_1 \partial \tau_2} = (b-1)^2[-1 + \frac{1}{3} - \frac{2}{9}] + (-.5)(2)[\frac{-4(b-1)^2}{9} + \frac{2(b-1)}{3}]$$
$$= \frac{-4(b-1)^2}{9} - \frac{2b}{3} + \frac{2}{3}$$

Since $0 \leq b < 1$, both $\frac{\partial^2 W_{tot}}{\partial \tau_1^2} < 0$ and $\frac{\partial^2 W_{tot}}{\partial \tau_1^2}\frac{\partial^2 W_{tot}}{\partial \tau_2^2} - (\frac{\partial^2 W_{tot}}{\partial \tau_1 \partial \tau_2})^2 > 0$ will always be satisfied. □

Social Standard:

$$\frac{\partial^2 W_{tot}}{\partial \tau_1^2} = \frac{\partial^2 W_{tot}}{\partial \tau_2^2} = \frac{10(b-g)^2}{9} - 2 < 0$$

$$\frac{\partial^2 W_{tot}}{\partial \tau_1 \partial \tau_2} = (b-g)^2[-1 + \frac{1}{3} - \frac{2}{9}] = \frac{-8(b-g)^2}{9}$$

Since $0 \leq b < 1$ and under $0 \leq g < 1$, both $\frac{\partial^2 W_{tot}}{\partial \tau_1^2} < 0$ and $\frac{\partial^2 W_{tot}}{\partial \tau_1^2}\frac{\partial^2 W_{tot}}{\partial \tau_2^2} - (\frac{\partial^2 W_{tot}}{\partial \tau_1 \partial \tau_2})^2 > 0$ will always be satisfied. □

9 Appendix B: Robustness Check with Heterogeneous Goods

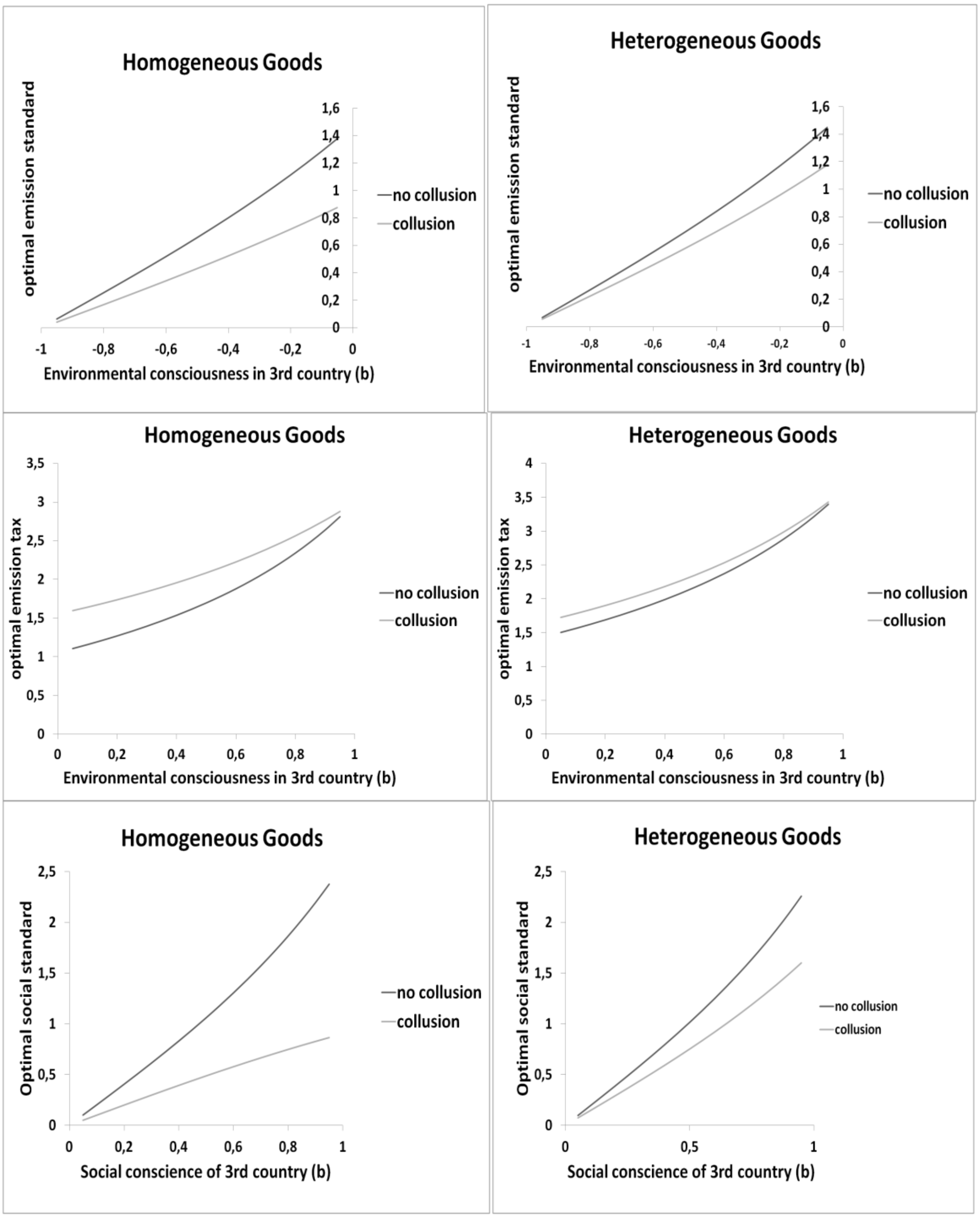
The specification of the demand function for the world market used in this paper assumed homogeneous goods. When relaxing this assumption and allowing for heterogeneous goods, all of the results derived in propositions 4 to 27 still stand except for one. For both cases of environmental dumping, going from homogeneous goods to heterogeneous goods reduces the magnitude of the gap between the non-collusive outcome and the collusive outcome. On the other hand, the optimal policy instrument and social welfare still behave in the same way as b changes. As for the social dumping case, the optimal policy instrument still behaves in the same way, but the conclusions for welfare differ slightly. While there is still divergence between the collusive case and the non-collusive case, welfare increases with b in the non-collusive case. This is in contradiction with proposition 24.

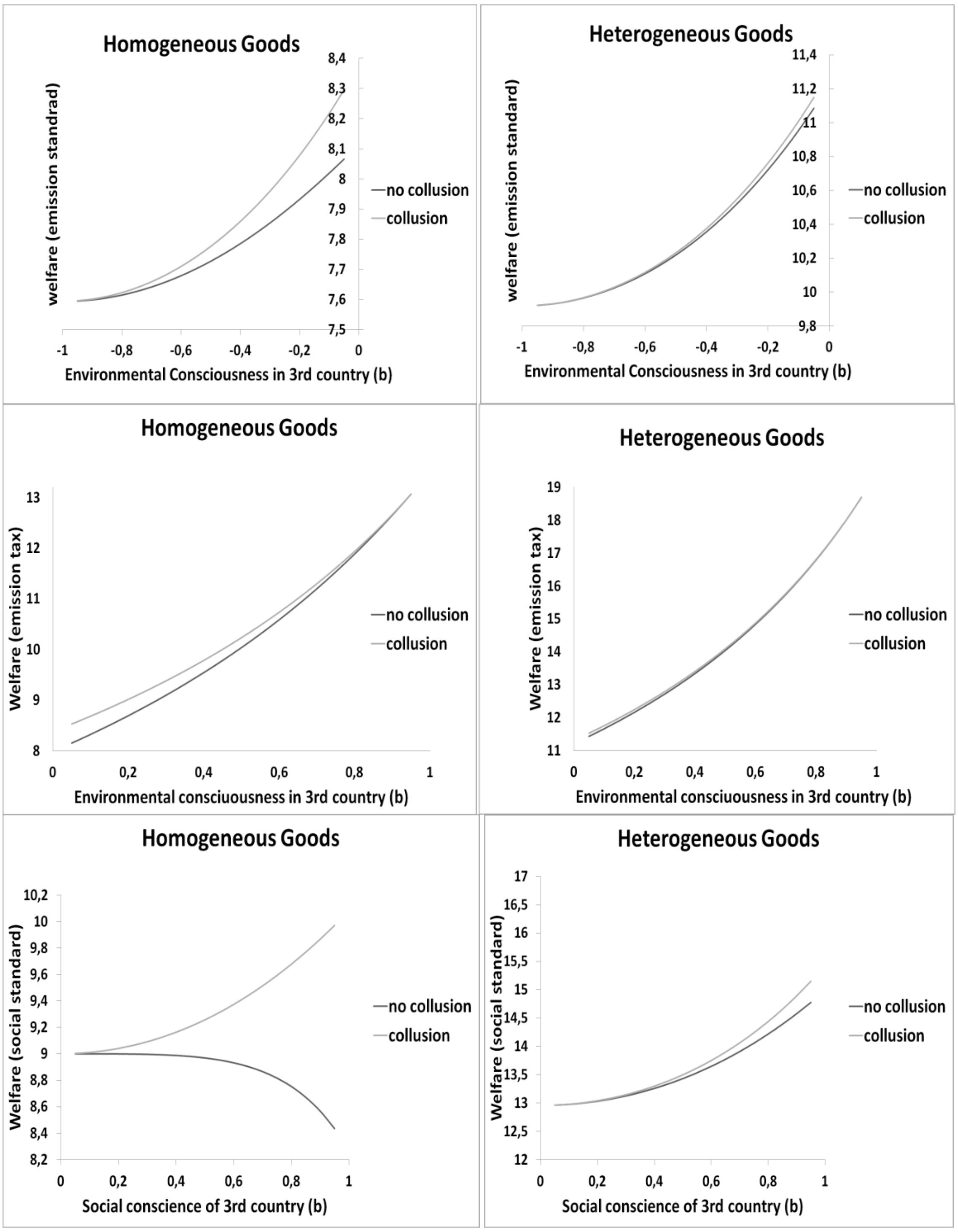
The specification used for demand in the case of heterogeneous goods is:

$$p_1(q_1, q_2, \tau_1) = a - q_1 - .5q_2 + b\tau_1$$

$$p_2(q_1, q_2, \tau_2) = a - .5q_1 - q_2 + b\tau_2$$

The following graphs contrast the case of homogeneous goods with the case of heterogeneous goods (using the same values for parameters as in Section 4). Homogeneous goods is illustrated on the left and heterogeneous goods on the right.


Homogeneous Goods
optimal emission standard
Environmental consciousness in 3rd country (b)
no collusion
collusion
Heterogeneous Goods
optimal emission standard
Environmental consciousness in 3rd country (b)
no collusion
collusion
Homogeneous Goods
optimal emission tax
Environmental consciousness in 3rd country (b)
no collusion
collusion
Heterogeneous Goods
optimal emission tax
Environmental consciousness in 3rd country (b)
no collusion
collusion
Homogeneous Goods
Optimal social standard
Social conscience of 3rd country (b)
no collusion
collusion
Heterogeneous Goods
Optimal social standard
Social conscience of 3rd country (b)
no collusion
collusion


Homogeneous Goods
welfare (emission standrad)
Environmental Consciousness in 3rd country (b)
no collusion
collusion
Heterogeneous Goods
welfare (emission standard)
Environmental Consciousness in 3rd country (b)
no collusion
collusion
Homogeneous Goods
Welfare (emission tax)
Environmental consciuousness in 3rd country (b)
no collusion
collusion
Heterogeneous Goods
Welfare (emission tax)
Environmental consciuousness in 3rd country (b)
no collusion
collusion
Homogeneous Goods
Welfare (social standard)
Social conscience of 3rd country (b)
no collusion
collusion
Heterogeneous Goods
Welfare (social standard)
Social conscience of 3rd country (b)
no collusion
collusion