Does Trade Restriction on Secondhand Goods Reduce Hazardous Recycling in Importing Countries?*

Keisaku Higashida†

Version: May 1, 2012

Abstract

This paper examines monitoring activities on illegal trade and restriction on legal trade of secondhand goods. We assume that the home (the foreign) country exports (imports) secondhand goods both legally and illegally. We demonstrate that when trade restriction is non-binding and a part of legally imported goods are used as materials, an increase in monitoring probability may increase expected foreign environmental damage. When trade restriction is binding, if a part of legal imports (no legal import) is resold for material use, a stricter trade restriction decreases (increases) expected foreign environmental damage. We also demonstrate that when governments choose monitoring probabilities non-cooperatively, the foreign monitoring probability is necessarily higher than that in the second best situation. In such a case, a commitment of monitoring probability by the home government improves welfares of both countries, and this commitment arises in the extended game. Moreover, when the foreign government chooses the level of an import quota on legal imports, it is possible that the foreign trade restriction is stricter than the second-best level. In such a case, any commitment by either government cannot improves welfares of both countries simultaneously.

Keywords: Hazardous wastes, monitoring, secondhand goods, trade restriction.
JEL Code: F13, F18, Q53.

*I would like to thank Takao Okawa and other participants at Nagoya International Economics Group Meeting at Chukyo University for helpful comments. I gratefully acknowledge financial support from Japan Society for the Promotion of Science under the Grant-in-Aid for Scientific Research (B) (21330060).

†School of Economics, Kwansei Gakuin University, 1-155, Ichiban-cho, Uegahara, Nishinomiya, Hyogo 662-8501, Japan. Email: *keisaku@kwansei.ac.jp*

1 Introduction

Transboundary movements of secondhand goods and wastes have been increasing constantly for the past few decades.[1] Imports of secondhand goods often cause serious environmental pollution in importing/developing countries because they are dismantled and recycled without used as secondhand. In developing countries, people prefer pecuniary gains to environmental protection. Moreover, the recycling sector is often unskilled labor intensive. People who are engaged in recycling in the informal sector have little understanding of toxicity of hazardous substances. Therefore, they extract materials to draw their income without taking care of the environment. A troublesome point is that it is impossible for the governments of importing countries to permit or prohibit importation of secondhand goods according to the purpose of use.

Having faced serious environmental damage caused by imported secondhand goods, developing countries have restricted trade in secondhand goods. Usually, they prohibit older secondhand goods. Some countries prohibit certain kinds of secondhand products, such as electric appliances, irrespective of the age of the products.[2]

International rules, such as the Basel convention, also stipulate trade restriction on hazardous waste. Several kinds of secondhand goods, such as used computers, contain toxic substances.[3] Therefore, the Basel Convention may be applied to trade in secondhand goods. It is estimated that a stricter rule, which is called the Basel Ban Amendment, will come into effect in the next few years.[4]

However, it is estimated that a large amount of secondhand goods is traded illegally. They are disguised as recycled materials which are supposed not to include hazardous substances. Formally, those substances should be removed in the exporting country before exportation. Custom officers of both exporting and importing countries inspect exports of materials/wastes and scrap. In fact, ship-back is often observed because custom officers of importing countries discover illegally traded products. However, due to imperfect monitoring and corruption, this problem has not been settled yet.[5]

[1]See also Kellenberg (2010), Ray (2008), Shinkuma and Huong (2009), and Wong et al. (2007) among others for the real situations of trade in secondhand goods and wastes.

[2]See the website of the Asian Network for Prevention of Illegal Transboundary Movement of Hazardous Wastes on import control on secondhand goods (http://www.env.go.jp/en/recycle/asian_net/Country_Information/Import_ctrl_on_2ndhand.html).

[3]When they are exported for material use or for dumping, they are classified as E-waste (Electronic and Electrical Waste).

[4]See the website of the Basel Convention (http://www.basel.int/)

[5]See also Shinkuma and Managi (2011) for a comprehensive analysis on waste and recycling.

We examine the effect of monitoring policies and trade restriction on legal and illegal trade of secondhand goods and, accordingly, environmental damage in importing countries. Moreover, we investigate the governments' behavior of choosing monitoring probabilities and the level of trade restriction. In particular, our research questions are as follows: (a) should/do exporting/developed countries commit to stricter monitoring activities; and (b) should international rules restrict trade in secondhand goods more strictly? We consider a scenario in which imported secondhand goods may be used as secondhand or as materials. Environmental pollution is emitted when secondhand goods, which contain hazardous wastes, are recycled for material use in importing countries.

Cassing and Kuhn (2003) investigated the effect of trade restriction when wastes are traded. Copeland (1991) also examined trade restriction in the presence of illegal dumping. However, they did not distinguish between legal and illegal trade. Therefore, monitoring systems are not analyzed. Clerides and Hadjiyiannis (2008) and Kinnaman and Yokoo (2011) focused on the effect of trade in durable goods, and demonstrated the policies that achieve efficiency. However, they did not consider trade policies and monitoring issues. On the monitoring issue, Harford (1978, 1987), Macho-Stadler and Pérez-Costirillo (2006), and Ino (2011) investigated enforcement policies when environmental policies are imperfectly enforceable. As far as we know, there are few studies that tackled strategic monitoring and trade restriction in the context of trade in secondhand goods.

We assume that the home (the foreign) country exports (imports) secondhand goods both legally and illegally. Then, we demonstrate that when trade restriction is non-binding and a part of legally imported goods are used as materials, an increase in monitoring probability may increase expected foreign environmental damage. When trade restriction is binding, if a part of legal imports (no legal import) is resold for material use, a stricter trade restriction decreases (increases) expected foreign environmental damage. We also demonstrate that when governments choose monitoring probabilities non-cooperatively, the foreign monitoring probability is necessarily higher than that in the second best situation. In such a case, a commitment of monitoring probability by the home government improves welfares of both countries, and this commitment arises in the extended game in which both governments choose the timing of move in the first stage and monitoring probabilities in the second stage. Moreover, we consider a situation in which the foreign government chooses not the monitoring probability but the level of an import quota on legal imports. It is possible that the foreign trade restriction is stricter than the second-best level. In such a case, any commitment by either government cannot improves welfares of both countries simultaneously.

The rest of the paper is organized as follows. Section 2 describes the model and legal/illegal trade. Section 3 defines environmental damage and examines the effects of policy changes: monitoring probabilities and trade restriction. Section 4 investigates a scenario in which both governments choose their monitoring probabilities non-cooperatively. Section 5 examines the choice of the level of trade restriction by the government of an importing country. Section 6 extends the analysis in the case in which home recycling activities exist. Section 7 provides concluding remarks.

2 The Model

Consider a developed country, which is referred to as *home* country, and a developing country, which is referred to as *foreign* country. The home (the foreign) country exports (imports) secondhand goods (X). For simplicity, it is assumed that there is no demand for (no supply of) secondhand goods in the home (the foreign) country. Consumers in the home country use goods X for one period and discard them. On the other hand, consumers in the foreign country purchase secondhand goods and use them for one period: after use, they also discard those secondhand goods.

2.1 Supply of and Demand for Secondhand Goods

The supply of secondhand/discarded goods (X) in the home country is constant, which is denoted by X_s. Collectors in the home country collect discarded goods from consumers. Any collector does not have market power. They have two alternatives: exporting those secondhand goods to the foreign country *legally* or *illegally*.[6] These alternatives reflect the following situation. In developed countries, recycling is usually very costly, while that in developing countries is much less costly. This is partly because recycling is often conducted using unskilled labor, although this type of recycling causes serious environmental damage. Then, home collectors have incentives to export secondhand goods either legally or illegally. When exported illegally, secondhand goods are exported not for secondhand use but for material use without removing hazardous substances. They are disguised as *recycled materials/wastes and scrap* which are supposed not to include hazardous wastes.

[6] Another alternative, selling them to home recyclers, will be examined in Section 6.

Then, foreign recyclers extract materials from those goods. Moreover, we consider a scenario in which even legally imported goods may be recycled directly for material use, which also generates serious environmental pollution. Hereafter, we also use *exporters* to represent home collectors.

When collectors export discarded goods legally, they have to repair those goods.[7] The marginal cost of repairing depends on how a secondhand good was used. The repairing costs for some goods are low, while those for other goods which are broken seriously may be high. Those costs may also depend on skills of recyclers. Thus, we define the marginal cost curve of legal export for the whole collecting industry as follows:

$$MC_l = MC_l(X_l), \quad MC_l' > 0,$$

where X_l denotes the quantity of legal exports. The shipping cost is included in MC_l.[8]

When collectors export secondhand goods illegally, they have to disguise secondhand goods as materials. Thus, they have to pay disguising cost, MC_d, which is constant. The shipping cost is also included in MC_d.

There are two types of demand for secondhand goods in the foreign country. First, consumers purchase and use them as secondhand. Second, recyclers in the foreign country buy secondhand goods, and make profits by extracting materials from those goods. The inverse demand curve of goods X for secondhand use in the foreign market is given by

$$p^u = P^u(X_u), \quad P^{u'} < 0, \tag{1}$$

where X_u denotes the quantity of legal imports which are used as secondhand. When a good X is recycled for material use, it makes the revenue, p^m, which is exogenous.[9] When $p^u > p^m$ ($p^u < p^m$) holds, an additional one unit of import of secondhand goods is sold to a consumer (a foreign recycler). Therefore, in equilibrium, $p^u \geq p^m$ holds. The equality holds when there are legal imports which are directly recycled for material use. Hereafter, let X_l and X_m denote the quantity of total legal imports and the quantity of legal imports which are directly recycled for material use. Note that $X_l = X_u + X_m$ holds.

[7] In reality, they have to do so, because customs officers in the importing country often regard broken goods that they cannot be used as secondhand. In such cases, importation is not allowed.

[8] We do not explicitly describe the transactions between consumers and collectors. Implicitly, we consider a situation in which the government sets a disposal fee on one unit of good X for consumers. Then, consumers have incentives to pay a collection fee to collectors if the collection fee is equal to or lower than the disposal fee.

[9] This assumption implies that the material market is competitive and the demand is elastic. Moreover, we implicitly consider that the foreign recycling sector is an informal sector and that foreign recyclers receive subsistence wage. Therefore, precisely, p^m is considered to denote the price of material minus subsistence wage.

2.2 Policies

We consider two kinds of policies. First, the foreign government may restrict the legal import of secondhand goods. An international trade rule may also restrict export of those goods. In this paper, we consider an import quota on legal imports, which is denoted by $\bar{X}_l$. In the real world, importing countries of secondhand goods often ban the import of older secondhand goods, because their prices as secondhand are lower than relatively new secondhand goods and, therefore, older ones are likely to directly go to recycling processes after imported. Although we do not take into consideration the age of secondhand goods explicitly, the effects of import quotas in our theoretical analysis can be applied to the effect of trade prohibition on older secondhand goods in the real world.[10]

Second, both the home and foreign governments monitor illegal trade. Because illegal exports are disguised as recycled materials, the governments inspect all of material trade. Custom officers may not be able to identify illegal trade with certainty. Or, they may intentionally overlook it. We let α_i $(i = h, f)$ denote the monitoring probability; precisely, the product of monitoring probability and identifiability. Then, the governments choose the level of α_i.

It is costly for the governments to monitor exports/imports. Moreover, when illegal trade is identified, the government has to keep the goods temporarily, hand over them to home collectors. In addition, the foreign government makes collectors ship back those goods to the home country. Hence, the expected operating cost of monitoring system increases as the expected amount of identified illegal trade increases. The expected amount also depends on the strictness of the import quota. Thus, the expected operating cost of monitoring system is represented as:

$$E[C_{G,i}] = E[C_{G,i}(\alpha_i, \bar{X}_l)], \quad i = h, f, \tag{2}$$

Throughout the paper, the combinations of E and square brackets denote expected values. On the shape of this cost function, we set up the following assumption.

Assumption 1

$$\frac{\partial E[C_{G,i}]}{\partial \alpha_i} > 0, \quad \frac{\partial^2 E[C_{G,i}]}{\partial \alpha_i^2} > 0, \quad \frac{\partial E[C_{G,i}]}{\partial \alpha_j} = 0,$$

[10]The home government is also able to set an export restriction. However, in reality, importing countries and/or international environmental agreements usually try to set stricter restriction because importing countries suffer from environmental/health damage from pollution caused by imported secondhand goods. In such a case, exporting countries respect the restrictions set by importing countries. Thus, we focus on trade restriction by importing countries and as an international trade rule.

$$\frac{\partial E[C_{G,i}]}{\partial \bar{X}_l} < 0, \quad \frac{\partial^2 E[C_{G,i}]}{\partial \bar{X}_l^2} > 0, \quad \frac{\partial^2 E[C_{G,i}]}{\partial \alpha_i \partial \bar{X}_l} < 0,$$

where $i, j = h, f, \ i \neq j$.

The first two inequalities in the first line is intuitive. The total quantity of traded materials, which are classified as waste and scrap according to trade classifications, is very large.[11] Therefore, the quantity of secondhand goods monitored does not affect the total monitoring cost. Thus, the home (the foreign) monitoring probability does not affect the foreign (the home) monitoring cost: see the third equality in the first line. A laxer trade restriction, which means a larger $\bar{X}_l$, leads to less monitoring cost, because the expected amount of identified illegal trade decreases: see the three inequalities in the second line.

The fine set by each government is F_h and F_f, respectively.[12] It is assumed that these fines are exogenous in this model. The reason is that the level of fine for the illegal export/import should be balanced with fines for other types of illegal activities. Thus, we exclude an infinitely large amount of fine.[13]

2.3 Legal Trade, Illegal Trade, and Recycling in the Home Country

Assuming that the supply of discarded goods in the home country is sufficiently large so that illegal trade necessarily exists, we consider the determination of the quantities of legal and illegal imports of secondhand goods. We assume the following situation. An foreign broker, which is referred to as an importer, and an exporter make a deal to trade one unit of secondhand goods. The net expected profit from the deal is divided by the two stakeholders. The ratio that the exporter (the importer) gains is β $(1-\beta)$, where $0 < \beta < 1$.[14]

First, taking into consideration the monitoring by both the home and foreign countries, we redefine the cost of illegal export. Because an exporter or an importer have to pay the fine and ship-back cost when illegal trade is unearthed. Thus, the expected marginal

[11] An example of trade classification is the Harmonized Commodity Description and Coding System (HS) of tariff nomenclature.

[12] Not only importing countries but also exporting countries usually set fines. For example, in Japan, the Waste Disposal and Public Cleaning Law stipulates fines on illegal exports of secondhand goods and wastes. See the website of the Ministry of the Environment (http://www.env.go.jp/en/laws/recycle/index.html).

[13] The possibility of mistaken arrests is also a basis that fines should not be infinitely large.

[14] We do not delve into the details on the problem of contracts between exporters and importers.

cost of illegal export ($E[C_{il}]$) is greater than MC_d in the presence of monitoring:

$$E[C_{il}] = MC_d + \alpha_h F_h + \alpha_f(1 - \alpha_h)(F_f + \lambda),$$

where λ denotes the ship-back cost. We set up the following assumption.

Assumption 2 *$\partial E[C_{il}]/\partial \alpha_h > 0$, i.e. $F_h - \alpha_f(F_f + \lambda) > 0$.*

This assumption implies that an increase in the home identifying probability increases the expected cost of illegal export.

Some of discarded goods that exporters try to export illegally are identified by customs officers of both countries and shipped back to the home country. We assume that those shipped back goods are recycled in the home country. Let $\tilde{X}_{il}$ and X_{il}^* denote the quantity of discarded goods that home recyclers try to export illegally and the realized quantity of illegal exports, respectively. Then, it holds that

$$E[X_{il}^*] = (1 - \alpha_h)(1 - \alpha_f)\tilde{X}_{il}, \tag{3}$$

Moreover, total expected import of discarded goods ($E[IM]$) is given by

$$E[IM^*] = X_l + E[X_{il}^*].$$

In addition, it holds that

$$X_s = X_l + \tilde{X}_{il} = X_l + X_{il}^* + X_r,$$

where X_r denotes the quantity of discarded goods which are recycled in the home country.

There are four possible cases. In the first case, an import quota is binding, and a part of legally imported secondhand goods are resold for material use (see Figure 1 (a)). In this case, $X_l = \bar{X}_l$ and $p^m - MC_l(\bar{X}_l) > (1 - \alpha_h)(1 - \alpha_f)p^m - E[C_{il}]$ hold. In the second case, an import quota is also binding. Contrary to the first case, no legally imported secondhand goods are resold for material use (see Figure 1 (b)). $X_l = \bar{X}_l$ and $P^u(\bar{X}_l) - MC_l(\bar{X}_l) > (1 - \alpha_h)(1 - \alpha_f)p^m - E[C_{il}]$ hold. In the third case, trade restriction is non-binding, and a part of legally imported secondhand goods are resold for material use (see Figure 1 (c)). The quantity of legal imports is determined so that

$$p^m - MC_l(X_l) = (1 - \alpha_h)(1 - \alpha_f)p^m - E[C_{il}] \tag{4}$$

holds. In the fourth case, trade restriction is non-binding. Contrary to the third case, no legally imported secondhand goods are resold for material use (see Figure 1 (d)). The quantity of legal imports is determined so that

$$P^u(X_l) - MC_l(X_l) = (1-\alpha_h)(1-\alpha_f)p^m - E[C_{il}] \tag{5}$$

holds.

3 Foreign Environmental Damage

Recycling of secondhand goods in the foreign country generates environmental pollution. When imported goods are used as secondhand, those goods will be recycled in the future. The technology and environmental management may be advanced in the future. The environmental damage in the future is also discounted when we consider present values. Therefore, we assume that the environmental damage from the recycling of (a) illegal imports (X_{il}) and (b) legal imports for material use (X_m) is greater than that of legal imports for secondhand use (X_u): one unit of recycling in the foreign country at present generates μ_f^M units of pollution, while that in the future generates μ_f^S units of pollution, where $\mu_f^M > \mu_f^S$. Assuming that one unit of pollution generates one unit of environmental damage, foreign environmental damage is defined as

$$e_f = \mu_f^M \cdot (E[X_{il}^*] + X_m) + \mu_f^S \cdot X_u. \tag{6}$$

The recycling activity itself in the home country is costly. It is properly managed, and accordingly does not generate environmental damage. However, the home country faces the scarcity problem of landfills. An increase in the recycling activity in the home country leads to an increase in the residuals disposed into landfills. Thus, recycling in the home country also generates an external cost. Assuming one unit of recycling in the home country generates μ_h units of external cost, the cost related to home recycling is defined as

$$e_h = \mu_h \cdot (X_s - E[IM^*]).$$

3.1 Policy Effects

We now investigate whether monitoring or trade restriction can decrease foreign environmental damage.

First, we examine the effect of an increase in monitoring probability. In terms of importers and exporters, α_h and α_f have similar effects. Thus, we focus on α_h. When an import quota is binding, a change in monitoring probability does not affect the quantities of legal import for both secondhand and material use, which also implies that $\tilde{X}_{il}$ does not change. Then, from (3), it is obtained that

$$\frac{\partial E[X_{il}^*]}{\partial \alpha_h} = -(1-\alpha)\tilde{X}_{il}.$$

The quantity of realized illegal imports decreases, because an increase in the monitoring probability increases the quantity of identified illegal trade.

When an import quota is non-binding, the monitoring probability affects the quantity of legal imports. When a part of legal imports are recycled for material use (Figure 1 (c)), from (4) and Assumption 2, it is obtained that

$$\frac{dX_m}{d\alpha_h} = \frac{(1-\alpha_f)p^m + \frac{\partial E[C_{il}]}{\partial \alpha_h}}{MC_l'(X_l)} > 0.$$

Because $\tilde{X}_{il} = X_s - X_l$ and because X_u does not change, it also holds that

$$\frac{d\tilde{X}_{il}}{d\alpha_h} = -\frac{dX_m}{d\alpha_h} < 0,$$

$$\frac{dE[X_{il}^*]}{d\alpha_h} = -(1-\alpha_f)\tilde{X}_{il} + (1-\alpha_h)(1-\alpha_f)\frac{d\tilde{X}_{il}}{d\alpha_h} < 0. \tag{7}$$

Whether total expected quantity of imports for material use ($X_m + E[X_{il}^*]$) increases or decreases depends on the supply of secondhand goods, the values of fines, the shape of marginal repairing cost curve, the level of α_h, and the ship-back cost. Precisely, two effects arise. First, the type of trade of secondhand goods for material use partly changes from illegal to legal trade. In this respect, the quantity of imports for recycling increases. Second, an increase in monitoring probability increases the probability of being identified. In this respect, the quantity of imports for recycling decreases. In total, the former effect may dominate the latter.

When no legal imports are recycled for material use (Figure 1 (d)), from (5), it is obtained that

$$\frac{dX_u}{d\alpha_h} = \frac{dX_l}{d\alpha_h} = -\frac{(1-\alpha_f)p^m + \frac{\partial E[C_{il}]}{\partial \alpha_h}}{p^{u\prime}(X_l) - MC_l'(X_l)} > 0$$

Note that (7) and $dX_u/d\alpha_h = -d\tilde{X}_{il}/d\alpha_h$ also hold in this case. Therefore, the amount of increase in the legal imports for secondhand use is smaller than the amount of decrease in illegal imports. Because $\mu_f^S < \mu_f^M$, foreign environmental damage necessarily decreases.

Proposition 1

An increase in monitoring probability ($\alpha_i,\ i = h, f$) necessarily decreases expected foreign environmental damage (a) when trade restriction is binding, and (b) when trade restriction is non-binding and no legal imports are used for materials. On the other hand, when trade restriction is non-binding and a part of legal imports are used for materials, an increase in monitoring probability may increase expected foreign environmental damage.

Next, we examine the effect of a stricter trade restriction: a decrease in $\bar{X}_l$. It is obvious that when an import quota is non-binding, a stricter trade restriction does not affect the quantity of legal imports and the expected quantity of illegal imports. There is no effect on the quantity of goods used for secondhand and materials.

On the other hand, when an import quota is binding, $\partial X_l / \partial \bar{X}_l > 0$ holds.

Lemma 1

Suppose that an import quota is binding. Then, given the monitoring probabilities of both countries, a stricter trade restriction necessarily decreases (increases) the quantity of legal (illegal) trade.

Lemma 1 implies that a part of imports for material use changes from legal to illegal trade. When a part of legal imports is resold for material use, a stricter trade restriction leads to a decrease in imports for material use. The reason is that when discarded goods are imported legally for material use, custom officers cannot distinguish goods for material use from those for secondhand use. On the other hand, when discarded goods are imported illegally, foreign custom officers may be able to identify those goods and ship back them to the home country. Contrarily, when no legal imports are used for materials, a stricter trade restriction leads to an increase in imports for material use. This is because a part of imports changes from legal trade for secondhand use to illegal trade for material use. Consequently, the following result is established.

Proposition 2

When trade restriction is binding, if a part of legal imports (no legal import) is resold for material use, a stricter trade restriction decreases (increases) expected foreign environmental damage.

Three important policy implications should be noted. First, when an import quota is non-binding, an increase in monitoring probability may deteriorate foreign environmental damage, because the quantity of imports for material use increases. Interestingly, the purpose of monitoring is originally to decrease foreign environmental damage. However, it may give rise to the opposite effect. In such a case, the foreign government does not have an incentive to increase the monitoring probability. In other words, for the foreign government to have an incentive to monitor illegal imports to mitigate foreign environmental damage caused by recycling of imported secondhand goods, a binding import quota is needed.

Second, the smaller is α_i $(i = h, f)$, the larger is the gains from illegal trade, and accordingly, the smaller is the quantity of legal trade. This implies that a decrease in α_i increases the possibility that trade restriction is non-binding given $\bar{X}_l$. Therefore, it can be said that trade restriction cannot be effective when monitoring systems do not function well. Thus, it can be said that monitoring activities and trade restriction are complements.

Third, in the literature, when illegal activities cannot be punished with certainty, trade restriction is justified to achieve the second-best situation. On the other hand, in the present case, trade restriction induces an increase in illegal imports. Therefore, trade restriction is not always justified.

4 Non-cooperative Choices of Monitoring Probabilities

We have obtained that a binding import quota can be important for the foreign government to have an incentive to monitor illegal trade when a part of legal imports is resold to foreign recyclers for material use. Then, in the presence of such binding trade restriction, each government can choose its monitoring probability non-cooperatively to maximize welfare of its country. In this section, assuming that the level of trade restriction ($\bar{X}_l$) is exogenous, we consider a situation in which the governments choose monitoring probabilities (α_i $(i = h, f)$). For example, an international environmental agreement may stipulate trade restriction. For clarity of the analysis and applicability to real situations, we focus on the case in which an import quota is binding and a part of legally imported goods goes to the recycling process of the foreign country directly for material use ($X_m > 0$, see Figure 1 (a)).

Home welfare is defined as the sum of the net profits of exporters, the government revenue, minus the cost for the government which arise from identification of illegal trade

(T), the cost related to home recycling, and the monitoring cost:

$$\begin{aligned} E[W_h] &= \beta \cdot \left(p^m \bar{X}_l - \int_0^{\bar{X}_l} MC_l(y)dy \right) + \beta \cdot \{(1-\alpha_h)(1-\alpha_f)p^m - E[C_{il}]\} \cdot \tilde{X}_{il} \\ &\quad + \alpha_h F_h \tilde{X}_l - \alpha_f (1-\alpha_h) T \tilde{X}_{il} - \mu_h \cdot (\alpha_h + \alpha_f - \alpha_h \alpha_f) \tilde{X}_{il} - E[C_{G,h}]. \end{aligned} \tag{8}$$

Note that $\tilde{X}_{il} = X_s - \bar{X}_l$. Moreover, T is the cost for the home government related to detection of illegal export by the foreign government. Sometimes, the detection leads to a diplomatic issue including complete ban of waste and scrap for a certain periods. The home government may also lose reputation in particular, when it joins an international environmental agreement. Because this cost is a kind of external cost, each exporter does not take into consideration.

Foreign welfare is defined as the sum of consumer surplus from secondhand use (CS_u), the net profits of importers, the government revenue, minus environmental damage and the monitoring cost:

$$\begin{aligned} E[W_f] &= CS_u + (1-\beta) \cdot \left(p^m \bar{X}_l - \int_0^{\bar{X}_l} MC_l(y)dy \right) \\ &\quad + (1-\beta) \cdot \{(1-\alpha_h)(1-\alpha_f)p^m - E[C_{il}]\} \cdot \tilde{X}_{il} + \alpha_f (1-\alpha_h) F_f \tilde{X}_{il} \\ &\quad - \mu_f^M \cdot \left\{ (1-\alpha_h)(1-\alpha_f)\tilde{X}_{il} + \bar{X}_l - X_u \right\} - \mu_f^S X_u - E[C_{G,f}] \end{aligned} \tag{9}$$

4.1 Monitoring Game

Because seriousness of environmental damage from recycling goods X for material use is different from that from using them as secondhand, for the first best situation to be achieved, the markets must be segmented according to the purpose of use. In other words, the price of goods for secondhand use should be different from that for recycling. However, in the situation we focus on, it is difficult for custom officers to distinguish secondhand goods for secondhand use from those for material use when they are legally traded. It is considered that both types of markets are integrated in the foreign country. Therefore, we consider the second best situation as benchmark given the integration of the markets. Because the level of trade restriction is exogenous, the first-order conditions (FOCs) for the second best situation is given by

$$\frac{\partial (E[W_h] + E[W_f])}{\partial \alpha_h} = 0, \quad \frac{\partial (E[W_h] + E[W_f])}{\partial \alpha_f} = 0.$$

The combination of monitoring probabilities that satisfies the FOCs above can be regarded as a cooperative equilibrium. The second-order conditions (SOCs) are assumed to hold.

By contrast, when each government chooses its monitoring probability non-cooperatively, from (8) and (9), the FOCs are

$$\begin{aligned} \frac{\partial E[W_h]}{\partial \alpha_h} &= -\beta \tilde{X}_{il} \cdot \{(1-\alpha_f)p^m + F_h - \alpha_f(F_f+\lambda)\} + (F_h + \alpha_f T)\tilde{X}_{il} \\ &\quad -\mu_h \cdot (1-\alpha_f))\tilde{X}_{il} - \frac{\partial E[C_{G,h}]}{\partial \alpha_h} = 0, \end{aligned} \tag{10}$$

$$\begin{aligned} \frac{\partial E[W_f]}{\partial \alpha_f} &= -(1-\beta)(1-\alpha_h)(p^m + F_f + \lambda)\tilde{X}_{il} \\ &\quad (1-\alpha_h)(F_f + \mu_f)\tilde{X}_{il} - \frac{\partial E[C_{G,f}]}{\partial \alpha_f} = 0. \end{aligned} \tag{11}$$

We let $\alpha_i^N (i = h, f)$ denote equilibrium probabilities in non-cooperative Nash equilibrium.[15] We also refer to this equilibrium as *the simultaneous move equilibrium*. In the following, we focus on the case in which the home government chooses a positive amount of monitoring probability. The home government can save the external cost related to identification of illegal trade at the foreign customs and gain the government revenue by increasing the monitoring probability. Thus, it follows from (10) that the home government is likely to choose a positive monitoring probability (a) unless α_f and/or T are very small and (b) unless μ_h is large.

Moreover, we obtain the following partial derivatives:

$$\begin{aligned} \frac{\partial E[W_h]}{\partial \alpha_f} &= -\beta \cdot (1-\alpha_h)(p^m + F_f + \lambda)\tilde{X}_{il} \\ &\quad -(1-\alpha_h)(T + \mu_h)\tilde{X}_{il} \\ &\quad < 0. \end{aligned} \tag{12}$$

$$\begin{aligned} \frac{\partial E[W_f]}{\partial \alpha_h} &= -(1-\beta)\tilde{X}_{il}\{(1-\alpha_f)p^m + F_h - \alpha_f(F_f+\lambda)\} \\ &\quad -\alpha_f F_f \tilde{X}_{il} + \mu_f \cdot (1-\alpha_f)\tilde{X}_{il}. \end{aligned} \tag{13}$$

Thus, we obtain the following result.

[15] From Assumption 1, and Equations (10) and (11), we obtain

$$\frac{\partial^2 E[W_i]}{\partial \alpha_i^2} = -\frac{\partial^2 E[C_{G,i}]}{\partial \alpha_h^2} < 0, \quad i = h, f.$$

Moreover, as we will show in (14) and (15), $\partial^2 E[W_h]/\partial \alpha_h \partial \alpha_f > 0$ and $\partial^2 E[W_f]/\partial \alpha_h \partial \alpha_f < 0$ hold. Thus,the SOCs are satisfied.

Proposition 3

In the simultaneous move equilibrium, the foreign monitoring probability is necessarily higher than that in the second best situation. On the other hand, whether the home monitoring probability is higher than that in the second best situation is generally ambiguous. It is likely that the home monitoring probability is lower (higher) than that in the second best situation, if (a) foreign environmental damage is serious (not serious) and (b) the ratio of the net profits gained by importers are small (large).

An increase in the foreign monitoring probability decreases the realized import for material use and increases the external cost related to the ship-back and recycling in the home country. Both of those effects reduces home welfare. Because the foreign government does not take into consideration the loss of the home country, the foreign monitoring probability in the simultaneous move equilibrium is necessarily higher than that in the second best situation. An increase in the home monitoring probability also decreases the realized import for material use. This decrease gives rise to three effect: first, the pecuniary benefit from illegal import decreases; second, the foreign government revenue decreases; and third, foreign environmental damage is mitigated. Thus, the third effect dominates the sum of the first two effects, the home monitoring probability in the simultaneous move equilibrium is lower than that in the second best situation.

4.2 Commitment

Given the level of trade restriction, can commitment by either government improve welfare of both countries? First, we note the following second partial derivative.

$$\frac{\partial^2 E[W_h]}{\partial \alpha_h \partial \alpha_f} = \beta \cdot (p^m + F_f + \lambda)\tilde{X}_{il} + (T + \mu_h)\tilde{X}_{il} > 0, \tag{14}$$

From (11), we also obtain that

$$\frac{\partial^2 E[W_f]}{\partial \alpha_h \partial \alpha_f} = (1-\beta) \cdot (p^m + F_f + \lambda)\tilde{X}_{il} - (F_f + \mu_f)\tilde{X}_{il} < 0. \tag{15}$$

The first inequality implies that the home government increases the monitoring probability in response to an increase in the foreign monitoring probability. The intuition is that an increase in the foreign monitoring probability increases the possibility of ship-back. The home government can avoid the ship-back by increasing its own monitoring probability. On the other hand, the second inequality implies that the foreign government decreases the monitoring probability in response to an increase in the home monitoring probability.

It is costly to monitor material trade. The foreign government can save the monitoring cost when the home government increases its monitoring probability. The situation in the case of $\partial E[W_f]/\partial \alpha_h > 0$ ($\partial E[W_f]/\partial \alpha_h < 0$) is shown in Figure 2(a) (2(b)). R_i $(i = h, f)$ and I_i $(i = h, f)$ denote the reaction function and social indifference curve, respectively.

Suppose that $\partial E[W_f]/\partial \alpha_h > 0$, and consider a situation in which the home government commits itself to a certain monitoring probability: i.e., the home (the foreign) government is the leader (the follower) in determining monitoring probabilities. In this case, the equilibrium is shown by Point A in Figure 2(a). It is clear that welfares of both countries are improved as compared with those in non-cooperative Nash equilibrium. As proved by Hamilton and Slutsky (1990, Theorem V), the home government moves first and the foreign government moves second in the unique subgame perfect equilibrium in the extended game between both the governments: they choose the timings of moves in the first stage and monitoring probabilities in the second stage.

Proposition 4

Suppose that $\partial E[W_f]/\partial \alpha_h > 0$. A commitment of monitoring probability by the home government improves both countries' welfares as compared with those in the simultaneous move equilibrium. Moreover, in the subgame perfect Nash equilibrium of the extended game, the home (the foreign) government moves first (second), which implies that the home government chooses to make a commitment.

Proposition 4 provides an interesting policy implication. A binding import quota not only gives the foreign government an incentive to monitor illegal imports of secondhand goods but also generates a Pareto superior set of monitoring probabilities as compared with those in non-cooperative Nash equilibrium through the choices of timings of moves.

In the case of $\partial E[W_f]/\partial \alpha_h < 0$, the foreign government chooses to make a commitment in the subgame perfect Nash equilibrium of the extended game. In other words, the foreign (the home) government becomes a leader (follower). Similar to the case of $\partial E[W_f]/\partial \alpha_h > 0$, a Pareto superior set of monitoring probabilities as compared with those in the simultaneous move equilibrium arises, although a situation in which both monitoring probabilities in the simultaneous move equilibrium are higher than the second-best ones seems to be less realistic.

5 The Choice of Trade Restriction by the Importing Country

Now let us turn to a scenario in which the foreign monitoring probability has the upper limit: $\alpha_f = \bar{\alpha}_f$. For example, slow decision making processes of bureaucratic organization may make it difficult for the foreign government to increase its monitoring probability in the short run, because the policy change needs personnel changes. In such a case, the foreign government may choose the level of trade restriction to maximize its own welfare at least in the short run. On the other hand, similar to the previous section, the home government chooses its monitoring probability, and a part of legal imports is resold to foreign recyclers for material use.

In non-cooperative Nash equilibrium, the FOC for the home government is the same as (10), while the FOC for the foreign government is given by

$$\begin{aligned}\frac{\partial E[W_f]}{\partial \bar{X}_l} &= (1-\beta)(p^m - MC_l(\bar{X}_l)) - (1-\beta)\cdot\{(1-\alpha_h)(1-\alpha_f)p^m - E[C_{il}]\} \\ &\quad -\alpha_f(1-\alpha_h)F_f - \mu_f\cdot(\alpha_h + \alpha_f - \alpha_h\alpha_f) - \frac{\partial E[C_{G,f}]}{\partial \bar{X}_l} \\ &= 0\end{aligned}$$

We assume that the SOCs and stability condition are satisfied.

For the level of trade restriction, we obtain that

$$\begin{aligned}\frac{\partial E[W_h]}{\partial \bar{X}_l} &= \beta\cdot(p^m - MC_l(\bar{X}_l)) - \beta\cdot\{(1-\alpha_h)(1-\alpha_f)p^m - E[C_{il}]\} \\ &\quad -\alpha_h F_h + \alpha_f(1-\alpha_h)T + \mu_h(\alpha_h + \alpha_f - \alpha_h\alpha_f) - \frac{\partial E[C_{G,h}]}{\partial \bar{X}_l} \qquad (16)\end{aligned}$$

$p^m - MC_l(\bar{X}_l) > (1-\alpha_h)(1-\alpha_f)p^m - E[C_{il}]$ holds when an import quota is binding. Thus, from Assumption 1, the following result is obtained.

Proposition 5

In the simultaneous move equilibrium, foreign trade restriction is stricter than that in the second best situation if the expected amount of punishment by the home government is smaller than the sum of the expected government cost when ship-back is realized and the expected home environmental damage. On the other hand, it is likely that the home monitoring probability is higher than that in the second best situation if (a) foreign environmental damage is serious and (b) the ratio of the net profits gained by importers are small.

Similar to the previous section, focusing on the case of $\partial E[W_f]/\partial\alpha_h > 0$, we consider the commitment problem. Using (10) and Assumption 2, we obtain

$$\frac{\partial^2 E[W_h]}{\partial \bar{X}_l \partial \alpha_h} = \beta \cdot \{(1-\alpha_f)p^m + F_h - \alpha_f(F_f + \lambda)\} - F_h - \alpha_f T + \mu_h(1-\alpha_f) < 0.$$

The intuition is the same as the case of monitoring game: a stricter trade restriction increases the possibility of ship-back. The home government can avoid the ship-back by increasing its own monitoring probability.[16] Moreover, from (13), we obtain

$$\frac{\partial^2 E[W_f]}{\partial \alpha_h \partial \bar{X}_l} = (1-\beta) \cdot \{(1-\alpha_f)p^m + F_h - \alpha_f(F_f + \lambda)\} + \alpha_f F_f - \mu_f \cdot (1-\alpha_f) < 0.$$

Contrary to the case of monitoring game, the foreign government chooses stricter trade restriction in response to a higher home monitoring probability. An increase in the home monitoring probability means that the realized illegal import decreases given the foreign monitoring probability. Therefore, the foreign government can decrease the import of secondhand goods for material use more effectively by stricter trade restriction on legal imports. Note that strategic complements hold for both governments.

The case in which $\partial E[W_h]/\partial \bar{X}_l > 0$ is shown in Figure 3(a). In this case, a commitment by either government or an international agreement on stricter trade restriction cannot improve both countries' welfare simultaneously. This situation is sharp contrast to the case in which the foreign government chooses its monitoring probability. To achieve a Pareto superior situation, trade restriction on legal imports should be laxer and the home monitoring probability should be higher as compared with those in the simultaneous move equilibrium. Moreover, as proved by Hamilton and Slutsky (1990, Theorem V), both governments move simultaneously even in the extended game between both the governments. In this situation, import quotas should not be set by importing countries non-cooperatively.

The case in which $\partial E[W_h]/\partial \bar{X}_l < 0$ is shown in Figure 3(b). In this case, a commitment by either government can improve both countries' welfare simultaneously. And, the extended game has multiple equilibria. It is important for the home (or foreign) government to commit to the second-best level of monitoring probability (or import quota).

[16] We may recall that a smaller $\bar{X}_l$ implies a stricter trade restriction.

6 Recycling in the Home Country

We have so far considered that home collectors export discarded goods legally or illegally. However, they may have three alternatives: exporting discarded goods legally; exporting those goods illegally; or selling them to home recyclers. Even if we consider such a scenario, the similar results are obtained about the policy effects on foreign environmental damage. Similar to the previous sections, we assume that the supply of discarded goods is sufficiently large so that illegal exports exist.

Let us define the marginal cost curve of recycling in the home country:

$$MC_r = MC_r(X_r), \quad MC_r' > 0,$$

Then, in addition to the conditions described in Subsection 2.3 for the possible four cases, such as (4) and (5), the following condition holds:

$$(1-\alpha_h)(1-\alpha_f)p^m - E[C_{il}] = p^m - MC_r(\tilde{X}_r),$$

where $\tilde{X}_r$ denotes the quantity of discarded goods that home recyclers determine to recycle in the home country: $\tilde{X}_r = X_s - X_l - \tilde{X}_{il}$. This condition depends on neither whether trade restriction is binding nor whether a part of legal imports are resold to foreign recyclers. Because a part of illegal exports are shipped back, the expected quantity of total home recycling is:

$$E[X_r^*] = \tilde{X}_r + (\alpha_h + \alpha_f - \alpha_h\alpha_f)\tilde{X}_{il}.$$

The effect of a higher home monitoring probability on $\tilde{X}_r$ is given by

$$\frac{d\tilde{X}_r}{d\alpha_h} = \frac{(1-\alpha_f)p^m - \frac{\partial E[C_{il}]}{\partial \alpha_h}}{MC_r'} > 0.$$

This implies that when the home government increases its monitoring probability, not only the quantity of legal imports but also the sales of discarded goods directly from home collectors to home recyclers increase. The increase of the sales to home recyclers reduces foreign environmental damage. Thus, the possibility that a higher monitoring probability causes more serious foreign environmental damage is lower as compared with the alternative of selling discarded goods to home recyclers. However, Propositions 1 and 2 hold for this situation.

When both the home and foreign governments choose their own monitoring probabilities given the level of trade restriction, the slope of the reaction function of the home government is not necessarily positive. The reason is that an increase in the foreign monitoring probability increases the recycling cost in the home country. Because the marginal recycling cost also increases, an increase in the home monitoring probability becomes more costly. Then, the home government decreases its monitoring probability in response to an increase in the foreign monitoring probability. However, when the slope of the reaction function of the home government is negative, if $\partial E[W_f]/\partial \alpha_h > 0$, the multiple equilibria exist in the extended game. This means that a situation in which the home (the foreign) government is a leader (a follower) achieves a Pareto superior set of monitoring probabilities as compared with that in the simultaneous move equilibrium.

7 Conclusion

Assuming that the home (the foreign) country exports (imports) secondhand goods, we examine the effect of monitoring policies and trade restriction on legal and illegal trade of secondhand goods and, accordingly, environmental damage in importing countries. Moreover, we investigate the governments' behavior of choosing monitoring probabilities and the level of trade restriction.

First, we demonstrate that when trade restriction is non-binding and a part of legally imported goods are used as materials, an increase in monitoring probability may increase expected foreign environmental damage. When trade restriction is binding, if a part of legal imports (no legal import) is resold for material use, a stricter trade restriction decreases (increases) expected foreign environmental damage.

Second, we find that when governments choose monitoring probabilities non-cooperatively, the foreign monitoring probability is necessarily higher than that in the second best situation. In such a case, a commitment of monitoring probability by the home government improves welfares of both countries, and this commitment arises in the extended game in which both governments choose the timing of move in the first stage and monitoring probabilities in the second stage. The reason is that the home government increases its monitoring probability in response to an increase in the foreign monitoring probability.

Third, we consider a situation in which the foreign government chooses not the monitoring probability but the level of an import quota on legal imports. It is possible that the foreign trade restriction is stricter than the second-best level. In such a case, any commitment by either government cannot improves welfares of both countries simultaneously.

Finally, the answers for our research questions are as follows. First, exporting countries should commit to stricter monitoring probabilities if the present situation seems to correspond to the simultaneous move equilibrium. However, in the presence of binding trade restriction, the Pareto superior situation will arise. Second, when importing countries choose the levels of trade restriction, it is possible that they are too strict. Thus, the level of trade restriction should be set by international trade organizations.

References

[1] Baggs, J., 2009. International trade in hazardous waste. *Review of International Economics* 17, 1-16.

[2] Berglund, C., and P. Söderholm, 2003a. Complementing empirical evidence on global recycling and trade of waste paper. *World Development* 31, 743-754.

[3] Berglund, C., and P. Söderholm, 2003b. An econometric analysis of global waste paper recovery and utilization. *Environmental and Resource Economics* 26, 429-456.

[4] Cassing, J., and T. Kuhn 2003. Strategic environmental policies when waste products are tradable. *Review of International Economics* 11, 495-511.

[5] Clerides, S., and C. Hadjiyiannis, 2008. Quality standards for used durables: an indirect subsidy? *Journal of International Economics* 75, 268-282.

[6] Copeland, B. R., 1991. International trade in waste products in the presence of illegal disposal. *Journal of Environmental Economics and Management* 20, 143-162.

[7] Hamilton, J. H., and S. M. Slutsky, 1990. Endogenous timing in duopoly games: Stackelberg or Cournot equilibria. *Games and Economic Behavior* 2, 29-46.

[8] Harford, J. D., 1978. Firm behavior under imperfectly enforceable pollution standards and taxes. *Journal of Environmental Economics and Management* 5, 26-43.

[9] Harford, J. D., 1987. Self-reporting of pollution and the firm's behavior under imperfectly enforceable regulation. *Journal of Environmental Economics and Management* 14, 293-303.

[10] Kellenberg, D., 2010. Consumer waste, backhauling, and pollution havens. *Journal of Applied Economics* 13, 283-304.

[11] Kinnaman, T., and H. Yokoo, 2011. The environmental consequences of global reuse. *American Economic Review* 101, 71-76.

[12] Macho-Stadler, I.,and D. Pérez-Costrillo, 2006. Optimal enforcement policy and firms' emissions and compliance with environmental taxes. *Journal of Environmental Economics and Management* 51, 110-131.

[13] Ray, A., 2008. Waste management in developing Asia: can trade and cooperation help? *Journal of Environment and Development* 17, 3-25.

[14] Shinkuma, T., and N. T. M. Huong, 2009. The flow of E-waste material in the Asian region and a reconsideration of international trade policies on E- waste. *Environmental Impact Assessment Review* 29, 25-31.

[15] Shinkuma, T., and S. Managi, 2011. *Waste and Recycling — Theory and empirics* —. Routledge.

[16] Van Beukering, P.J.H., and M.N. Bouman, 2001. Empirical evidence on recycling and trade of paper and lead in developed and developing countries. *World Development* 29, 1717-1737.

[17] Wong, M. H., S. C. Wu, W. J. Deng, X. Z. Yu, Q. Luo, A. O. W. Leung, and C. S. C. Wong, W. J. Luksemburg, and A. S. Wong, 2007. Export of toxic chemicals ? A review of the case of uncontrolled electronic-waste recycling. *Environmental Pollution* 149, 131-140.

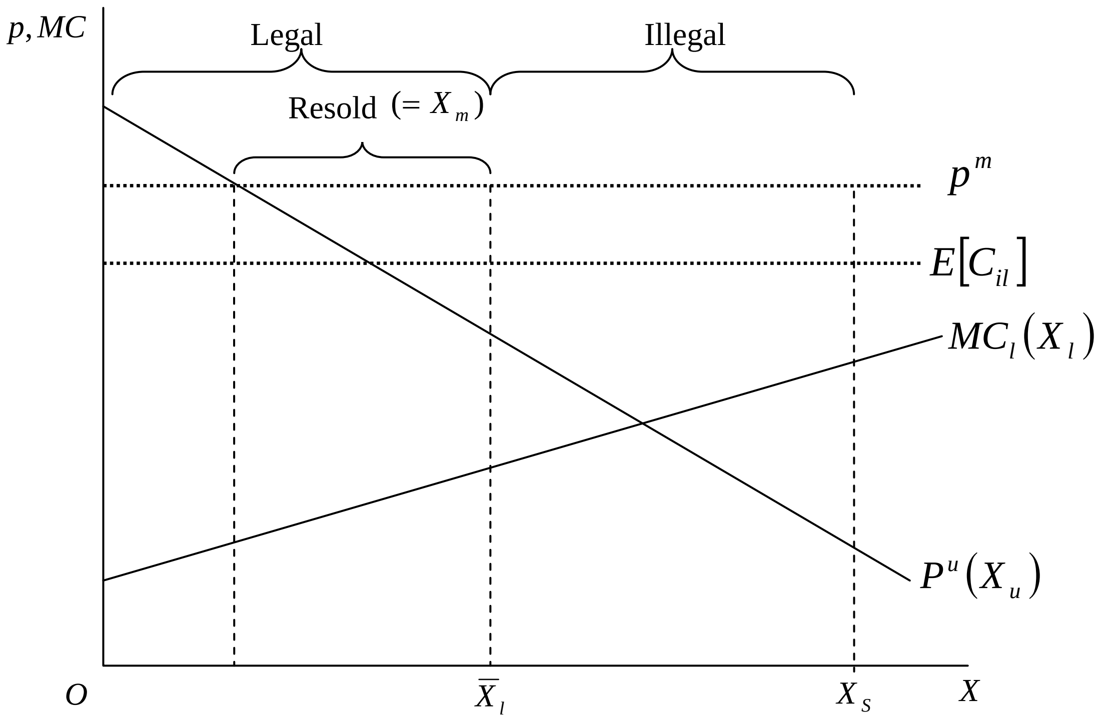

Figure 1 (a): The case of binding trade restriction when a part of legal imports are resold to foreign recyclers for material use.

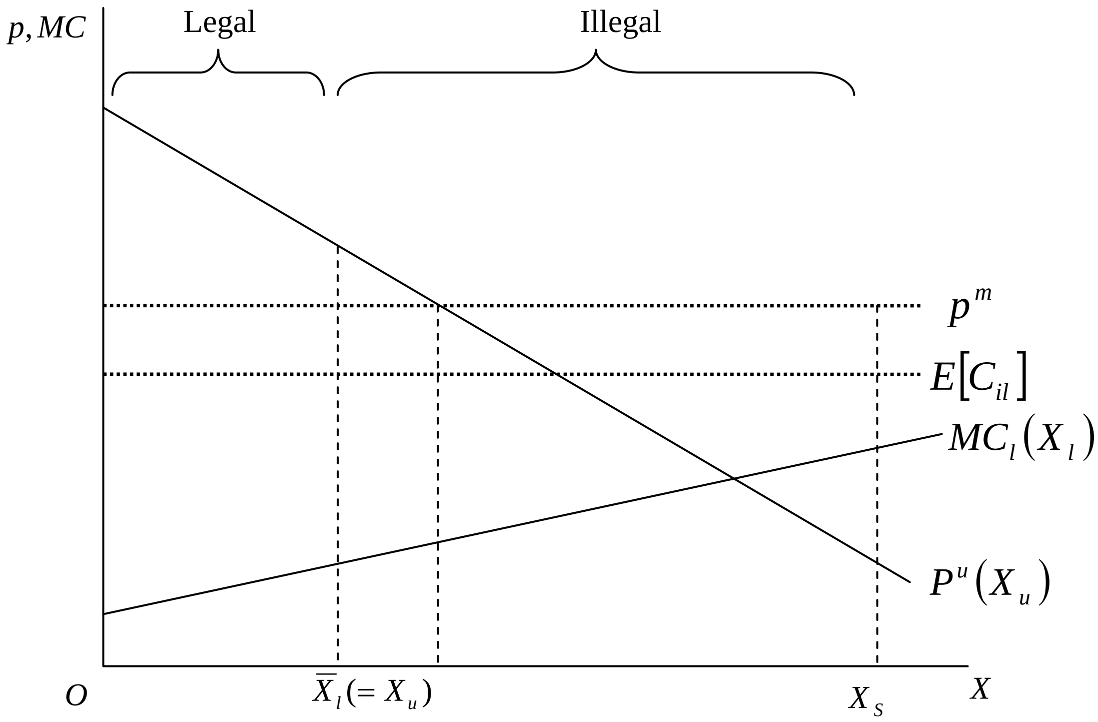

Figure 1 (b): The case of binding trade restriction when no legally traded imports are resold to foreign recyclers.

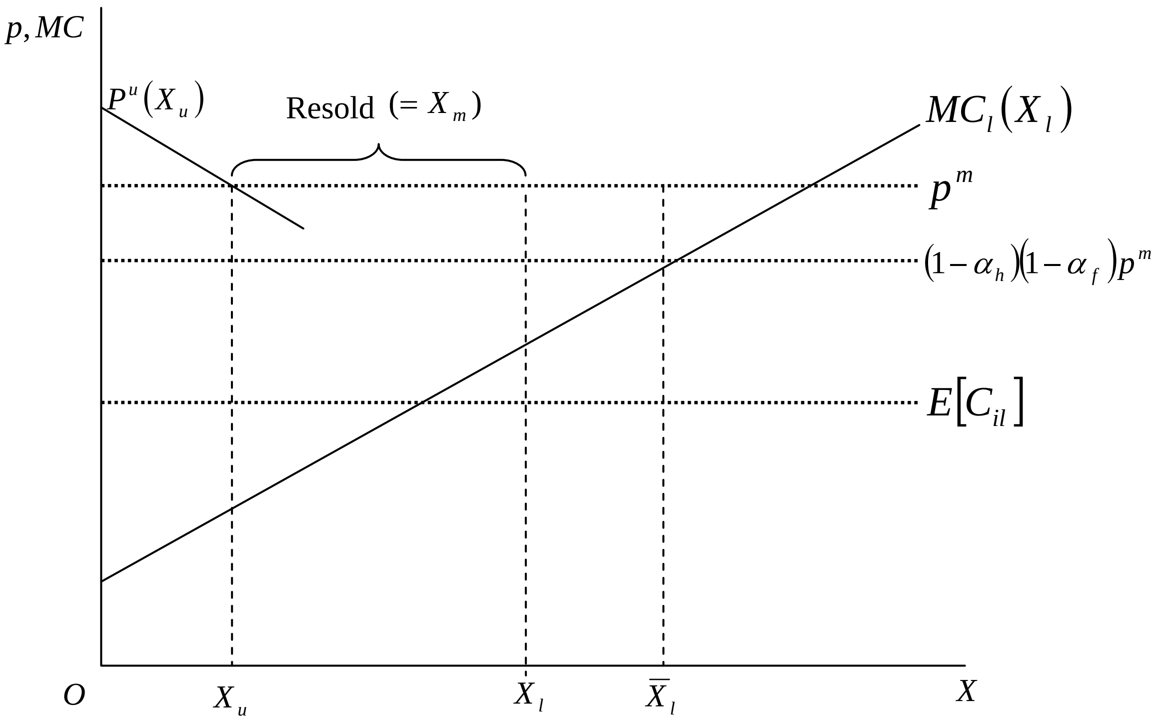

Figure 1 (c): The case of non-binding trade restriction when a part of legal imports are resold to foreign recyclers for material use.

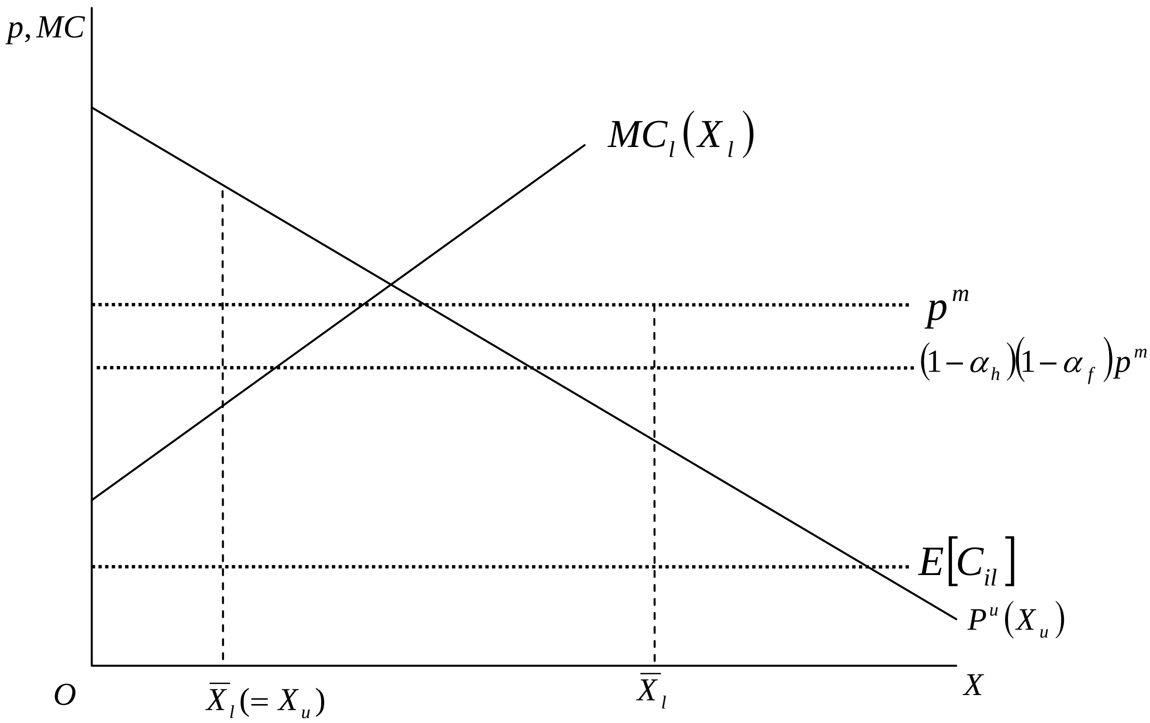

Figure 1 (d): The case of non-binding trade restriction when no legally traded imports are resold to foreign recyclers.

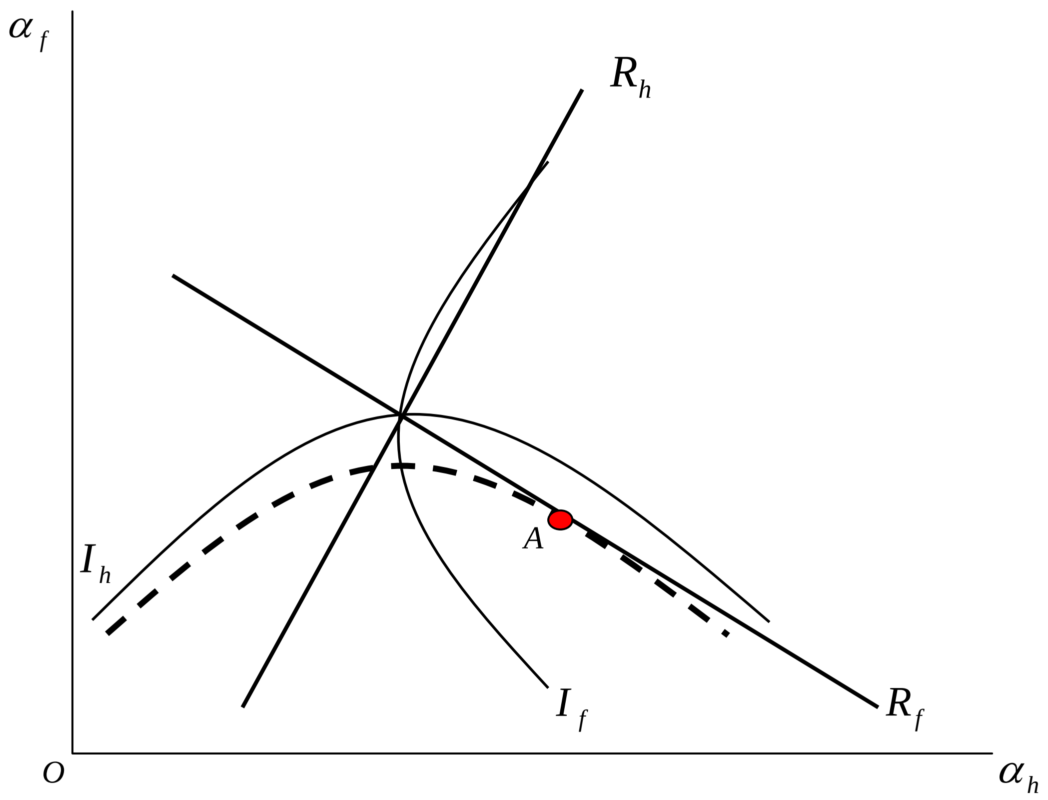

Figure 2(a) : Equilibrium in the monitoring game when $\partial E\lfloor W_f \rfloor / \partial \alpha_h > 0$

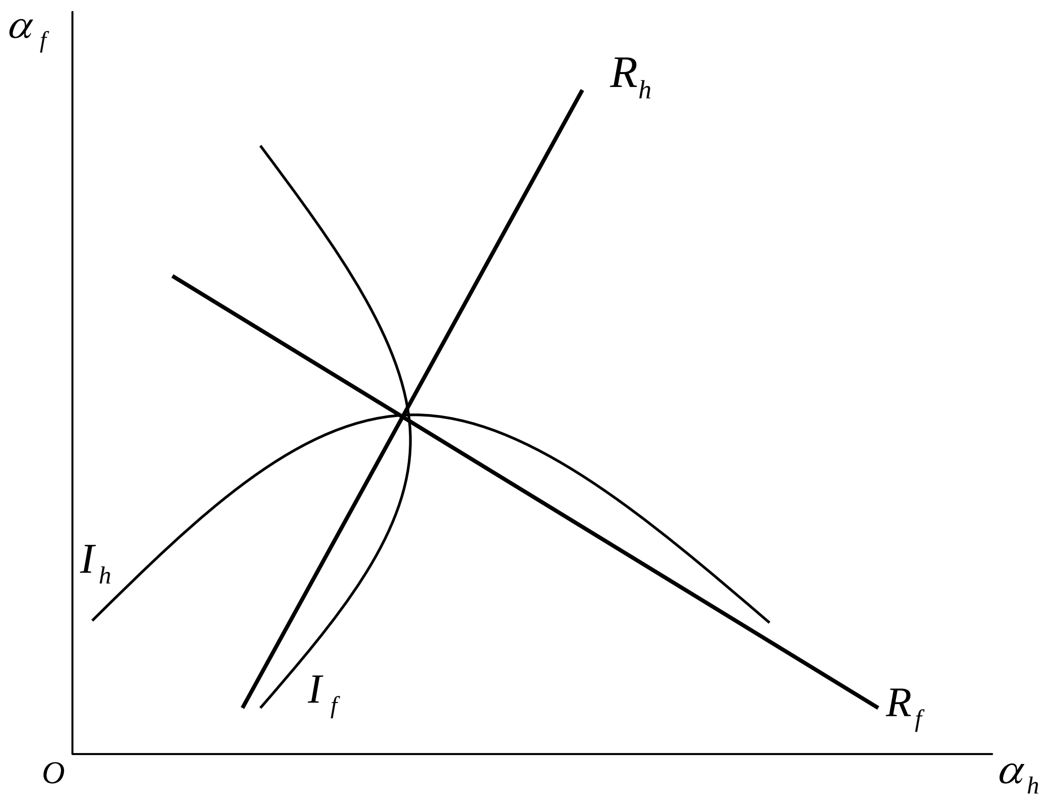

Figure 2(a) : Equilibrium in the monitoring game when $\partial E\lfloor W_f \rfloor / \partial \alpha_h < 0$

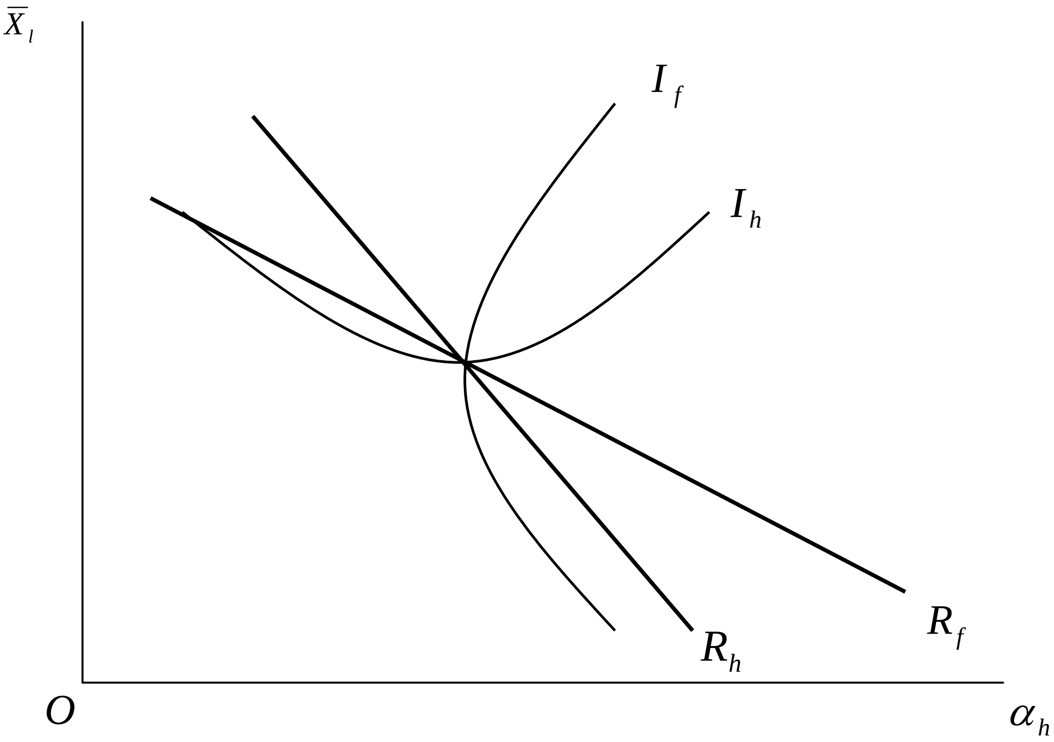

Figure 3 (a): The choice of trade restriction by the foreign government when

$\partial E[W_h]/\partial \overline{X}_l > 0$

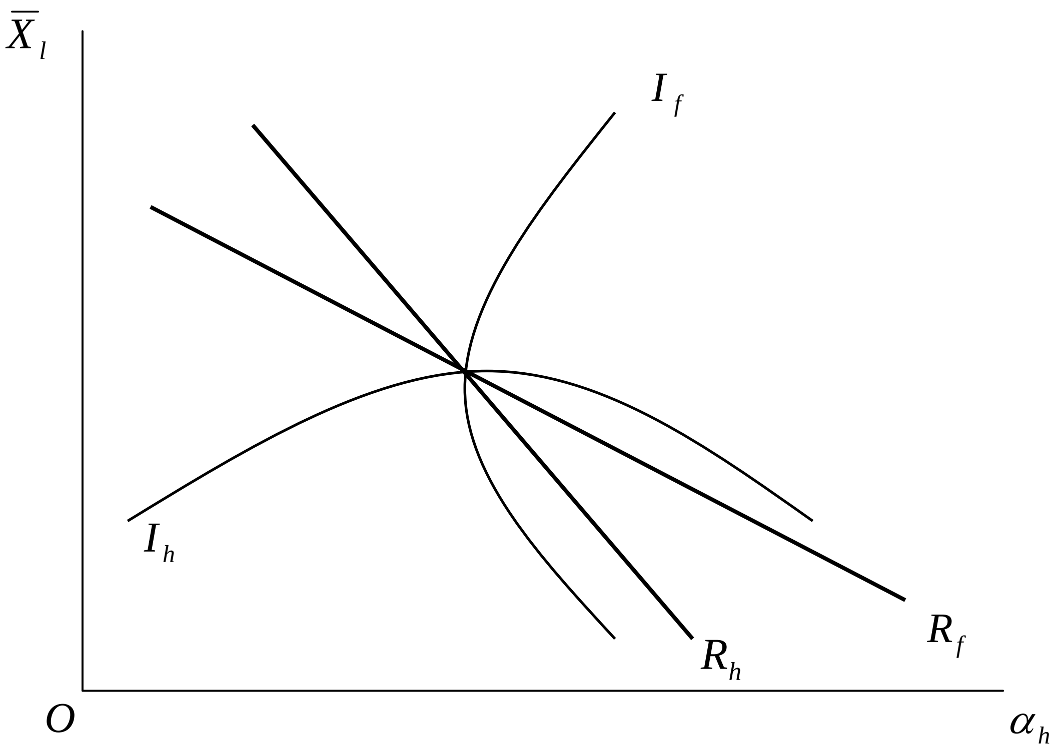

Figure 3 (b): The choice of trade restriction by the foreign government when

$\partial E[W_h]/\partial \overline{X}_l < 0$