Export Taxes on Recyclable Materials*

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1 Introduction

As economies grow, so do the generation of wastes. In order to achieve sustainable growth, recycling is promoted around the world. In a globalized world, not only the commodity trade but also international trade in recyclable materials has increased significantly. Indeed, the world trade volume of recyclable aluminum, lead, zinc, copper and paper combined increased from 2.5 million tons in 1970 to 21.5 million tons in 1997.1) Such rapid growth of trade in recyclable materials exceeded the speed of growth in primary resources.

Expansion of trade in recyclable material was in part due to the rising prices of raw materials. The demand for recyclable materials increased to substitute for the more expensive raw materials. However, the major trade flow of recyclable materials is quite distinct from the trade patterns of primary resources. Recyclable materials are mainly traded from the developed countries to the developing countries. The North-South trade of recyclable materials is to meet the expanding resource demand in developing countries on one hand, and to alleviate the cost of waste treatment and landfills in the developed countries, on the other hand.

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* I would like to thank Prof. Satake for helpful comments on earlier version of the paper. Remaining errors are of course mine.

1) See Van Beukering (2001). The trade to output ratio for the recycled copper, paper and aluminum nearly tripled in the same period.
As the significance of international trade in recyclable materials increased, discussions on trade policies emerged. One concerns with the effects of environmental damage associated with the recycling operations in the importing countries. In the 1980’s, exports of recyclable materials from the US and EU to developing countries contained hazardous wastes and created serious concerns for the environmental damages in developing countries. The so-called pollution dumping lead to the enactment of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (the Basel Convention in short) in 1992, and resulted in prohibiting transboundary movements of unrecoverable wastes and hazardous recyclable wastes.

Another trade policy discussion relates to the exporting countries. Rapid expansion of trade in recyclable materials also created concerns in the exporting countries, for it puts strains on the domestic recycling system by pulling necessary inputs of recyclable materials away from the domestic recycling system.

The recycling system in Japan, as originally designed by the Basic Law for Promoting the Creation of a Recycling-oriented Society, was to establish a domestic or closed recycling system. It was over the last two decades that Japan experienced a very rapid increase in exports of recyclable materials mainly to China. For example, exports of plastic wastes in 2009 increased by 36 times in weight tones compared to the year 1990, and scrap iron and copper increased by 24 times and 30 times respectively.\(^2\) Rising prices and exports consequently lead to the consideration of protecting the domestic recycling system through the use of trade

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policies such as export taxes or non-tariff measures. Japan, in fact, amended the recycling law to discourage exports of used plastic bottles.\(^3\)

Effects on importing countries and exporting countries both lead to policy discussions of adopting restrictive trade policies on recyclable material trade. However, there is little theoretical understanding regarding the effects of trade policies on recyclable materials. Although there are a sizable number of studies on recycling policies and waste management policies in a closed economy framework, there are only a few papers that study trade in recyclable materials. One of the first papers to analyze trade in recyclable materials is Grace et al. (1978). More recently, Van Beukering (2001) and Van Beukering et al. (2006) formalize the international material product chain to investigate the optimal recycling policies. Higashida and Managi (2008) attempts to explain the trade patterns of recyclable materials among developing countries both theoretically and empirically by using a gravity model. Effects of exporting recyclable materials are studied in Satake et al. (2010).

However, there are even fewer papers that provide some basic understanding of the effects of trade policies, which is crucial for the designing the actual trade policies for recyclable materials. This paper is one of the first attempts to analyze the effects of trade policies on recyclable materials. In particular, we examine the effect of export taxes on recyclable materials on final good production by constructing a simple general equilibrium model of a small open economy. The recyclable material is to be characterized as traded intermediate goods, which are produced by

\(^3\) In the Japanese recycling law for containers and packaging, “smooth delivery of waste plastic bottles for sound recycling” is encouraged. Local municipalities are expected to transfer used plastic bottles to the domestic recyclers and not to the exporters.
This paper can also be seen as an extension of effective protection literature analyzing the effects of trade policies on traded intermediate goods. Findlay (1987) showed that export taxes on raw materials, which are used as inputs for the production of a final good, do provide effective protection on final good production. Our model will provide some insights on whether the export taxes on recyclable materials generate effective protection on final goods as well. An optimal export policy on the recyclable materials is also going to be analyzed in this paper.

The organization of the paper is as follows. Section 2 presents the model and lays out the basic properties of an economy. Section 3 analyzes the effects of an export tax on the recyclable material on domestic outputs of the final goods and the recyclable material. In Section 4, the optimal export tax on recyclable material is derived. We conclude the paper with some remarks in Section 5.

2 A Model

The economy consists of two sectors producing a recyclable material, $R$, and a final product $F$, which uses $R$ as an input. The production function for the final good is

$$X_F = F_F(L_F, R_F)$$

(1)

where $L_F$ and $R_F$ are the inputs of labor and a recyclable material used in the production of the final good. $F_F$ is assumed to exhibit constant returns to scale and diminishing returns to each factor.

The production function for the recyclable material is
where \( L_R \) denotes labor and \( Z_R \) is a used final good engaged in the production of recyclable material.\(^4\) \( F_R \) is assumed to exhibit constant returns to scale and diminishing returns to labor and used final good.

Through consumption of the final good, recycling wastes \( Z_F \) are generated. They are to be reused in the production of the final good. Let \( C_F \) denote the consumption of the final good.\(^5\)

\[
Z_F = \alpha C_F, \tag{3}
\]

where \( \alpha \) is the recycling rate; \( 0 < \alpha < 1 \).\(^6\) It should be noted that post consumption wastes are generated by consuming both the domestically produced final goods and imports.

\[
L_F + L_R = \tilde{L} \tag{4}
\]

\[
R_F + R_E = R \tag{5}
\]

\[
Z_F = Z_R \tag{6}
\]

where \( \tilde{L} \) is the amount of labor supply and \( R_E \) is the export of the recyclable material.

The final good \( F \) is the only consumption good in the economy and is assumed to be imported from the rest of the world. In exchange for \( R_E \),

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\(^4\) For example, used PET bottles are used as inputs to produce recyclable products such as plastic flakes or pellets.

\(^5\) The consumer’s problem of choosing between garbage disposal and recycling is discussed, say, in Fullerton and Kinnaman (1995). They consider more general form of “technologies” of household consumption.

\(^6\) Non-recycled wastes are assumed to be disposed of at no cost. Environmental costs associated with non-recycled wastes are beyond our scope of the paper.
imports are obtained in the form of the final good. The trade balance equation is then given as follows.

\[ P_F C_F = P_F X_F + P_R R_E \]  \hspace{1cm} (7)

where \( P_i \) is the international price of commodity \( i \). Since the economy is assumed to be a small open economy, \( P_F \) and \( P_R \) are determined exogenously.

Assuming producers act competitively, the marginal productivity pricing conditions hold.

\[ w = P_F \frac{\partial F_F}{\partial L_F} = P_R \frac{\partial F_R}{\partial L_R} \]  \hspace{1cm} (8)

\[ P_R = P_F \frac{\partial F_F}{\partial R_F} \]  \hspace{1cm} (9)

\[ P_Z = P_R \frac{\partial F_R}{\partial Z_R} \]  \hspace{1cm} (10)

We can now write down the unit-cost equations as follows.

\[ a_{FL} w + a_{FR} P_R = P_F \]  \hspace{1cm} (11)

\[ a_{RL} w + a_{RZ} P_Z = P_R \]  \hspace{1cm} (12)

where \( a_{ij} \) is the input requirement of factor \( j \) for the production of commodity \( i \). It should be noted that the international prices of the final good and the recyclable material, \( P_F \) and \( P_R \), solely determine wage \( w \) and the price of recycling wastes \( P_Z \). It is assumed that consumers own the recycling wastes; consumers earn factor rewards \( P_Z \) from the recycling sector.\(^7\)

\(^7\) If local governments are responsible for collecting garbage, the property rights
Upon totally differentiating the unit-cost equations, we obtain

\[
\begin{bmatrix}
\theta_{FL} & 0 \\
\theta_{RL} & \theta_{RZ}
\end{bmatrix} \begin{bmatrix}
\hat{w} \\
\hat{P}_Z
\end{bmatrix} = \begin{bmatrix}
\dot{P}_F - \theta_{FR}\dot{P}_R \\
\dot{P}_R
\end{bmatrix}
\]

(13)

The hat notation indicates the rate of change in that variable such that \( \hat{x} = dx/dx \), and \( \theta_{ij} \) is the factor payment share of \( j \) in commodity \( i \).

Solutions of the price system give us the following.

\[
\hat{w} = \frac{1}{\theta_{FL}} (\dot{P}_F - \theta_{FR}\dot{P}_R)
\]

(14)

\[
\dot{P}_Z = \frac{1}{\theta_{FL}\theta_{RZ}} (-\theta_{RL}\dot{P}_F + \theta_{RL}\theta_{FR}\dot{P}_R + \theta_{FL}\dot{P}_R)
\]

(15)

The structure of the model is reminiscent of a specific factor model in trade theory. An increase in the international price of the final good increases \( w \) while decreases \( P_Z \). The directions of the change in the international price of the recyclable material are reversed; an increase in \( P_R \) decreases \( w \) while increases \( P_Z \).

We now turn to the resource constraints for labor and the recyclable material:

\[
a_{FL}X_F + a_{RL}R = \dot{L}
\]

(16)

\[
a_{FR}X_F = R_F
\]

(17)

\[
a_{RZ}R = Z_R = \alpha C_F
\]

(18)

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on wastes are transferred to local governments once garbage is disposed. Local governments earn revenue by selling recycling garbage to the recycling sector. See Satake et al (2010) for detailed description of the recycling system for used plastic bottles in Japan. During some period, the price of recycling garbage took negative values, meaning local governments paid the recycling sector for the garbage to be processed.
By substituting (7) and totally differentiating,

\[
\begin{bmatrix}
\lambda_{FL} & \lambda_{RL} & 0 \\
\lambda_{FR} - 1 & \lambda_{ER} & 0 \\
\beta_F - 1 & \beta_R & 0
\end{bmatrix}
\begin{bmatrix}
\hat{X}_F \\
\hat{R} \\
\hat{R}_E
\end{bmatrix}
= 
\begin{bmatrix}
\hat{L} + (\delta_{FL} - \delta_{LR})\hat{\omega} - \delta_{LF}\hat{P}_F - \delta_{LR}\hat{P}_R \\
- \lambda_{FR}\theta_{FL}(\hat{\omega} - \hat{P}_F) \\
\theta_{RL}\gamma_{RL}(\hat{\omega} - \hat{P}_R) + \beta_R\hat{P}_F - \beta_R\hat{P}_R - \hat{\alpha}
\end{bmatrix}
\tag{19}
\]

\(\lambda_{il}\) is labor employment share in commodity \(i\), \(\lambda_{ER} = \frac{R_{il}}{R}\) is the share of exports in recyclable material, \(\gamma_{il}\) is the elasticity of the factor substitution in sector \(i\), such that \(\gamma_{FL} = -\frac{\hat{\alpha}_{FL}}{\hat{\omega} - \hat{P}_F}\), \(\gamma_{RL} = -\frac{\hat{\alpha}_{RL}}{\hat{\omega} - \hat{P}_R}\), and \(\beta_i = \frac{p_i}{p_F} c_F\) is the GDP share of sector \(i\).

By solving the system,

\[
\begin{bmatrix}
\hat{X}_F \\
\hat{R} \\
\hat{R}_E
\end{bmatrix}
= \frac{1}{D}
\begin{bmatrix}
- \beta_R + \lambda_{ER} & - \lambda_{RL}\beta_R & \lambda_{RL}\lambda_{ER} \\
- \beta_R + \lambda_{ER} & \lambda_{FL}\beta_R & - \lambda_{FL}\lambda_{ER} \\
- \beta_R + \lambda_{ER} & 1 - \lambda_{RL}\beta_R & 1 + \lambda_{RL}\lambda_{ER}
\end{bmatrix}
\begin{bmatrix}
B_1 \\
B_2 \\
B_3
\end{bmatrix}
\tag{20}
\]

where \(D = - \beta_R + \lambda_{ER}\) is the determinant of the \(3 \times 3\) matrix and is clearly \(D > 0\). By using (14) and (15)

\[
B_1 = \hat{L} + (\lambda_{FL}\frac{\theta_{FR}}{\theta_{FL}}\gamma_{FL} + \lambda_{RL}\frac{1}{\theta_{FL}}\gamma_{RL})(\hat{P}_F - \hat{P}_R)
\]

\[
B_2 = - \lambda_{FR}\theta_{FL}\gamma_{FL}(\hat{\omega} - \hat{P}_F) = - \lambda_{FR}\gamma_{FL}(\hat{P}_F - \hat{P}_R)
\]

\[
B_3 = \theta_{RL}\gamma_{RL}(\hat{\omega} - \hat{P}_R) + \beta_R\hat{P}_F - \beta_R\hat{P}_R - \hat{\alpha}
\]

\[
= \gamma_{RL}\frac{\theta_{RL}}{\theta_{FL}\theta_{RZ}}(\hat{P}_F - \hat{P}_R) + \beta_R(\hat{P}_F - \hat{P}_R) - \hat{\alpha}
\]

It is straightforward to obtain

\[8\) We have used the fact that \(\beta_R = \frac{p_R}{p_F} c_F\lambda_{ER}.\]
The term \( \frac{\hat{X}_F - \hat{R}_E}{P_F - P_R} \) indicates that the “production possibility frontier” between the final good and the exports of recyclable material is concave around the equilibrium; The final good to the recyclable material export ratio increases as the relative price of the final good increases. Conversely, as the relative price of recyclable materials increases, the exports of recyclable materials increase relatively more than the increase in the production of the final good.

Equation (21) also reveals the role of recycling policy variable, \( \alpha \), in determining the comparative advantage. As \( \alpha \) increases, \( \frac{X_F}{R_E} \) ratio decreases. A country with higher recycling rate has a comparative advantage in recyclable materials, while a country with lower rate has a comparative advantage in the final good. Recycling policy can be an instrument in altering the comparative advantage.

3 An Export Tax on the Recyclable Material

3.1 Effects of an Export Tax

In this subsection, we are going to analyze the effects of export taxes on the recyclable materials. In order to distinguish the domestic price and the international price, we introduce the * notation to indicate the international price. Let \( P_R^* \) be the international price of recyclable material and \( P_R \) be the domestic price of the recyclable material. Suppose an export tax on the recyclable materials is imposed at a rate \( t \) such that \( P_R^* = (1 + t)P_R \), and the final good is traded freely; \( P_F^* = P_F \).

\[
\frac{\hat{X}_F - \hat{R}_E}{P_F - P_R} = -\frac{1}{D} (B_2 - B_3 )
\]

\[
= \frac{1}{D} [ (\lambda_{FR} \gamma_{FL} + \frac{\theta_{RL}}{\theta_{FL}} \gamma_{RL} + \beta_R)(\hat{P}_F - \hat{P}_R ) + \hat{a} ] \quad (21)
\]
An increase in an export tax reduces the domestic price of the recyclable material. In order to examine the effects of an export tax on the recyclable material, we first analyze the comparative statics of output changes with respect to the changes in $P_R$. From (20) and by substituting (14) and (15), we obtain

$$\frac{\dot X_F}{\dot P_R} = \frac{1}{D}((-\beta_R + \lambda_{ER})B_1^R - \lambda_{RL}\beta_R B_2^R + \lambda_{RL}\lambda_{ER}B_3^R)$$

(22)

$$\frac{\dot R}{\dot P_R} = \frac{1}{D}((-\beta_R + \lambda_{ER})B_1^R + \lambda_{FL}\beta_R B_2^R - \lambda_{FL}\lambda_{ER}B_3^R)$$

(23)

$$\frac{\dot R_E}{\dot P_R} = \frac{1}{D}((-\beta_R + \lambda_{ER})B_1^R + (1 - \lambda_{RL}\beta_R)B_2^R - (1 - \lambda_{RL}\lambda_{ER})B_3^R)$$

(24)

where

$$B_1^R = - (\lambda_{FL}\frac{\theta_{FR}}{\theta_{FL}}\gamma_{FL} + \lambda_{RL}\frac{1}{\theta_{FL}}\gamma_{RL}) < 0$$

$$B_2^R = \lambda_{FR}\gamma_{FL} > 0$$

$$B_3^R = - (\frac{\theta_{RL}}{\theta_{FL}\theta_{RZ}}\gamma_{RL} + B_R) < 0$$

Clearly, the supply response of the final good is positive with respect to an increase in an export tax (or a reduction in $P_R$). The output level of the final good expands as an export tax on the recyclable material increases. The domestic production of the final good is thus protected by the export tax on the recyclable material.

The effects on the recyclable material sector, on the other hand, is less clearcut. If export share of the recyclable material is sufficiently large, imposing an export tariff on the recyclable material reduces the

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9) Suppose $dP_F^* = dP_R^* = 0$, and $dL = 0$, then $(1 + t)dP_R + P_R dt = dP_R^* = 0$, or by using the hat notations, $\hat{\imath} = -\hat{P}_R$ where $\hat{\imath} = \frac{dL}{1+t}$. 

□ 180 □
output level of the recyclable material and its exports; \( \frac{\dot{R}}{R} < 0 \) and \( \frac{\dot{E}}{E} < 0 \). An export tax on the raw material will decrease the domestic price of the raw material and reduces the output and the export level of the raw material.

### 3.2 An Optimal Export Tax on Recyclable Materials

In this subsection, we proceed to analyze the welfare effects of an export tax on the recyclable material based on the social welfare function \( U(C_F) \). Let \( g(P_F, u; P_R) \) be the minimum expenditure required to attain the welfare level \( u \) at given prices \( P_F \) and \( P_R \). When export taxes are imposed, we can write the national income-expenditure identity as follows:

\[
g(P_F, u; P_R) = P_F X_F + (1 + t)P_R R_E - tP_R R_E
\]

\[
= P_F F_F (L_F, F_R (L_R, Z_R) - R_E) + (1 + t)P_R R_E - tP_R R_E
\]

The minimum expenditure function is assumed to be equipped with the following properties: i) positively homogeneous of degree one in \( P_F \), ii) concave in \( P_F \), and iii) \( \frac{\partial g}{\partial P_F} = C_F \).

By differentiating (25) with respect to \( t \),

\[
g_0 \frac{du}{dt} = P_F \frac{dX_F}{dt} + (1 + t)P_R \frac{dR_E}{dt} - tP_R \frac{dR_E}{dt}
\]

\[
= (1 + t)P_R \frac{\partial F_R}{\partial Z} \frac{\partial Z}{dt} + tP_R \frac{\partial R_E}{\partial t} = P_Z \frac{\partial Z}{\partial t} + tP_R \frac{\partial R_E}{\partial t}
\]

The optimal export tax on the recyclable material, \( t^* \), can be derived by setting \( g_0 \frac{du}{dt} = 0 \). The optimal tax rate can now be expressed as:

\[
0 \Rightarrow \frac{\dot{R}}{R} > 0 \text{ if } \beta_R(1 + \lambda_{FL}) > \lambda_{ER}, \text{ and } \frac{\dot{E}}{E} > 0 \text{ if } 1 + \beta_R > \lambda_{ER}(1 + \lambda_{RL}).
\]
It is easy to see that \( t^* = 0 \), if \( \frac{\dot{R}_E}{\dot{t}} = 0 \). This corresponds to the case where the intermediate good is a raw material produced with natural resources supplied in fixed amount. The optimal export tax is positive if the signs of \( \frac{\dot{Z}_R}{\dot{t}} \) and \( \frac{\dot{R}_E}{\dot{t}} \) are opposite, and negative if otherwise.

In order to evaluate the optimal export tax rate, we need to determine the changes in \( Z_R \). By using \( \dot{Z}_R = \dot{a}_{RZ} + \dot{R} \) and (23), we can write down the following.

\[
\frac{\dot{Z}_R}{\dot{t}} = (\theta_{RL} \gamma_{RL}) - \frac{1}{D} \left( (-\beta_R + \lambda_{ER})B^R_1 + \lambda_{FL}\beta_R B^R_2 - \lambda_{FL}\lambda_{ER}B^R_3 \right) \tag{28}
\]

Further calculation indicates that \( \frac{\dot{Z}_R}{\dot{t}} < 0 \) if the GDP share of the recycling sector is sufficiently large, \( \beta_R \lambda_{ER} \lambda_{FL} > \frac{\theta_{RL}}{\theta_{FL}\gamma_{RL}} \), so that the output effect of \( \dot{Z}_R \) exceeds the substitution effect of \( \dot{a}_{RZ} \). Recall that from (24), we know that \( \frac{\dot{R}_E}{\dot{t}} < 0 \). Therefore, we know that the optimal export tax rate on the recyclable material is negative, \( t^* < 0 \), meaning that it is optimal to subsidize exports of the recyclable material. By subsidizing exports of the recyclable material, exports expand and hence the income increases. Welfare as reflected by the consumption of the final good, then, increases. Subsidizing exports of the recyclable material also has positive impact on the production of recyclable materials, for an increased consumption creates more wastes which turn into recyclable materials. As a result of an export subsidy, a productive factor, \( Z_R \), is generated and increases income.

In a related literature on trade policy on resource trade, Findlay (1987) showed that the optimal export tax on the raw material is positive when the raw material is monopolistically traded. It is through the monopolistic power that taxing at a rate equal to the elasticity of foreign demand for
the raw material that equalizes domestic marginal cost of raw material ex-
port with the marginal revenue, and attains the maximum utility. However,
in the absence of monopoly, the optimal trade policy is free trade. Sup-
pose instead that the final good is produced by using raw materials which
is in fixed supply, such that $\hat{Z}_r = 0$ in (28). The optimal export tax rate
for the raw material is going to be zero. In case of the recyclable material,
it is optimal to subsidize exports even in the absence of monopoly. Raw
materials and recyclable materials are often seen as close substitutes for
production of final goods, however, the roles of trade policies on them are
quite distinct.

4 Concluding Remarks

In this paper, we analyzed the effects of an export tax on the recyclable
material in a simple model of a small open economy by formalizing the
recyclable material as a traded intermediate good, which is produced by
using consumption. The recyclable materials are substitutes for the raw
materials, yet, at the same time, they are wastes. The effects of an export
tax on the recyclable material are very much like that of the raw material,
such that it can protect domestic production of the final good. Whereas,
the effects of an export tax on the recyclable material differs from the one
on the raw material because it is produced by using consumption wastes.
There exists an optimal export tax on the recyclable material, which is
negative, even in the absence of neither monopoly nor environmental
effects. If an intermediate good is a raw material, the optimal export tax is
zero in such cases. It is worth noting that even without waste collection
and treatment costs, it was shown to be optimal to subsidize exports of
recyclable materials.
To conclude the paper, a few disclaimers are in order. In our very simplified model, the costs of collecting and dumping wastes were assumed away. By introducing such costs, determination of the recycling rate, $\alpha$, now becomes a decision problem. As we have shown in the paper, $\alpha$ plays an important role in determining the trade patterns of recyclable materials. Endogenously determined $\alpha$ is considered in Van Beukering et al. (2006); they showed that countries (developed countries) with high charges on waste disposal achieve high recycling rates, and hence result in exporting the recyclable materials.

Environmental costs associated with dumping and recycling are another aspect which was beyond the scope of our analysis, but certainly worth examining, since environmental concerns are one of the major reasons behind the use of trade policies on recyclable materials. Different environmental standards lead to different interpretations on the definition of “hazardous wastes” whose trade is prohibited by the Basel Convention, and hence to disputes over trade policies among developed and developing countries. Once wastes are transformed into resources, we found that providing export subsidies on recyclable materials is optimal even in the absence of environmental costs. Of course, any policy design should not be based on a small number of studies, but our analysis does raise some questions regarding the optimality of export taxes. More studies on the issue, that include collection costs and the environmental effects, are certainly called for.

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11) See, for example, Palmer and Walls (1997) for the analysis in the context of a closed economy.
References


