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Abstract

Exporting used durable goods for additional consumption in a developing economy, a concept we call "global reuse", has unfortunate negative consequences if those goods contain toxic substances. The cathode ray tubes (CRTs) of televisions and personal computers contain large amounts of lead oxide and cadmium - substances harmful to the natural environment and to human health. But unfortunately the importers of used durable goods rarely possess the technologies, policies, and enforcement infrastructures necessary to appropriately dispose hazardous waste. A

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simple general equilibrium model of two-country trade is constructed to discover solutions to the problems associated with global reuse, focusing on policies in developed country. This paper shows that the dual policy of waste tax and exporting tax can achieve social optimum under global reuse economy with negative externality of waste. When developed country is unable to assess exporting tax perhaps due to some pressure from a domestic industry, the waste tax or subsidy can be the alternative policy.

Keywords: international trade, pollution tax, reuse, second-hand market, waste.

1 Introduction

Advances in communications coupled with reductions in transportation costs have increased the scope of global trade over the past 100 years. More recently, this global trade has involved used durable goods exported from developed economies for further use by consumers in less developed economies. Between 2000 and 2004, for example, the percentage of used computers exported from Japan to developing nations increased from 8% of all computers collected in Japan in 2000 to 26% of all computers collected in 2004 (Yoshida et al. [12]). In addition, over 2.5 million used cars and trucks were exported from the United States to Mexico between 2005 and 2008 (Davis and Kahn [3]) and about 10.2 million used computers - roughly 80% of all computers collected in the United States - were exported from the United States to Asia in 2002 (Puckett and Smith [6]).

Exporting used durable goods for additional consumption in a developing economy, a concept we call "global reuse", has unfortunate negative consequences if those goods contain toxic substances. The cathode ray tubes (CRTs) of televisions and personal computers, for example, contain large amounts of lead oxide and cadmium - substances harmful to the natural environment and to human health. The circuit boards of computers and cell phones also contain lead and cadmium. Modern flat-screen panel monitors contain mercury, another harmful pollutant potentially damaging to human organs[1].

[1]Inorganic mercury mixed with water is transformed to methylated mercury. Methylated mercury easily accumulates in living organisms and concentrates through the food chain. Cadmium compounds accumulate in the human body, particularly the kidneys, and have irreversible consequences for human health, (Puckett and Smith [6]). From the study

For these reasons, the waste from these durable goods can be considered hazardous - suggesting sophisticated disposal techniques are necessary to mitigate external effects. Such disposal technologies are often utilized in developed country such as the United States and Japan. But unfortunately the importers of used durable goods - developing nations such as China, Philipine, India, Pakistan, Mexico or Nigeria - rarely possess the technologies, policies, and enforcement infrastructures necessary to appropriately dispose hazardous waste. In Guiyu, China, for example, broken CRTs are regularly dumped on open land or pushed into rivers (Puckett and Smith [6]). In Nigeria, televisions and computers are used to fill swamps (Puckett [7]).

A simple general equilibrium model is developed in this paper to discover policy solutions to the problems associated with global reuse. The model draws from three literatures. The model developed in this paper expands upon a domestic waste policy model developed by Fullerton and Kinnaman [4] and Fullerton and Wu [5] to an international framework. This paper also expands upon the literature devoted to the economics of reuse where Thomas [10] focuses on the relationship between material consumption and transaction costs of second-hand markets and Yokoo [11] examines the impact of reuse activity on consumer welfare. This paper expands these models from partial to general equilibrium and is focused on policy analysis. Finally, this study relates to the literature of trade and the environment, a literature focused on the relationship between international trade and the pollution from the production process. Only a few studies combine trade with issues

of Yoshida [13], each cathrode ray tube contains about 2kg of lead, enough to damage human central and peripheral nerves, which can have a deleterious effect on the growth and development of children. Lead is also an endocrine disruptor.

related to household waste. Copeland [2] and Rauscher [8] examine the international trade of waste itself, not durable goods containing waste. The study most close to ours is Shinkuma [9], who develops a general equilibrium model of international trade in durable goods to assess the extended producer responsibility measures on trade, the environment and social welfare. The policy focus in this paper is on waste taxes and import/export tariffs. The next section will develop the basic model of reuse in a closed economy. Section 3 extends model to two-country setting and discuss the globally optimal policy. Section 4 concludes.

2 No Global Reuse

To help define the notation, confirm previous results, and provide a frame of reference to policy results derived below, we begin with a closed economy with no imports or exports. Assume a closed economy is comprised of n identical consumers producing a single durable good (d). Once consumed, the durable good can be reused (r) or discarded as waste (w), thus $d = r + w$. The condition that $d = r + w$ implies that the stock of used goods for sale is constant - a steady state condition.

Household utility depends on the quantity consumed of the new (d) and used (r) durable good and the total amount of waste disposed (nw)

$$u = u(d, r, nw), \tag{1}$$

where first derivatives $u_d > 0$, $u_r > 0$, and $u_w < 0$.

An economic resource such as capital or energy (k) constitutes the only input to several production processes. First, the durable good is produced using the economic resource (with quantity k^d) according to the production function

$$d = f(k^d), \tag{2}$$

where the first derivative $f' > 0$. Second, waste (w) is collected and processed using the economic resource (k^w) according to the production function

$$w = g(k^w) \tag{3}$$

where $g' > 0$. Finally, assume reused goods require no further production, but employ the household resource (k^r) to process, market, and transport to durable good to another consumer according to the production function

$$r = r(k^r),$$

with first derivative $r' > 0$, which can be inverted to give

$$k^r = k^r(r), \tag{4}$$

with first derivative $k^{r\prime} > 0$. The total amount of the household resource available to the three production processes is $\bar{k}$, thus

$$\bar{k} = k^d + k^r + k^w. \tag{5}$$

2.1 Pareto Optimum

The social planner maximizes the utility of a representative household (1) subject to the resource constraint (5), the three production functions (2, 3, and 4), and the material balance condition that $d = r+w$. Upon substitution, the problem is to choose r and k^w to maximize

$$L = u(r + g(k^w), r, ng(k^w)) + \gamma[f(\bar{k} - k^r(r) - k^w) - r - g(k^w)]$$

where γ is the Lagrange multiplier equal to the marginal utility of producing one additional unit of the durable good. The first-order conditions are

$$\begin{aligned} u_d + u_r &= \gamma[f' k^{r\prime}(r) + 1] \\ u_d + u_w n &= \gamma[f'/g' + 1]. \end{aligned} \tag{6}$$

These equations equate marginal benefits of increasing r and w, respectively, with marginal cost. Increasing either r or w increases consumption of the durable good and therefore generating marginal utility u_d. Adding r also generates utility, u_r, whereas adding w generates the waste externality nu_w (negative). The cost of adding either r or w is the opportunity cost of allocating the resource away from producing the durable good.

2.2 Competitive Equilibrium

Assume a disposal tax (t_w) is available to the local government to encourage waste producers to internalize the social costs of disposal. The representative consumer in a decentralized economy will maximize utility (1) subject to the materials balance constraint $d = r + w$ and the budget constraint

$$I - p_k k^r = p_d d + (p_w + t_w)w,$$

where I is the exogenously determined endowment of household income, p_k is per-unit price of the economic resource (owned by the representative household), p_d is price of the durable good that is assumed equal to 1 (the numeraire), p_w is the cost of waste disposal, and t_w is once again the tax on waste disposal. A household choosing to transfer the durable good to another consumer must commit their household resource and experiences a loss of income ($p_k k^r$) from these efforts. Because the number of household is large (n), the representative household considers their own contribution to the overall waste externality to be zero. The aggregate quantity of waste (nw) is therefore exogenous to the representative household. The household then chooses r and w to maximize

$$L = u(r + w, r, nw) + \delta[I - p_k k^r - (r + w) - (p_w + t_w)w],$$

where δ is the marginal utility of household income. The first-order conditions are

$$\begin{aligned} u_d + u_r &= \delta[p_k k^{r\prime} + 1] \\ u_d &= \delta[1 + p_w + t_w]. \end{aligned} \tag{7}$$

The representative household can consume and reuse a durable good such the sum of the marginal utilities is equal to the price of durable good plus the opportunity cost of reusing it. The second condition equates the marginal utility benefit of consuming the durable good with the cost of purchase plus the full disposal costs.

Assume a representative firm producing the durable in a perfectly competitive industry chooses the quantity of the economic resource to maximize profit

$$\pi = f(k^d) - p_k k^d.$$

Profit is maximized when

$$p_k = f'. \tag{8}$$

Finally, a representative competitive firm collects and disposes waste. The firm chooses the quantity of waste to collect and dispose to maximize profit

$$\pi = p_w g(k^w) - p_k k^w.$$

From this profit-maximizing behavior we obtain the competitive price paid for waste management p_w as

$$p_w = \frac{p_k}{g'}. \tag{9}$$

Substitute (8) into the first equation of (7), compare to (6), and notice that the two Lagrangian multiplier are equivalent, or $\gamma = \delta$. Also substitute (9) into the second equation of (7) and we find the decentralized equilibrium can be characterized by the two equations.

$$\begin{aligned} u_d + u_r &= \delta[f' k^{r\prime} + 1] \\ u_d &= \delta[1 + f'/g' + t_w]. \end{aligned}$$

Notice that the competitive equilibrium will equal the Pareto Optimum when

$$t_w^* = -\frac{nu_w}{\gamma}. \tag{10}$$

The optimal tax rate must equal the external marginal cost of waste disposal. Controlling for a few changes in notation and a few other features of the model, this result is similar to Fullerton and Kinnaman [4], the model from which it was derived from.

3 Global Reuse

Consider the same general economy as described above with the added assumption that the durable good can be exported for reuse rather than consumed again domestically. Assume the durable good is produced and initially consumed in Country A. After initial consumption, households in Country A can either dispose the good in Country A or export it for reuse and eventual disposal in Country B. Furthermore, owing to the lack of production technologies in Country B, the durable good is only produced in Country A.

Let e denote the quantity of the durable good exported to Country B and w^A the quantity disposed in Country A. The new materials balance constraint is

$$d = w^A + e.$$

Assume once again there are n households in Country A. A representative household has utility defined by

$$u^A = u^A(d, nw^A), \tag{11}$$

with first derivatives $u_d > 0$ and $u_w < 0$.

As above, assume an international household resource (k) such as capital or oil is can be allocated to several production processes. The production functions for the firm producing the durable good and the firm disposing the durable good in Country A are defined as in (2) and (3) above. For this economy, assume the household resource (with quantity k_e) is allocated to exporting the material to Country B according to the household production function

$$e = e(k^e)$$

with first derivative $e' > 0$. As was done above, this production function can be inverted to solve for k_e.

$$k^e = k^e(e) \tag{12}$$

with first derivative $k^{e\prime} > 0$.

Assume country B is comprised of m identical consumers. A representative consumer in country B gains utility from the consumption of the durable good exported from Country A (e) and a non-durable good produced in Country B (call it c).

$$u^B = u^B(c, e, mw^B) \tag{13}$$

where mw^B denoted the aggregate quantity of waste disposed in Country B, where $w^B = e$. First derivatives are $u_c^B > 0$, $u_e^B > 0$, and $u_w^B < 0$. Waste resulting from the imported durable good generates a negative externality. Assume any disposed waste from the consumption of c does not generate a negative external. Perhaps domestically produced food could serve as a worthwhile example.

The non-durable good is produced by a competitive firm in Country B using the economic resource k^c

$$c = h(k^c), \tag{14}$$

with first derivative is $h' > 0$.

The global supply of the economic resource is constrained at $\bar{k}$:

$$\bar{k} = k^d + k^c + k^w + k^e. \tag{15}$$

Finally for simplicity assume the economic resource is not involved in waste disposal in Country B. Perhaps only primitive disposal methods are utilized.

3.1 Global Pareto Optimum in Global Reuse Model

The Global Pareto optimum is found by maximizing the utility of the representative consumer in County B (13) subject to holding the utility of the representative consumer in Country A (11) constant, subject to production constraints (2), (3), (12), and (14), the economic resource constraint (15), and materials balance constraints $d = w^A + e$ and $e = w^B$. Upon the substitution of these constraints, the Lagrange function for this maximization problem is

$$L = u^A(g(k^w) + w^B, ng(k^w)) + \gamma_1[\bar{u^B} - u^B(h(k^c), w^B, mw^B]$$
$$+\gamma_2[f(k - k^w - k^c - k^e(w^B)) - g(k^w) - w^B],$$

where $\bar{u^B}$ is a constant, and γ_1 and γ_2 are Lagrange multipliers. This function is maximized over k^w, k^c and w^B. The first-order conditions are

$$\begin{aligned} u_d^A + u_w^A n &= \gamma_2[1 + f'/g'] \\ -\gamma_1[u_c^B] &= \gamma_2[f'/h'] \\ u_d^A - \gamma_1[u_e^B + mu_w^B] &= \gamma_2[f'k^{e\prime} + 1]. \end{aligned} \tag{16}$$

These three conditions suggest the marginal social benefit of producing the durable good in County A, producing the non-durable good in Country B, and exporting the durable good from Country A to Country B be set equal to the opportunity cost of devoting the economic resource to each of these respective options.

The second equation of (16) can be solved for γ_1 and substituted into the third equation of (16). This new equation and the first equation of (16) can both be solved for u_d^A. Dividing these two equations yields

$$1 = \frac{1 + f'/g' - nu_w^A/\gamma_2}{1 - u_e^B f'/u_c^B h' + f'k^{e\prime} - mu_w^B f'/u_c^B h'}. \tag{17}$$

This condition characterizes the global Pareto Optimum for an economy with global reuse.

3.2 Competitive Equilibrium with Global Reuse

Assume the government of Country A has two instruments available to internalize social disposal costs - a disposal tax assessed in Country A (t_w) and a tax on exports of the durable goods to Country B (t_e). Assume the government in Country B has no effective tax instruments available. Assume that all the product markets in Countries A and B are competitive. Consumers in Country A maximize utility in (11) subject to the materials balance condition $d = w^A + e$ and the budget constraint

$$I^A - p_k k^e(e) = p_d d + (p_w + t_w)w^A - (p_e - t_e)e,$$

where I^A is the endowed household income in country A, p_d is the purchase price of durable good in Country A, and p_e is the price of used durable for global reuse. Upon substitution, the representative household maximizes over w and e. First-order conditions are

$$\begin{aligned} u_d^A &= \delta^A[1 + p_w + t_w] \\ u_d &= \delta^A[1 - (p_e - t_e) + p_k k^{e\prime}]. \end{aligned} \tag{18}$$

The representative household chooses each disposal option such that the marginal utility of consuming the durable good equals the price of the durable good (which recall is assumed equal to 1) plus the marginal cost of disposal.

The behavior of competitive firm producing the durable good in country A and the firm disposing waste in Country A are identical as section 2, thus $f' = p_k$ and $p_w = f'/g'$.

In Country B, the representative consumer maximizes utility (13) subject to the budget constraint

$$I^B = p_e e + p_c c,$$

where p_c is price of the non-durable good. Recall that it is costless to dispose waste in Country B. Because the number of household in Country B is large, the representative household considers the aggregate quantity of used durable goods disposed in Country B to be exogenous. The first-order conditions for utility maximization in Country B can be simplified to the single condition:

$$\frac{u_e^B}{p_e} = \frac{u_c^B}{p_c}. \tag{19}$$

The competitive firm producing the non-durable good in country B maximizes profit $\pi = p_c h(k_c) - p_k k^c$ by satisfying the condition

$$p_c = \frac{p_k}{h'}. \tag{20}$$

Upon substituting (2) (3), (19) and (20) into (18) we get

$$\begin{aligned} u_d^A &= \delta^A[1 + f'/g' + t_w] \\ u_d^A &= \delta^A[1 - f'u_c^B/h'u_c^B + f'k^{e\prime} + t_e]. \end{aligned}$$

Divide the first of these equations by the second to get

$$1 = \frac{1 + f'/g' + t_w}{1 - f'u_e^B/h'u_c^B + f'k^{e\prime} + t_e}. \tag{21}$$

The objective of the social planner is to assign tax rates for t_w and t_e such that this equation (21) will equal that representing the Pareto Optimum (17). Upon inspection, it is clear that the two optimal tax rates are:

$$\begin{aligned} t_w^* &= -\frac{nu_w^A}{\gamma_2} \\ t_e^* &= -\frac{mf'u_w^B}{h'u_c^B}. \end{aligned} \tag{22}$$

The waste tax in County A (t_w) is identical to the case with no global reuse. The domestic disposal tax should reflect the magnitude of the disposal externality in that country. But because County B is unable to enforce tax measured domestically, the waste disposal tax in Country A must be combined with an export tax to achieve the global Pareto Optimum. The magnitude of the export tax increases with the disposal externality in Country B and with the marginal productivity of the economic resource in producing the durable good. The export tax decreases with increases in the marginal productivity of the economic resource in producing the non-durable good in Country B (h') and the marginal utility of that good to the consumers in County B (u_c^B).

Notice that if the waste disposal externality in Country B is zero, then the export tax is zero. The export tax would also be zero if the government in Country A was setting tax policy and did not internalize disposal costs in County B.

Suppose Country A is unable to assess an export subsidy ($t_e = 0$) perhaps due to some previously agreed upon trade agreement. To focus on the policy instrument issue and make the analysis simple, the production functions f,

g, k^e, and h are assumed as constant-returns-to-scale[2]. In this case, a single disposal tax in County A can still achieve the social optimum. Let

$$\theta = 1 - u_e^B f'/u_c^B h' + f'k^{e\prime}.$$

Also, let

$$\lambda = f'/g' + 1.$$

And note also that $\lambda > 0$. The equation representing the Pareto Optimum can now be written as

$$1 = \frac{\lambda + t_w^*}{\theta + t_e^*},$$

Where t_w^* and t_e^* are defined as in (22). The equation representing the competitive equilibrium can now be written as

$$1 = \frac{\lambda + t_w}{\theta}.$$

Setting these equations equal to each other and solving for t_w gives

$$t_w = \frac{\theta t_w^* + \lambda t_e^*}{\theta + t_e^*}. \tag{23}$$

The domestic waste tax in County A can now be positive or negative depending upon the magnitudes of the waste externalities in each country. Suppose the disposal technology in Country A is sufficient to eliminate the waste disposal externality ($u_w^A = 0$). Recall that under this assumption $t_w^* = 0$. The

[2]This assumption is also adopted by Aalbers and Vollebergh [1].

disposal optimal tax rate then becomes

$$t_w = -\frac{\lambda t_e^*}{\theta + t_e} < 0.$$

Thus, the optimal disposal tax in Country A is negative - a disposal subsidy. The government in County A should subsidize domestic disposal of the domestic good to make up for the lack of disposal policy in Country B and the lack of an export tax.

More generally, examining the optimal tax rate in (23) suggests the optimal tax rate is negative whenever

$$\lambda t_e^* > \theta t_w^*,$$

that is, the disposal externality is large in Country B (making t_e^* large) relative to that in County A (where t_w^* is small).

4 Conclusion

This paper showed that two methods can achieve social optimum under Global Reuse economy with negative externality of waste. The first method is the dual policy of waste tax and exporting tax. The second method is the waste tax or subsidy in exporting country. Since the developed country has a technology to manage hazarodous waste appropriately, the incentive to manage the waste in developed becomes optimal policy. However, we can easily imagine that both methods are not acceptable in the real world. For the first method, it is not acceptable under the recent free trade agreement. For the second method, it is unrealistic since developed country have to consider for other country's welfare to carry out the subsidies on waste disposal. Therefore, further studies are required to solve the problem with Global Reuse.

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