May 2011

Economic Policies to Address the Environmental Consequences of Global Reuse

Thomas C. Kinnaman
Bucknell University, kinnaman@bucknell.edu

Recommended Citation
Kinnaman, Thomas C.. "Economic Policies to Address the Environmental Consequences of Global Reuse." *American Economic Review* (2011) : 71-76.

Economic Policies to Address

The Environmental Consequences of Global Reuse

By THOMAS KINNAMAN AND HIDE-FUMI YOKOO*

The international trade of used consumer electronics, a concept we call global reuse, has been growing rapidly over the past decade. Japan, for example, has increased its exports of used personal computers from just 0.18 million units in 2001 to 1.42 million units in 2008 (PC3R Promotion Center, 2010). Japan also exported 2.25 million used television sets in 2008 (Aya Yoshida and Atsushi Terazono, 2010) and the United States exported 10.2 million used personal computers in 2002. Most of these exports go to developing countries.

Used electronic goods exported to developing countries become electronic wastes (e-wastes) that are usually disassembled in those developing countries. E-waste is often comprised of toxic substances such as lead, mercury, cadmium, and flame retardants. Because e-waste disposal and disassembly practices vary widely between developed and developing countries, exporting used personal electronics may have consequences on both human health and the global environment.

This paper presents a model to solve for economically efficient tax and subsidy rates in an economy with international trade in used consumer electronics. The two-country model considers disposal taxes levied in both the developed and developing country, an import tax on used consumer electronics, and a subsidy paid for the return of the e-waste to developed countries for disassembly.

I. Disassembling Practices

E-waste in developing countries is dismantled by individuals and small businesses using labor intensive methods in order to collect embedded precious metals (Alejandra Sepúlveda, Mathias Schluep, Fabrice Renaud, Martin Streicher, Ruediger Kuehr, Christian Hagelüken and Andreas C. Gerecke, 2010). This dismantling process, which can include open burning of circuit boards, cables, and plastics, and the manual dismantling of cathode ray tubes, involves the release of toxic substances. For example, ambient dioxin and furan concentrations in the air around an e-waste dismantling site in China are the highest in the world (Huiru Li, Liping Yu, Guoying Sheng, Jiamo Fu, and Ping'an Peng, 2007). As a result, blood lead levels in children within proximity to this Chinese dismantling site significantly exceed the Chinese mean. Concentrations of lead, dioxins and furans in e-waste dismantling sites in India also exceed World Health Organization guidelines (Sepúlveda et al., 2010).

High labor costs and labor safety standards in many developed countries make labor intensive methods of dismantling e-waste uneconomical. Instead, used consumer electronics are first shredded and then magnets and blowers separate the precious metals from the various plastics. The metals are then sent to a smelter and the plastics to a recycler. Threats to human health and environment are reduced relative to those associated with labor-intensive methods in developing countries. E-waste in the United States is also disposed into landfills.

But most e-waste collected in the United States (roughly 80%) is exported to developing countries for reuse or for human dismantling[1]. Economic policy instruments may be partly responsible for the export of used electronics. Japan implemented in 2003 a producer responsibility measure that requires manufactures to send consumers shipping

* Kinnaman: Bucknell University, Department of Economics, Lewisburg, Pennsylvania 17837 (e-mail: kinnaman@bucknell.edu). Yokoo: National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan (email: yokoo.hidefumi@nies.go.jp).

[1] In 2005, the U.S. discarded 1.36-1.72 million metric tons of e-waste in landfills. Only 0.31-0.34 million metric tons were dismantled domestically. E-waste accounts for 70% of the heavy metals in U.S. landfills (U.S. EPA, 2007).

labels for sending used personal computers to nearby reclaiming locations (consumers pay the yen equivalent of a $35 fee). One half to three quarters of all personal computers sold in Japan are returned in this fashion, but these reclaiming facilities often export used personal computers to developing countries (Aya Yoshida, Tomohiro Tasaki, and Atsushi Terazono, 2009). In the United States, twenty four states either ban the disposal of e-waste in landfills or require manufacturers to subsidize the "recycling" process. The states of California, Hawaii, Massachusetts, South Carolina and New Jersey require residents to pay an advanced recycling fee of between US$6 and US$10 for each new TV or PC purchased[2]. These policies represent an implicit tax on the domestic disposal of e-waste in developing countries. This paper examines whether such taxes are consistent with global economic efficiency.

II. The Theory of Global Reuse

Within the economics literature, only Takayoshi Shinkuma (2009) has modeled the international trade in used personal electronics and argues that producer responsibility measures such as those implemented in Japan are inefficient. Brian Copeland (1991) examines the international trade in solid waste and argues for the elimination of such trade if waste receiving countries lack waste disposal policies. Other papers consider the unilateral strategic use of waste taxes to improve domestic importing and exporting industries. Hide-Fumi Yokoo (2010) theoretically analyzes whether the reuse of consumer electronics decreases e-waste.

This paper extends upon the work of Shinkuma (2009) and Copeland (1991) by evaluating incentive-based policy alternatives to internalize the social costs associated with exporting consumer electronics. A model is developed to structure the tax and subsidy policies available to internalize the disposal costs of used durable goods.[3] The model consists of a wealthy developed country (Country A) and a less wealthy developing country (Country B). A representative consumer in Country A derives utility from the consumption of durable good such as a personal computer. After consumption, the durable good is either disposed or disassembled in Country A or exported as a used durable good to Country B for additional consumption. The representative consumer in Country B derives utility from the used durable good and a locally produced non-durable good such as an agricultural product, a local service, or leisure. The disposal of this non-durable good is assumed to generate no hazardous e-waste. All used durable goods imported to Country B must also be disassembled in Country B (we allow later for the possible return of e-waste from the used durable good for processing in Country A). The representative consumer in both Country A and B gain disutility from the aggregate quantity of e-waste disposed or disassembled in their own country. In the absence of tax policies, this loss in utility is not internalized by agents in the economy – a source of market failure.

The economies in both countries utilize a single economic resource such as capital, labor, or energy for five production and transportation activities. This resource can be allocated to (1) produce the consumer electronic in Country A, (2) disassemble e-waste in Country A, (3) transport the used consumer electronic to Country B, (4) disassemble e-waste from the imported consumer electronic in Country B, and (5) produce the non-durable good in Country B. The global supply of the economic resource is constant.

The Pareto Optimum is found by allocating the economic resource to maximize the utility of the representative consumer in Country A subject to holding constant the utility of the representative consumer in Country B, subject to the 5 production technologies defined above, subject to the assumed constant supply of the economic resource, and subject to the materials

[2] See Hai-Yong Kang and Julie M. Schoenung (2005) and Ramzy Kahhat, Junbeum Kim, Ming Xu, Braden Allenby, Eric Williams and Peng Zhang (2008) for details of U.S. e-waste management policies.

[3] See Hide-Fumi Yokoo and Thomas Kinnaman (2010) for a thorough presentation of this model.

balance constraints governing the flow of the used durable good.

Having characterized the Pareto Optimum, the model next solves for rates of various taxes necessary for the decentralized competitive economy to achieve the Pareto Optimum. Three tax instruments are available to this economy – a tax on e-waste in Country A, a tax on e-waste in Country B, and a tax on the import of the used durable good to Country B.

The representative consumer in Country A maximizes utility by allocating their income between purchasing the used durable good and paying to disassemble the e-waste. The consumer can also earn income from exporting and selling the used durable good to the representative consumer in Country B, but must pay a competitive firm to export the used durable good to Country B. The representative consumer in Country B maximizes utility by allocating income to purchase the (taxed) imported used durable good, to purchase the local non-durable good¸ and to pay to disassemble e-waste from used durables.

Representative competitive firms from each of the five industries defined above each employ the economic resource and a production technology to maximize profit. In Country A, one representative firm chooses the quantity of the durable good to produce, a second chooses the quantity of e-waste to disassemble (and pays a disposal tax), and a third chooses the quantity of the used durable good to export to the representative consumer in Country B. In Country B, one firm chooses the quantity of the non-durable good to produce¸ and a second chooses the quantity of e-waste to disassemble and potentially pays a disposal tax on each unit disassembled.

Given the assumptions of this model, the Pareto Optimum can be achieved by utility and profit maximizing agents with several intuitive combinations of these three tax instruments, which are summarized in Table 1.

In the first scenario, both countries are able to assess a tax on their own domestic e-waste and set the e-waste tax equal to their own external marginal cost of e-waste (defined as EMC_A and EMC_B). The import tax is not necessary. In the second scenario, Country B is unable to tax e-waste. Perhaps the economy lacks the necessary technology (such as scales for weighing e-waste hauling trucks as they enter and exit a disposal site) or the government lacks administrative resources to discourage illegal dumping that might arise with the implementation of an e-waste tax. The Pareto Optimum can be recovered in this economy by implementing an import tax set equal to the external marginal cost in County B. Either the import tax or the e-waste tax results in the representative consumer in Country B internalizing the social costs of their e-waste. The efficiency of the import tax relies heavily on the assumption that no other disposal or recycling methods are available to the consumer in Country B. If the consumer has more than one disposal option, and those options involve different external costs, then an "upstream" tax such as the import tax does not encourage consumers to efficiently choose among those options.

TABLE 1

Scenario	Country A E-waste Tax	Country B E-waste Tax	Country B Import Tax
1	EMC_A	EMC_B	Zero
2	EMC_A	Zero	EMC_B
3	EMC_A-EMC_B	Zero	Zero

In the third scenario, we assume no policy instrument is available to Country B. Mexico, for example, eliminated trade restrictions on all 10-15 year-old vehicles in 2005 in accordance with NAFTA. The only remaining tax instrument to this economy is the e-waste tax in Country A. The Pareto Optimum can still be achieved by setting this tax equal to the difference between the marginal cost of disposal in Country A and that of Country B. If willingness to pay for environmental quality is higher in Country A than in Country B, perhaps owing to higher income levels, then the e-waste tax in Country A remains positive but will be set at a level below the external marginal cost in Country A. If instead external costs of disposal are higher in B than in A, perhaps owing to primitive open dumping practices that threaten human health, then e-waste disposal should be subsidized in Country A. This subsidy will discourage exports to Country B.

Examining the three tax scenarios in Table 1 suggests that the difference in e-waste taxes matters for efficiency, not their levels. Although differences in e-waste tax across countries almost certainly matter to the efficient flow of e-waste resources, simplifying assumptions in the model might overstate the flexibility among scenarios 1, 2, and 3. Such perfect flexibility would likely disappear in a model comprised of more than two countries or with alternative disposal options (such as recycling) in Country B. We also note that the e-waste tax does not induce a substitution effect in Country A.

III. A Return Economy

Consider a similar economy where a technology is available to return e-waste from the used durable good back to Country A for disposal. This process requires the global economic resource as the sole input – bringing to six the number of industries utilizing the economic resource. For reasons articulated above, assume the import tax and Country B e-waste tax are not available. The remaining policy options are the e-waste tax in Country A and a subsidy on the return of e-waste to Country A. The return subsidy can be administered by the government in Country B, a benevolent government in Country A, or by the original producers of the durable good as part of a producer responsibility policy.

Once again, differences in tax rates are important to achieving the Pareto Optimum rather than tax levels. Four such policy scenarios are summarized in Table 2.

To represent the various policy scenarios generated by the model, the external marginal cost in Country A (originally EMC_A) is separated into that from the aggregate e-waste generated by consumers in Country A (EMC_{AA}) and the that from the aggregate returned e-waste generated from consumers in Country B (EMC_{BA}). The e-waste from these two sources is identical from the consumer's viewpoint, but the quantities may differ. If consumers in Country A disassemble domestically more e-waste than they export to Country B for reuse, then $EMC_{AA} > EMC_{BA}$ for the simple reason that there will be less e-waste material returned to Country A than was originally disassembled in Country A. EMC_{BA} will exceed EMC_{AA} only if the amount returned to Country A exceeds the amount originally disassembled in Country A. The external marginal cost of e-waste disassembled in Country B continues to be defined as EMC_B.

TABLE 2

Scenario	Country A E-Waste Tax	Country B Return Subsidy
1	- (EMC_B)	- (EMC_{BA})
2	EMC_{AA}	EMC_B+EMC_{AA} - EMC_{BA}
3	EMC_{BA}	EMC_B
4	EMC_{BA} - EMC_B	Zero

In Scenario 1, the Pareto Optimum can be obtained by combining an e-waste subsidy in County A with a return tax in Country B. The subsidy in Country A must equal the external marginal cost of disposal in County B. Consumers in Country A therefore internalize the social costs of exporting the used durable good to Country B. The return subsidy is also negative, a tax on the return of e-waste to Country A. This tax is set equal to the external marginal cost of the returned e-waste for disassembly in Country A.

Although theoretical efficient, neither of these two policies in Scenario one would be popular within each country. Considers the second scenario where Country A acts unilaterally by setting its e-waste tax equal to the external marginal cost of e-waste in Country A (EMC_A). The global Pareto Optimum can be achieved if Country B were to set its return subsidy equal to external marginal cost of e-waste disassembled in Country B (EMC_B – to internalize domestic social costs for consumers in Country B) plus the external marginal cost in Country A (EMC_{AA} – to neutralize the positive e-waste tax in Country A) minus the external marginal cost of disassembling returned e-waste in Country A (EMC_{BA} – to internalize international social costs for consumers in Country B). In the event that $EMC_{AA} > EMC_{BA}$, the return subsidy will be greater than the external marginal cost of disassembly in Country B.

Country B acts unilaterally in Scenario 3 by setting the return subsidy equal to the external marginal cost of e-waste in Country B such that their consumers internalize domestic social e-waste disassembly costs. The Pareto Optimum can only be achieved if Country A sets their e-waste tax equal to the external marginal cost of disposing Country B's returned e-waste in Country A (EMC_{BA}), a rate that may be below the unilateral tax rate in Country A if the quantity returned from Country B is exceeded by the quantity originally disassembled In Country A.

If both countries act unilaterally, the resulting tax and subsidy rates will achieve the Pareto Optimum only in the rare case that $EMC_{AA} = EMC_{BA}$ (the quantity of original e-waste disassembled in Country A is equal to the quantity returned from Country B). This condition is also met when e-waste disassembly in Country A generates no external costs ($EMC_{AA} = EMC_{BA} = 0$). External disassembly costs are zero if environmental policies in developed countries result in disassembly plants internalizing all social costs of the disassembly process.

In the fourth scenario assume that lacking administrative resources, the return of e-waste to Country A cannot be subsidized. The only available policy instrument is the e-waste tax in Country A. The global Pareto optimum can be achieved by reducing the e-waste tax in Country A to an amount equal to the external marginal cost of disassembling the returned e-waste (such that consumers in County B internalize social disposal costs in Country A) less the external marginal cost of disposal cost in Country B (such that consumers in Country A internalize social disposal costs in Country B). The optimal e-waste tax could be positive or negative depending upon the magnitudes of these two externalities. Country A would subsidize domestic e-waste disposal if the external cost of disposal in Country B exceeds the external cost of returning the e-waste to Country A.

If the e-waste tax in Country A is the only available policy instrument, then by comparing the Scenario 3 e-waste tax rate in the simple economy with the Scenario 4 e-waste tax from the return economy suggests the emergence of the return technology serves to change the e-waste tax in County A by an amount equal to the difference between EMC_{AA} and EMC_{BA}. If $EMC_{AA} > EMC_{BA}$, then the e-waste tax decreases with the emergence of the return technology.

Finally, the results of the model provide efficiency conditions for an economy void of e-waste policy instruments. A policy regime of no e-waste taxes or subsidies in either country will achieve the Pareto Optimum if external disposal costs are equal across Countries A and B ($EMC_{BA} = EMC_{B}$). Willingness to pay for environmental quality is likely higher in developed Country A than in Country B, but exposures to toxins from labor-intensive disassembly processes in Country B are likely higher than for mechanized processes in Country A. Combine these two effects, and the two external costs may not be far apart.

The current policy environment features implicit e-waste taxes in many developed countries such as Japan and the United States. These implicit e-waste taxes derive from policies that ban e-waste from landfills in developed countries and producer responsibility measures that subsidize the return of used consumer electronics for "recycling," which usually involves exporting the goods for disassembly in developing countries. Developing countries impose no known taxes on e-waste disassembly or any import tariffs on used durable goods. This policy environment is likely inefficient if the implicit e-waste taxes in developed countries do not consider external disassembly costs in developing countries as is called for in the final scenario of each economy modeled above (Tables 1 and 2).

IV. Conclusion

This paper has provided a broad blueprint of what international policy could look like to manage the negative externality associated with global reuse – the potential ill health effects of employing labor-intensive dismantling of electronic waste. If e-waste taxes or import taxes are available in the developing country, then setting these instruments equal to the marginal external costs of disassembly are warranted. Subsidy the return of e-waste following the reuse of the consumer electronics can also have lead to economic efficiency. But in the absence of these policy options, the implicit e-waste disposal taxes in many developed countries should be lowered to rates below external marginal costs in developed countries to achieve global economic efficiency.

The model also suggests that optimal policies change only slightly when considering the trade in used consumer electronics relative to unusable e-waste. Optimal policy rates displayed in Tables 1 and 2 are about the same.

Finally, the model has a few weaknesses that could be addressed in future research. First, the economic resource used to produce consumer electronics and transport and disassemble e-waste is free to flow between the developed and developing country. A more realistic model would place constraints on this flow or assume each country has a domestic economic resource. Second, the model assumes only one disassembly process (a labor intensive one) in Country B. If other processes are available, and if those processes vary with respect to external costs, then some of the policy options discussed in this paper are no longer efficient. Finally, consumers in Country A gain utility only from electronics. The lack of a second good prevents a substitution effect if e-waste taxes increase. If developing countries are unable to implement e-waste policies, then developed countries should reduce the implicit e-waste disposal taxes.

REFERENCES

Copeland Brian R. 1991. "International Trade in Waste Products in the Presence of Illegal Disposal." *Journal of Environmental Economics and Management,* 20(2): 143-162.

Kahhat, Ramzy, Junbeum Kim, Ming Xu, Braden Allenby, Eric Williams and Peng Zhang. 2008. "Exploring E-Waste Management Systems in the United States." *Resources, Conservation and Recycling* 52(7): 955-64.

Kang, Hai-Yong, and Julie M. Schoenung. 2005. "Electronic Waste Recycling: A Review of U.S. Infrastructure and Technology Options." *Resources, Conservation and Recycling,* 45(4): 368-400.

Li, Huiru, Liping Yu, Guoying Sheng, Jiamo Fu, and Ping'an Peng. 2007. "Severe PCDD/F and PBDD/F Pollution in Air Around an Electronic Waste Dismantling Area in China." *Environmental Science and Technology,* 41(16): 5641-6.

PC3R Promotion Center. 2010. http://www.pc3r.jp/e/index.html (accessed December 2010).

Sepúlveda, Alejandra, Mathias Schluep, Fabrice G. Renaud, Martin Streicher, Ruediger Kuehr, Christian Hagelüken and Andreas C. Gerecke. 2010. "A Review of the Environmental Fate and Effects of Hazardous Substances Released from Electrical and Electronic Equipments During Recycling: Examples from China and India." *Environmental Impact Assessment Review,* 30: 28-41.

Shinkuma, Takayoshi. 2009. "Extended Producer Responsibility in a Developed Country and the Effect on International Trade, the Environment, and Social Welfare." Unpublished.

United States Environmental Protection Agency (U.S. EPA). 2007. "Management of Electronic Waste in the United States." http://www.epa.gov/ecycling/manage.htm (accessed May 2007).

Yokoo, Hide-Fumi. 2010. "An Economic Theory of Reuse." *Sustainability Science* 5: 143-150.

Yokoo, Hide-Fumi and Thomas Kinnaman. 2010. "Global Reuse and Optimal Waste Policy." Unpublished.

Yoshida, Aya, Tomohiro Tasaki, and Atsushi Terazono. 2009. "Material Flow Analysis of Used Personal Computers in Japan." *Waste Management* 29(5): 1602-1614.

Yoshida, Aya and Atsushi Terazono. 2010. "Reuse of Secondhand TVs Exported from Japan to the Philippines." *Waste Management* 30(6): 1063-72.