ECONOMIC IMPACT IN THE UNITED STATES FROM BANNING HAZARDOUS ELECTRONIC WASTE EXPORTS

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ECONOMIC IMPACT IN THE UNITED STATES

FROM BANNING HAZARDOUS ELECTRONIC

WASTE EXPORTS

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DEDICATION

This dissertation is dedicated to my wife

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who always stood beside me in time of difficulty and in time of happiness to attain this degree, and to my special and beloved children Hafsa, Sadia, and Aisha, and to my parents, Farah Ahmed Qanyare (may Allah have mercy upon him) and Marian Arif Fiqow.

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After passing my comprehensive exam and paving the way for writing a dissertation, it brought an excitement and unbelievable expectation of becoming part of academia, but that happiness was shattered right after I realized that I had to decide the topic area of my dissertation. Dr. Sarah Kimball came to my rescue when she suggested that electronic waste disposal might be an interesting topic. Without delay I started to explore that idea and without hesitation I employed my imagination to bring together all the ingredients and spices needed for a great dissertation. After several weeks of thinking loud as a mad man, I came to Dr. Kent Olson, my principal advisor, and he at once provided me the ingredient that I was waiting for. Dr. Olson suggested it would be a great thing to do if I would estimate the economic impact in the United States of banning hazardous electronic waste exports. Excitement and hope visited me again but that guaranteed only many sleepless nights and days to come. One day followed another and one month followed another and over a year passed. I was about to give up but Dr. Olson promised to help me and share with me his experience and told me that, without patience, he would not have finished his dissertation. After that I felt relieved and started to work and stopped complaining.

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Introduction

1.1 Background

Various episodes of international hazardous waste trafficking that took place in the late 1980s prompted a U.N.-sponsored meeting in Basel, Switzerland in 1989. This meeting resulted in the Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and Their Disposal; more commonly referred to simply as the Basel Convention. The objectives of the Basel Convention include reducing the amount of hazardous waste generated, minimizing trans-boundary movements (especially from developed to developing countries) of hazardous waste, and assuring that such waste is disposed of in an environmentally sound manner. It was the intention of those who wrote this treaty that trans-boundary movements of hazardous waste materials and their disposal would fall under the control of the Basel Convention. In addition, the Basel Action Network (BAN) was created to serve as the global watchdog for environmental agreements on hazardous waste materials.

The Basel Convention was signed by 166 nations between 1989 and 1992, and ratified by all signees except the United States, Haiti, and Afghanistan. The agreement became binding on May 5, 1992. Discussions at the 1995 Basel Conference led to a decision to add the Basel Ban Amendment to the Basel Convention (Basel Ban). The Amendment prohibits the export of hazardous waste, including hazardous electronic waste, from a list of developed (mostly OECD) countries to developing countries. This amendment applies to export for any reason, including recycling. The purpose of the Basel Ban is to eliminate disposal practices in developing countries that are harmful to both the natural environment and humans. It has received the support of many governments (including the 62 needed for ratification) and NGOs, but it has been strenuously opposed by a number of industry groups and several developed nations, including the United States. The U.S. Chamber of Commerce has said that it will not endorse the Basel Ban because a ban on trade in waste for recycling between OECD and non-OECD countries, alone, would adversely affect some $2.2 billion of U.S. trade in such commodities annually (Goodwin, 1994).

1.2 What Is Electronic Waste?

Electronic waste consists of electronic products that have been retired from use. The products considered electronic waste (e-waste) in this dissertation are:

- Cathode ray tubes - CRTs (primarily computer monitors and television sets)
- Central processing units – CPUs (primarily from personal computers)
- Other Electronic Waste (computer mice, keyboards, cell phones. printers, scanners, and fax machines)

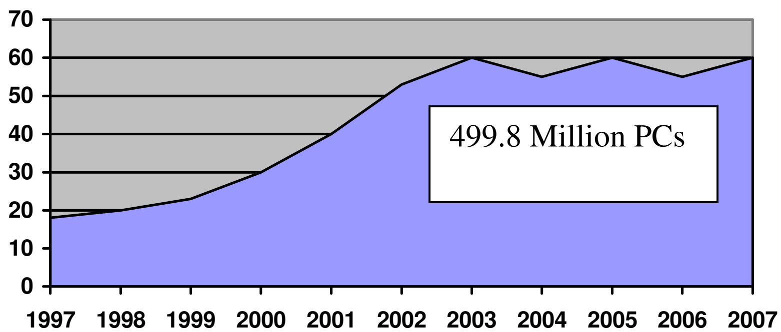
1.3 How Much Electronic Waste Is There?

Every year, approximately 20 to 50 million tons of electrical and electronic equipment waste are generated world-wide (United Nations Environmental Programme, 2005). The decreasing lifespan of electronic products increases the amount of e-waste requiring disposal. From

1997 to 2007, the total number of personal computers, alone, that became available in the United States for disposal is estimated to be nearly 500 million, as illustrated with Figure 1.1.

Figure 1.1

Estimated Computer Disposal in the United States



(Source: National Safety Council, 1999)

Perhaps the biggest reason for concern is the rapidly growing volume of e-waste as technology advances. The production of electrical and electronic devices is the fastest-growing manufacturing sector in industrialized countries. Another aspect of the problem is the diminishing average life span of personal computers; now only two to three years in the United States. Internationally, the United Nations utilizes a figure of two to four years (United Nations Environmental Programme, 2005). The United Nations has explained that technological innovation and intense marketing seem to prompt a rapid replacement process.

The innate drive to have faster equipment with more capacity, coupled with peer pressure to have the "latest and greatest," seem to push consumers into purchasing new models and retiring many functional pieces of electronic equipment, particularly in the

United States. This problem is escalated by the increasing use of electronics in the United States. Figures show that sales of personal computers in the United States have been increasing since 1985 at a rate of more than 23% annually (Boon, Isaacs, and Gupta, 2002).

The scope of the e-waste disposal problem goes well beyond personal computers, however. The most extensive study to date of the management of e-waste was conducted by the U.S. Environmental Protection Agency and reported in a two volume study: *Electronics Waste Management in the United States, Approach One* (U.S. Environmental Protection Agency, 2007a), and *Electronics Waste Management in the United States, Approach Two* (U.S. Environmental Protection Agency, 2007b). According to these sources, over 3.365 million tons of electronic wastes were being actively managed in the United States in 2005.

1.4 Why the Concern about Electronic Waste Management?

The quantity of e-waste in the United States accounts for approximately four billion pounds of plastics, one billion pounds of lead, 1.9 million pounds of cadmium, 1.2 million pounds of chromium, and nearly 400,000 pounds of mercury, along with large amounts of other harmful elements. The magnitude of the problem becomes more obvious when one considers; for example, that researchers have concluded that consumer electronics account for 40% of the lead in landfills (Peterson, 2003).

The seriousness of the problem is illustrated by research done at the University of Florida. There, researchers tested 36 computers with cathode ray tubes to determine the threat they pose for the environment and for human health (Townsend, et al. 1999). The computer monitors and cathode ray tubes were crushed and mixed with an acid solution to simulate the leaching condition that may exist in landfill. The test used was the Toxicity Characteristic Leaching Procedure, a standard test used by the U.S. Environmental Protection Agency. The test indicated that 21 of the crushed tubes exceeded the hazardous waste standard of five milligrams of lead per liter, with concentrations averaging 18.5 milligrams per liter. The necks of the cathode ray tubes, the part furthest from the screen, were found to contain concentrations of lead high enough for them to be considered hazardous.

Another group of researchers that has done much work to reveal that cast-off computers are indeed creating a serious problem around the world because of the hazardous waste materials they contain is located at the Laboratory for Responsible Manufacturing. Based on the work of this laboratory, Boon, Isaacs, and Gupta (2001), identified which electronic parts contain which types of hazardous materials.

According to their findings (Boon, Isaacs, and Gupta, 2002), these typically include the following:

- printed circuit boards which contain lead known to be harmful to the human nervous system, causing permanent negative effects on brain development in children and also affecting the blood and kidneys, in addition to acute toxic effects on animals and plants (Christian, Turner, and Romanov, 1999)
- cathode ray tubes containing cadmium whose effects from renal toxicity (Nomiyama, 1980) and problems with lung emphysema are well-known, as well as lead, the dangers from which have already been presented

- mercury in the relays, which has the potential to damage the central nervous system, kidneys, and liver, after either high-level/short-term or low-level/long-term exposure (Satarug, et al, 2002)
- mineral oil capacitors which have polychlorinated biphenyls, a source of lower birth weights
- batteries, widely known to have corrosive impacts on people and property
- photoreceptor drums that have arsenic, long known to be a poison, and selenium, which adversely affects the human endocrine system
- gas springs which contain oil that is also widely recognized as a pollutant.

In addition, computers have traces of precious metals that are not harmful themselves. A single computer contains only traces of precious metals, but when the huge volume of retired computers is considered, the picture changes. In fact, one precious metals refiner has discovered that electronic scrap is literally a gold mine, with more gold to be recovered from this source than from the ground (Taylor, 1999). The precious metals are so valuable that scavengers work to recover them by a process employing cyanide, a known poison. This process is harmful not only to those using it, but also to individuals adversely affected by improper disposal of the cyanide-laden wastes.

This is probably not a serious problem in the United States, but it may be in developing countries. Some of the electronic waste produced in the United States is exported to developing countries where this process is used. For example, analytical results of landfill testing in places such as Guiyu, China, showed that sediments attributable to e-waste processing were seriously contaminated with cadmium, copper, nickel, lead, and zinc (Wong, et al., 2006).

1.5 Objectives of This Study

Although the Basel Ban is generally recognized by economists as a constraint on international trade it has not yet been examined thoroughly from this perspective. This dissertation structures the problem in the context of a model of the market for waste disposal services, where the United States is viewed as an importer of waste disposal services. The model implies that the United States would suffer net social costs as a result of adopting the Basel Ban. The model also implies that jobs would be created in the United States if electronic waste were to be diverted from the international market, but at some cost in terms of a net social cost per job created. Accordingly, the primary objectives of the study are

a. to determine the probable size of the net social cost resulting from adoption of the Basel Ban,

b. to determine the magnitude of the domestic jobs likely to be created by adopting the Basel Ban,

c. to determine the cost of protection (net social cost per job created) that would be attributable to adoption of the Basel Ban, and

d. to compare the cost of protection attributable to the Basel Ban with estimates of the cost of protection that have been determined for other restraints on trade.

The findings of this dissertation will further our understanding of the economic effects of the Basel Ban.

1.6 Dissertation Plan

Chapter 2 will present a model of the market for e-waste disposal services, using traditional microeconomic theory. This model will be used to illustrate what is meant by the net social costs from adopting the Basel Ban. It will be used to specify the information that is required in order to develop an estimate of those costs. It will also be used to illustrate the meaning of the cost of protection and specify the information required to determine its magnitude.

Chapter 3 will develop a profile of the scope of the e-waste disposal management problem. Statistics will be reported on the volume of e-waste generated and the disposition, or fate, of this waste by type of disposal.

Chapter 4 will develop summaries of the costs of the principal alternative means of e-waste disposal, drawing upon a growing, but still relatively small, literature. This information is required to simulate the supply side of the market for e-waste disposal services illustrated in Chapter 2.

In Chapter 5, we review U.S state laws pertaining to electronic waste disposal. The objective of this chapter is to explain the trends that seem to be emerging in the management of e-waste. In the United States, this trend is being established largely at the initiative of the various states, rather than by the federal government.

Chapter 6 brings together the findings in Chapters 4 and 5 to determine the probable fate of the e-waste that would require domestic disposal if the Basel Ban were adopted.

The data and findings in Chapters 4-6 will be applied in Chapter 7 to develop measures of the net social cost and cost of protection attributable to adopting the Basel Ban.

Chapter 8 will summarize and further explain the principal findings of this study, compare the cost of protection attributable to adopting the Basil Ban with similar metrics for other products, and provide some suggestions for future research.

CHAPTER II

Economic Model of Electronic Waste Disposal Services

2.1 Previous Literature

In a two-part series of articles in *Competitive Enterprise,* entitled "Trashing Free Trade, The Basel Convention's Impact on International Commerce," James Sheehan treats the proposed Basel Ban as a restraint on international trade and warns of the trade-related costs that would be imposed on the United State economy if the Basel Ban were to be adopted (Sheehan, 1996). Up until now, however, no estimates of the impact of adopting the Ban have appeared in the literature. This dissertation is intended to begin filling this gap.

The only study that appears to be comparable in intent to what we do in this study is a study by Eduard Ley, Molly Macauley, and Stephen Salant that examines the costs of restricting inter*state* trade in waste (Ley, Macauley, Salant, 2000) They examine the inter-temporal and spatial allocation of the solid waste of selected cities in the United States to determine the size of the net social costs attributable to proposed restrictions on interstate shipments.

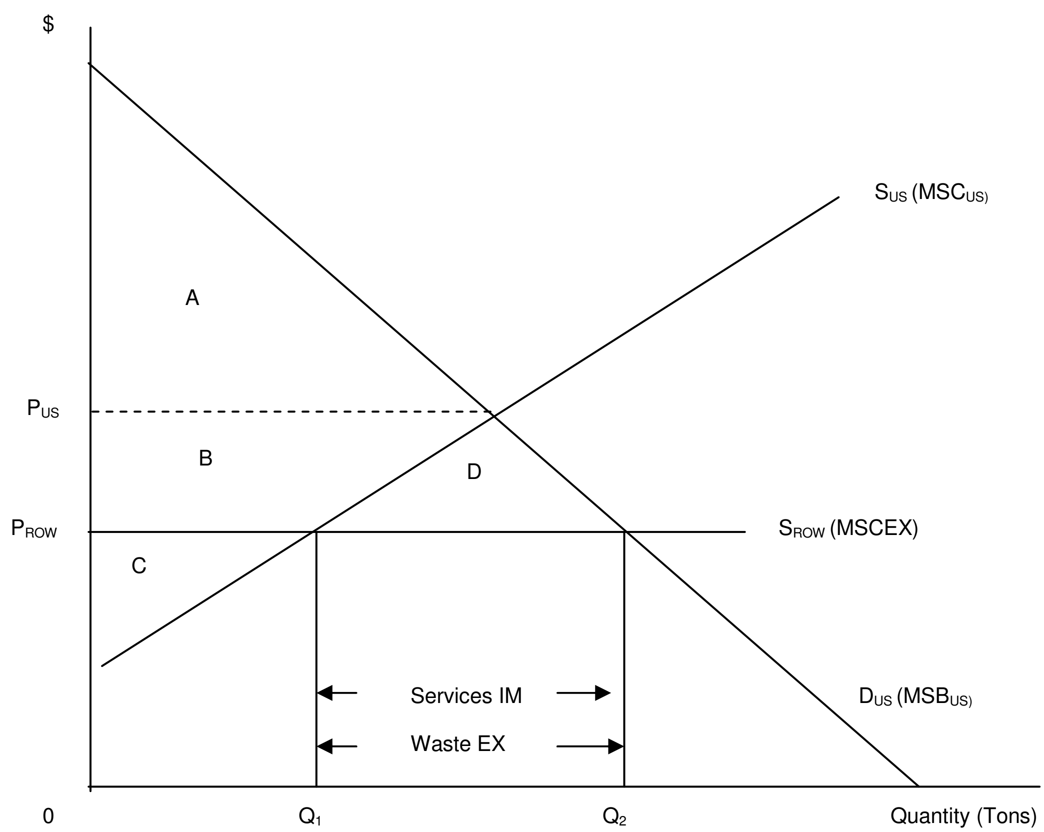
2.2 The Model

The trans-boundary shipment of e-waste is a means of acquiring e-waste disposal *services*, such as recycling, landfill disposal, and incineration from other countries. The economic effects of the Basel Convention ban on trans-boundary shipments of e-waste can be illustrated, then, with a model of the market for e-waste services. In this context, the United States *imports* e-waste services and developing countries *export* e-waste services.

The situation in the importing country (the United States) is illustrated in Figure 2.1.

Figure 2.1

The Market for Electronic Waste Disposal Services



The supply curve, S_{US}, depicts the marginal social costs in the United States (MSC_{US}) of the various domestic management practices or technologies that are used to dispose of e-waste, where marginal social cost includes both the cost paid by the providers of the disposal services (such as landfill owners and recycling enterprises) and all external costs (such as those arising from air, water, and noise pollution). The upward slope of the supply curve reflects the assumption that increasing volumes of e-waste require disposal by methods that increase in cost per unit as the volume of waste disposed increases. The supply curve is drawn on the (usual) assumption that waste is disposed of initially by the cheapest method. Eventually users of that method encounter rising marginal costs and that method is replaced, at the margin, by the next cheapest method. The second method has an economic advantage until it encounters rising marginal costs and is replaced at the margin by a third method, and so on.

The supply curve for e-waste disposal services in the rest of the world (S_{ROW}) reflects the marginal social cost of the resources used to *export* e-waste from the United States (MSC_{EX}); that is, to collect, treat, and transport e-waste to international shipment points. These are actions necessary to "import" international e-waste disposal services. MSC_{EX} represents the value of U.S. resources required to facilitate international trade in e-waste. It is assumed to be constant, as illustrated in this diagram, but it may also be an increasing function of the volume of e-waste exported.

The demand curve for e-waste disposal in the United States (D_{US}) is assumed to have the usual downward-sloping shape. That is, U.S. consumers of e-waste disposal services will purchase a larger volume, the lower the price. It is also assumed to include all of the benefits (no external benefits) produced by the disposal of e-waste; hence, it is labeled MSB_{US}, for marginal social benefits in the United States from e-waste disposal services.

From 0 to Q_1, the marginal social cost of domestic e-waste disposal is less than the marginal social cost of importing disposal services (exporting e-waste). Beyond Q_1, the marginal social cost of exporting e-waste is less than the marginal social cost of domestic e-waste disposal. Given the demand for e-waste disposal, the market would clear at Q_2, where the quantity demanded is equal to the marginal social cost of exported e-waste, provided there were no restrictions on international trade in e-waste. Thus, Q_1-Q_0 tons of e-waste disposal services would be provided domestically and Q_2-Q_1tons of e-waste disposal services would be imported.

If imports of e-waste disposal services were banned, as under the Basel Convention, the market would clear at the intersection of the U.S. supply and demand curves. On the supply side of the market, there would be an increase in the quantity of e-waste disposal services supplied domestically. On the demand side of the market, there would be a decrease in the quantity of e-waste disposal services demanded. The market-clearing price of e-waste disposal services would rise from P_{ROW} to P_{US}.

The higher price would harm consumers, imposing a loss in consumers' surplus of area B plus area D. Domestic producers of e-waste disposal services would reap a higher price and realize a gain in producers' surplus of area B. Additional workers would be hired in domestic firms to accomplish the increase in the quantity of e-waste disposal services supplied domestically.

The losses to consumers would be partially offset by gains to producers; that is, area B represents a loss to consumers and a gain to producers. Consumers, however, suffer the loss of area D, for which there is no offset. Workers newly hired in the domestic e-waste disposal industry would experience gains, of course, but these gains would be offset by losses elsewhere in the economy as the workers transfer from other industries to work in this industry. Thus, there is a *net loss* to society – a net social loss - of area D.

The net social loss from adopting the Basel Ban could be determined by estimating equations for the three curves in Figure 2.1, provided the data required for this approach were available. They are not. Fortunately, there is an alternative method - a limited-information method - that will yield a reasonable approximation of the net social loss.

This reasonable approximation is made in four steps. First, the quantity of e-waste not exported if the Ban is adopted (Q_2-$Q_{1)}$ is determined. Second, the fate of that volume if it is not exported is determined; i.e., the methods of waste management that will be used to treat it in the United States are determined. Third, the marginal social costs of those methods are estimated, based on existing studies. This is equivalent to simulating the marginal social cost of domestic waste disposal over the range from Q_1 to Q_2. Fourth, the cost of exporting e-waste (importing e-waste disposal services) is estimated, based on existing studies. This is equivalent to simulating the MSC_{EX} curve over the range from Q_1 to Q_2.

Another measure of interest to policy makers is the cost of protection. The cost of protection is the net social cost per direct job that would be created in the United States by the Basel Ban. A direct job is a job in the e-waste management industry. An expansion of the e-waste management industry will also create additional jobs in other industries in the United States – "indirect" jobs. These "count" as a source of economic welfare, however, only to the degree that they do *not* displace jobs that otherwise would have been provided by the economy. In an economy that is close to, or at, full employment, most indirect jobs are offset by jobs displaced. We assume such conditions normally prevail in the United States.

The cost of protection is a metric that is commonly used to assess the effects of restraints on international trade. Given the net social cost, an estimate of the cost of protection requires an estimate of the number of direct jobs created. Once the volume and method of disposal of e-waste that would have been exported are determined, the number of direct jobs created can be determined from existing data on output and employment in the e-waste industry.

CHAPTER III

Management of U.S. Electronic Waste in 2005

The purpose of this chapter is to provide estimates of the volume of e-waste managed in the United States and the proportion of that waste that is exported. The estimates generated in this chapter will be used to determine the management scenarios in Chapter 6 and the net social cost and cost of protection in Chapter 7. The data presented are for 2005, the latest year for which reliable data could be obtained.

3.1 Total Electronic Waste Managed

Different studies have offered different estimates of the volume of electronic products that have been discarded. One estimate is that a total of 130,000 computers, TVs, VCRs, cell phones and monitors were disposed of each day in 2005 (U.S. Environmental Protection Agency, 2007a). According to the Consumer Electronics Association, 304 million obsolete electronic products, the majority of which were still in working condition, were discarded in 2005 (United States Environmental Protection Agency, 2007a).

The most extensive study to date of the management of e-waste was conducted by the U.S. Environmental Protection Agency and reported in a two volume study: *Electronics Waste Management in the United States, Approach One* (2007a) and *Electronics Waste Management in the United States, Approach Two* (2007b).

According to the authors, Approach One "relies primarily on market research data on sales of electronic products. It then applies these sales data to some of the most comprehensive collection information available to estimate product life spans and the amounts of particular products that are ready for EOL (end-of-life) management. From these EOL estimates, we subtract the estimated quantity recycled to yield the quantity disposed. This approach also provides information on the export of CRT monitors and TVs, as well as the amount of selected electronics cumulatively in storage." (U.S. Environmental Protection Agency, 2007a, p.2)

Alternatively, "Approach Two relies primarily on government statistics on sales of electronic products. It then uses the same lifespan data (with some modifications) as Approach One to estimate EOL quantities. From these EOL estimates, we subtract the quantity of selected electronics disposed to yield the quantity recycled. This approach also provides information on the composition of electronic products, as well as the number of select electronic devices entering storage/reuse annually." (U.S. Environmental Protection Agency, 2007b, p.2)

The estimates provided by both approaches are quite similar, but those produced by Approach Two contain more detail by type of management, a feature that is useful in establishing alternative management scenarios in the event the Basel Ban is adopted. The aggregate estimates by management method from Approach Two are summarized in Table 3.1.1.

Table 3.1.1

Aggregate Volume by Management Method for Select Electronics Products - 2005
Thousands of Tons

Product	Recycled	Landfilled	Incinerated	Total Disposed	Total Stored/ Reused	Total
Desktops	67.8	186.5	5.3	259.5	349.0	608.5
Laptops	8.0	22.1	0.6	30.8	28.4	59.3
Monitors (CRT)	95.7	286.0	8.1	389.8	269.4	659.2
Monitors (LCD)	1.2	3.6	0.1	4.9	7.7	12.6
TVs (CRT)	101.5	639.5	18.2	759.1	552.1	1,311.2
TVs (Projection)	17.8	111.9	3.2	132.8	0.0	132.8
Cell Phones	2.2	9.2	0.3	11.7	7.3	19.0
Printers	68.9	189.5	5.4	263.8	291.5	555.3
Keyboards	15.0	41.3	1.2	57.5	43.4	100.9
Mice	0.9	2.6	0.1	3.6	3.2	6.8
All Products	379.0	1,492.2	42.4	1,913.6	1,552.1	3,465.7

Source: U.S. Environmental Protection Agency (2007b)
Constructed by author from XLS Tables accompanying report.

The data in Table 3.1.1 are aggregated further in Table 3.1.2. The aggregation in 3.1.2 provides a better match with the data available on the costs of alternative methods of managing e-waste, as reported in Chapter 4. Table 3.1.2 also indicates the percentage distribution by type of management, data that are used again in Chapter 7.

Table 3.1.2

Electronic Waste Managed in 2005

	Quantity (Thousands of Tons)				
Product	Recycled	Landfilled	Incinerated	Stored	Total
CPUs	67.8	186.5	5.3	349.0	608.6
CRT Monitors	95.7	286.0	8.1	269.4	659.2
CRT TVs	101.5	639.5	18.2	552.1	1311.3
Total CRTs	197.2	925.5	26.3	821.5	1970.5
Other E-Waste	114.0	380.2	10.9	381.5	886.6
Total	379.0	1492.2	42.5	1552.0	3465.7

Product	Percent of Total				
CPUs	11.1%	30.6%	0.9%	57.3%	100.0%
CRT Monitors	n.a.	n.a.	n.a.	n.a.	n.a.
CRT TVs	n.a.	n.a.	n.a.	n.a.	n.a.
Total CRTs	10.0%	47.0%	1.3%	41.7%	100.0%
Other E-Waste	12.9%	42.9%	1.2%	43.0%	100.0%
Total	10.9%	43.1%	1.2%	44.8%	100.0%

n.a. not available

3.2 Electronic Waste Exported

The objective of this study is to determine the costs associated with adoption of the Basel Ban on the exportation of e-waste. Thus, an accurate estimate of the latter is critical.

In the United States, the e-waste that is exported is normally collected and sorted for recycling before it is diverted instead and exported. Thus, only part of the 379,000 tons reported as recycled in Table 3.1.2 was actually exported. In fact, the USEPA reports that only 243,100 tons of e-waste was actually exported in 2005 (U.S. Environmental Protection Agency, 2007a, 2007b, *Storage & Reuse Worksheet*). Using percentages reported in this source, we determined the allocation of this total by principal type of product, as indicated in Table 3.2.

Table 3.2

Electronic Waste Exported in 2005

Product	Thousands of Tons
CPUs	45.4
CRTs	132.1
Other E-Waste	65.6
Total	243.1

CHAPTER IV

Costs of Electronic Waste Management

The focus of this chapter is the information available on the costs of managing e-waste. The objectives are to determine the costs per ton of exporting e-waste *and* the costs per ton of managing that waste within the United States if it were not exported. According to the data examined in Chapter 3, 54 percent of the e-waste exported in 2005 consisted of cathode ray tubes (CRTs) used as computer monitors or television screens. Central processing units (CPUs) of computers accounted for about 19 percent of exported e-waste and the remainder (27 percent) consisted of a variety of small electronic products - other e-waste. The discussion in this chapter is organized, first, according to the cost estimates related to these three types of e-waste. This is followed by a description of the principal studies on which these estimates are based. The management options for which some cost data are available are recycling, landfill disposal, incineration, storage, and exporting. Data are not available, however, for all of these options for each of the three types of e-waste. The costs of all of these management options are available for CRTs, but only the costs of recycling and exporting CPUs and Other Electronic Waste are available.

4.1 Cathrode Ray Tubes

Table 4.1.2 summarizes the data available on the costs of recycling and exporting CRTs. Recycling consists of the following processes: collecting, processing in materials recovery facilities, and smelting of metals and glass. Items in a materials recovery facility are sorted and de-manufactured. Scrap metals and glass are sent to smelters to recycle glass and recover valuable metals. CRTs that are exported must be collected and sorted and then transported to seaports for shipment to other countries.

All of the costs in Table 4.1.1 are operating costs, except the costs of buildings and equipment for materials recovery facilities. Building and equipment costs are included on the assumption that new facilities would be required, or existing facilities would have to be expanded, to process the electronic waste that would have otherwise been exported. Although, as noted, de-manufacturing occurs in materials recovery facilities, data on this aspect of the recycling process is not reported separately in any of the available studies, but it is presumably a significant part of the "Other or Can't Classify" category.

TABLE 4.1.1

Costs of Recycling and Exporting CRTs in the U.S. - Basic Data
($ Per Ton)

	Collecting	Materials Recovery				Smelting	Exporting	
Source	Collection	Sort	Bldg	Equip	Other or Can't Classify	Glass/ Metals	Trans	Total
Kang & Schoenung, 2006			119	97				
Humboldt & Beck, 2007	420				618		74	494
Minnesota OEA (Monitors), 2001	349	48			125	150		397
Minnesota OEA (TVs), 2001	349	48			89	120		397
Macauley, et al, 2001					1167			
Jung & Bartel, 1998					528	1000	100	
USEPA, 1999 (Hennepin Cty)						667		
USEPA, 1999 (NJ)					316			
Snohomish Cty (Monitors), 2007					596			
Snohomish Cty (TVs), 2007					667			
Lane Cty (TVs 21-30"), 2007					500			
Lane Cty (Monitors), 2007					340			

Table 4.1.2 summarizes the data available on the costs of disposing of CRTs in landfills and incinerators. It also contains estimates of the cost of storing CRTs in apartments and commercial facilities.

TABLE 4.1.2

Costs of Other Management of CRTs - Basic Data
$ Per Ton

Source	Landfill or Incineration	Storage in Apartments	Storage in Commercial Facilities
Minnesota OEA (Monitors), 2001	409		
Macauley, et al, 2001	415	1340	933

Table 4.1.3 summarizes the *range* of costs for each management option in Tables 4.1.1 and 4.1.2 as estimates of the low, high, and average cost per ton. These estimates are used subsequently to determine the costs of three management scenarios and the costs of protection for those scenarios in Chapter 7.

TABLE 4.1.3

Costs of Recycling and Exporting CRTs: Summary Statistics
$ Per Ton

Alternative	Collection	Sorting	Bldg	Equip	Other or Can't Classify	Glass/ Metals Recovery	Total Cost Recycling	Transport for Export	Total Cost Export
Low Cost	349	48	119	97	107	135	855	74	471
Average Cost	385	48	119	97	448	568	1663	87	519
High Cost	420	48	119	97	700	1000	2383	100	568

4.2 Central Processing Units

Table 4.2.1 summarizes the data available on the costs of recycling and exporting CPUs. As was the case with CRTs, recycling consists of the following processes: collecting, processing in materials recovery facilities, and smelting – in this case, of metals only. Items in a materials recovery facility are sorted and de-manufactured. Scrap metals are sent to smelters to recover valuable metals. CPUs that are exported must be collected and sorted and then transported to seaports for shipment to other countries.

All of the costs in Table 4.2.1 are operating costs, except the costs of buildings and equipment for materials recovery facilities. Building and equipment costs are included, as noted above, on the assumption that new facilities would be required, or existing facilities would have to be expanded, to process the electronic waste that would have otherwise been exported.

TABLE 4.2.1

Costs of Recycling and Exporting CPUs in the U.S. - Basic Data
$ Per Ton

	Collecting	Materials Recovery				Smelting	Exporting	
Source	Collection	Sorting	Bldg	Equip	Other or Can't Classify	Glass/ Metals	Trans	Total
Kang & Schoenung, 2006			119	97				
Humboldt & Beck[a], 2007							74	
Minnesota OEA, 2001	349	48			270	636		397
Jung & Bartel[a], 1998							100	
Lane County, 2007					417			

a: Cost of transporting CRTs for export

There were no data reported in the literature for the costs of transporting CPUs for export or the costs of disposing of CPUs by landfill and incineration. We assume, in Table 4.2.1, that the costs of transporting CRTs for export is a good proxy for the costs of transporting CPUs for export. We also assume, in Chapter 7, that the costs of landfill and incineration are the same for CPUs and CRTs. Finally, we assume that CPUs are stored, but that they take up only half of the storage space as CRTs. This assumption is also evident in the cost scenarios developed in Chapter 7.

Table 4.2.2 summarizes the range of costs for each management option in Table 4.2.1 as estimates of the low, high, and average cost per ton. These estimates will be used subsequently to determine the costs of three management scenarios and the costs of protection for those scenarios in Chapter 7.

TABLE 4.2.2

Costs of Recycling and Exporting CPUs: Summary Statistics
$ Per Ton

Alternative	Collection	Sorting	Bldg	Equip	Other or Can't Classify	Glass/ Metals Recovery	Total Cost of Recycling	Transport for Export	Total Costs of Exports
Low Cost	349	48	119	97	270	636	1519	74	471
Average Cost	349	48	119	97	344	636	1592	87	484
High Cost	349	48	119	97	417	636	1665	100	497

4.3 Other Electronic Waste

Table 4.3.1 summarizes the data available on the costs of recycling and exporting Other Electronic Waste. As was the case with CRTs and CPUs, recycling consists of the following processes: collecting and processing in materials recovery facilities. Unlike CRTs and CPUs, no precious metals are recovered via smelting. Items in a materials recovery facility are sorted and de-manufactured. Other Electronic Waste that is exported must be collected and sorted and then transported to seaports for shipment to other countries.

All of the costs in Table 4.3.1 are operating costs, except the costs of buildings and equipment for materials recovery facilities. They are included (from Kang and Schoenung, 2006), as noted above, on the assumption that new facilities would be required, or existing facilities would have to be expanded, to process the electronic waste that would have otherwise been exported. The costs of transporting Other E-Waste for export come from the estimates by Humboldt and Beck (2007) and Jung and Bartel (no date) for CRTs. The total costs of exporting combine the costs of collecting and sorting, from Minnesota (2001), and transport for export (Humboldt and Beck, 2007, and Jung and Bartel, no date).

TABLE 4.3.1

Costs of Recycling and Exporting Other E-Waste in the U.S. - Basic Data
($ Per Ton)

Source	Collection	Sorting	Building	Equip	Other or Can't Classify	Transport for Export	Total Costs of Exporting
Kang & Schoenung, 2006			119	97			
Humboldt & Beck[a], 2007						74	471
Jung & Bartel[a], 1998						100	497
Minnesota OEA, 2001	349	48			86		484

a: Cost of Transporting CRTs for Export

Table 4.3.2 summarizes the range of costs for each management option in Table 4.3.1 as estimates of the low, high, and average cost per ton. These estimates will be used subsequently to determine the total costs of three possible management scenarios and the costs of protection for those scenarios in Chapter 7.

TABLE 4.3.2

Costs of Recycling and Exporting Other E-Waste: Summary Statistics
($ Per Ton)

Alternative	Collection	Sorting	Bldg	Equip	Other or Can't Classify	Glass/ Metals Recovery	Total Cost of Recycling	Transport for Export	Total Costs of Exports
Low Cost	349	48	119	97	86	100	799	74	471
Average Cost	349	48	119	97	86	100	799	87	484
High Cost	349	48	119	97	86	100	799	100	497

4.4 Principal Studies

4.4.1 Kang and Schoenung

Hai-Yong Kang and and Julie M. Schoenung of the University of California-Davis, in their study of "*Economic Analysis of Electronic Waste Recycling: Modeling the Cost and Revenue of a Materials Recovery Facility in California,*" (2006) developed an input/output model to estimate the costs and revenues of recycling personal computers from materials recovery facilities in California. They focused on personal computers as a target product since PCs (consisting of CRTs and CPUs) are the most common source of electronic waste (Kang and Schoenung, 2006).

To discover the most significant cost and revenue drivers, their model incorporated all the items that can increase cost or revenue, such as materials, labor and system/component resale. The state of California treats CRTs as hazardous waste and thus makes it illegal to incinerate or to send them into landfills. Therefore, the only option for disposal of CRTs in California is to recycle them. The method of technical cost modeling (TCM) was employed to estimate the costs and the revenues related to materials recovery facilities.

Unfortunately, their materials recovery facility data combines data on CRTs and CPUs and it is not possible to separate them, given the information provided in this source. Also, some of their data are for *net* costs (costs net of revenues from the sale of recovered materials) and it is gross costs that are required in this study. Their estimate of 33 cents per kilogram (=$300 per ton) for recycling CRTs can be used, however, in the CRT cost tables. And their costs of building and equipment can be used for materials recovery facilities in the cases of CRTs, CPUs and Other Electronic Waste.

4.4.2. Humboldt and Beck

The electronic e-waste collectors and recyclers under the California Recyclers Act (CRA) are obliged to prepare and submit an annual net cost report to the California Integrated Waste Management Board (CIWMB) by March first every year. The objective of this report is to assist the CIWMB in managing e-waste and determining future changes. The scope of the CRA includes recycling services for covered electronic wastes (CEWs) with viewable screen size greater than four inches. The CEWs covered by the CRA are: cathode ray tube (CRT) devices (including televisions and computer monitors); LCD desktop monitors; laptop computers with LCD displays; LCD television; and plasma televisions.

The method of reporting requires submitting self-reported data to a team from Humboldt State University's Office for Economic and Community Development and R.W. Beck Inc.. This team is charged with developing a reporting system and evaluating the first two net cost reports. The collectors and recyclers of e-waste were given a guide to net cost reporting and asked to submit three different forms. Table 4.4.2.1 is an example of a report sample analyzed by the research team (Humboldt and Beck, 2007).

Table 4.4.2.1

Summary of Sample of Reports Analyzed

Item	Analyzed Sample	Percent 2005 totals
Number of Collector Reports	29	11%
Number of Dual Entity Reports*	20	71%
Total Recovered pounds CEW	43,100,991	66%
Total Recycled Pounds CEW	44,716,438	69%

* Dual entity reports cover both recovery and recycling, so total of 49 reports covering recovery activities were included in the study sample.
Source: Humboldt and Beck, 2007

The majority of the collectors and recyclers who participated in this program reported similar net cost per pound, but a small number of the participants reported a cost that is either significantly higher or lower than the rest of the participants. The only explanation given was that net cost reporting differences were due to different management practices, differences in targeted generated types, volume of collection, etc. The findings that are relevant for this study are reported on Tables 4.4.2.2, 4.4.2.3, and 4.4.2.4, below.

Table 4.4.2.2 provides a summary of the revenues, costs, and net costs of recovering (collecting and transporting) e-waste. The weighted average cost data were converted to a per ton basis and used in this study.

Table 4.4.2.2

Summary of Recovery Net Cost per Pound Estimates

	Item	Weighted Average	Mean	Median	Percentage lower than standard payment Rate
	Revenue	3.9	3.8	0.0	NA
Recovery	Cost	21.0	24.6	17.9	NA
	Net cost	17.1	20.8	15.3	63%

1) Based on a sample of 49 reviewed and confirmed reports.
2) If only the 22 reports listing recovery revenue are considered, the weighted average recovery revenue is 6.7 cents per pound, the mean is 8.5 cents per pound, the median is 8.0 cents per pound and 59% of reports showed recovery net costs greater than the standard payment rate.
3) Net cost equals costs minus revenue. However, due to the nature of the statistics, this formula does not hold exactly for the median column.

Source: : Humboldt and Beck, 2007

Table 4.4.2.3 provides a summary of the revenues, costs, and net costs of recycling (sorting, de-manufacturing, etc.) e-waste. The weighted average cost data were converted to a per ton basis and used in this study.

Table 4.4.2.3

Summary of Recycling Net Cost per Pound Estimates

	Item	Weighted Average	Mean	Median	Percentage Lower than Standard Payment Rate
	Revenue	5.7	5.5	5.1	NA
Recycling	Cost	30.9	39.1	31.8	NA
	Net Cost**				

* Based on a sample of 20 reviewed and confirmed reports.
** Net cost equals cost minus revenue. However, due to the nature of the statistics, this formula does not hold exactly.

Source: : Humboldt and Beck, 2007

Table 4.4.2.4 provides a summary of the sources of the revenues, costs, and net costs of recycling (sorting, de-manufacturing, etc.) e-waste. As above, the weighted average cost data were converted to a per ton basis and used in this study.

Table 4.4.2.4

Breakdown of Weighted Average Recycling Costs

Measure	Labor	Transportation	Other*	Total
Percent of Total cost	40%	6%	54%	100%
Cents per Pound	12.2	2.0	16.7	30.9

Source: : Humboldt and Beck, 2007

4.4.3 Minnesota OEA

To find out the barriers to, and the cost of, recycling e-waste, Minnesota's Office of Environmental Assistance, together with industry partners (Sony Electronics, Waste Management-Asset Recovery Group and Panasonic) and local communities and counties, organized a joint project to collect and recycle electronic wastes. Industry partners donated $25,000 to the project. There was no specific target as to what should be collected; accept "anything with a cord or a battery" seemed to be the message for the public. The project targeted approximately 1.3 million participants; however, only 9,000 people took part in the collection project. Within three months, the organizers of the Minnesota project collected 575 tons of electronic waste products.

The data from the project were analyzed extensively in an 87-page report (Minnesota Office of Environmental Assistance, 2001). Detailed data on costs per pound of recycling (collection, sorting, de-manufacturing, smelting, other types of materials recovery, and transporting) appear on page 47 for televisions, page 48 for computer monitors, page 49 for CPUs, and page 50 for Other Electronic Waste. These costs were converted to dollars per ton and used in the construction of Tables 4.1.1, 4.2.1 and 4.3.1.

4.4.4 Macauley, et al

Macauley, et. al, of Resources for the Future conducted a study, "*Modeling the Cost and Environmental benefits of Disposal Options for End-of-Life Electronic Equipment: the Case of Used Computer Monitors*," (2001), in which they used a three-step approach built on a CRT life-cycle framework and a computer monitor policy simulation (COMPS) model to calculate private and social costs of alternative methods of disposing of CRTs. The disposal methods examined in this study are storage, incineration, municipal solid waste landfill, drop-off-center recycling for residential consumers, hazardous waste disposal for non residential consumers, and commercial recycling.

The model was designed to determine the fate of residential and nonresidential monitors in the United States as soon as they reach their end of life. They also estimated the retired numbers of CRTs based on 1998 historical sales data at the national level, although CRTs were not reported there as a separate item.

The model assumes that residential and nonresidential consumers, consisting of a sample of 2000 each, will act rationally and use the least cost disposal method. Macauley, et al,(2001) assumed that residential and nonresidential consumers cannot make the choice between incineration and landfill but that waste haulers will make that decision for them. They also divided the residential consumers into those who live in apartments and in houses, facing "with or without" scenarios of unit pricing to pay disposal costs. Nonresidential consumers are divided into hazardous and non-hazardous waste generators in order to calculate storage cost differences and the different disposal options for each. Monte Carlo simulation techniques were used to estimate the distribution of obsolete monitors into the six disposal options. The simulations were done in Microsoft Excel and the COMPS model calculated the private and the social cost of each allocation. Table 4.4.4.1 exhibits the estimated mean social cost per monitor, with standard deviations in parentheses.

Table 4.4.4.1

Baseline Case: Mean Social Costs*
($ Per Monitor)

	Residential Consumers				**Nonresidential Consumers**	
	Apartment dwellers		House dwellers			
End of Life Option	with unit pricing	without unit pricing	with unit pricing	without unit pricing	Hazardous waste generators	Nonhazardous waste generators
Storage	26.80 (10.55)	26.80 (10.55)	0	0	18.65 (4.14)	18.65 (4.14)
Incineration	3.00 (1.08)	1.03 (0.09)	3.00 (1.08)	1.03 (0.09)	NA	1.03 (0.09)
Landfill	3.00 (1.08)	0.72 (0.27)	3.00 (1.08)	0.72 (0.27)	NA	0.72 (0.27)
Drop off	22.53 (9.04)	22.53 (9.04)	22.53 (9.04)	22.53 (9.04)	NA	NA
Hazardous	NA	NA	NA	NA	6.06 (0.38)	NA
Recycling	25.50 (7.55)	25.50 (7.55)	25.50 (7.55)	25.50 (7.55)	25.50 (7.55)	25.50 (7.55)

Source: Macauley et al. (2001)

The number of monitors discarded was estimated, but the allocations to landfill and incineration were based on the municipal solid waste national average (22% to incineration and 78% to landfill). A little less than 0.5% of the collected monitors were designated hazardous. Table 4.4.4.2 shows the end of life (EOL) percentage allocation by consumer group. Table 4.4.4.3 shows the number of CRTs.

Table 4.4.4.2

Baseline Case: EOL Allocation by Consumer Group
(%)

	Residential Consumers				Nonresidential Consumers	
	Apartment dwellers		House dwellers			
EOL Option	with unit pricing	without unit pricing	with unit pricing	without unit pricing	Hazardous waste generators	Nonhazardous waste generators
Storage	1.05	0.85	98.50	33.02	0.35	0
Incineration	21.33	21.60	0.20	14.53	NA	12.70
Landfill	75.62	76.60	0.35	51.51	NA	87.25
Drop off	1.55	0.90	0.90	0.90	NA	NA
Hazardous	NA	NA	NA	NA	99.20	NA
Recycling	0.45	0.05	0.05	0.05	0.45	0.05

Source: Macauley et al. (2001)

Table 4.4.4.3

Baseline Case: EOL Quantity Allocation
(Number of CRTs)

	Residential Consumers				Nonresidential Consumers		
	Apartment dwellers		House dwellers				
EOL Option	With Unit Pricing	Without Unit Pricing	With Unit Pricing	Without Unit Pricing	Hazardous waste generators	Nonhazardous waste generators	Total
Storage	1,078	7,924	144,700	438,200	466	0	592,368
Incineration	21,910	201,400	294	19,2800	NA	1,674,000	2,090,404
Landfill	77,660	714100	514	683,600	NA	11,500,000	12,975,874
Drop off	1,592	8,390	1,322	11,940	NA	NA	23,244
Hazardous	NA	NA	NA	NA	132,000	NA	132,000
Recycling	462	466	73	664	599	6,589	8,853
Total	102702	932,280	146,904	1,327,204	133,064	13,180,589	15,822,743

Source: Macauley et al. (2001)

The data in 4.4.4.1, 4.4.4.2, and 4.4.4.3 were used in conjunction with data on average weight per monitor to determine the weighted average cost per ton of each disposal option.

4.4.6 Jung and Bartel

Leah B. Jung of Vista Environmental and Thomas Bartel of Unisys Corporation wrote a paper about The San Jose Project (Jung and Bartel, 1998). Three retailers in San Jose, CA - Computer City, Fry's Electronics, and OfficeMax - volunteered as locations for the collection of computer equipment. In five weeks, 61,600 pounds of computer equipment was collected. 49% of the total collected was computer monitors that were not in working order. The San Jose Computer Collection and Recycling Project sold the collected equipment if it was in working condition and scrapped it for materials recovery if it was not usable. The breakdown of items collected, by percent of total weight, is indicated in Table 4.4.6.1. Over two-thirds of the items were CPUs and Monitors.

Table 4.4.6.1

Equipment Mix and Percent of Items Collected

Type of Equipment Collected	Percent
CPU's	35
Monitors	33
Printers	15
Keyboards	12
Peripherals	2
Misc. Parts (circuit boards, fans, etc)	2
Laptops	1

Source: Jung and Bartel, 1998

Table 4.4.6.2 summarizes the principal total recycling costs. These costs were combined with the quantities reported in the study to determine the cost per ton of recycling and transportation.

Table 4.4.6.2

Cost Summary: Monitors Recycled in the U.S.

Type of Cost	Cost
Transportation	$ 480.00
Sorting and Dismantling	7,500.00
Monitor Recycling	15,130.00
Computer Recycling Cost	$ 23,110.00

Source: Jung and Bartel, 1998

4.4.7 USEPA, 1999

The United States Environmental Protection Agency is the sponsor of a pilot program aimed at examining alternative models of electronic waste disposal. One product of this program is the Common Sense Initiative (CSI), a study of residential e-waste collection and disposal in five "communities." The objective of this study was to create a report from data gathered from existing CSI sponsored pilot programs, as well as End-of-Life Electronics and Electrical (EEE) waste collection programs. The five communities are Binghamton/Somerville (New York), Naperville/Wheaton (Illinois), Union and other counties in New Jersey, San Jose (California), and Hennepin County (Minnesota). As noted above, the San Jose project is the subject of the Jung and Bartel study (1998).

The CSI study could not establish reliable relationships between the findings for the five projects from the data collected, because each program used different collection methods to gather data. Thus, we were unable to use the collection cost data in this study.

The most reliable data were those of the cost of glass and metals recovery (smelting) for Hennepin County and the costs of materials recovery facilities in New Jersey. Both of these costs appear in Table 4.1.1.

4.4.8 Snohomish County

The Snohomish County (Washington) Solid Waste Management Division did research on take-back programs. A take back program is one in which, when a desktop computer, laptop or printer becomes obsolete, it is packaged and shipped by the owner to the manufacturer. The objective of the research was to examine the cost and the accuracy of the take back programs. In this research Snohomish County found that HP, Dell and IBM computers and peripherals cost $68.00 per unit and that Lexmark desktop printers cost $50. Given average weights of the various units, it was possible to convert these costs to a cost per ton basis.

4.4.8 Lane County

Residents of Lane County (Oregon) have the option of discarding electronic waste in a landfill or transporting it for recycling. Disposal fees are charged in both instances, with higher fees charged for recycling. We assume that the fees charged for both management options are a good proxy for costs.

Table 4.4.8.1 lists the charge per item. Average weights of these items were used to determine the cost per pound and multiplied by 2000 to determine the cost per ton.

Table 4.4.8.1

Cost Per Unit of Landfilling and Recycling Electronic Waste

	Landfill Cost	Recycling cost
Computer System	$7 to $13	$13.00
Big Screen TV	$13.00	20.00
TV set < 10 Inches		5.00
TV set 11 – 20 Inches		10.00
TV set 20 – 30 Inches		15.00
Consoles and TV > 30 Inch		20.00
CPU’s		5.00
Laptops		5.00
Monitors		8.00
Copy Machines		35.00

Source: Lane County, 2007

CHAPTER V

The Evolving State Legal Environment

If the Basel Ban were adopted by the United States, what would happen to the disposal of e-waste that would have been exported? One possibility is the application of current management practices, or "business as usual." In this scenario, the e-waste diverted from exports would be allocated as described in Chapter 3. It is notable that less than 1 percent of the e-waste is currently disposed of in hazardous waste facilities (McCauley, et al, 2002), even though many scientists consider much of it to be "hazardous." This is a clear indication that only a small percentage of the e-waste stream is subject to the federal government's Resource Conservation and Recovery Act (RCRA).

The bulk of the country's e-waste is not subject to RCRA because it is currently generated by thousands of entities (households and firms) whose contribution to the waste stream is below the RCRA aggregate weight threshold. So far, this part of the regulatory effort has been left up to the U.S. states. Many of them are simply in the process of considering e-waste disposal legislation. A growing number, however, have banned landfill disposal of CRTs. A few have adopted take-back and/or recycling mandates. Some have imposed disposal fees to help pay the costs of recycling and a couple of the states have even required the ban of certain substances in the manufacture of new electronic equipment. Although it is too early to tell for certain, the legislation and regulations that appear to be evolving in the states indicate that a growing percentage of the e-waste diverted from exports will probably be recycled. Although only a relatively small part of e-waste is currently recycled, this review indicates that a growing portion of e-waste is likely to be recycled in the future. For the purposes of this study, this means that it is necessary to assume that recycling will play a role, perhaps an important role, in the management of e-waste that would not be exported if the Basel Ban were adopted by the United States. As noted in Chapter 6, recycling is important in two of the three policy scenarios for the management of e-waste no longer exported.

5.1 Growing Recognition of the Problem

At the beginning of the twentieth century, households and families were responsible for managing their own solid waste, which at that time was mainly composed of organic materials that could be used for fuel, crop fertilizers or livestock feed. Industrialization and population growth in American cities, however, eventually generated large amounts of both domestic and industrial wastes (Tavares, 2001), the disposal of which exceeded the capabilities of individual households and firms. Governments became involved in solid waste disposal.

The federal government passed the first Solid Waste Disposal Act in 1965. It was amended in 1970 by the passage of the RCRA. The objectives of these actions were to facilitate government participation in, and oversight of, solid waste disposal, and to provide technical and financial help (Luton, 1996; United States Environmental Protection Agency, 1989). RCRA amendments in 1976 made all open dumps illegal and allowed for contracting by private companies for resource recovery (Luton, 1996). To promote environmentally safe disposal, in 1979 the EPA prepared guidelines for state solid waste management (Tavares, 2001). In 1990, landfill standards were amended, designs for new landfills and upgrades for existing landfills were suggested, new closure and post-closure standards were specified, and the use of double liners of flexible materials and leachate collection systems was enforced (Steuteville and Goldstein, 1993). In the event of a state's failure to abide by the minimum regulatory standards of RCRA's Subtitle D, the federal government promised to regulate the development and the implementation of the state's programs (United States Environmental Protection Agency, 1989; Luton, 1996).

Electronic waste has been (and still is) a relatively small part of the solid waste disposal stream. Accordingly, the federal government has not singled out e-waste for special legislation. In so far as it regulates e-waste, it does so according to the provisions of the RCRA. As noted above, this means that only relatively large commercial and industrial sources of e-waste are under its purview and that the bulk of e-waste regulation is a state government responsibility.

Although the issue of electronic waste disposal is in its early stages in state legislatures, the states have taken several measures to find solutions for disposing of the increasing volume of e-waste, including recycling programs, donation and reuse, banning CRT's from landfills, income tax credits, requiring advanced recovery fees, and launching extended producer responsibility programs for obsolete electronic products (Griffin, 2005). By the end of the 2006-2007 legislative session, 13 states had enacted laws related to the disposal of electronic waste and 14 additional states were considering e-waste disposal legislation in 2008.

In Oklahoma, the House of Representatives began looking at the disposal of CRTs in 2002. A bill which required the Department of Environmental Quality to set up recycling or handling regarding electronic equipment with CRTs was referred to the

Rules Committee, but never reached the floor for a vote. In 2003 and 2004, several more bills related to e-waste disposal were proposed. In 2006, electronic waste was brought to the forefront with proposed legislation requesting a study and the formation of a task force.

At the end of the summer of 2003, the Governor of Oregon signed SB 867 into law. This act encourages the state to participate with the National Electronics Products Stewardship Initiative and to follow national guidelines for the management of end-of-life electronics. A state advisory committee was created along with a pilot program on recycling and re-using electronics. This program promotes shared responsibility with the involvement of individual owners, retailers, and manufacturers.

During 2004, work began in Connecticut on four bills involved with recycling. One would have established recycling programs operated by municipalities and other qualified organizations, to be funded by an advance recovery fee (ARF) of $10 per item. At the same time, a similar proposal which allowed only municipalities to run programs and did not specify fees was under consideration.

In 2002, legislation which would put into place extended product responsibility for hazardous electronic equipment and mandatory collection centers was referred to committees of the Illinois Legislature. In 2005, both the Illinois State House of Representatives and the Illinois Senate passed electronic waste disposal legislation and the Illinois governor signed it. The Computer Equipment Disposal and Recycling Commission were established by this legislation. This commission is charged with investigating problems associated with the disposal and recycling of computers.

5.2 The Growing Movement to Ban Landfill Disposal of E-Waste

In April, 2000, the Massachusetts Department of Environmental Protection was the first state agency to receive authority to ban the disposal of any electronic equipment with cathode ray tubes (CRT) in landfills and incinerators (Northeast Recycling Council, 2001). Shortly thereafter, Florida passed stringent regulations regarding landfill and incineration after recognizing CRTs as hazardous waste (Macauley, 2002). California state legislators also recommended recycling and recovery of electronic wastes and in 2001 and 2002 banned the landfill of televisions and computer monitors (Totten and Glen, 2002).

Minnesota considers CRTs as the largest source of lead in the municipal waste stream and in 2003 passed a law banning the disposal of electronic wastes containing CRTs as garbage. The claim that high levels of lead and cadmium in the municipal waste streams are due to CRT disposal, however, has been challenged by industry experts who claim that there are no available data that show the exact quantity of CRTs (Macauley, 2002).

5.3 Increasing Reliance on Disposal Fees

Thirty-nine county solid waste systems in Washington were surveyed in 1997 to examine the feasibility of total dependence on disposal fees as a source of revenue. The survey found that all counties were spending money on active and closed landfills or recycling programs and had incurred debt for waste management (Washington Solid Waste Policy Forum, 1999).

CRT recycling is an expensive option; in fact, recycling costs normally exceed the value of products recovered. Charging an amount sufficient to make up this difference may increase disposal cost so much that illegal dumping would increase. An association between end-of-life fees and illegal disposal was found according to a government survey. People started abandoning CRTs along country roadways and creek beds, and in thrift stores and television repair shops (Dowell, 2002). Therefore, an alternative option to the high cost of recycling was needed. States started to experiment with a variety of ways to finance the disposal of electronic wastes.

California has long been associated with the Green Movement. In fact, there are more environmentally-related laws in California than in most other states. An advanced recovery fee specifically related to hazardous electronic waste, to be collected at the point of sale, was established by Senate Bill 20 in September of 2003. These funds, which have been collected since January 1st of 2005, are to be used to cover costs involved with recycling electronics. The fees are modest, ranging from $6 for the smallest monitors up to $10 for the largest. Because of the large number of items involved in the State of California, however, $73 million was collected in the first year alone. Minimal administrative fees, to cover the costs to manufacturers to facilitate collection and dispersal of these funds, are not included in the $73 million figure. Subsequent fine-tuning to adjust for electronics of unknown geographic origin and other minor challenges occurred in 2006. Manufacturers and retailers are now required to affix permanent labels identifying "sold in California" to mark eligible pieces. In addition, they are required to submit reports on quantities sold. This California act, the Electronic Waste Recycling Act of 2003, mirrors recent European Union directives on disposal of electronic waste. It also restricts the use of lead, mercury, cadmium and hexavalent chromium in product manufacturing.

These programs form the core of California's policy on electronic waste recycling. Hewlett-Packard operates a large recycling facility there, and Sony Corporation participates heavily, too. According to California state law, generators have a great deal of responsibility. They must address collection, handling, transportation, processing, recovery, reuse, and recycling of electronics products which they sell. However, flexibility is given in that manufacturers do have an option to pay a fee instead of handling all the steps themselves. Actually, responsibility is considered to be shared, because, as noted, consumers pay a modest advance recycling fee which provides the funding. In California, all electronics which have a 4-inch monitor (diagonally) or greater for all possible categories of owners fall under these regulations.

5.4 Take-Back and Recycling Mandates

The proliferation of electronic waste products has forced municipal governments to subsidize and bear much of the cost of state unfunded mandates. In most instances, the manufacturers of products have shifted the full responsibility of disposal costs to tax payers and local governments at a cost of billions of dollars a year. Product take-back policies could save significant money for both consumers and local governments, reduce waste, increase recycling, and create an economic incentive to design a product that is an environmental friendly (Grassroots Recycling Network, 2005).

The state of Maine in 2001 established a pilot program that required consumers to hold onto their receipts and return items to the place of purchase, instead of sending them to municipal waste disposal facilities. This program, To Protect Public Health and the Environment through the Collection and Recycling of Electronic Waste, was passed by the Maine Legislature in May of 2003. This bill requires all producers of electronic equipment sold in Maine to submit a plan for the collection, recovery, and recycling of electronic waste. These plans are to be funded by the producers. This is considered to be an Extended Producer Responsibility [EPR] system, although there is some shared responsibility for electronic waste with the consumer.

Maryland took a similar approach in summer 2005 when state legislators required manufacturers to offer a take-back program to customers free of charge or pay a fee to the state. Manufacturers who produced an average of more than 1000 computers during the past three years were assessed an initial $5000 fee. If the producer properly labels, registers, and operates a free take-back program, then their annual fee will be reduced to $500. Most of these funds are put into a trust fund with monies being used to administer collection and recycling programs; a small share goes to the state's General Fund.

In January 2006, Maine became the first state to pass a law that obligates television and computer manufacturers to take back their discarded products, and to recycle or safely dispose of them. Jon Hinck, an attorney with the Natural Resources Council of Maine, said "It's time to bring them out of the attics, out of the garages, out of the closets, out of the basements," and added "It's going to be a lot cheaper than it's been before, and we're happy to say that these things will all be recycled in an environmentally sound way."(Maine Revised Statutes, 2003)

In 2005, New York legislators proposed an Electronic Equipment Recycling Act that provided for research into an effective and efficient recycling program for the state.

By May of 2005, the legislation had evolved to a policy that assigns responsibility for collecting and recycling to product manufacturers who must submit their plans to state authorities. Encouraging recycling is further accomplished with an amendment that gives tax credits to people who recycle any of a long list of electronic equipment. More thorough guidelines were be formulated by the commissioner of environmental conservation.

5.5 State E-Waste Laws and Bills under Consideration for 2008

Table 5.5.1 summarizes the legal actions related to e-waste disposal that the states had taken prior to the 2008 legislative session. Nine states had landfill disposal bans and/or mandatory recycling. Five of these states had established mechanisms for funding disposal, especially recycling. An additional four states had funding mechanisms, but no landfill disposal bans. Altogether, these 13 states accounted for 35.5 percent of the nation's population.

Figure 5.5.1 indicates that, by the end of 2008, there could be another 11 states added to the seven that already require "producer responsibility" and two more states joining California in requiring advance recovery fees. Thus, it is conceivable that the number of states with e-waste disposal legislation could double and the percentage of the population subject to state e-waste disposal legislation could be as high as 64 percent.

Given the review outlined in this chapter, it is hard to escape the conclusion that state governments are going to force the recovery or recycling of a significantly greater percentage of the nation's electronic waste.

Table 5.5.1

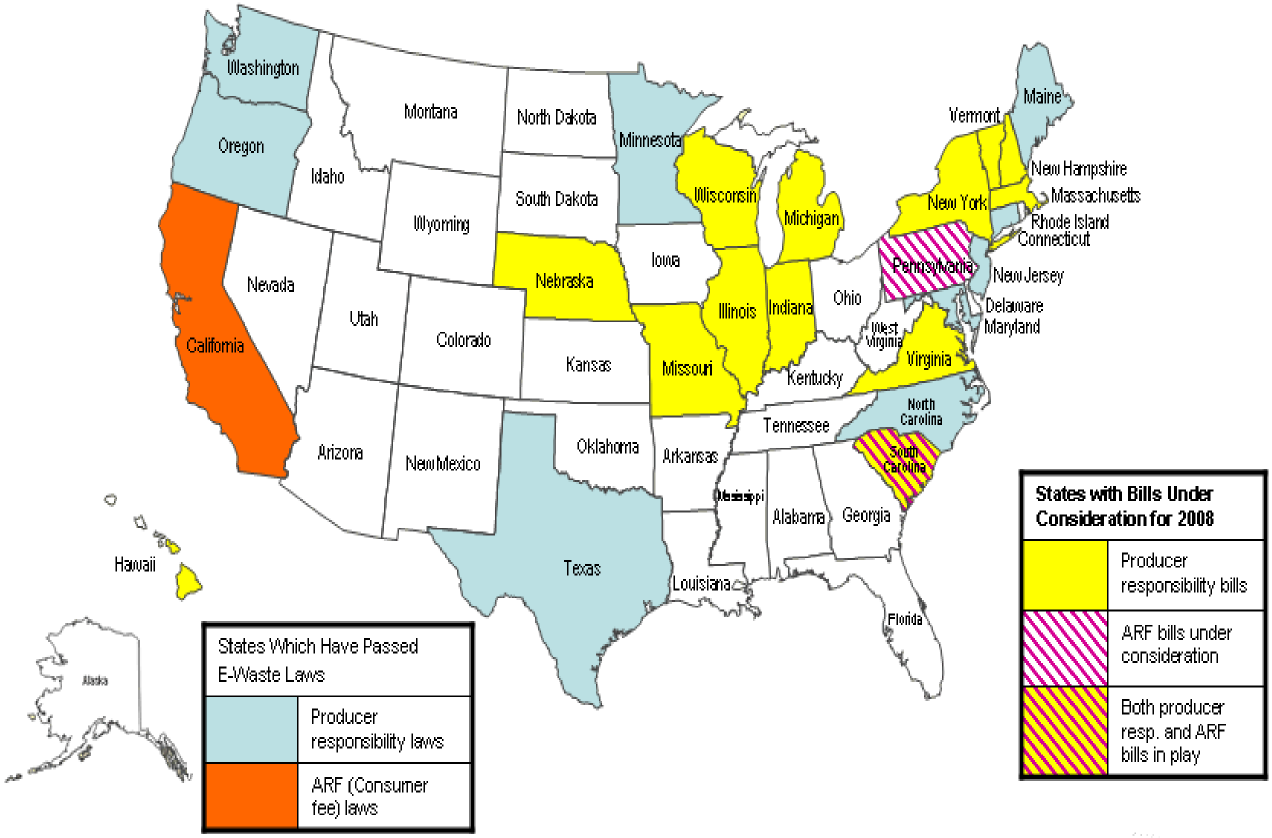
Comparison of Selected Elements of State E-Waste Laws

Legislative Element	AR	CA	CT	ME	MD	MA	MN	NH	NC	OR	RI	TX	WA
Funding Mechanism													
ARF		✓											
Producer pays			✓	✓			✓		✓	✓		✓	✓
Flat fee					✓								
Collection & Recycling Standards or Restrictions													
Landfill ban	✓	✓	✓	✓		✓	✓	✓		✓	✓		
Export restrictions		✓	✓										
Ban on prison labor							✓					✓	✓
Recycling standards			✓	✓								✓	✓
Mandatory recycling goals							✓						
Product Requirements or Restrictions													
Product label to identify manufacturer or brand		✓	✓	✓	✓		✓		✓	✓		✓	✓
Provisions tied to the RoHS Directive regarding the use of certain hazardous substances		✓					✓						

(Source: Luther, 2007, Managing Electronic Waste: An Analysis of State E-Waste Legislation August 29, 2007)

Figure 5.5.1

State E-Waste Laws and Bills under Consideration for 2008



Source: http://www.e-takeback.org/docs%20open/Toolkit_Legislators/state%20legislation/state_leg_main.htm

CHAPTER VI

Post-Ban Management of Currently-Exported Electronic Waste

In chapter 3, we determined that approximately 243,000 tons of e-waste were exported in 2005. The objective of this chapter is to determine what would have been done with this e-waste if exports had been banned. In essence, this is an application of the principle of cost-benefit analysis that the appropriate comparison for a policy is the situation *with* the policy versus the situation *without* the policy.

Given the uncertain future of U.S. laws and regulations regarding the management of e-waste, there is no obvious alternative management scenario. To represent the possible range of management options, we develop three scenarios: (1) the e-waste that would have been exported is managed as was the e-waste not exported in 2005, (2) landfill disposal and incineration of CRTs that would have been exported are banned and their recycling is subsidized, instead, and (3) all e-waste that would have been exported is recycled, instead.

6.1. Scenario 1: E-Waste Managed As In 2005

Scenario 1 is designed to represent the case where the policy environment remains largely unchanged from what it was in 2005. It turns out that this scenario also produces the lower bound of the cost of managing e-waste that would have been exported.

Table 6.1 summarizes the estimates of the allocation of the 243,000 tons as if they were not exported, assuming that they would be managed in the same way as the e-waste not exported was managed in 2005.

Table 6.1

Post-Ban Management of Electronic Waste Not Exported
Scenario 1: Managed As In 2005

Waste Product	Recycle	Landfill	Incinerate	Store - Apts	Store - Comm Estabs	Store - Houses	Total Not Exported
CPUs							
Tons (000)	5.06	13.92	0.40	0.40	0.01	25.65	45.43
% CPUs Not Exported	11.14%	30.64%	0.87%	0.87%	0.01%	56.46%	
CRTs							
Tons (000)	13.22	62.06	1.76	0.84	0.04	54.20	132.12
% CRTs Not Exported	10.01%	46.97%	1.33%	0.63%	0.03%	41.02%	
Other E-Waste							
Tons (000)	8.43	28.11	0.81	28.21	0.00	0.00	65.55
% Other Not Exported	12.86%	42.88%	1.23%	43.03%	0.00%	0.00%	
Total E-Waste							
Tons (000)	26.71	104.09	2.96	29.44	0.05	79.85	243.10

Source: Percentages and tons exported are author's calculations based on data in United States Environmental Protection Agency (2007b)

Table 6.1 represents how the 243,000 tons is allocated based on data from Electronic Waste Management in the United States (United States Environmental Protection Agency, 2007b). For the e-waste not exported because of the assumed adoption of the Basel Ban, we assume that the pre-ban methods of management; that is, recycling, landfill disposal, incineration, and storage in apartments, houses, or commercial facilities as they were applied to the e-waste that was actually not exported in 2005.

The total amount of CPU's generated in 2005 and allocated to exports was 45,430 tons. Under the assumptions of this scenario, 11.14% of it would have been recycled, 30.64% would have been landfilled, 0.87% would have been incinerated, and 57.34% would have been stored in apartments, houses or commercial facilities. CRT's exported accounted for 132,120 tons, 10.01% of which would have been recycled, 46.97% of which would have been landfilled, 1.33% of which would have been incinerated, and 41.69 of which would have been stored. Other e-waste exported totaled 65,550 tons, of which: 12.86% would have been recycled, 42.88% would have been landfilled, 1.23% would have been incinerated, and 43.03% would have been stored.

Figures 6.1.1 – 6.1.3 illustrate the actual allocation of e-waste that was not exported in 2005; that is, the percentages from Table 6.1

Figure 6.1.1: Post-Ban Management of CPUs Not Exported Scenario 1: Managed As In 2005 (% by weight)

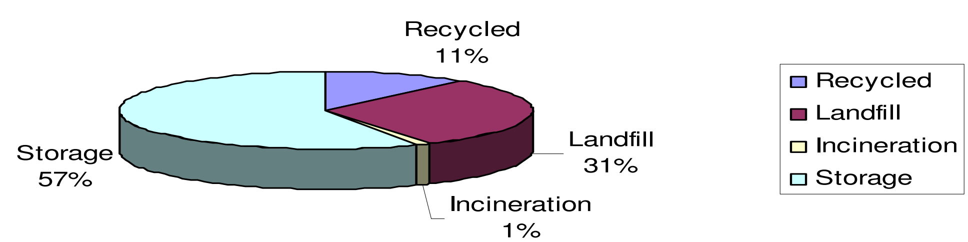


Figure 6.1.2: Post-Ban Management of CRTs Not Exported Scenario 1: Managed As In 2005 (% by weight)

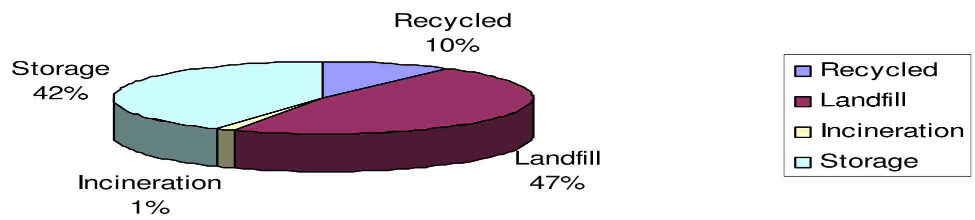
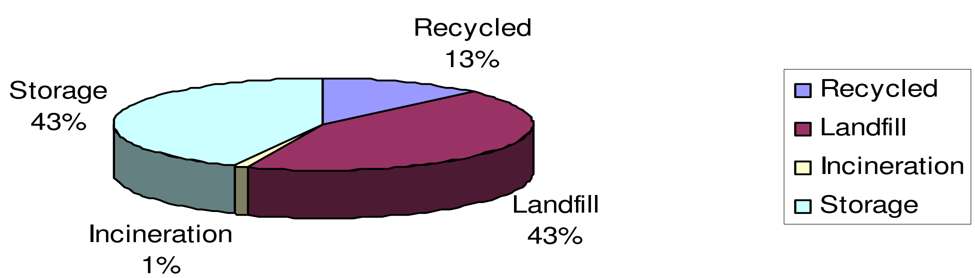


Figure 6.1.3: Post-Ban Management of Other E-Waste Not Exported Scenario 1: Managed As In 2005 (% by weight)



6.2. Scenario 2: CRTs Regulated and Subsidized; CPUs and Other E-Waste Managed As In 2005

This scenario reflects the growing movement to ban the landfill disposal and incineration of CRTs, as outlined in Chapter 5. It also reflects the observation that recycling of CRTs would not occur in large numbers without a subsidy to recyclers (as currently in California). It is essentially the baseline scenario for the management of CRTs outlined in McCauley, et al (2001).

Table 6.2 summarizes the allocation of e-waste that would have been exported under the assumptions of Scenario 2.

Table 6.2

Post-Ban Management of Electronic Waste Not Exported
Scenario 2: Landfill and Incineration Disposal of CRTs Banned,
CRT Recyclers Paid $10 Per Unit,
CPUs and Other E-Waste Managed As In 2005
(Thousands of Tons)

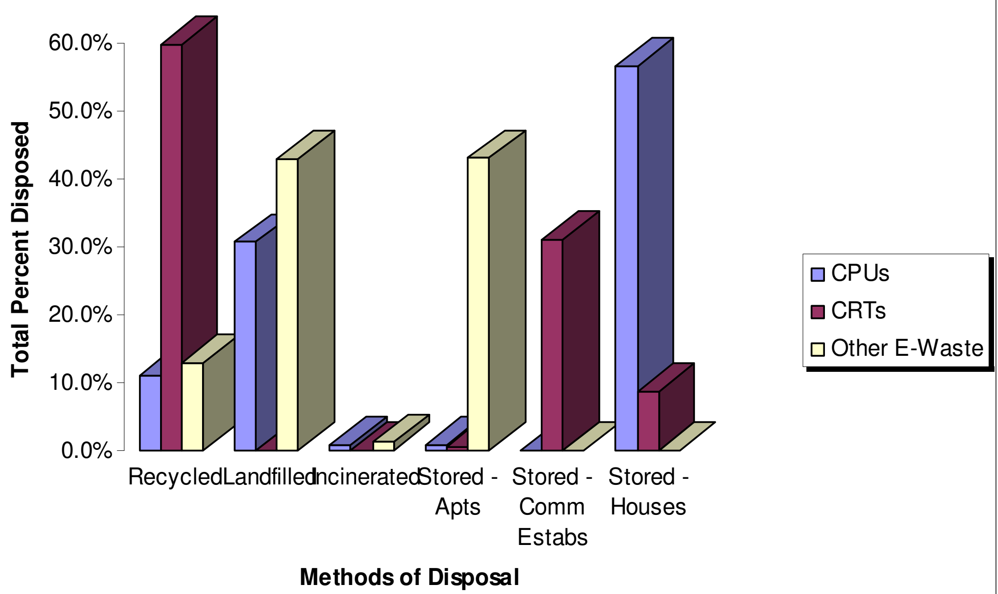
Product	Recycled	Landfilled	Incinerated	Stored - Apts	Stored - Comm Estabs	Stored - Houses	Total
CPUs	5.1	13.9	0.4	0.4	0.0	25.6	45.4
CRTs	78.9	0.0	0.0	0.7	41.0	11.6	132.1
Other E-Waste	8.4	28.1	0.8	28.2	0.0	0.0	65.6
Total	92.4	42.0	1.2	29.3	41.0	37.2	243.1

Sources: CPUs and Other E-Waste - author's calculations based on data in United States Environmental Protection Agency (2007b); CRTs - author's calculations based on data in McCauley, et al (2001), Tables D-B1and D-B2

When the disposal of CRTs is banned from incineration and landfill, and recyclers are required to pay $10 per unit, the recycling rate increases from 10% to 60%, according to the cost-minimization model developed in McCauley, et al.(2001). Due to the high cost of recycling, the quantity stored in commercial facilities also increases (Macauley, et al, 2001). The management of CPUs and other e-waste stays the same as shown in table 6.1 and figures 6.1.2 and 6.1.3 since the ban does not apply to them.

Figure 6.2.1 illustrates the allocation of the various types of e-waste under the assumptions of Scenario 2. It is clear from comparing this figure with figure 6.1.1 that a ban on landfill disposal and incineration of CRTs greatly increases the percentage recycled.

Figure 6.2.1: Post-Ban Management of E-waste Not Exported: Scenario 2 CRT Recyclers Paid $10 Per Unit



6.3. Scenario 3: All E-Waste Recycled

This scenario demonstrates the possibility that all of the e-waste that would have been exported is recycled, instead. Given the current economics of recycling, this seems like an unlikely scenario, but it serves to establish the basis of the upper limit on the possible costs of banning e-waste exports. That is, given the costs of recycling, this becomes (as will be shown in Chapter 7) the most expensive allocation of e-waste not exported.

Table 6.3

Post-Ban Management of E-Waste Not Exported
Scenario 3: All Electronic Waste Recycled
(Thousands of Tons)

Waste Product	Quantity Recycled
CPUs	45.4
CRTs	132.1
Other Electronic Waste	65.6
Total	243.1

Source: author's calculations based on data in U.S. Environmental Protection Agency (2007b)

Table 6.3 above shows the total number of CPUs, CRTs and other e-waste that would be recycled, given the assumptions of this scenario. The numbers in table 6.3 are simply those reported as exports in Table 6.1.

CHAPTER VII

Net Social Cost and Cost of Protection from Ratifying the Basel Ban

In this chapter, we use the data developed in Chapters 3, 4, and 6 to estimate the magnitude of the net social cost and the cost of protection that would have been created in 2005 by ratification of the Basel Ban.

The net social cost is the cost of managing the electronic waste that would have been exported in the absence of the Basel Ban *minus* the cost of exporting that waste. It tells us how much the cost of managing electronic waste would change if the Basel Ban were adopted. It is a proxy for the ideal measure – area D in Figure 2.1. As noted there, the ideal measure requires the estimation of supply and demand curves, tasks that are outside the scope of this dissertation. We will address the issue of how good a proxy this is in Chapter 8.

The cost of protection is the net social cost *divided by* the number of jobs created directly (in electronic waste management) by the adoption of the Basel Ban. As noted in the model in Chapter 2, jobs are created because the Ban would require the management of electronic wastes in the United States that would otherwise have been managed by exporting them. Thus, the Ban is a source of new jobs in the United States. As noted in Chapter 2, however, jobs created indirectly by expansion of the electronic waste management industry are not counted. This decision reflects the fact that the economy is normally at or close to full employment; thus, jobs that would be created indirectly by the Ban would be largely offset by indirect job losses. The failure to count indirect jobs created also serves as an offset to jobs that would be lost in e-waste exporting, for which data are not available.

7.1. Total Costs of Managing Electronic Waste That Would Have Been Exported

Table 7.1.1 provides the estimates of the total cost of managing the electronic waste that would have been exported, but is assumed to be managed in the same way as the e-waste that was not exported in 2005 (Scenario 1). There are nine total management cost estimates; namely, three estimates (low, average, and high) for each of the three types of electronic wastes.

To understand how this table works, consider the 5,100 tons of CPUs recycled (row 1, column 2). We developed three estimates in Chapter 4 (Table 4.2.2) of the cost per ton of recycling CPUs: a low of $1,519 per ton, a high of $1,665 per ton, and an average cost of $1,592 per ton. Multiplying these costs per ton by the total tons of CPUs recycled yields low, average, and high estimates of the total cost of recycling CPUs in this management scenario of $7.7 million, $8.1 million, and $8.4 million.

The cost per ton of landfill disposal of CPUs, as estimated in Table 4.1.2, ranges from $409 to $415 (column 3, rows 2-4, in Table 7.1.1). Combining these costs per ton with the 13,900 tons subject to landfill disposal yields estimates of the total costs of landfill disposal of CPUs as high as $5.8 million and as low as $5.7 million, with an average cost of $5.7 million.

Table 7.1.1

Management of Electronic Waste Not Exported

Scenario 1: Electronic Waste Managed As In 2005

1	2	3	4	5	6	7	8
Product	Recycled	Landfilled	Incinerated	Stored - Apts*	Stored - Comm Estabs*	Stored - Houses	Total Cost
1- CPUs (000 tons)	5.1	13.9	0.4	0.4	0.01	25.6	
2- Low Cost Per Ton ($)	1,519	409	409	670	466	0.0	
3- Ave Cost Per Ton ($)	1,592	412	412	670	466	0.0	
4- High Cost Per Ton ($)	1,665	415	415	670	466	0.0	
Low Total Cost ($million)	7.7	5.7	0.2	0.3	0.003	0.0	13.8
Ave Total Cost ($million)	8.1	5.7	0.2	0.3	0.003	0.0	14.2
High Total Cost $(million)	8.4	5.8	0.2	0.3	0.003	0.0	14.6
5- CRTs (000 tons)	13.2	62.1	1.8	0.8	0.0	54.2	
6 - Low Cost Per Ton ($)	855	409	409	1,340	933	0.0	
7 - Ave Cost Per Ton ($)	1,663	412	412	1,340	933	0.0	
8 - High Cost Per Ton ($)	2,383	415	415	1,340	933	0.0	
Low Total Cost ($million)	11.3	25.4	0.7	1.1	0.04	0.0	38.6
Ave Total Cost ($million)	22.0	25.6	0.7	1.1	0.04	0.0	49.5
High Total Cost ($million)	31.5	25.8	0.7	1.1	0.04	0.0	59.2
9 - Other (000 tons)	8.4	28.1	0.8	28.2	0.0	0.0	
10 - Low Cost Per Ton ($)	799	409	409	0.0	0.0	0.0	
11 - Ave Cost Per Ton ($)	799	412	412	0.0	0.0	0.0	
12 - High Cost Per Ton ($)	799	415	415	0.0	0.0	0.0	
Low Total Cost ($million)	6.7	11.5	0.3	0.0	0.0	0.0	18.6
Ave Total Cost ($million)	6.7	11.6	0.3	0.0	0.0	0.0	18.7
High Total Cost ($million)	6.7	11.7	0.3	0.0	0.0	0.0	18.7
All E-Waste	26.7	104.1	3.0	29.4	0.0	79.8	
Low Total Cost ($million)	25.7	42.6	1.2	1.4	0.0	0.0	71.0
Ave Total Cost ($million)	36.8	42.9	1.2	1.4	0.0	0.0	82.3
High Total Cost ($million)	46.7	43.2	1.2	1.4	0.0	0.0	92.5

* Assumed to be one-half of cost of storing CRTs

Table 7.1.1 also contains estimates of the (small) costs of incinerating and storing CPUs, calculated in the same manner as the costs of recycling and landfill disposal of CPUs. When the costs of all the management alternatives are added together, they produce an estimate of the total costs of managing CPUs in Scenario 1 that range from $13.8 million to $14.6 million.

The costs of managing CRTs and other e-waste are estimated the same way as the costs of managing CPUs. When these costs are combined with the costs of managing CPUs they produce estimates of the total cost of managing all e-waste not exported in 2005 ranging from $70.4 to $92.5 million.

Table 7.1.2 provides the estimates of the total cost of managing the electronic waste that would have been exported, but is assumed to be managed instead in an environment of a ban on domestic landfill disposal and incineration of CRTs and a subsidy for the recycling of CRTs (Scenario 2). There are nine total management cost estimates; namely, three estimates (low, average, and high) for each of the three types of electronic wastes.

In scenario 2, CPUs and other e-waste are managed as usual; therefore, the cost estimation for them is the same as in Scenario 1. The quantity of CRTs in scenario 1 was 13,200 tons. Under the assumptions of scenario 2, however, the quantity of CRTs increases dramatically to 78,900 tons. Therefore, the cost of managing CRTs also increases dramatically – from $67.5 million to as much as $188.1 million. This drives up

Table 7.1.2

Management of Electronic Waste Not Exported
Scenario 2: Landfill and Incineration Disposal of CRTs Banned in U.S.
CRT Recyclers Paid $10 Per Unit
CPUs and Other E-Waste Managed As In 2005

1	2	3	4	5	6	7	8
Product	Recycled	Landfilled	Incinerated	Stored - Apts*	Stored - Comm Estabs*	Stored - Houses	Total Cost
1- CPUs (000 tons)	5.1	13.9	0.4	0.4	0.01	25.6	
Low Cost Per Ton ($)	1,519	409	409	670	466	0.0	
Ave Cost Per Ton ($)	1,592	412	412	670	466	0.0	
High Cost Per Ton ($)	1,665	415	415	670	466	0.0	
Low Total Cost ($million)	7.7	5.7	0.2	0.3	0.0	0.0	13.8
Ave Total Cost ($million)	8.1	5.7	0.2	0.3	0.0	0.0	14.2
High Total Cost $(million)	8.4	5.8	0.2	0.3	0.0	0.0	14.6
2- CRTs (000 tons)	78.9	0.0	0.0	0.7	41.0	11.6	
Low Cost Per Ton ($)	855	409	409	1,340	933	0.0	
Ave Cost Per Ton ($)	1,663	412	412	1,340	933	0.0	
High Cost Per Ton ($)	2,383	415	415	1,340	933	0.0	
Low Total Cost ($million)	67.5	0.0	0.0	0.9	38.2	0.0	106.6
Ave Total Cost ($million)	131.3	0.0	0.0	0.9	38.2	0.0	170.4
High Total Cost ($million)	188.1	0.0	0.0	0.9	38.2	0.0	227.2
3 - Other (000 tons)	8.4	28.1	0.8	28.2	0.0	0.0	
Low Cost Per Ton ($)	799	409	409	0.0	0.0	0.0	
Ave Cost Per Ton ($)	799	412	412	0.0	0.0	0.0	
High Cost Per Ton ($)	799	415	415	0.0	0.0	0.0	
Low Total Cost ($million)	6.7	11.5	0.3	0.0	0.0	0.0	18.6
Ave Total Cost ($million)	6.7	11.6	0.3	0.0	0.0	0.0	18.7
High Total Cost ($million)	6.7	11.7	0.3	0.0	0.0	0.0	18.7
All E-Waste	92.4	42.0	1.2	29.3	41.0	37.2	
Low Total Cost ($million)	81.9	17.2	0.5	1.2	38.2	0.0	138.9
Ave Total Cost ($million)	146.1	17.3	0.5	1.2	38.2	0.0	203.3
High Total Cost ($million)	203.3	17.4	0.5	1.2	38.2	0.0	260.6

* Assumed to be one-half of cost of storing CRTs

the total costs of managing all electronic waste in scenario 2 to $138.9 - $260.6 million.

Table 7.1.3 provides the estimates of the total cost of managing the electronic waste that would have been exported, but is assumed to be entirely recycled, instead (Scenario 3). There are nine total management cost estimates: three estimates (low, average, and high) for each of the three types of electronic wastes.

Table 7.1.3

Management of Electronic Waste Not Exported
Scenario 3: All Electronic Waste Recycled

1	2	3	4	5	6	7	8
		Cost Per Ton ($)			Total Cost ($ millions)		
Product	Quantity (000 tons)	Low	Average	High	Low	Average	High
CPUs	45.4	1519	1592	1665	69.0	72.3	75.6
CRTs	132.1	855	1663	2383	112.9	219.8	314.9
Other E-Waste	65.6	799	799	799	52.4	52.4	52.4
Total	243.1				234.3	344.5	442.9

In Table 7.1.3 the quantities of CPUs, CRTs and other e-wastes are from Table 3.2. and Columns 3 to 5 are from table 7.1.1. Recycling all CPUs under the assumption of scenario 3 results in costs as low as $69.0 million (45,400 X $1519) and as high as $75.6 million (45.4 X $1,665), with an average cost of $72.3 million (45.4 X 1592). The recycling of 132,100 tons of CRTs would cost from $112.9 million to $314.9 million. Other e-waste recycling (65,600 tons) would cost approximately $52.4 million. Total costs of recycling all electronic waste ranges from $234.3 million to $442.9 million.

7.2 Costs of Exports

Table 7.2 provides estimates of the cost per ton and the total cost of exporting CPUs, CRTs and Other Electronic Waste. Three estimates (low, average, and high) are provided for each type of electronic waste.

Table 7.2

Cost of Exports

1	2	3	4	5	6	7	8
		Cost Per Ton ($)			Total Cost ($ millions)		
Product	Quantity (000 tons)	Low	Average	High	Low	Average	High
CPUs	45.4	471	484	497	21.4	22.0	22.6
CRTs	132.1	471	519	568	62.2	68.6	75.0
Other E-Waste	65.6	471	484	497	30.9	31.7	32.6
Total	243.1				114.4	122.3	130.1

The quantities of CPUs, CRTs and other e-waste in column 2 of table 7.2 are from table 3.2. The three cost estimates (low, average and high) in columns 3 to 5 are from tables 4.2.2, 4.1.3 and 4.3.2. The total cost of exporting CPUs, CRTs and other e-wastes is estimated to range from $114.4 million to $130.1 million.

7.3 Jobs Created

Table 7.3 provides estimates of the direct jobs that would have been created by adopting the Basel Ban in 2005. Estimates are made for each of the 3 scenarios in this study.

The data on e-waste managed in table 7.3 comes from tables 6.1, 6.2, and 6.3. For all three scenarios, every one thousand tons of electronic waste recycled creates 15 jobs. In scenario 1 this results in a total of 401 jobs (26.7 X 15) created in recycling. Every one

Table 7.3

Jobs Created by Ban on E-Waste Exports

Scenario 1: All E-Waste Not Exported Managed in U.S. As In 2005

Product	Quantity Recycled	Quantity Landfilled	Quantity Incinerated	Quantity Stored - Apts	Quantity Stored - Comm Estabs	Quantity Stored - Houses	Total Managed	Total Direct Jobs
E-Waste (000 Tons)	26.7	104.1	3.0	29.4	0.0	0.0	243.1	
Jobs Per 1000 Tons[a]	15	1	1					
Direct Jobs Created	401	104	3					508

Scenario 2: Landfill and Incineration Disposal of CRTs Banned in U.S.
CRT Recyclers Paid $10 Per Unit
CPUs and Other E-Waste Managed As Usual

Product	Quantity Recycled	Quantity Landfilled	Quantity Incinerated	Quantity Stored - Apts	Quantity Stored - Comm Estabs	Quantity Stored - Houses	Total Managed	Total Direct Jobs
E-Waste (000 Tons)	92.4	42.0	1.2	29.3	41.0	37.2	243.1	
Jobs Per 1000 Tons[a]	15	1	1					
Direct Jobs Created	1386	42	1					1429

Scenario 3: All E-Waste Not Exported is Recycled

Product	Quantity Recycled	Total Direct Jobs
E-Waste (000 Tons)	243.1	
Jobs Per 1000 Tons[a]	15	
Direct Jobs Created	3647	3647

a: Illinois Department of Commerce and Economic Opportunity (2008)

thousand tons of e-waste land-filled or incinerated creates one job. Thus, 107 jobs (107.1 X 1) were created in Scenario 1 by landfill disposal and incineration. The total jobs created in scenario 1 are 508.

If the recycling of CRTs were increased due to adoption of the Basel Ban, as in Scenario 2, the total number of jobs created would be nearly tripled (increased from 508 to 1429). If all electronic wastes were recycled, as in Scenario 3, the number of jobs created would be over seven times larger than the number of jobs created in Scenario 1.

7.4 Net Social Costs and Costs of Protection

Table 7.4 provides estimates of the net social costs and costs of protection resulting from the adoption of the Basel Ban in 2005. There are nine estimates of both the net social costs and the costs of protection, corresponding to the low, average, and high versions of each of the three scenarios of this study.

Table 7.4

Determination of Cost of Protection
(Net Social Cost Per Direct Job Created)

Scenario	Management Cost ($Millions)	Cost of Exporting ($Millions)	Net Social Cost ($Millions)	Direct Jobs Created	Net Social Cost Per Direct Job Created ($)
Scenario 1					
Low Total Cost	71.0	114.4	-43.5	508	-85,602
Ave Total Cost	82.3	122.3	-39.9	508	-78,633
High Total Cost	92.5	130.1	-37.6	508	-73,973
Scenario 2					
Low Total Cost	138.9	114.4	24.5	1429	17,162
Ave Total Cost	203.3	122.3	81.0	1429	56,672
High Total Cost	260.6	130.1	130.5	1429	91,288
Scenario 3					
Low Total Cost	234.3	114.4	119.9	3647	32,882
Ave Total Cost	344.5	122.3	222.2	3647	60,943
High Total Cost	442.9	130.1	312.8	3647	85,791

Table 7.4 combines the estimates of jobs created (Table 7.3) with the net social cost estimates for the three management scenarios (from Tables 7.1.1, 7.1.2, and 7.1.3 and 7.2) to determine the costs of protection.

If Scenario 1 prevailed, the adoption of the Basel Ban would actually save more in costs of exporting than the additional cost of managing the waste domestically. That is, it would be a restraint on trade that actually improved domestic economic welfare. This would occur because the costs of exporting electronic waste are actually quite high relative to the costs of managing the waste domestically. In both Scenarios 2 and 3 the cost of protection and the net social cost per job created are positive. In these instances, there is a net cost of creating jobs via adoption of the Basel Ban. In Chapter 8, we compare these costs with costs associated with restraints on international trade in other products.

CHAPTER VIII

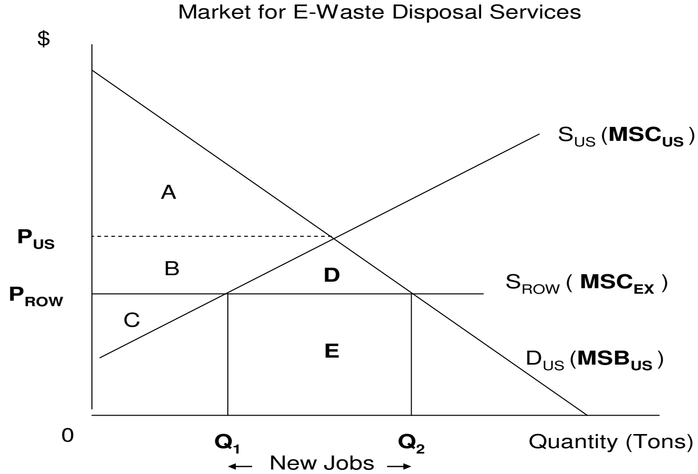
Summary, Policy Implications and Suggestions for Future Research

The purpose of this dissertation has been to examine the effect on U.S. economic welfare of ratifying the Basel Ban on exports of electronic waste. In this chapter, we summarize and evaluate the principal findings of this study, compare them to estimates of the costs of trade restraints imposed on other products, and offer some suggestions for further research.

8.1 Summary and Evaluation

In Chapter 2, a model was introduced (Figure 2.1) that illustrates the essence of the problem examined in this study. Figure 8.1.1 reproduces this model, with some small changes from Figure 2.1.

Figure 8.1.1
Market for E-Waste Disposal Services



The principal estimates developed in this study are the net social cost and the cost of protection. The former is area D in Figure 8.1.1; the latter is area D *divided by* the new jobs associated with the volume of waste disposal services imported (or waste exported) from Q_1 to Q_2.

8.1.1 Net Social Cost

Given the lack of data required to estimate the demand and supply curves, our approach was to use existing cost data to estimate the area beneath the intersection of the S and D curves and between Q_1 and Q_2 (area D + area E) and subtract area E from area D + area E, leaving area D as the net social cost in the United States from adopting the Basel ban. Thus, the net social loss was approximated by the additional cost of managing e-waste in the United States if exports were banned.

Given the uncertainty regarding how e-waste that had been exported would be managed in the United States if it were no longer exported, we developed 3 possible scenarios. Scenario 1 assumed that the e-waste that would have been exported was allocated, instead, across management options in the same proportions as e-waste not subject to export. Scenario 2 assumed that the retired CRTs that would have been exported were recycled (because of a ban on landfill disposal and incineration and a subsidy of $10 per unit to recyclers) and that the remainder of the e-waste that would have been exported - retired CPUs and Other E-Waste - was allocated across management options in the same proportions as retired CPUs and Other E-Waste not subject to export. Scenario 3 assumed that all e-waste that would have been exported was recycled, instead. These scenarios represent the probable range of options and costs. Given the trend in the development of state environmental laws and regulations regarding the disposal of e-waste (Chapter 5), however, Scenario 2 seems more likely than Scenario 1, and something between Scenarios 2 and 3 will probably develop. Given the scarcity of data on the costs of alternative management options, three cases – low cost, average cost, and high cost - were developed for each scenario. This produced 9 cost estimates of the empirical counterpart of area D + area E in Figure 8.1.1. These estimates range from $71.0 million (Scenario 1, low cost case) to $442.9 million (scenario 3, high cost case). The median cost (Scenario 2, average cost case) is $203.3 million.

The cost of importing e-waste services – area E, alone – was estimated from existing cost data as the sum of the costs of collecting, sorting, and transporting the waste products to international shipment points. These costs do not vary across scenarios, but three estimates – low cost, average cost, and high cost – were developed. These (surprisingly high) costs range from $471 a ton to $568 a ton. Total cost of the e-waste that would have been exported ranges from $114.4 million to $130.1 million, with the average total cost at $122.3 million.

The "bottom line," area D + area E *minus* area E, is an impact on net social cost ranging from -$43.5 million to $312.8 million. The most surprising finding is that, in the absence of legislation banning landfill disposal and incineration of CRTs, adoption of the Basel ban would produce net social *gains* (e.g., the negative $43.5 million). We do not, however, consider the possibility of net social gains very likely. As noted, the trend in the development of environmental legislation points to a greater likelihood of Scenarios 2 and 3, both of which are associated with net social losses.

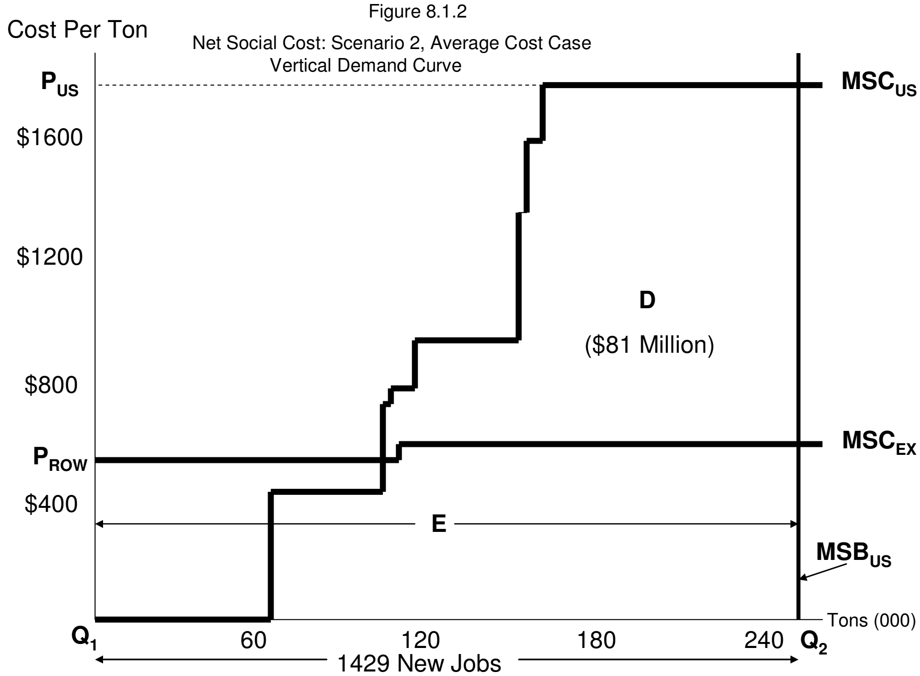
The most likely scenario at present is probably Scenario 2, and the most likely representative case is probably the Scenario 2, average cost case. Figure 8.1.2 illustrates how the estimates developed in this case are related to the basic model used in this study – Figure 8.1.1.

The horizontal distance noted in Figure 8.1.2 encompasses the same distance as that between Q_1 and Q_2 in Figure 8.1.1; that is, Figure 8.1.2 focuses solely on the quantity of e-waste services that would have been imported in the absence of the Basel Ban. Areas D and E in Figure 8.1.2 are the empirical counterparts of areas D and E in Figure 8.1.1.

Figure 8.1.2

Net Social Cost: Scenario 2, Average Cost Case

Vertical Demand Curve



The **MSC_{US}** curve is constructed from the cost data in Table 7.1.2. The **MSC_{EX}** curve is constructed from the data in Table 7.2. The method used in this study – a comparison of costs of managing and exporting e-waste – implicitly assumes that the demand curve for e-waste services (**MSB_{US}**) is vertical (more on this below). The **MSC_{US}** data are reproduced in Table 8.1.

Table 8.1 MSC_{US}, Scenario 2, Ave Cost Case		
Cost Per Ton (MSC_{US})	Tons (Thousands)	Tons - Cumulative Total (Thousands)
0	65.42	65.42
412	43.23	108.65
466	0.04	108.69
670	0.40	109.09
799	8.43	117.52
933	40.95	158.47
1,340	0.68	159.15
1,592	5.06	164.21
1,663	78.92	243.13

8.1.2 Cost of Protection

Nine estimates were also made of the number of jobs that would be created in the United States by adoption of the Basel Ban, corresponding to each of the 9 estimates of net social costs. These estimates range from a cost per job of -$85.6 thousand (a negative cost, or gain) to $91.3 thousand. In the most probable Scenario 2, the cost per job ranges from $17.2 to $ 91.3 thousand. In the case represented by Figure 8.1.2, 1429 jobs would be created at a cost of $81 million (area D), or $56,672 per job.

As noted, the method of comparing costs implicitly assumes that the demand curve (**MSB_{US}**) for waste disposal services is vertical. It is very likely to be less than vertical, but this cannot be confirmed in this study. This means that our estimates of the net social loss and cost of protection are biased upward. This point is illustrated by Figure

8.1.3, where the net social loss is areas $D_1 + D_2 + D_3$ (equal to area D in Figure 8.1.2) when the demand curve is vertical (**MSB_1**), but is smaller for a flatter demand curve. In fact, the flatter the demand curve, the smaller the net social loss. With MSB_2, it is $D_1 + D_2$. With MSB_3, it is only D_1.

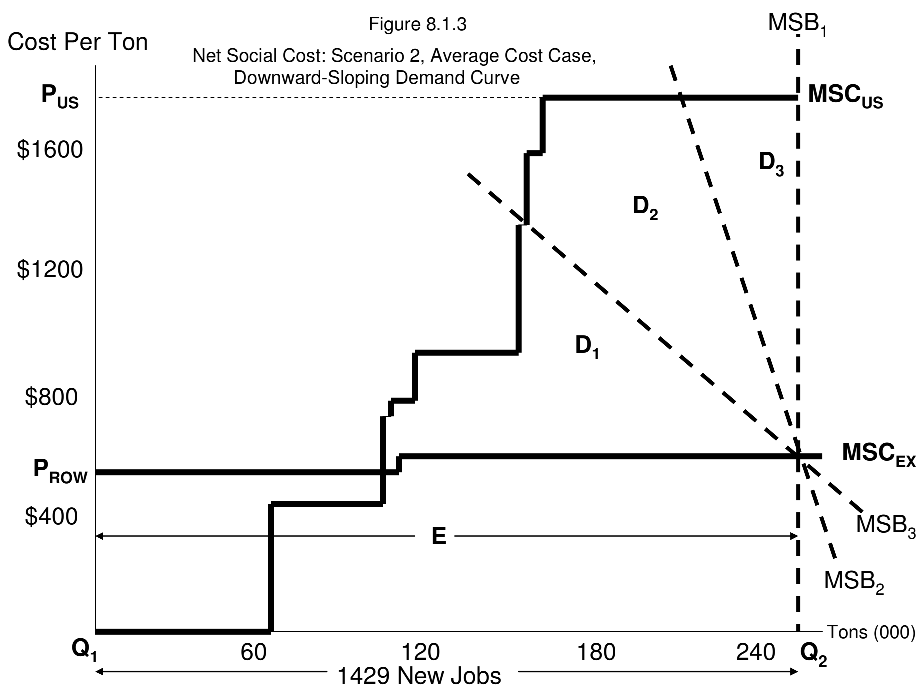


Figure 8.1.3
Net Social Cost: Scenario 2, Average Cost Case, Downward-Sloping Demand Curve

8.2 Cost of the Basel Ban Depends on Developments in Regulatory Policy

As noted, one of the surprising findings is that adoption of the Basel Ban might actually be a source of net social *gains* in the absence of government policy which encourages or requires recycling. Alternatively, the trend in the development of U.S. environmental policy makes this outcome unlikely. The general point, however, is that the effect of adopting the Basel ban depends on the legal and regulatory environment in which a ban is imposed.

8.3 The Basel Ban Would Probably Be A Relatively Low-Cost Restraint on Trade

It is difficult to tell how important the cost of protection is without some basis for comparison. Many studies in the international trade literature have produced estimates of the cost of protection for products made or commodities produced in the United States. Some of the better known estimates were summarized in the *2002 Annual Report* of the Federal Reserve Bank of Dallas (2002), reproduced here as Table 8.2.

Given the estimates in Table 8.2, it appears that the cost of protection due to adoption of the Basel Ban, even in scenarios where U.S. environmental policy elevates the cost, would be fairly small in comparison to these 20 cases.

8.4 Future Research

The analysis above indicates that a study to establish the slope or elasticity of the demand curve for e-waste disposal services should be high on the agenda for future research. The sketchy nature of some of the cost data used in this study indicates the need for updating as additional data become available. Future changes in the legal and regulatory environment should be tracked carefully and additional scenarios should be developed, if necessary.

Table 8.2

Cost of Protection for Selected Industries

Protected Industries		Jobs Saved	Total cost (in millions)	Annual cost per job saved
1	Benzenoid chemicals	216	$ 297	$ 1,376,435
2	Luggage	226	290	1,285,078
3	Softwood lumber	605	632	1,044,271
4	Sugar	2,261	1,868	826,104
5	Polyethylene resins	298	242	812,928
6	Dairy products	2,378	1,630	685,323
7	Frozen concentrated orange juice	609	387	635,103
8	Ball bearings	146	88	603,368
9	Maritime services	4,411	2,522	571,668
10	Ceramic tiles	347	191	551,367
11	Machine tools	1,556	746	479,452
12	Ceramic articles	418	140	335,876
13	Women's handbags	773	204	263,535
14	Canned tuna	390	100	257,640
15	Glassware	1,477	366	247,889
16	Apparel and textiles	168,786	33,629	199,241
17	Peanuts	397	74	187,223
18	Rubber footwear	1,701	286	168,312
19	Women's nonathletic footwear	3,702	518	139,800
20	Costume jewelry	1,067	142	132,870
	Total	**191,764**	**$44,352**	
	Average (weighted)			**$231,289**

Source*:* Federal Reserve Bank of Dallas (2002)

For example, many states are also in the early stages of considering manufacturers' or vendors' take-back programs and requirements that manufacturers design and manufacture electronic products for the environment to spare themselves the cost of unfunded mandates. The adoption of such requirements could reduce the demand for waste disposal services, from both domestic and foreign suppliers, and increase the likelihood of the relevance of Scenarios 2 and 3.

The likelihood of the relevance of Scenarios 2 and 3 would also increase in the face of continued increases in the prices of precious metals and transportation fuels. These trends appear to be so strong, in fact, that they would be worthy of a study using simulation methods similar to those employed in Macauley, et al (2002).

Finally, it is possible that states will require recycling of electronic waste without providing means of funding some of the high cost of this option. In that event, illegal dumping is likely to occur. This would introduce an option that has not been addressed in this study, but one that would be worthy of future research.

ABBREVIATIONS AND ACRONYMS

BAN: Basel Action Network

Basel Ban: Amendment to the Basel Convention

CEW: Covered Electronic Wastes

CIWMB: California Integrated Waste Management Board

COMPS: Computer Monitor Policy Simulation

CPU: Central Processing Unit

CRA: California Recyclers Act

CRT: Cathode Ray Tubes

CSI: Common Sense Initiative

EEE: End-of-Life Electronics and Electrical

EOL: End-of-Life

EPR: Extended Producer Responsibility

LCD: Liquid Crystal Display

Minnesota OEA: Minnesota Office of Environmental Assistance

NGO: Non-Governmental Organization

OECD: Organization for Economic Co-operation and Development

RCRA: Resource Conservation and Recovery Act

TCM: Technical Cost Modeling

USEPA: United States Environmental Protection Agency

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VITA

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Scope and Method of Study: The purpose of this dissertation is to examine the effect on U.S. economic welfare of ratifying the Basel Ban on exports of electronic waste. The dissertation structured the problem as a model of the market for waste disposal services, where the United States is viewed as an importer of waste disposal services. The model implies that the United States would suffer net social costs as a result of the Basel Ban. The net social loss from adopting the Basel BAN was determined by estimating and comparing the costs of three scenarios for managing electronic waste that would not be exported and the costs of importing waste disposal services. These scenarios represent the probable range of options and costs.

Findings and Conclusions: In Scenario 1 the United States would save more in costs of exporting than the costs of managing the waste domestically; that is, adoption of the Basel Ban would improve domestic economic welfare. In the more probable Scenario2, and in Scenario 3, both the net social cost and the net social cost per job created are positive. The latter, however, appears to be modest in comparison with other instances of restraints on trade.

ADVISER'S APPROVAL: Dr. Kent Olson