SOLID WASTE DISPOSAL AND ENFORCEMENT WITH AN APPLICATION TO VIRGINIA'S SCRAP TIRES

by

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(ABSTRACT)

This dissertation fills a void in the economics literature related to the effect of enforcement costs on solid waste disposal policy. The analysis demonstrates that the choice of a cost effective policy tool, be it either an enforcement mechanism or targeted subsidy, is an empirical question dependent on the particular attributes of the current waste disposal situation and the cost of enforcement.

A solid waste disposal market simulation model is developed. The model is applied to the development of a policy aimed at solving Virginia's scrap tire disposal problem. The policy options considered are criminal enforcement, regulatory enforcement, and subsidies.

The results of the case study indicate that in every case criminal enforcement is more expensive than regulatory enforcement. With regard to the question of what the role of enforcement versus subsidies should be, the most important indicator is the objective function. If the policy makers are concerned with total costs, and are not public

budget constrained, then subsidies were found to dominate. If however, officials are concerned with gross or net public costs, due to a budget constraint, then enforcement dominates.

The dissertation also documents the author's involvement in the development of Virginia's scrap tire management regulations. This experience shows that the model, although accurate, would only be useful as a policy development tool under certain conditions.

Lastly, although this research provides a sophisticated means to determine least cost solutions to solid waste disposal problems, such as, used oil disposal, hazardous waste disposal, animal waste disposal, or human sludge disposal, it can be even more powerful as a means to demonstrate the need to consider the cost of enforcement when developing policy.

Dedication

To all my teachers.

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1.1 A Typology Of Waste

1.1.1 Definitions

Waste can be broadly defined as a by-product of economic activity, resulting from either production or consumption, which has negative value to the waste generator. Since waste has negative value to those that generate the waste, the generators demand disposal of the waste. Furthermore, waste is often classified by the manner in which society allows the generator to dispose of the waste. The three main avenues for waste disposal from the point of generation are emissions into the air, discharges into a waterbody, or transport to a disposal facility. Particulate matter or gases which result from production, for example sulfur dioxide from a coal burning furnace, or from consumption, for instance, carbon monoxide from an automobile, are often discharged into the atmosphere as air contaminants. Likewise, particulate matter or liquids which result from production, such as animal waste from a feed lot, or from consumption, for example, municipal sewage, are often discharged into a waterbody as liquid effluent. Both air contaminants and liquid effluents are often further classified as coming from a point source or non-point source. These distinctions are made because the management of a point source and non-point source of air contaminants or liquid effluents is very different. A point source has a single point of origin, or is introduced into the air, or a receiving waterbody, from a specific outlet. A non-point source is defined as diffuse pollution sources, with numerous points of origin.

Solid waste is generally defined as non-liquid, non-soluble material that contains complex and sometimes hazardous materials. However, technically solid waste also refers to liquids or gases in containers. Solid waste is really a catch all for waste which society has decided should not be discharged into the air or water until it is treated and made less hazardous, or that society has decided should be disposed of on land. Hence, a unique characteristic of solid waste, unlike air emissions or liquid effluent, is that it is most often transported from its point of origin to a treatment or disposal site. This characteristic makes the management of solid waste very different from the management of other wastes. It is also this characteristic which makes solid waste disposal and enforcement the focus of this research.

Solid waste is classified under the Resource Conservation and Recovery Act as either hazardous waste (Subtitle C) or non-hazardous waste (Subtitle D). Hazardous waste is solid waste that can pose a substantial or potential hazard to human health or the environment when improperly managed. They possess at least one of four characteristics--corrositivity, reactivity, ignitability, or toxicity--or are specially listed by the Environmental Protection Agency. In 1993, 258 million tons of hazardous waste were generated by 24,362 facilities. This hazardous waste was treated at one of the 2,584 treatment facilities located throughout the United States. The waste was shipped from the waste generating facilities to the treatment sites by 23,964 haulers. This information only includes hazardous waste generated by so called "large quantity generators," those that generate more than 1.1 tons of hazardous waste in a single month. Therefore, the amount of hazardous material generated and shipped, and disposed of in 1993 was much more than 238 million tons (U.S. EPA, 1995).

Non-hazardous waste consists of municipal solid waste and industrial solid waste. Municiple solid waste (MSW) includes wastes such as: durable goods, nondurable goods, containers and packaging, food scraps, yard trimmings, and miscellaneous inorganic waste from residential, commercial, institutional, and industrial sources. Examples of these categories include: appliances, automobile tires, newspapers, clothing, boxes, disposable tableware, office and classroom paper, wood pallets, and cafeteria wastes. In

1993, 207 million tons, or 4.4 pounds per person per day of MSW were generated. Twenty-three percent was then recycled or composted, while 61 percent was landfilled, and 16 percent incinerated. Industrial waste is non-hazardous materials discarded from industrial operations or derived from manufacturing. No reliable data concerning the quantity of industrial waste are available (U.S. EPA, 1994).

1.1.2 Methods Of Waste Disposal

Waste is defined by the manner in which society allows for its disposal. Therefore, each type of waste will require a unique approach by government agencies responsible for insuring the proper disposal of the waste. Point sources of air contaminants and liquid effluents, for example, are often monitored at the source, to insure that the sources are only emitting the proper quantity and types of waste. There are many ways in which this can be accomplished, including inspections by permitting agencies, self-inspection and reporting, and often a combination of the two. The government may induce less waste from being discharged by permitting generators, taxing discharges, issuing marketable pollution permits, or subsidizing pollution control technologies. The important point to consider for this research, however, is that point sources of air contaminants and liquid effluents are monitored for compliance at a single point--the point where the waste is both generated and discharged.

Non-point sources of air contaminants and liquid effluents do not have a known point of origin, or have numerous points of origin. Therefore, monitoring at the source is not an efficient means to insure legal disposal. Often, rather than monitoring discharges, government agencies require certain behavior by individuals or firms which are known to result in lower levels of discharges. An example of these so called "best-management practices" are catalytic converters in automobiles to reduce air emissions and lower levels of fertilizer use by farmers to lower the level of nitrogen leaching into groundwater.

With regard to solid waste, a unique challenge is posed to the responsible government agencies. Solid wastes are generated by every individual and firm, and are transported to numerous waste disposal facilities. This means that solid waste, in general, is transported between its point of origin and its final disposal point. Therefore, in most cases, solid waste is handled by two individuals--the generator and the transporter--before reaching its point of disposal. Thus, insuring proper solid waste disposal requires insuring proper behavior by both of these individuals. An example of this type of monitoring is the hazardous waste policy under RCRA, which requires a manifest to be filled out by both the generators and transporters.

1.2 The Market For Solid Waste Disposal

Since solid waste is negatively valued by the generator, resulting from the need to pay storage costs or having to put up with the nuisance associated with solid waste, the generator has a demand for disposal services. Therefore, the generator will pay to have the solid waste taken from his property, as long as the price is less than the expected cost of self-disposal--keeping the waste or disposing of the waste himself. Most often, it is illegal for the generator to self-dispose, and the generator faces an expected fine if he does so. For example, it is illegal to litter MSW or to "midnight-dump" hazardous waste. The expected fine is the fine level multiplied by the probability of being caught.

If the generator pays to have the solid waste taken away, the solid waste is then taken, for a fee, by a solid waste transporter. The transporter will either take the waste to a disposal site or self-dispose, whichever has a lower cost. The cost of taking the solid waste to a disposal site is the transportation cost plus the amount charged by the disposal firm, known as the tipping fee. The cost of self disposal is the transportation cost to some illegal disposal site. It is most often illegal for the transporter to self-dispose of solid waste, and if so, then the cost to self-dispose includes an expected fine as well.

The transactions described above, between the solid waste generator, transporter, and disposal firm, suggest there are three ways to increase the likelihood that solid waste will be disposed of legally, assuming that self-disposal by the solid waste generator and transporter is illegal. First, the tipping fee charged by the disposal firm can be lowered by providing the disposal firm with a subsidy. Second, the expected fine can be increased by raising the fine level if one is caught self-disposing. Third, the expected fine can be increased by raising the probability that one is caught self-disposing. This is done by increasing the enforcement effort. Raising the fine for illegal disposal is a straight forward policy decision. The other two policy alternatives, a subsidy to disposal firms and increasing the enforcement effort require more explanation. The following questions will be addressed in the next section: How will a subsidy affect illegal solid waste disposal? What is meant by enforcement effort? What enforcement mechanisms are appropriate to deter the illegal disposal of solid waste?

1.3 The Economics And Law Of Solid Waste Disposal

1.3.1 Subsidies To Disposal Firms

In many solid waste management programs, the use of targeted subsidy payments as a way to facilitate the "creation of markets" has been an area of interest.[1] The argument used to defend the subsidy is that the market prices that can be received for recycled, reclaimed, or reused solid waste materials are less than the costs incurred by the solid waste disposal businesses, and they therefore charge a tipping fee. If the government makes a subsidy payment to solid waste disposal firms, and if the sum of the price they

[1] Although the difficulty in providing waste generators with subsidy payments has long been understood by economists (Baumol and Oates), the subsidies in the case of most waste management policies are to waste handlers (collectors and processors), not to the waste generators. Therefore, if the cost of disposal is not a significant portion of the purchase price, and the demand for the good is price inelastic, the subsidy should not cause a significant increase in the quantity of the original good demanded.

receive in the market--the tipping fee--plus the government subsidy payment remains relatively stable, then the higher the subsidy, the lower the tipping fee. This reduction in tipping fee reduces the incentive to dispose of solid waste illegally. The revenue for making these subsidy payments is expected to come from taxes on the products or people who generate the solid waste, and hence, the possibility that the presence of the subsidy may increase the aggregate quantity of waste generated is reduced.

A recent paper by Fullereton and Kinnaman (1995) shows that, in the case of municipal solid waste, where enforcement is assumed to be non practical, subsidies to solid waste disposal firms are more efficient than taxing waste disposal, when illegal disposal by waste generators is possible. Besides assuming that there was no enforcement option, they also assumed that the agency was not budget constrained, and thus, could subsidize disposal to the point where disposal was free to the waste generators. This dissertation will examine how subsidies fare as a policy option when an enforcement option is not assumed away and the agency is budget constrained. In the next section, the enforcement options considered in this dissertation will be discussed.

1.3.2 Enforcement Mechanisms

1.3.2.1 A General Theory Of Enforcement Mechanisms

Shavell provides a framework for understanding the efficiency arguments for the three possible enforcement mechanisms: tort law, regulation, and criminal law. He argues that an important dimension of enforcement is when to intercede, and he lists three options. Intervention can take place prior to the act in order to prevent the act. Prevention requires some physical force, for example, building a fence around a lake to stop people from dumping toxins in it, or having police patrol an area to discourage would be criminals. The second stage of legal intervention is act-based intervention. Here, intervention is triggered by an act before the act causes harm. Sanctions are based on the commission of an act, not on the harm the act could or did cause. For example, if a landfill is fined for not providing the proper daily cover, regardless if the lack of cover caused any harm, then act-based intervention has been practiced. Legal intervention also may be put off until actual harm has occurred. At this point, any sanctions are based on the presence and level of harm done, and thus are labeled, harm-based sanctions. Harm-based sanctions, like act-based sanctions, can give incentives to avoid harmful behavior, but they do not necessarily prevent it.

The second part of Shavell's typology of enforcement mechanisms is the form of sanctions imposed. Two types of sanctions are possible. The first, a monetary sanction, is a simple wealth transfer from the wrongful party to the party initiating the enforcement action. The second type of sanction, non-monetary, which usually means imprisonment or other restriction of freedom--community service--requires the use of resources to carry out the sanction, in terms of prisons and personnel, as well as a possible loss of productive activity by those incarcerated.

The last dimension of Shavell's typology is who brings the enforcement action. If private parties provide the information which results in legal intervention, and carry the entire burden of seeing the request for intervention through, then this is termed private enforcement. The other case is when a public official provides the information and seeks the intervention. This is public enforcement. Table one outlines the characteristics of tort law, regulation, and criminal law under Shavell's typology.

Table 1. Characteristics of Enforcement Mechanisms

General Method of Enforcement	Stage of Intervention	Form of Sanction	Private versus Public
Tort Law	Harm-based	Monetary	Private
Regulation	Prevention and Act-based	Monetary	Public
Criminal Law	Prevention, Act-based, and Harm-based	Monetary and Non-Monetary	Public

(Shavell,p.260)

The question now becomes, when is one stage of intervention, or one form of sanction, or one instigator of intervention, better than the alternatives. Shavell points to two determinants of the optimal stage of intervention. First, the lower, in terms of dollars, the sanction, the less likely, ceteris paribus, the sanction will be able to deter unwanted behavior. Therefore, at low levels of sanctions, intervention before the act, in the form of prevention, will be necessary. As the possible sanctions increase, act-based sanctions will be more able to deter, and as they increase further, harm-based sanctions will gain deterrence capability. The second determinant of the optimal stage of intervention is the probability of effective intervention at each stage. If it will be very unlikely that intervention will be possible at a certain stage, then intervention at that stage is less desirable. For example, it would be likely that placing an enforcement agent in each chemical manufacturing plant would prevent the illegal dumping of residue into the river, while in the same scenario, it would be difficult to intervene when harm results from residue disposal, because of the problem of proving causation. Therefore, the better stage of intervention in this case, ceteris paribus, is prevention.

Shavell offers three determinants of the optimal form of sanctions. The first is the level of the perpetrator's wealth. The lower her wealth, the less likely a sanction equal to her wealth will deter unwanted behavior, thus the more desirable non-monetary sanctions become. This is because the lower the wealth, the more likely that the dollar value of the benefit from conducting illegal activities will be greater than her wealth. Thus, sanctions greater than the perpetrators wealth will be required to deter illegal behavior. The only type of sanction greater than the perpetrators wealth are non-monetary sanctions. The second determinant of the optimal form of sanction is the level of private benefits derived from committing unwanted acts. The higher the expected benefit of committing unwanted acts, the higher the sanction will have to be to deter, and the less likely that monetary sanctions alone will be enough to deter. The third determinant of the optimal form of sanction is the probability of imposing sanctions. The higher the probability that a sanction will be imposed, the lower the sanction has to be to deter, and the more likely that monetary sanctions alone will be enough to deter.

The desirability of private versus public enforcement is determined by the level of knowledge held by private parties about to the identity of the perpetrator and the incentives present to provide this information to the state. It is often the case that private individuals know their injurers, and have an incentive to make use of the force of law. An example would be an automobile accident. After the accident, both parties exchange identifying information. However, cases often occur where such information is not available to the injured parties, such as a hit and run automobile accident. In this second case, resources must be expended to identify the perpetrator. Shavell points out that in the former case, enforcement actions should be private, because private individuals are capable of identifying their injurer, and it is less costly for these individuals to provide this information to the state than for the state to use resources to make such an identification. Also, the private individuals have an incentive to take such an action--to recover their loss. In the latter case, public enforcement may be appropriate, because economies of scale may exist in "crime solving," thus resources can be used more efficiently in the public sector. The last case is when private parties may be able to identify the wrongdoer, but have little incentive to do so. Take for example the polluting of a lake. Each user of the lake suffers a small amount, but the incentive to provide the identity of the wrongdoer may not be great enough to overcome the costs--possibility of retribution for example. In this case, the apprehension of the wrongdoer takes on a public good character, it becomes a crime "against the state" and public enforcement may be necessary (Shavell).

1.3.2.2 Enforcement Mechanisms For Solid Waste Disposal

It has been argued above that each type of enforcement mechanism can be characterized by the stage of intervention, the form of sanction, and the role of private and public enforcement agents. Also, the strengths and weakness' of the alternative stages of intervention, forms of sanctions, and use of private versus public enforcement were described. Given this information, what enforcement mechanism will best--at least cost--deter the illegal disposal of solid waste? It will be necessary to again look at the characteristics of the enforcement mechanisms.

<u>Stage of Intervention: Prevention, Act-based, or Harm-based?</u>

The level of possible sanction is often exogenous to the policy arena, and if endogenous, it is usually constrained by the willingness of the court to impose the sanction. Therefore, we are unable to say anything a priori about the best level of intervention based on the magnitude of possible sanctions. Solid waste disposal is characterized by many firms who generate solid waste, numerous firms who transport the solid waste, several legal disposal sites, and an almost infinite number of illegal disposal sites. The almost infinite number of illegal disposal options open to the numerous transport firms makes prevention of illegal disposal almost impossible. Therefore, we can say a priori that the imposition of sanctions is more likely than the prevention of illegal solid waste disposal. Act-based sanctions are more likely to be imposed than harm-based sanctions, because harm-based sanctions require the proof of causation between the illegal disposal and some harm. Also, with solid waste disposal, the extent of harm is usually not known for a long period of time because the effects can be latent. Thus, with respect to the stage of intervention, regulation or criminal law seem to have the best chance of stopping illegal disposal. Tort law, with its dependence on harm-based sanctions, appears to be a less effective enforcement mechanism.

Form of Sanction

The level of wealth of the solid waste disposers plays an important determinant in deciding if monetary sanctions alone will provide enough incentive to deter illegal solid waste disposal. Small private hauling firms, often present in the solid waste disposal industry, are more likely to have low levels of wealth and thus more likely to require non-monetary sanctions in order to become deterred from improper behavior. Large solid waste generating firms, or large hauling firms, are more likely to have higher wealth levels, and thus respond to monetary sanctions. With regard to actions against corporations, all fines are monetary in nature. Therefore, the effect of wealth levels on the optimal form of sanction is industry dependent, and those solid waste generating industries with a high proportion of small firms will more likely require non-monetary sanctions in order to be deterred.

The private benefits from the illegal disposal of solid waste will be a function of the cost of legal solid waste disposal. The cost of legal disposal of solid waste is in turn dependent on the price, or tipping fees, charged by disposal firms, as well as the transportation costs incurred during transport of the solid waste from the point of generation to the disposal site. Therefore, the magnitude of the private benefit from illegal disposal of solid waste is also industry dependent. In industries where solid waste is expensive to dispose of, and legal disposal sites are few in number and distant from points of generation, non-monetary sanctions are more likely to be required in order to deter illegal disposal.

As mentioned above, due to the incentive for illegal solid waste disposers to conceal their identity, the probability of imposing a sanction for illegal dumping is quite low unless resources are employed in the identification of illegal disposers. As the probability of imposing the sanction decreases, the level of sanction necessary to deter will increase. At some low level of probability, monetary sanctions will no longer be able to deter. The trade-off between probability of imposing the sanction on illegal solid waste disposers and the sanction type and level is also industry specific. However, due to the "midnight-dumper" scenario associated with illegal solid waste disposal, either the probability of imposing sanctions needs to be raised significantly, through the use of resources, or non-monetary sanctions have to be imposed in order to deter.

The form of sanction needed to deter illegal solid waste disposal has been shown to be industry dependent, and is a function of such factors as: the wealth level of solid waste generators and haulers, the cost of legal solid waste disposal, the geographical proximity of legal disposal sites to solid waste generating firms, the per mile cost of solid waste transportation, and the level of resources devoted to identifying illegal disposers, as well as the effectiveness of this identification.

Private versus Public Enforcement

Illegal solid waste disposal, is above all else, illegal! Thus, it can be inferred that parties, such as landowners who wake up and find they have 100 barrels of toxic solid waste on their land, don't know the identity of the solid waste disposal firm who placed the toxins there. Neither do the people who may be harmed by the toxins when they leach into the ground water. Also, although the landowner, unlike those potentially harmed by ground water contamination, may have an incentive to devote enough resources to making such an identification, they are most likely under a budget constraint which will not allow them to do so. Even if they did have the financial resources, they are prohibited from gaining access to certain information, due to privacy concerns, which we have granted to government agents. Therefore, in the case of illegal solid waste disposal, an enforcement mechanism which utilizes public enforcement will be more efficient than one which relies on private enforcement.

The structure provided by Shavell has allowed for an ex ante investigation of what enforcement mechanisms should be more efficient in deterring illegal solid waste disposal. It was shown above that those enforcement mechanisms which allow for act-based sanctions and public enforcement will provide more incentive to dispose of solid waste legally. This would include regulation and criminal law, but not tort law. This should not be surprising, in that tort law has been the status quo enforcement mechanism, and any illegal disposal problems which have occurred are the result of the tort law's inadequacy (Posner).

1.4 Objectives

Following from the above discussion, it is clear that the choice between subsidies, and enforcement, either via regulation or criminal law, is an empirical one which is industry, or solid waste, specific. This research offers a framework by which policy makers can choose between a subsidy to disposal firms and these two enforcement mechanisms to insure that solid waste gets from the generation site to the legal disposal site. The distinction between legal and illegal disposal sites, as well as proper versus improper transport methods, is considered exogenous. More specifically, the objectives of this research are:

1. To develop a model: (a) to compare the cost effectiveness of two possible enforcement mechanisms, regulation and criminal law, when applied to the objective of deterring illegal solid waste disposal; (b) to compare enforcement with subsidizing solid waste disposal firms.

2. To apply this model to the solid waste disposal problem currently being experienced with waste tires in Virginia.

3. To examine the usefulness of this model in solid waste management policy development.

Chapter 2. Waste Disposal Behavior And Enforcement Models

2.1 Models Of Waste Disposal Enforcement

The literature on subsidies aimed at changing polluting behavior is quite robust and straightforward, and therefore, will not be discussed here (Baumol and Oates, 1988; Fullerton and Kinnaman, 1995). However, the literature concerning models dealing with enforcement of waste disposal rules is less well known, thus, it is reviewed in some detail in this chapter. After this literature is reviewed, the need for a model which focuses on solid waste disposal is made clear. Therefore, an empirical model which compares the cost effectiveness of subsidies, criminal enforcement, and regulatory enforcement, as applied to solid waste disposal, is presented.

Russell et al. provide a taxonomy of the waste disposal enforcement models developed up until 1984. The example of a steel mill which gives off sulfur dioxide emissions will illustrate each model. The first type of model, which they term "common environmental economics" assumes that firms are capable of perfect discharge control, firms comply with the standard set by the regulatory agency, and the agency does not monitor behavior. Therefore, the steel mill uses whatever means necessary to meet the standard as set by agency, and is able to do so without any technological difficulties. Also, the agency needs to expend zero resources in the enforcement of the standard. These models are concerned with a comparison of efficiency between optimal charges and standards. In effect they assume zero enforcement costs. Two references are Bohm and Russell (1985) and Tietenberg (1980).

The second type of model they label "Product quality standard." Here the firm is capable of perfect discharge control, firms will comply only if such behavior is in their self-interest, and the agency does not monitor. In this case the steel mill will comply with the standard if the expected profit of compliance is at least as high as the expected profit of non-compliance--including a fine for non-compliance. If the steel mill chooses to comply, they can do so with no technological difficulty. Again, the cost of monitoring is assumed to be zero. This model shows the effect of non-compliance on the standard's effectiveness. This model was developed by Viscusi and Zeckhauser (1979).

The third model type, "pollution standard," assumes firms are again capable of perfect discharge control, will comply only if in their self-interest, and the regulatory agency monitors without error. The situation here is the same as the second case, however the monitoring costs of the agency are now positive, rather than zero. These models also attempt to find the implications of non-compliance on the effectiveness of the standard, as well as the effect of non-compliance on the standard versus pollution charge decision. These models were developed by Viscusi and Zeckhauser (1979), Storey and McCabe (1980), and Harford (1978).

The fourth type of model, "pollution standard with stochastic measurement" assumes the firm does not have perfect discharge control and discharges are stochastic, the firm does attempt to comply, and the agency monitors but with measurement error. Here, the steel plant attempts to comply, however, they have technological difficulties in complying. For example, their scrubbers may remove a constant amount of pollution, while the discharge of pollution is not constant. The agency attempts to monitor behavior, however the agency can only do so with some amount of measurement error. These models focus on the effect of stochasticity on the choice of technology by the firm and the design of the agency monitoring scheme. Three references are Downing and Watson (1973,1975) and Vaughan and Russell (1983).

The last type of model, "pollution standard with stochastic measurement and cheating," is the same as model number four, except the firms will only attempt to comply if it is in their own self interest. Therefore, the steel plant will only attempt to comply if the expected profit of compliance is at least as great as the expected profit of non-compliance--including a fine for non-compliance. This model, developed by Linder and McBride (1984), focuses on the implications of non-compliance and stochasticity for choice between standards and pollution charges.

Since 1985, several other studies have been done to determine such things as the optimal enforcement effort and fine (Polinsky and Shavell, 1992) and the effect of firm avoidance behavior on optimal enforcement (Malik, 1990). All of these studies examined different aspects of environmental policy enforcement costs from within a given enforcement mechanism--the regulatory agency and its ability to fine for violation of permit conditions. Also, this past research concerned itself with point source enforcement. Segerson and Tietenberg (1992) consider the use of criminal sanctions as well as the choice between corporate and individual sanctions using a principal-agent model. Their model is not specific to either air contaminants, liquid effluents, or solid waste. They center their discussion around the avoidance of "accidents," where they assume that the number of accidents is a function of the level of care taken by the employee of a firm.

Sullivan (1987) tackled the problem of enforcement with regard to solid waste disposal, and provided a framework to choose the optimal level of subsidy and enforcement effort. However his work assumed a fixed enforcement mechanism, which is not well specified but rather reduced to an elasticity of law enforcement efficacy which he drew from the literature and incorporated into his model. Also, Sullivan assumed the agency was attempting to maximize social welfare. Finally, he assumed a fixed fine level and cost of legal disposal.

This study is unique, in that it determines how the cost of enforcement alters the choice of enforcement mechanism, as well as other policy tools, aimed at reducing illegal solid waste disposal. Also, the effects of different fine levels, the cost of legal disposal, and different agency objectives, on this choice, are investigated. In Innovation in Environmental Policy: Economic and Legal Aspects of Recent Developments in Environmental Enforcement and Liability, Russell points out the gap in the literature with respect to solid waste disposal that this research will attempt to close:

> In the first case (point sources of pollution) the agency knows where to look for violations, and it can choose how often and with what precision to look. A particular source may have an option that allows it to change the timing of its discharges...but it is very unlikely to change location. Small quantities of spent solvents, on the other hand can be put in containers, shipped away from the plant and disposed of anywhere...the conventional model, however refined and extended with criminal penalties, for example, only represents potential solutions to part of the environmental enforcement conundrum. It also suggests that this is a wonderfully rich are for future research (pp.220-221).

Table two summarizes the past environmental enforcement studies discussed above, and illustrates the gap in the literature which this study fills.

Table 2. Enforcement Literature

Model	Type of Waste	Assumptions about firm	Assumptions about agency	Assumed or taken as given	Focus of Analysis
Common Environmental Economics (assumed Compliance)[1]	Air or Liquid Point Source	Capable of perfect discharge; complies regardless of self-interest	Does not monitor; regulatory enforcement	Discharge standard or emissions charge; firms costs; compliance	Optimal standards or charges; choice between standards or charges
Product Quality Standard (some compliance privately optimal)[2]	Air or Liquid Point Source	Capable of perfect discharge control; may or may not comply according to self-interest	Does not monitor; regulatory enforcement	Quality standard; firms costs	Implications of non-compliance for effectiveness of standard
Pollution Standard (simplest monitoring case)[3]	Air or Liquid Point Source	Capable of perfect discharge control; may or may not comply according to self-interest	Monitors without error; regulatory enforcement	Discharge standard; firm's costs; probability of a "visit"; fine for violation	Implications of non-compliance for effective standard; implications of non-compliance on choice between standard and charge
Pollution Standard (stochasticity in measurement)[4]	Air or Liquid Point Source	Stochastic discharges; tries to comply regardless of self-interest	Monitors with measurement error; regulatory enforcement	Discharge standard; firm's costs; probability function of discharges; attempts to comply	Implications of stochasticity for optimal technology choice of firm; implications of stochasticity on optimal monitoring scheme
Pollution Standard (stochasticity in measurement and cheating by source)[5]	Air or Liquid Point Source	Stochastic discharges; may or may not comply according to self-interest	Monitors with measurement error; regulatory enforcement	Discharge standard; firm's costs; probability function of discharges [5]	Implications of stochasticity on choice between standard and charges

Table 2. Enforcement Literature, continued.

Model	Type of Waste	Assumptions about firm	Assumptions about agency	Assumed or taken as given	Focus of Analysis
Optimal Enforcement Effort and Fine[6]	Air or Liquid Point Source	Capable of perfect discharge control; may or may not comply according to self-interest	Monitors without error; regulatory enforcement	Discharge standard; firm's costs	Determining the optimal level of enforcement effort and fine
Effect of Avoidance Behavior[7]	Air or Liquid Point Source	Capable of perfect discharge control; may or may not comply according to self-interest, capable of avoidance behavior	Monitors without error; regulatory enforcement	Discharge standard; firm's costs	The effect of avoidance behavior on the optimal level of enforcement effort and fine
Corporate or Individual Sanctions[8]	Air or Liquid Point Source or Solid Waste related accidents	Made up of employee and firm, each capable of perfect discharge control; may or may not comply according to self-interest	Criminal or regulatory enforcement	Discharge standard; firm's costs	The effect on compliance of the liability rule between the firm and employee
Optimal Level of Enforcement and Subsidies[9]	Solid Waste	Capable of perfect discharge control; may or may not comply according to self-interest	Enforcement mechanism not specified; can provide subsidies	Firms cost's (of legal and illegal disposal); cost of enforcement; enforcement mechanism; social cost of illegal disposal; agency's objective function; fine level	Optimal choice between enforcement and subsidies.

Table 2. Enforcement Literature, continued.

Model	Type of Waste	Assumptions about firm	Assumptions about agency	Assumed or taken as given	Focus of Analysis
This Research	Solid Waste	Capable of perfect discharge control; may or may not comply according to self-interest	Criminal or regulatory enforcement; can provide subsidies	Firms cost's of illegal disposal; cost of enforcement;	Choice between criminal enforcement, regulatory enforcement, and subsidies; effect of fine level, cost of legal disposal, and agency's objective function on this choice

[1] Bohm and Russell (1985) and Tietenburg (1980)
[2] Viscusi and Zeckhauser (1979)
[3] Viscusi and Zeckhauser (1979), Storey and McCabe (1980) and Harford (1978)
[4] Downing and Watson (1973, 1975) and Vaughan and Russell (1983)
[5] Linder and McBride (1984)
[6] Polinsky and Shavell
[7] Malik (1990)
[8] Segerson and Tietenburg (1992)
[9] Sullivan (1987)
Source: Russell et. al. (1986) (first five rows of table; modified)

2.2 *A Model Of Solid Waste Disposal And Enforcement*

2.2.1 An Overview Of The Model

As Table 2 shows, in order to accomplish the objectives laid out in chapter one, it will be necessary to develop an empirical model specific to the task. In this section, a model developed in order to accomplish these objectives will be discussed. The modeling task is broken down into three sub-tasks: simulating the current market for solid waste disposal using a non-linear programming model, determining the cost of enforcement under both the criminalization and regulatory approaches, and analyzing the results of the simulations to determine the sensitivity of the results to certain assumptions. The manner in which each of these sub-tasks will be solved is discussed below.

2.2.1.1 Simulating The Market For Legal Solid Waste Disposal

Each solid waste generating firm (i) will dispose of solid waste legally up until the point where the cost to do so is less than or equal to the expected cost of disposing of solid waste illegally. The cost of legal disposal includes the tipping fee charged by a legitimate disposal site, plus the cost of transporting the solid waste to that site. The cost of illegal disposal includes the tipping fee paid to the owner of the illegal disposal site, if any, the cost of transportation to the site, and the expected fine. The expected fine equals the fine level, set by the state, multiplied by the probability of getting caught. Therefore, the objective function of the model becomes the minimization of the sum of these costs: disposal costs at both legal and illegal disposal sites, transportation costs, and the expected fine. Constraining this cost minimization problem is the constraint that all solid waste go to either a preferred disposal site, a legal disposal site, or an illegal disposal site. Thus, minimization of costs over the whole system is equivalent to minimizing the costs of each individual solid waste generator simultaneously.

As mentioned above, the model requires that each solid waste generator take their solid waste to either a "preferred disposal site" a "legal disposal site" or an "illegal disposal site." It is necessary to define these terms. In this research, a preferred disposal site is one which is licensed by the state to dispose of the solid waste, and does so in a manner which the state is willing to subsidize. Therefore, the price received by these firms is equal to the tipping fee they receive plus the subsidy. An example is a newsprint recycler. A legal disposal site is a legal disposal option, but not preferred and thus not eligible for a subsidy. An illegal disposal site is one which is not licensed by the state. It may be an authorized illegal disposal site, meaning the property owner knows solid waste is being dumped on his property, and collects a small fee from the solid waste generator, or it may be an unauthorized disposal site, in which case no fee is charged.

The model takes the form of the following non-linear programming model:

Minimize $C = \sum_i \sum_j D_{ij} \times M \times Q_{ij} + \sum_i \sum_j Q_{ij} \times P_j + \sum_i \sum_l D_{il} \times M \times L_{il} + \sum_i \sum_l L_{il} \times TF_l +$
$\sum_i \sum_k D_{ik} \times M \times I_{ik} + \sum_i \sum_k I_{ik} \times EF + \sum_i \sum_k I_{ik} \times Y$

Subject to:

(1) $T_i = \sum_j Q_{ij} + \sum_l L_{il} + \sum_k I_{ik} \quad \forall i$

(2) $P_j = f\left(Q_j\right) - (S_j - R_j) \quad \forall j$

(3) $Q_j = \sum_i Q_{ij} \quad \forall j$

where:

D_{ij}= the distance between point of solid waste origin (i) and preferred disposal site (j).
D_{il}=the distance between point of solid waste origin (i) and legal disposal site (l).
D_{ik}=the distance between point of solid waste origin (i) and illegal disposal site (k).
M=the per mile cost of transporting a unit of solid waste.
Q_{ij}=the amount of solid waste from point of origin (i) going to preferred disposal site (j).
L_{il}= the amount of solid waste from point of origin (i) going to legal disposal site (l).
I_{ik}=the amount of solid waste from point of origin (i) going to illegal disposal site (k).
TF_l=the tipping fee charged by legal disposal site (l).
P_j = the price received by preferred disposal site (j)
T_i=the amount of solid waste generated at point of origin (i).
S_j=the per unit subsidy given to preferred disposal site (j).
R_j=the per unit cost to the preferred disposal site (j) of participating in the subsidy program
EF=the expected fine, per unit of solid waste, faced by those who illegally dispose of solid waste.
Y= is the per unit of solid waste cost of disposing of solid waste illegally in the basecase. This can be the price paid to the owner of an illegal disposal site, the perceived expected fine, or both.

Q_j=the total amount of solid waste going to preferred disposal site (j).

The following accounting rows are added to the model in order to more easily track the results of the model:

(4) $$L_l = \sum_i L_{il} \qquad \forall l$$

(5) $$I_k = \sum_i I_{ik} \qquad \forall k$$

(6) $$Q = \sum_i \sum_j Q_{ij}$$

(7) $$L= \sum_i \sum_l L_{il}$$

(8) $$I= \sum_i \sum_k I_{ik}$$

(9) $$R_m = \sum_k I_k^m \div X \qquad \forall m$$

where:

L_l=the total amount of solid waste going to legal disposal site (l).
I_k=the total amount of solid waste going to illegal disposal site (k).
Q=the total amount of solid waste going to any preferred disposal site.
L=the total amount of solid waste going to all legal disposal sites.
I=the total amount of solid waste being illegally disposed.
R_m=the number of illegal disposal incidents occurring in region m.
I^m_k=the amount of solid waste going to illegal disposal site (k) which is located in region (m).
X=the amount of solid waste composing an average shipment.

The model was calibrated, through the use of the (Y) parameter, to achieve a baseline which corresponded to certain known characteristics of the real solid waste disposal market. These characteristics are: the equilibrium prices and quantities of each preferred-disposal site, the amount of solid waste taken to a legal disposal site, and the amount of solid waste disposed of illegally. The level of the (Y) parameter necessary to reach this baseline condition is the subjective expected cost faced by current solid waste generators. This can be explained by liability exposure under current common law, the fear of loosing the "goodwill" of others if it is discovered that they are an illegal solid waste disposer, as well as an amount that solid waste generators are willing to pay to avoid "feeling guilty".

After the baseline model is achieved, the model is solved at many levels of expected fine and subsidy. For each expected fine and subsidy pair, the non-linear programming model produces the following information: the cost of preferred-legal, legal, and illegal disposal, the transportation costs, amount of solid waste going to each preferred disposal site, legal disposal site, and illegal disposal site, and the number of illegal disposal incidents occurring in each region or locality. The next step is to estimate the cost of implementing the expected fines which gave rise to these numbers.

2.2.1.2 Estimating The Costs Of Enforcement Under Criminal Law

Criminal prosecution of illegal solid waste disposal activity can take many forms. In this research it is defined as the proclamation, by statute, that anyone who knowingly disposes of the specified solid waste at a site that is not permitted to accept the solid waste has committed a criminal act, which is punishable by a fine or imprisonment. The deterrence and/or detection of illegal disposers is the responsibility of the local police departments. The processing of arrests made is the responsibility of magistrates or lower courts. Finally, any case that goes to trial is adjudicated in the courts. Thus, the costs, borne by the state, of enforcing against illegal solid waste disposal via criminal law can be broken down into three main categories: the cost of deterrence and/or apprehension, the cost of processing arrests, and the cost of adjudication.[2]

For each level of fine, the expected fine is a simple function of the probability of being fined. Therefore, for each fine level, the cost of reaching a given expected fine level is:

$$C_m = C1_m(P_m)+C2_m(A_m)+C3_m(T_m)$$

where:
C_m=total enforcement cost in region m to reach expected fine (EF)
$C1_m$=cost of police effort level P

[2] In some states, if the illegal disposal of solid waste is determined to be a serious offense, public prosecutors may become involved, thus increasing the cost of the criminal approach of enforcement. This study will assume that the police department will present the charges against the defendant to the court. This is the case in Virginia for most misdemeanors.

$C2_m$=cost of processing A_m arrests
$C3_m$ = cost of adjudicating T_m firms
P_m = police effort in region m
A_m=number of arrests in region m
T_m = number of trials in region m

For each expected fine and subsidy combination, there is a corresponding level of police effort, arrest processing, and adjudications that are required. The level of police effort can be found as follows:

$$P_m = (R^{*}_m \times EF) / [zF1+(1-z)g(F2)] \quad \text{for all m}$$

where:

R^{*}_m = number of illegal disposal incidents in region m when expected fine equals zero.
z= probability a firm pleads guilty, and pays fine, if arrested
F1=per solid waste unit fine level if a firm pleads guilty
F2=per solid waste unit fine level if a firm pleads not guilty but found guilty
g= probability a firm is found guilty, and pays fine, if it pleads not guilty

Thus, the amount of police effort required to effect an expected fine is equal to the police effort that would be required to arrest (R^{*}_m x EF / Fine) illegal disposers. In other words, all potential illegal disposers--all those firms that will dispose of solid waste illegally if the expected fine is zero, given a subsidy level--must now feel that they face the expected fine set in the non-linear programming model. The number of actual arrests in the region necessary to implement the expected fine will equal:

$$A_m = (R_m \times EF) / [zF1+(1-z)g(F2)] \quad \text{for all m}$$

In other words, given police effort P_m, R_m illegal solid waste disposal incidents will occur, and A_m of these illegal solid waste disposers will be arrested and processed. The cost of processing these arrests is $C2(A_m)$. An example of this processing cost would be the cost involved in the magistrate processing the arrest. Also, the number of adjudications that will be required to effect a given expected fine is equal to the number of arrests, since each arrest must be adjudicated. Therefore:

$T_m = A_m$

$T_m(1\text{-}z)$ will result in not-guilty pleas and trials, and $T_m(z)$ will result in guilty pleas and no trial.

Therefore, for each subsidy and enforcement expenditure pair, we now know the level of legal and illegal disposal under the criminal approach. Thus, if the costs of police effort, arrest processing, and adjudicating an illegal disposer in each region, as well as the probability of case depositions, are known, then the relative effectiveness of enforcement and subsidy expenditures is known under the criminal enforcement mechanism.

2.2.1.3 Estimating The Cost Of Enforcement Under Regulation

In order to determine the cost of enforcing against illegal solid waste disposal through regulation, the form of regulation needs to be specified. The assumed regulatory format is based on the regulations adopted by the federal government to ensure the legal disposal of hazardous wastes. The regulations only include those measures which are designed to insure legal disposal, however defined, and not the command and control regulations which set out to define legal disposal. Again, this study is only concerned with the question, did the solid waste get from the generation site to the legal disposal site? The distinction between legal and illegal disposal sites, as well as proper versus improper transport methods, will be considered exogenous.

The basis of the regulation is a change in the liability rule. Most often, anyone who disposes of wastes improperly is subject to a harm-based sanction brought by the person harmed. Also, most states can bring civil charges on behalf of the citizenry. Under the regulatory framework, solid waste generators will be held strictly liable for any solid waste they generate which is disposed of illegally--without regard to any contract they had with another firm to transport the solid waste. The logic of this regulation presupposes one condition. That is, the generator of solid waste can control the behavior of any hauler who she contracts with to transport her solid waste. Given that the generator chooses which hauler to do business with, and that they can withhold payment from the hauler until proof of legal delivery is provided, this condition seems realistic. The main idea behind this type of regulation is that the solid waste generators have the power to control the behavior of the haulers they hire, and the strict liability rule provides the incentive to do so.

The regulations will require each generator of solid waste to self-monitor their production of solid waste and to keep records of this generation. The information to be recorded includes the amount of solid waste generated, the disposal site for the solid waste, and a receipt from the disposal firm confirming receipt of the solid waste. The reports of the solid waste generators will be audited by a state agency for any irregularities or discrepancies. Any such irregularities will result in an administrative fine being levied against the solid waste generator.

As in the criminalization case, the question that needs to be answered is, what is the cost of imposing each level of expected fine under the regulatory enforcement mechanism? The cost of regulatory enforcement is the cost of detection, or the auditing costs. The state agency can audit the reports from between zero and 100 percent of the solid waste generators. As the number of audits increases, so do the total audit cost and the expected fine facing the solid waste generators.

The enforcement costs under a regulatory approach are:

$C^* = C1(a)$

where: $a = EF \times N / F$

C^*=total enforcement cost
$C1$=cost of auditing a firm
a=number of audits (policy variable)
EF=level of expected fine per unit of solid waste
N= Total number of firms
F=the per unit of solid waste fine

Thus, the number of audits required to reach each expected fine level is now known. Therefore, for each subsidy and enforcement expenditure pair, we now know the level of legal and illegal disposal under the regulatory approach. Thus, if the cost of performing an audit is known, the relative effectiveness of subsidy and enforcement expenditures under the regulatory enforcement mechanism can be determined.

2.2.1.4 The Cost Of The Subsidy Program

The cost of the subsidy program depends on the accounting stance taken during the analysis. Two accounting stances are important to this research, the total cost of the subsidy program, and the agency's fiscal cost of the subsidy program. First, lets consider the agency's fiscal cost of running the subsidy program. This cost can be broken down into two components, the administrative cost and the actual subsidies. The administrative costs (PUAC) can be represented as a function of the total solid waste subsidized:

$$\text{PUAC} = f(\text{Q})$$

The second component, the actual subsidies to the preferred disposal sites (TS), are calculated as the subsidy level multiplied by the units of solid waste subsidized:

$$\text{TS} = \sum_{j} \text{Q}_j x \text{ S}_j$$

Therefore, the total fiscal cost to the agency (TFC) are:

$$\text{TFC} = \text{PUAC} + \text{TS}$$

The private sector also faces an administrative cost of participating in the subsidy program (PRAC) which can be calculated as the per unit cost to the preferred disposal site (j) of participating in the subsidy program (R_j) , multiplied by the number of units of waste disposed by preferred disposal site (j):

$$PRAC = \sum_{j} R_j \times Q_j$$

The total cost of the subsidy program consists of three components, the agency's administrative cost (PUAC), and the private sector's administrative cost (PRAC). Note, since the actual subsidies (TS) are a transfer payment, they should not be included in the total cost of the subsidy program. Therefore, the total cost of the subsidy program (TSC) is:

$$TSC = PUAC + PRAC$$

2.2.2 Model Summary

The above model can provide several important insights. For each enforcement mechanism--criminal law and regulation, it will allow a three dimensional matrix of information to be produced. This matrix shows the subsidy level and enforcement expenditure necessary to reach different levels of compliance. Also, this analysis provides a detailed accounting of the distribution of costs among solid waste generators, haulers, and the state.

The next chapter will outline the case study to which this model will be applied, the scrap tire problem in Virginia. The current situation will be described, as well as how the model will be tailored to fit the Virginia scrap tire case study. This will include a discussion of the data used.

Chapter 3. The Problem Of Improper Scrap Tire Disposal

3.1 The Creation Of Stockpiles

Over 240 million waste tires are generated every year in the United States. In 1992, 27 percent of the waste tires were recycled as retreads, reused in some other form--for example, fishing reefs--or were burned as an energy source. The remaining tires are scrap. In the past, scrap tires were disposed of in landfills along with other solid waste. However, due to the tires' volume, shape, and unique ability to capture methane gas and rise in a landfill and break the daily cover, many communities recently have banned scrap tires from landfills (STMC,1992). As a result, about 73 percent of the used tires, over 175 million tires, are being "stockpiled" each year (U.S. EPA,1991).

Virginia residents generate about four million waste tires per year. The Virginia Division of Waste Management estimates that half of these are disposed of in dispersed stockpiles through-out the state, adding two million tires per year to the existing stockpile of 18 million tires. With the number of automobiles in the state growing, the size of the state's stockpiles should double in less than 12 years (VDWM, 1989).

Stockpiles are quite diverse in size and nature. One in Ohio contains 30 million tires, but many are small piles of illegally dumped tires often not exceeding a few thousand tires (STMC,1992). Simply as a tire-pile, the environmental effects are limited to breeding pests such as rats and mosquitoes. The more serious environmental problem is the risk of fire. Tire-piles have a propensity to ignite, creating air pollution as well as an oily and toxic runoff to streams and ground water. Piles can be managed to minimize their environmental risk but this is the exception. Virginia has a tire fire occur almost monthly, and a similar frequency of fires occurs in other states.

To reduce the current flow to stockpiles new uses for the scrap tires need to be found. At present the most promising uses appear to be rubberized asphalt, crumb rubber products such as park benches and floor mats, civil engineering applications such as reefs and highway crash barriers, and energy production (EPA, 1991). A short term solution to the pest breeding problems and fire risk is to shred the tires and store the shreds (monofilling).

Of these alternative uses, the United States Environmental Protection Agency (U.S. EPA), as well as the tire industry's Scrap Tire Management Council, supports energy production as having the greatest potential to utilize large volumes of tires at lowest cost. Whole tires may be used as a fuel, but it is more common to shred the tires into chips and at the same time remove the wire from the steel belts. Whether burned in dedicated boilers or in boilers where tires are used as a supplemental fuel, scrap tires can be incinerated in compliance with even the most strict air emission regulations (STMC,1992).

However, the price of obtaining a British thermal unit from coal or fuel oil versus the cost from burning tires, including shredding costs, makes tire derived fuel a more costly energy source. Therefore, for boilers to be willing to burn tires they demand a payment for each tire they burn. In effect, even at the energy plant site, scrap tires have a negative price. This negative price is analogous to the "tipping" fee a waste hauler pays when they take trash to a landfill.

3.2 Understanding The Used Tire Market

In the past, landfills accepted tires at no charge or with only a minimal tipping fee. Meanwhile retail tire stores accumulated used tires in direct proportion to the number of new tires they sold. Some could be resold as used tires, some were purchased for retreading, but the majority of the tires were simply a waste product of the tire business. This meant that a secondary, and often informal business developed in used tire hauling. These tire haulers--often termed "tire jockeys" to represent the informal nature of the business--would collect waste tires from the retail tire stores in return for a payment adequate to cover the cost to haul the tires to the local landfill and pay the small tipping fee.

As long as local landfills accepted tires, the number of tire derived fuel plants, or other uses for scrap tires, were limited. The tipping fee these plants could charge had to be less than the modest charge at local landfills. More important, the fuel plants needed a large volume of tires, so they had to draw tires to the plant from a large region. This meant that the transportation costs for the tire jockey to the regional plant were typically higher than to the local landfill. As a result, the economic feasibility of investing in tire derived fuel plants was limited to a few areas with a high concentration of tires. The scrap tire market did little to encourage alternatives to landfilling.

These same market forces explain the recent rapid growth of illegal stockpiles. First, the unwillingness of landfills to accept scrap tires came suddenly with new US EPA regulations on landfill design (40 CFR Parts 257-258). Because these design requirements sharply increased the cost of replacement landfills, communities began to ban large volume items such as tires or radically raised tipping fees. When this occurred there were few alternative facilities that were willing to take tires at any price.

An even more critical factor leading to the growth of stockpiles is the organization of the market for scrap tire hauling. The current market for scrap tires encourages leakage of tires between the tire retailers who collect used tires and the endusers of used tires. Consider how this occurs. The tire dealerships have little incentive to be concerned about the fate of the scrap tires once they have made payment to the tire hauler to take them away from their store. This is due to the fact that the responsibility for proper disposal rests with the tire hauler once they take possession of the scrap tires. In effect, the tire haulers take on the duty to dispose of the tires properly from the tire retailers, in return for a payment made to the hauler from the retailer.

However, once the tires are on the hauler's truck, every mile the hauler drives is a reduction in the net return he can earn on the payment received from the tire retailer. The hauler wants to minimize the sum of the transportation costs and the tipping fee at the point of delivery, say to a tire-derived fuel plant. These costs can be minimized by driving a shorter distance and by finding places that will accept tires at the lowest tipping fee. The lowest tipping fee might include unauthorized illegal dumping, that is a zero fee, but more often there is some landowner in the area who is willing to take the tires and "stockpile them" for a small fee. Hence, this rational market behavior is the explanation for the growing stockpiles. The tire hauler will dispose of his tires legally as long as the cost of legal disposal are less than or equal to the costs of illegal disposal. The cost of legal disposal includes the transportation cost to the legal disposal site plus the tipping fee paid to the disposal firm. The cost of illegal disposal includes the transportation cost to some illegal disposal site plus a tipping fee paid to the illegitimate disposal site, if one is paid at all, plus some expected fine. The expected fine is some fine level set by the state multiplied by the tire hauler's subjective probability of incurring the fine.

Most states have laws that provide for the enforcement of a property owner's right not to have waste tires dumped on his/her land unknowingly, and also restrict the property rights of landowners who wish to stockpile tires. These laws also provide for civil penalties against persons who violate these statutes. However, the vast number of waste tire generators, haulers, and legal as well as illegal disposal sites, makes the enforcement of these property rights expensive under the current tort law remedies. This study will determine if the state can reduce the cost of deterring illegal disposal by altering the enforcement mechanism or providing subsidies to legal disposal firms. The next section will describe the possible policy actions that will be analyzed. This includes a tax-subsidy approach which has been adopted by many states, a regulatory approach which includes self-monitoring and reliance on the criminal law.

3.3 Policy Options Considered In The Scrap Tire Case Study

3.3.1 Tax-Subsidy

Due to the fact that scrap tires have some economic value, states have been inclined to stimulate the demand for scrap tires by a "tax and subsidize" program. Some states hope that by subsidizing scrap tire utilizers directly, the tipping fee these utilizers charge the tire haulers will fall, thus lowering the economic incentive for the tire haulers to dispose of the scrap tires improperly. Twenty states now provide grants to tire utilizers in return for taking the waste tires. These include start-up grants, per tire subsidies and low interest loans (Scrap Tire News). These subsidies are being paid from tire-tax revenue. Twenty-nine states have enacted legislation that provides for a tax on tire usage in order to fund scrap tire programs; these include: 22 have a tax on new tire sales that ranges from $0.50 to $2.00, two have a per tire disposal fee that ranges from $0.25 to $1.00, five have a surcharge on vehicle registration that ranges from $0.50 to $4.00 per vehicle, and one state charges a permit fee for tire storage sites (Scrap Tire News).

In 1989 Virginia enacted a $0.50 per tire tax which is dedicated to a waste tire trust fund. In 1992, the Virginia Assembly authorized the use of these funds for partial subsidies to persons who utilize scrap tires from Virginia. The Department of Environmental Quality has instituted such a subsidy program. This study will assume that per tire subsidies can be given to any firm that is permitted by their home state to dispose of Virginia scrap tires by any means.

3.3.2 Criminalization Approach

The criminalization approach would be operationalized by a law making the knowing disposal of scrap tires at any site not permitted by the state a misdemeanor, punishable by a maximum fine of $1,000.00, or one year in jail, or both. For use in this research, monetary penalties will be as a proxy for all penalties--criminal and regulatory.

The difference between criminal sanctions and regulatory sanctions is that a high fine level can be imposed via requiring prison time under the criminalization approach, while under the regulatory approach, high fine levels may not be collectable due to the offender's asset limit.

The enforcement of this law will be the responsibility of the local police departments with jurisdiction over the illegal disposal site. The police departments, after identifying and detaining a suspect, will bring charges against the suspect in front of a magistrate. The magistrate will turn the case over to the District court where the defendant can plead guilty or not guilty. Given a not-guilty plea, the case will go on to trial in a district court. No appeal process will be included in this analysis.

3.3.3 Regulatory Approach

The regulatory approach to be analyzed as part of this research will include self-monitoring, audits by the department of environmental quality, and a strict liability rule against illegal tire disposal placed on tire retailers.

The self-monitoring rule would require all Virginia tire retailers to record the amount of scrap tires they generate, the disposition of these tires, the name of the hauler who transported the scrap tires, and receipts from the disposal firms who took the tires confirming receipt. These records must be kept at the generator's establishment and made available to state officials on demand.

Agents from the Department of Environmental Quality will select at random some amount of tire dealerships to audit. The tire dealerships will be required to turn over their disposal records as well as any other information deemed necessary by the state--new tire invoices and financial records. These records will be compared, and if it is determined that the scrap tire generator did not dispose of their scrap tires legally, then the department of environmental quality will issue an administrative fine proportional to the amount of scrap tires disposed of illegally. No appeal of the administrative finding will be allowed in this analysis.

3.4 Case Study Data

The data necessary to complete the analysis can be broken down into three catagories--scrap tire market data, criminal enforcement mechanism costs, and regulatory mechanism costs. A discussion of each follows.

3.4.1 Virginia Scrap Tire Market Data

The market was simulated using data from calendar year 1992. In order to do this several categories of data concerning the current market for scrap tire disposal in Virginia were collected. These categories are: number of tires generated by each generating firm; the tipping fee charged by each landfill, illegal disposal site, and preferred disposal site;

the quantity of scrap tires taken by each disposal site; the distance between each generating firm and landfill, preferred disposal site, and illegal disposal site; and the cost of transporting scrap tires. Each of these data classes is described below.

3.4.1.1 Number Of Tires Originating From Each Generating Firm

As discussed above, the vast majority of scrap tires are generated when an old tire is replaced with a new one. The old tire is left by the consumer at the tire retail establishment, where it is then transported to some disposal site. Therefore, a good proxy for the number of scrap tires generated by each retail establishment each year is the number of new tires they sold each year. Since a tire tax is collected from each dealer for every new tire they sell, this information does exist, however due to the confidentiality of tax records, not all of this information was available for this study.

For any locality with five or more retail establishments, the Virginia Department of Taxation provided firm level data on the number of tires sold in 1992 (Virginia Department of Taxation, 1994). This firm level data showed that the average number of tires sold by each firm was 871.13. For those localities with fewer than five retail establishments, no information was provided. Also, firms with more than one retail location are allowed to file a single return, and no information with respect to these firms was provided. Therefore, for only 2,022,753 of the 4,471,430 tires sold in 1992, the location of origin is known with certainty. Another proxy was necessary to determine the point of origin for the remaining 2,448,677 tires.

The number of motor vehicles registered, as of December 31, 1991, in each Virginia county and city was obtained from the Department of Motor Vehicles (Virginia Department of Motor Vehicles, 1991-1992). There were 5,023,679 vehicles registered state wide. Therefore, 0.89 tires were purchased for each registered vehicle. In order to estimate the number of tires sold in each locality, the following procedure was used. First, the number of vehicles registered in each locality was multiplied by the tire-vehicle ratio of 0.89 to determine a first estimate of the number of tires sold in each locality. This number was compared to the firm level data obtained from the Department of Taxation. If the firm level data showed that a greater number of tires was sold than the vehicle based estimate, then the firm level data estimate was retained. This accounted for 23 localities and 612,405 tires. Next the procedure was done again for the remaining 3,859,025 tires, 4,618,601 vehicles, and 113 localities. A new tire-vehicle ratio of 0.835 was used. In order to determine the number of retail firms in each locality, the greater of the two following figures were used: the firm level data or 871.13 tires per firm. Statewide, 5152 retail locations were estimated to exist.

Two other points concerning the scrap tire generation data need to be discussed. First, the exact location of each tire retail firm within its designated locality was not known. Therefore it was assumed that each was located at the centroid of the locality. Second, the number of new tires sold, and thus the number of scrap tire generated, used above, does not distinguish between passenger vehicle tires and truck tires. Therefore, an adjustment was required. The Waste Tire Management Council (WTMC) has found that nationwide 90% of scrap tires generated are passenger tires and 10% are truck tires (1994). A passenger vehicle tire weights on average 20 pounds, while a truck tire has an average weight of 100 pounds (Serumgard,1994). In order to talk about both types of tires as a single unit, tire quantities will be converted to tons throughout the rest of this research. Assuming that the composition of scrap tires is the same in Virginia as it is nationwide, the number of tons generated in 1992 in Virginia was calculated as follows.

$$\text{Tons} = (\text{Total Number of Tires}) \times [(0.90 \times 20) + (0.10) \times (100)] / 2000$$

Therefore, 62,900 tons of scrap tires were generated in Virginia during 1992.

3.4.1.2 The Number Of Tires Received At Each Disposal Site And Their Tipping Fees

In December 1992, the Virginia Department of Environmental Quality (VA DEQ, 1992b) conducted a phone survey of all permitted solid waste landfills in the state. The operator of each landfill was asked: if the landfill accepted scrap tires; what tipping fee they charged for a passenger vehicle tire, if any; and if they require the tires to be split. Fifty six landfills were identified which landfilled scrap tires. Eleven of the landfills required the scrap tires to be split before they accepted them. All landfills are assumed to restrict access to residents of their respective localities.

The tipping fee per passenger tire ranged from zero to $2.50, with a mean tipping fee of $0.66. In order to adjust the tipping fee of those landfills which required the tires to be split, $0.62 per passenger tire was added to the tipping fee. This is the cost of splitting a passenger tire (Park,1994). The tipping fee for a ton was equal to one hundred times the tipping fee charged for a passenger vehicle tire.[3]

Between April and October 1993, the VA DEQ conducted an extensive statewide survey to determine the location of each illegal scrap tire disposal site. Enforcement agents from the department located 731 tire piles throughout the state. They recorded detailed information about each site, including: the site location--latitude and longitude, the locality where the site was located, the number of tires at the site, the date dumping began at the site (if available), and if evidence of recent dumping was available. In all 17,595,680 scrap tires were identified. The largest site was composed of 4,900,000 tires, while the smallest had only 30 scrap tires. The mean tire pile had 24,070 scrap tires (VA DEQ, 1993).

Of these 731 illegal disposal sites, 130 showed evidence of recent dumping, had more than 2,000 scrap tires, and were not landfills that were stockpiling tires with the intent of burying the tires.[4] These 130 illegal disposal sites were composed of 11,332,955

[3] Some landfills did report a tipping fee for truck tires, however the number doing so was so few that it was decided that using a weight based tipping fee schedule, as incorporated into the tonnage formula would provide for the greatest consistency.

[4] Only those illegal disposal sites with more than 2,000 scrap tires were included in the analysis in order to allow for a reasonable representation of the real market for scrap tire disposal in Virginia, without making the size of the simulation model unmanageable.

scrap tires, or 158,661 tons. Of these 130 sites, the smallest illegal disposal site had 2,000 tires (28 tons), the largest had 4,900,000 tires (68,600 tons), and the mean number of tires per site was 87,176 (1220 tons) (VA DEQ, 1993). The tipping fee charged at the illegal disposal sites is unknown. However, one of the environmental enforcement agents at DEQ was able to put a range of $0.25 and $0.75 per passenger tire on the tipping fee if the site was owned by a person who authorized the disposal of scrap tires on the land, or of course zero dollars if the disposal was unauthorized (Aukamp,1994). Since all of the tire piles are over 2000 tires, it is safe to assume the sites were all authorized because many return trips to the same unauthorized site would be uncommon. Therefore, this study assumed that all illegal disposal is authorized, and the tipping fee charged at each illegal disposal site ranges from $0.25 to $0.75 per passenger tire. Also, in order to construct the baseline model, the number of tons disposed of in 1992 at each site is required. However, only the cumulative number of tires at each site and the date disposal began at 64 of the 130 sites is known. Given this limited information, the baseline model will only be checked for reasonableness.

With regard to preferred disposal, the VA DEQ provided a list of all scrap tire disposal firms which they believed took Virginia scrap tires in 1992. Each of these firms was contacted and asked the number of Virginia scrap tires taken in 1992, and the tipping fee they charged per ton. The following information was obtained.

Table 3. Prefered Legal Disposal Site Phone Survey Results

Firm	Location	Tons of Virginia Tires	Tons of Non-Virginia Tires	Tipping fee per Ton
Tires, Inc.	Winston Salam, NC	480	41,503	$55.00
Virginia Recycling	Providence Forge, VA	7,350	0	$55.00
SPSA	Chesapeake, VA	4,424	0	$65.00
U.S. Tire	Concord, NC	0	42,000	$60.00
Emanuel Tire	Baltimore, MD	11,200	30,464	$50.00
Tire Derived Systems	Ashland, VA	1,500	0	$55.00 to $60.00

(Kuhn, 1994; Emanuel, 1994; Forester, 1994; Greenstein, 1994)

3.4.1.3 The Distance Between Each Region And Disposal Site

The latitude and longitude of each illegal disposal site is known from the survey conducted by the VA DEQ. The latitude and longitude of each locality centroid was obtained from a Geographic Information System. Therefore, given the assumption that all tire retailers are located at the centroid of the their respective localities, their position is known as well. A similar assumption was made about each landfill--it is assumed to be located at the centroid of its respective locality. The latitude and longitude of each legal disposal site was obtained by plotting the disposal sites' location on the GIS system and downloading the positions. Given that the latitude and longitude of each retail firm, landfill, illegal disposal site, and legal disposal site, is now known, the Euclidean distance between them was calculated using the following formula:

Given two points (a,b) the distance between them is:

$$\text{Distance} = [((\text{Long}_a - \text{Long}_b) \times \text{MPDLN})^2 + ((\text{Lat}_a - \text{Lat}_b) \times \text{MPDLT})^2]^{1/2}$$

where;

MPDLN = miles per degree longitude
MPDLT = miles per degree latitude

The MPDLT equals 69.057 and in Virginia the MPDLN is approximately 56.286. Of course this formula has several limitations. First, it doesn't consider the change in MPDLN as one moves closer, or further, from the equator. In Virginia, however, this error is bounded by approximately four miles. Second, the formula doesn't allow for the additional distance caused by the curvature of the Earth. Both of these errors are small compared to the fact that these distances are being used as linear approximations to road distances. In order to correct for all three of these errors, as best as possible, the following was done. The distances between 32 Virginia counties and cities, as compiled by the Virginia Department of Transportation were compared to linear distances between the centroids of the same localities as estimated with the above formula. The ratio between the road distances and the linear distances was 1.219. Therefore, the distances calculated above were multiplied by 1.219 before being used in the model.

3.4.1.4 The Cost Of Transporting Scrap Tires

The current scrap tire hauling industry is comprised of many small firms which are usually owned and operated by a single individual. The vehicle usually used for transporting scrap tires is a standard one-ton truck, which has a bed measuring eight feet wide and ten feet long. Tires can be stacked six feet high on these trucks. Therefore, a single truck load has a maximum volume of 480 cubic feet, or 17.78 cubic yards. It was assumed that the hauling firm minimized costs by hauling only full truckloads.

According to the Recycling Research Institute (1994), a scrap passenger vehicle tire has a volume of 0.1176 cubic yards, and a scrap truck tire has a volume of 0.3528 cubic yards. In order to calculate the volume of an average ton of tires, the following calculation was made:

Volume of Mean Ton $= 0.90 \times (2000/20) \times (0.1176) + 0.10 \times (2000/100) \times (0.3582) = 11.32 \text{ yards}^3$

Therefore, a single truckload of scrap tires consisted of 1.57 tons. In order to find the cost of transporting a ton a mile, it was necessary to determine the per mile cost of operating the one-ton truck, including the drivers wage and a return on the capital investment. A phone interview with a tire hauling firm revealed that $0.45 per mile was a good estimate of this cost (Kuhn,1994).

3.4.2 Criminal Enforcement Cost Data

3.4.2.1 Deterring And/Or Detaining Illegal Tire Disposers

Since the law under which the criminal enforcement mechanism is assumed to operate is hypothetical, no cost estimates with regard to deterring and/or detaining illegal tire disposers are available. Therefore, a proxy for these costs was used. A multi-output cost function was estimated for police services, where the output levels were the number of arrests made in three crime categories. The cost function was estimated using arrest levels and input prices for most of Virginia's counties and cities for the fiscal years 1987 to 1993. The cost function that was estimated is (see Appendix A for a discussion of the statistical properties of the cost function):

$$(\ln C1) = 9.09 + 0.0085 \ln(Y_1) - 0.1344 \ln(Y_2) + 0.5809 \ln(Y_3) + 0.624 \ln(P_P) - 0.032 \ln(P_C) + 0.408 \ln(P_K) + \frac{1}{2} [\, 0.0814 (\ln(Y_1))^2 + 0.0572 (\ln(Y_2))^2 - 0.2223 \ln(\ln(Y_3))^2 - 0.0679 \ln(Y_1) \ln(Y_2) + 0.0211 \ln(Y_1) \ln(Y_3) + 0.1372 \ln(Y_2) \ln(Y_3) + 0.0491 (\ln(P_p))^2 + 0.1354 (\ln(P_C))^2 - 0.1274 \ln(P_K))^2 - 0.0285 \ln(P_P) \ln(P_C) - 0.0205 \ln(P_P) \ln(P_K) - 0.1087 \ln(P_C) \ln(P_K)] - 0.0066 \ln(P_P) \ln(Y_1) - 0.0238 \ln(P_P) \ln(Y_2) + 0.0572 \ln(P_P) \ln(Y_3) + 0.0025 \ln(P_C) \ln(Y_1) + 0.0018 \ln(P_C) \ln(Y_2) - 0.0233 \ln(P_C) \ln(Y_3) + 0.004 \ln(P_K) \ln(Y_1) + 0.0221 \ln(P_K) \ln(Y_2) - 0.0339 \ln(P_K) \ln(Y_3) + 0.1915\, M$$

In order to use the estimated multi-output cost function as a proxy for the cost of arresting an illegal tire disposer a phone survey of 20 police chiefs and sheriffs was conducted. The police chiefs were then given a hypothetical illegal tire disposal scenario, and asked to compare the effort required to make an arrest under that scenario with the effort required to make an arrest with regard to the three crime types. The crime type that most closely matched the illegal disposal scenario, with regard to effort required, was used as a proxy for police effort to deter and/or detain illegal tire disposers. Also, the police chiefs were asked to estimate the number of such cases that, once an arrest was made, would result in a guilty plea, a not guilty plea and a dismissal, and a not guilty plea and a conviction. They were also asked to offer an opinion on the percentage of a maximum fine that would be handed down if a guilty plea or conviction was obtained.

Finally, the police chiefs were asked how many magistrate transactions, and court hearings--under both the guilty and not-guilty plea scenario-- would be required. The results of the phone survey follow.

Table 4. Police Chief Survey Results

Question	Minimum	Maximum	Mean	Standard Deviation
Number of Magistrate Hearings	1	2	1	0
Percent Who Plead Guilty	50	90	68	15
Percent Found Guilty	7	45	21	11
Number of Court Hearings if Guilty Plea Entered	1	3	1	1
Number of Court Hearings if Not Guilty Plea Entered	1	3	2	1
Fine Ratio (Found Guilty/Plead Guilty)	0	2	1	0

In addition to these results 13 of the 20 Police Chiefs said they were familiar with the scrap tire problem in Virginia, and the other seven said they had personal experience with the problem. Also, 19 Police Chiefs thought that illegal tire disposal was most similar, in relation to the effort required to apprehend a suspect, to the "Other" crime category which consists of mostly less serious crimes. One thought it was similar to the "Property" crime category (see appendix for a description of these categories). Therefore, the cost of deterrence and apprehension of illegal tire disposers was estimated using the "Other" crime category as a proxy for illegal tire disposal. Also, the police chiefs predicted that 68.25 percent of the defendants would plead guilty, and 21.37 percent would be found guilty. Also, they predicted that the fine if a defendant pleads not guilty and is found guilty at trial would be 1.55 times the fine if a guilty plea is entered.

The apprehension and deterrence cost of each scenario was determined by using the police cost function to predict costs at the current level of police effort at each police agency (P_P^*), and also at the new projected level--current level plus new scrap tire related police effort for each police agency ($P_P^* + P_P^{NEW}$). The difference between these two costs, for each scenario, is the predicted apprehension and deterrence cost attributable to the enforcement of scrap tire disposal law under the scenario for each police agency:

$C1_P = C1_P^{NEW}(P_P^* + P_P^{NEW}) - C1_P^*(P_P^*)$.

where:

$P_P^{NEW} = (R_P^* \times EF) / [(0.6825 \times Fine) + (0.2137 \times Fine \times 1.55)]$

R_P^* = the number of illegal incidents in police jurisdiction P if the expected fine is zero

To determine the total apprehension and deterrence cost for a scenario (C1), the individual police agency cost changes ($C1_P$) are summed across police agencies:

$C1 = \sum C1_P$

3.4.2.2 Processing And Adjudicating Illegal Tire Disposers

In order to determine the cost of processing an arrest and adjudicating a trial, two other cost functions were estimated. The first was for magistrates. Data on magistrate output (transactions) and input quantities and prices were obtained for the 32 magistrate districts in Virginia for the years 1987 to 1992 (Supreme Court of Virginia, 1986-1993). The cost function that was estimated is (see Appendix A for a discussion of the statistical properties of the cost function):

$$\begin{aligned}\ln(C2) = {} & 7.909 + 0.4665 \ln(Y) + 0.8576 \ln(P_{MagA}) + 0.9476 \ln(P_{MagB}) - 0.8052 \\ & \ln(P_O) + \tfrac{1}{2} [-0.101 \ln(Y)^2 - 0.4522 \ln(P_{MagA}) \ln(P_{MagB}) - 0.1413 \ln(P_{MagA}) \ln(P_O) \\ & + 00.881 \ln(P_{MagB}) \ln(P_O) + 0.5935 \ln(P_{MagA})^2 - 0.4288 \ln(P_{MagB})^2 - 0.7397 \ln(P_O)^2] \\ & - 0.2208 \ln(Y) \ln(P_{MagA}) + 0.4699 \ln(Y) \ln(P_{MagB}) - 0.2491 \ln(Y) \ln(P_O) - 0.4116 (R)\end{aligned}$$

The results of the phone survey of police chiefs showed that each arrest that was made resulted in an average of 1.15 "transactions" taking place before the magistrate. Therefore, by multiplying the number of arrests in each magistrate district for each scenario by 1.15, the number of additional magistrate transactions, resulting from scrap tire disposal enforcement, for each district (m) is computed. The processing cost of each scenario was determined by using the cost function to predict costs at the current level of hearings (A_M^*), and also at the new projected level--current level plus new scrap tire related hearings for each magistrate district ($A_M^* + A_M^{NEW}$). The difference between these two levels, for each scenario, is the predicted processing cost for each district attributable to the enforcement of scrap tire disposal law under the scenario:

$$C2_M = C2_M^{NEW}(A_M^* + A_M^{NEW}) - C2_M^*(A_M^*)$$

where:

$$A_M^{NEW} = (P_M^{NEW} \text{ x } EF) / [(0.6825 \text{ x Fine}) + (0.2137 \text{ x Fine x } 1.55)] \text{ x } 1.15$$

To determine the total processing cost for a scenario (C2), the individual magistrate district cost changes ($C2_M$) are summed across districts:

$$C2 = \sum C2_M$$

The second cost of processing an arrest and adjudication is the court cost. From the phone survey of police chiefs, it was learned that in the case where the defendant pleads guilty, usually their are 1.475 "hearings" held in the Virginia General District Court where the illegal disposal incident occurred, and if the defendant pleads not guilty, 2.35 hearings will have to be held. Thus, under each case scenario, the number of hearings in each court is known. The cost of a general district court hearing was determined by estimating a multi-output cost function for most of the Virginia District Courts. Data on court outputs (hearings for different case types) and input prices and quantities were obtained for the 123 district courts for fiscal years 1990 to 1993. The cost function that was estimated is (see Appendix A for a discussion of the statistical properties of the cost function):

$$\ln(C3) = 9.7944 + 0.1459 \ln(Y_1) + 0.1391 \ln(Y_2) + 0.1576 \ln(P_J) + 0.0571 \ln(P_G) + 0.0052 \ln(P_C) + 0.7799 \ln (P_S) + \tfrac{1}{2}[0.2102 \ln(Y_1)^2 + 0.1103 \ln(Y_2)^2 - 0.0839 \ln(Y_1) \ln(Y_2) - 0.0438 \ln (P_J)^2 + 0.0567 \ln (P_G)^2 + 0.0021 \ln (P_C)^2 + 0.1170 \ln(P_S)^2 + 0.0390 \ln(P_J) \ln(P_C) - 0.0406 \ln(P_G) \ln(P_C) + 0.0048 \ln(P_J) \ln(P_S) - 0.0005 \ln(P_C) \ln(P_S) - 0.0160 \ln(P_G) \ln(P_S)] + 0.0056 \ln(P_J) \ln(Y_2) - 0.0029 \ln(P_G) \ln(Y_1) + 0.0002 \ln(P_C) \ln(Y_1) - 0.00006 \ln(P_C) \ln(Y_2) + 0.0026 \ln(P_S) \ln (Y_1) + 0.0055 \ln(P_S) \ln(Y_2) - 0.2996 \times \text{Combined}$$

The court cost of each scenario was determined by using the cost function to predict costs at the current level of hearings (T_C^*),and also at the new projected level--current level plus new scrap tire related hearings for each court ($T_C^* + T_C^{NEW}$). The difference between these two levels, for each scenario, is the predicted court cost attributable to the enforcement of scrap tire disposal law under the scenario:

$$C3_C = C3_C^{NEW}(T_C^* + T_C^{NEW}) - C3_C^*(T_C^*).$$

where:

$$T_C^{NEW} = A_C^{NEW} \times [(0.6825 \times 1.48) + ((1-0.6825) \times (2.35)]$$

To determine the total court cost for a scenario (C3), the individual court cost changes ($C3_C$) are summed across courts:

$$C3 = \sum C3_C$$

3.4.3 Regulatory Enforcement Cost Data

In order to determine the cost of enforcement under the regulatory approach the cost of performing an audit of a firm's records needs to be calculated. Unfortunately, very little data are available with regard to scrap tire disposal audits, mainly because nobody has much experience with such activity. Minnesota is the one state with a somewhat active audit program. A phone interview with Mr. James Lungstrom, the Minnisotta Waste Tire Program Coordinator, on August 22, 1995, uncovered the following information. A single audit of an average size retailer's records, going back one year, takes approximately three days for a single staff person from their department. It then takes two days for the staff person to write up the results of the audit. Therefore, a full time employee can conduct 50 audits per year. In addition, Mr. Lungstrom stated that the only resources the auditor needed was an automobile, portable computer, and office supplies.

In order to determine the cost of an audit, salary information was needed. During a phone interview, Ms. Kelly Krolick, Human Resources Officer, Virginia Department of Environmental Quality, on August 23, 1995, provided this information. She determined, after hearing the audit scenario, that the job title appropriate to the audit task was either "Senior Level Environmental Inspector" or "Environmental Program Analyst." Both positions have a starting salary of $26,800, and a top salary of $40,919. Ms. Krolick estimated that the average person in these positions was at Step 13 in the salary schedule, and had a salary of $32,027. Using the Commonwealth's fringe benefit factor of 41.1 percent of salary, the annual labor costs of one full time auditor is $45,286.18.

The cost of the auditor's automobile is estimated to be $3,600.00 per year. This is at a rate of $0.30 cents per mile for 12,000 miles. This rate is representative of automobile leasing rates, including fuel costs. Finally, it was estimated that the lease of a portable computer, and office supplies, would come to about $1,000.00 per annum. Therefore, the estimated annual cost of a single full-time auditor, including equipment and supplies is $49,886.18. Given that the auditor can perform 50 audits per year, the approximate cost per audit is $997.72.

3.4.4 Cost Of Administering The Subsidy Program

Two assumptions concerning the costs of the scrap tire subsidy program are made. First, the administrative costs borne by the agency (PUAC) are assumed to be zero. This assumption seems plausible, considering that claims for the subsidy will only come from at most five preferred disposal firms (see Table 5), and these claims can be made periodically, perhaps quarterly. Therefore, it is unlikely that the agency will have to incur any significant additional administrative costs. The second assumption is that the administrative cost borne by the preferred disposal firms (PRAC) is also zero. This assumption is also plausible, since these firms already have to keep a record of their operations, and any additional paperwork would be minimal. These assumptions result in the total cost of the subsidy program (TSC) equaling zero--since the actual subsidies are transfers, and the agency fiscal cost of the subsidy program equaling the actual cost of the subsidies (TS).

3.4.5 The Supply Function For Legal Disposal

No information, beyond the single equilibrium price-quantity combination obtained in the phone survey, was available with regard to the supply function for the six legal disposal firms. In order to fully specify the non-linear programming simulation model, several assumptions were made and then a test of the results' sensitivity to some of these assumptions was conducted. First, the industry was assumed to be close to perfectly competitive, and second, all firms are assumed to be operating at the minimum of their long term average cost curve. These assumptions are not very strong when one considers the options open to those demanding disposal services--they can either take the tires to a landfill, legal disposal site, or any illegal disposal site. Thus in practice, the options are endless, and no firm can affect the total number of tires being disposed of--by some means--by changing their price. Given this assumption, firms, in the long run, can not operate at a lower tipping fee than that they are currently charging at the one equilibrium point (PBAR, QBAR). At quantities above the one known equilibrium, firms will increase their tipping fees. The rate at which they increase the tipping fees will depend on the elasticity of supply. Since this supply elasticity is not known, the model will be run at three different levels of elasticity, and the results will be compared to see how sensitive they are to the change in elasticity. Note that, each firm is assumed to have the same constant elasticity of supply. The model was run at elasticity of supply levels 0.33, 1.00 and 3.00. Thus, the model assumes three different constant elasticity of supply functions, with a relative range above the one known equilibrium point. Figure 1 illustrates the supply curves considered for a representative firm.

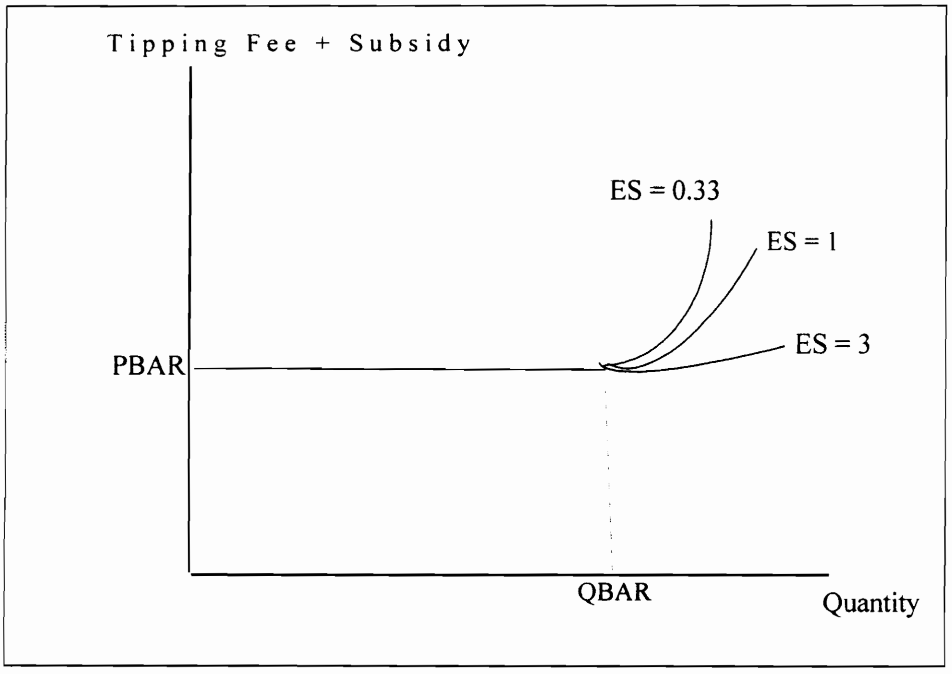

Figure 1. Elasticity of Supply for Legal Disposal

In order to incorporate these supply function assumptions, equation (2) must be replaced with the following equations:

$$\text{(2a)} \quad P_j = \left(\frac{(QB_j + QBAR_j + QNV_j)}{A_j}\right)^{(1/B_j)} - S_j \qquad \forall j$$

$$\text{(2b)} \quad XA_j + XB_j = Q_j \qquad \forall_j$$

$$\text{(2c)} \quad XB_j \geq 0 \qquad \forall j$$

$$\text{(2d)} \quad XA_j \leq QBAR_j \qquad \forall j$$

where;

$QBAR_j$ = Basecase quantity going to firm (j) from Virginia
QNV_j = Basecase quantity going to firm (j) from outside Virginia
B_j = Elasticity of supply for firm (j)
A_j = Constant in Supply equation = $(QBAR_j + QNV_j)/PBAR_j^{Bj}$
$PBAR_j$ = Basecase price charges by firm (j)
XA_j, XB_j are instrument variables.

3.5 The Basecase Scenario

Although the quantity taken, and price charged is known for all the disposal firms at the one known equilibrium point, and the number of tires going to landfills and stockpiles is also known, it is still necessary to calibrate the non-linear programming simulation model in an attempt to get the results of that model to closely mimic this equilibrium point. Two variables are able to be adjusted. First, is the tipping fee charged by Tire Derived Systems (TDS) (see Table 3). The price reported ranged from $55.00 to $60.00 per ton. Second, and much more important, is the expected fine currently perceived by the market participants (Y). In order to calibrate the model, a linear version of the model was developed by replacing equation (2) with the following equation (2L):

(2l) $P_j = PBAR_j \qquad \forall j$

The prices charged by legal disposal firms in the basecase ($PBAR_j$) were set to the level reported in the phone survey--except for TDS's price which was tried at many intervals between $55.00 and $60.00. Then, the (Y) parameter was adjusted upward from zero, until the model returned quantities to landfills, stockpiles and legal disposal sites, which most closely mimicked the one known equilibrium point. The combination of $PBAR_{TDS}$= $58.50 per ton and Y = $67.00 per ton was determined to cause the model to most closely mimic the one known equilibrium point.

In order to determine if this level of (Y) is "reasonable" it is important to reconsider what it is. It is the fee paid to illegal disposal site owners and/or the expected fine currently perceived in the market. Since the range of prices paid to illegal disposal site owners was earlier bounded between $25.00 to $75.00 per ton, this level of (Y) seems appropriate.

The Q_j for each firm generated by the linear simulation model was then used as $QBAR_j$ in the non-linear model simulation, along with the (Y) level of $67.00 per ton and the $PBAR_{TDS}$ level of $58.50. $PBAR_j$ for all firms except TDS was set equal to the levels obtained in the phone survey. Table 5 summarizes the basecase quantities which will be used in the simulation, as well as the actual quantities.

Table 5. Basecase Prefered Legal Disposal Quantities versus Actual Quantities

Disposal Site	Basecase Tons (QBAR)	Actual Tons	Percentage Difference
Tires, Inc	497	480	+ 3.4%
Virginia Recycling	7,943	7,350	+ 8.1%
SPSA	4,594	4,424	+ 3.8%
U.S. Tire	0	0	0%
Emanuel	11,536	11,200	+ 3.0%
Tire Derived Systems	2,102	1,500	+ 40.1%
TOTAL	26,671	24,954	+ 6.9%

As Table 5 shows, the basecase quantities are quite close to reality. In fact, the model overestimates the legal disposal by only 6.9 percent. One firm has a basecase quantity significantly different than the reported quantity. However, the reason for this difference is explainable. TDS is now out of business, and the reported quantity was obtained through an interview with a competitor, and thus, was that competitor's best guess. Therefore, confidence in the reported figure of 1,500 tons is low. Thus, considering this lack of confidence in the reported quantity, and the relatively small size of TDS's operation, the error is not cause for much concern. The linear model also projected that 9,322.80 tons of tires were landfilled, and 26,606.40 tons of tires were disposed of illegally through the commission of 16,946 illegal disposal incidents.

3.6 Simulation Scenarios

Before the simulations could be done, one additional enhancement to the non-linear programming simulation model needs to be made. Equation (9) recorded the number of number of illegal disposal incidents which occurred in a region. The scrap tire model will require that the number of illegal incidents in each police district, magistrate district and court district be recorded, thus three equations are necessary. Equation (9) must be replaced with:

(9a) $$Rp = \sum_{k} I_{k}^{p} \div X \quad \forall p$$

$$(9b) \quad R_m = \sum_k I_k^m \div X \qquad \forall m$$

$$(9c) \quad R_c = \sum_k I_k^c \div X \qquad \forall c$$

where;

p = police district
m = magistrate district
c = court district

The non-linear programming simulation model was run at 70 combinations of expected fines and subsidies. The expected fine levels considered (dollars per ton) were 0, 10, 20, 30, 40, 50, 60, 70, 80, and 90. The subsidy levels for which the model was run (dollars per ton) were 0, 10, 20, 30, 40, 50, 60. As mentioned above, these scenarios were developed under three different elasticity of supply assumptions(0.33, 1.00, 3.00), thus the model was run 210 times.

In order to see the effect of not allowing any landfilling of tires, the simulation was conducted with this restriction, but at only one elasticity of supply. Thus another 70 simulations were conducted.[5] In all, 280 simulation scenarios were done. After these simulations were completed, the enforcement costs, under both criminalization and regulation, associated with each scenario, were calculated as described above. This was

[5]The effect that elasticity of supply has on the results will be determined by comparing the results under the assumption of a constant elasticity of supply of 0.33 and the results under the assumption of a constant elasticity of supply of 3.00. The effect of a landfill ban will be illustrated by comparing the results with landfilling and without landfilling--assuming a constant elasticity of supply of 1.00 in each case.

done for two fine levels. Each fine level assumes a guilty plea or a finding of guilt under the regulatory regime. The fine levels are: $500.00 per truckload ($318.47 per ton) and $2,000.00 per truckload ($1,278.88 per ton). From the survey of police chiefs, it was estimated that a finding of guilt at trial, under the criminalization approach, would bring a penalty 1.55 times the above fines.

Now, for each scenario, the following can be determined: the elasticity of supply; the subsidy per ton; the total subsidy expenditures; the enforcement expenditures under both criminalization and regulation at each of the two fine levels; the expected fine per ton; the amount of tires disposed of in a preferred manner, illegally, and in a landfill; the preferred disposal cost; the landfilling cost; and the transportation cost.

3.7 Cost Effectiveness Analysis

Although there are 280 scenarios, each is not a cost effective solution. Those which are not cost effective--providing a given level of legal disposal at the lowest cost--should be deleted from further consideration. In order to do the cost effectiveness analysis, one must first determine what definition of cost to use. The research is concerned with how to minimize the cost of disposal. However, the cost of disposal can be defined many ways, depending on the accounting stance. The following costs of disposal were calculated, and each was used in the analysis: the public cost of disposal is the total subsidy expense plus the enforcement expenditures; the total cost of disposal is the sum of the public cost, the cost of landfilling, the after subsidy cost of preferred disposal, and the total transportation cost; and the net public disposal cost is the public cost of disposal less fines collected.

Forty-eight cost effectiveness analyses were done on the 280 scenarios. Assuming landfilling was legal, a cost effectiveness analysis was done for each of the 36--fine level, elasticity of supply, enforcement mechanism, and cost definition combinations. With landfilling assumed illegal, 12 additional cost effectiveness analyses were done--since only one elasticity of supply was considered within the math programming model under the no landfilling scenarios.

Each cost effectiveness analysis gives a locus of cost efficient points under the assumptions of the scenario. For example, one set of cost efficient points--each point is a subsidy level and enforcement effort pair that gave rise to a certain level of legal disposal-- will exist when landfilling is legal, the elasticity of substitution is 0.33, the fine level is $318.47 per ton, the enforcement mechanism is criminalization, and we are concerned with public disposal costs. A different set of cost efficient points will exist when landfilling is illegal, the elasticity of substitution is 3.00, the fine level is $1,278.88 per ton, the enforcement mechanism is regulation, and we are concerned with total disposal costs.

By comparing the different sets of cost efficient points, it will be possible to see the relative cost effectiveness of subsidies and enforcement with regard to the provision of legal waste tire disposal under each enforcement regime. It will also be possible to see how the fine level, elasticity of substitution, and cost accounting stance effect the relative efficiency. This will be done in the next chapter.

Chapter 4. Results

4.1 Overview

The results of the analysis described in Chapters two and three are discussed in this chapter. First, four tables are developed. Table 6 provides all the cost effective solutions for reaching different levels of illegal disposal under each assumption set. An assumption set is the type of enforcement--criminal or regulatory, the elasticity of supply --3.00 or 0.33, the fine level-- high or low, the subsidy per ton--$0.00 through $60.00, and the level of enforcement expenditures. From Table 6, Table 8 is developed. This table summarizes the information in Table 6, and allows for a simple discussion of the results. The key questions to be answered are: (1) which is more cost effective, criminal or regulatory enforcement? (2) what is a more cost effective means of reducing illegal tire disposal, subsidies or enforcement? (3) how does the elasticity of supply affect the choice of policy tools? and (4) how does the fine level affect the choice of policy tools?

Next, Table 7 provides all the cost-effective solutions for reaching different levels of illegal disposal under each assumption set with regard to the effect of a landfill ban on the results. In this case, an assumption set is the type of enforcement--criminal or regulatory, the presence of a landfill ban--yes or no, the fine level-- high or low, the subsidy per ton--$0.00 through $60.00, and the level of enforcement expenditures. From Table 7, Table 9 is developed. This table summarizes the information in Table 7, and allows for a simple discussion of the results. The question to be answered is: how does the presence of a landfill ban affect the results and the choice of policy tools?

Consider the first few entries in Table 6. The first row reads "Criminal Enforcement; Low Fine; Elasticity of Supply = 3.00; Public Cost." This is the assumption set under consideration. As one reads down the next eight rows, all of the cost effective scenarios for this assumption set are listed. In this case, cost effective is defined as public-cost effective, and it is the public costs which are listed in the "Cost Objective ($)" column. The rest is fairly self-explanatory. After the eight cost-effective scenarios are listed, the next assumption set is defined, and the cost effective scenarios for that assumption set are listed. Table 7 reads the same way, except the assumption sets assume a fixed elasticity of supply = 1, and landfilling is assumed to be either legal or illegal.

In order to illustrate the relationship between Table 6 and Table 8, and between Table 7 and Table 9, consider the first nine rows of Table 6 and the third row of Table 8. As can be seen, the first nine rows of Table 6 are summarized in the third row of Table 8. In Table 8 and Table 9, the assumption set parameters, except the enforcement mechanism, is found in the first column. Then for each assumption set, the cost range for both enforcement mechanisms is given in the second column. The cost range gives the cost--total cost, public cost, or net public cost--of the lowest cost scenario and of the highest cost scenario of each assumption set. Next, the maximum subsidy per ton of tires and the average subsidy expenditure, is listed for each assumption set. The four tables follow:

Table 6. Cost Effective Scenarios for Each Assumption Set.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
Criminal Enforcement; Low Fine; Elasticity of Supply = 3.00; Public Cost						
0	26,606	26,671	9,323	0	0	0
300,756	23,400	30,076	9,124	10	300,760	0
344,862	22,255	29,877	10,468	0	0	344,862
672,623	16,875	36,057	9,667	10	360,570	312,048
681,907	14,905	35,256	12,439	0	0	681,907
1,011,144	7,129	42,891	12,580	0	0	1,011,144
1,334,048	1,253	48,106	13,241	0	0	1,334,048
1,653,364	0	49,359	13,241	0	0	1,653,364
Criminal Enforcement; High Fine; Elasticity of Supply = 3.00; Public Cost						
0	26,606	26,671	9,323	0	0	0
86,783	22,255	29,877	10,468	0	0	86,783
172,703	14,905	35,256	12,439	0	0	172,703
257,690	7,129	42,891	12,580	0	0	257,690
342,050	1,253	48,106	13,241	0	0	342,050
426,409	0	49,359	13,241	0	0	426,409
Criminal Enforcement; Low Fine; Elasticity of Supply = 3.00; Total Cost						
2,176,078	26,606	26,671	9,323	0	0	0
2,413,350	23,400	30,076	9,124	10	300,760	0
2,840,516	22,255	29,877	10,468	0	0	344,862
2,906,325	17,385	36,091	9,124	20	721,820	0
3,253,854	16,875	36,057	9,667	10	360,570	312,048
3,736,784	9,042	46,838	6,720	30	1,405,140	0
3,965,949	8,150	44,782	9,667	20	895,640	224,874
4,419,186	7,271	43,692	11,638	10	436,920	615,990
4,547,507	1,381	55,443	5,776	40	2,217,720	0
4,716,188	0	56,824	5,776	40	2,272,960	12,374
Criminal Enforcement; High Fine; Elasticity of Supply = 3.00; Total Cost						
2,176,078	26,606	26,671	9,323	0	0	0

Table 6. Cost Effective Scenarios for Each Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
2,413,350	23,400	30,076	9,124	10	300,760	0
2,582,437	22,255	29,877	10,468	0	0	86,783
2,906,325	17,385	36,091	9,124	20	721,820	0
3,020,344	16,875	36,057	9,667	10	360,570	78,539
3,263,102	14,905	35,256	12,439	0	0	172,703
3,736,784	9,042	46,838	6,720	30	1,405,140	0
3,797,629	8,150	44,782	9,667	20	895,640	56,554
3,959,259	7,271	43,692	11,638	10	436,920	156,064
4,067,338	7,129	42,891	12,580	0	0	257,690
4,483,242	1,381	52,467	8,752	30	1,574,010	31,795
4,547,507	1,381	55,443	5,776	40	2,217,720	0
4,552,319	1,253	51,680	9,667	20	1,033,600	112,424
4,645,351	1,253	49,568	11,779	10	495,680	232,971
4,670,162	0	53,848	8,752	30	1,615,440	63,364
Criminal Enforcement; Low Fine; Elasticity of Supply = 3.00; Net Public Cost						
0	26,606	26,671	9,323	0	0	0
122,316	22,255	29,877	10,468	0	0	344,862
383,813	14,905	35,256	12,439	0	0	681,907
797,265	7,129	42,891	12,580	0	0	1,011,144
1,283,921	1,253	48,106	13,241	0	0	1,334,048
1,653,364	0	49,359	13,241	0	0	1,653,364
Criminal Enforcement; High Fine; Elasticity of Supply = 3.00; Net Public Cost						
-135,763	22,255	29,877	10,468	0	0	86,783
-125,391	14,905	35,256	12,439	0	0	172,703
43,812	7,129	42,891	12,580	0	0	257,690
291,923	1,253	48,106	13,241	0	0	342,050
426,409	0	49,359	13,241	0	0	426,409
Criminal Enforcement; Low Fine; Elasticity of Supply = 0.33; Public Cost						
0	26,606	26,671	9,323	0	0	0

Table 6. Cost Effective Scenarios for Each Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
274,420	25,835	27,442	9,323	10	274,420	0
345,173	24,690	27,442	10,468	0	0	345,173
617,424	24,077	28,054	10,468	10	280,540	336,881
683,338	20,258	28,054	14,288	0	0	683,338
960,813	18,891	29,421	14,288	10	294,210	666,599
1,014,674	15,632	29,421	17,546	0	0	1,014,674
1,294,506	14,581	30,473	17,546	10	304,730	989,777
1,339,229	10,397	30,239	21,964	0	0	1,339,229
1,623,626	9,645	31,733	21,222	10	317,330	1,306,293
1,657,537	5,842	30,761	25,997	0	0	1,657,537
1,937,291	5,446	32,050	25,104	10	320,500	1,616,787
1,972,524	4,558	31,431	26,611	0	0	1,972,524
2,248,368	4,319	32,443	25,839	10	324,430	1,923,943
2,283,347	4,168	31,821	26,611	0	0	2,283,347
2,558,798	2,681	33,308	26,611	10	333,080	2,225,721
2,867,850	1,509	34,480	26,611	10	344,800	2,523,053
3,175,194	0	35,989	26,611	10	359,890	2,815,305
Criminal Enforcement; High Fine; Elasticity of Supply = 0.33; Public Cost						
0	26,606	26,671	9,323	0	0	0
86,860	24,690	27,442	10,468	0	0	86,860
173,059	20,258	28,054	14,288	0	0	173,059
258,570	15,632	29,421	17,546	0	0	258,570
343,341	10,397	30,239	21,964	0	0	343,341
427,449	5,842	30,761	25,997	0	0	427,449
511,570	4,558	31,431	26,611	0	0	511,570
595,450	4,168	31,821	26,611	0	0	595,450
678,670	2,681	33,308	26,611	0	0	678,670
761,490	1,509	34,480	26,611	0	0	761,490

Table 6. Cost Effective Scenarios for Each Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
1,102,442	0	35,989	26,611	10	359,890	742,553
Criminal Enforcement; Low Fine; Elasticity of Supply = 0.33; Total Cost						
2,176,078	26,606	26,671	9,323	0	0	0
2,232,788	25,835	27,442	9,323	10	274,420	0
2,278,074	25,324	28,152	9,124	20	563,040	0
2,397,935	24,029	29,447	9,124	30	883,410	0
2,526,934	22,760	30,715	9,124	40	1,228,600	0
2,720,479	21,038	32,438	9,124	50	1,621,900	0
3,011,009	18,654	34,822	9,124	60	2,089,320	0
3,335,790	18,111	34,822	9,667	50	1,741,100	286,411
3,558,597	17,839	30,473	14,288	20	609,460	651,065
3,587,206	15,989	36,944	9,667	60	2,216,640	259,547
3,803,089	15,660	33,601	13,339	40	1,344,040	610,904
3,897,797	15,186	35,776	11,638	50	1,788,800	566,604
4,081,933	14,019	38,234	10,346	60	2,294,040	513,680
4,344,307	13,009	32,045	17,546	20	640,900	966,336
4,396,171	12,401	32,653	17,546	30	979,590	944,203
4,514,413	11,480	34,523	16,598	40	1,380,920	906,571
4,551,742	11,166	36,130	15,304	50	1,806,500	840,447
4,608,486	11,015	38,312	13,272	60	2,298,720	762,347
4,962,800	10,397	30,239	21,964	0	0	1,339,229
5,017,598	9,645	31,733	21,222	10	317,330	1,306,293
5,054,179	9,135	32,653	20,813	20	653,060	1,275,747
5,157,741	8,159	33,752	20,689	30	1,012,560	1,246,169
5,255,897	7,120	34,836	20,643	40	1,393,440	1,196,120
5,372,668	6,072	36,878	19,650	50	1,843,900	1,107,888
5,490,262	5,084	38,987	18,529	60	2,339,220	1,004,419
5,901,024	4,371	34,716	23,513	30	1,041,480	1,542,262

Table 6. Cost Effective Scenarios for Each Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
6,075,942	2,834	36,339	23,427	40	1,453,560	1,479,469
6,140,465	1,798	37,542	23,261	50	1,877,100	1,369,508
6,173,586	1,193	39,194	22,214	60	2,351,640	1,241,678
6,554,956	0	39,296	23,304	60	2,357,760	1,476,183
Criminal Enforcement; High Fine; Elasticity of Supply = 0.33; Total Cost						
2,176,078	26,606	26,671	9,323	0	0	0
2,232,788	25,835	27,442	9,323	10	274,420	0
2,278,074	25,324	28,152	9,124	20	563,040	0
2,397,935	24,029	29,447	9,124	30	883,410	0
2,526,934	22,760	30,715	9,124	40	1,228,600	0
2,575,836	22,710	29,421	10,468	20	588,420	82,817
2,680,641	21,659	30,473	10,468	30	914,190	80,934
2,720,479	21,038	32,438	9,124	50	1,621,900	0
2,836,614	20,495	32,438	9,667	40	1,297,520	77,766
2,847,778	20,258	28,054	14,288	0	0	173,059
2,969,694	18,891	29,421	14,288	10	294,210	168,851
3,011,009	18,654	34,822	9,124	60	2,089,320	0
3,072,477	17,839	30,473	14,288	20	609,460	164,945
3,245,716	16,267	32,045	14,288	30	961,350	161,145
3,347,037	15,660	33,601	13,339	40	1,344,040	154,852
3,352,813	15,632	29,421	17,546	0	0	258,570
3,453,224	14,581	30,473	17,546	10	304,730	252,292
3,624,352	13,009	32,045	17,546	20	640,900	246,381
3,692,756	12,401	32,653	17,546	30	979,590	240,788
3,839,164	11,480	34,523	16,598	40	1,380,920	231,322
3,925,936	11,166	36,130	15,304	50	1,806,500	214,641
3,966,912	10,397	30,239	21,964	0	0	343,341
4,046,318	9,645	31,733	21,222	10	317,330	335,012

Table 6. Cost Effective Scenarios for Each Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
4,231,356	8,159	33,752	20,689	30	1,012,560	319,784
4,366,946	7,120	34,836	20,643	40	1,393,440	307,169
4,549,631	6,072	36,878	19,650	50	1,843,900	284,852
4,555,311	5,842	30,761	25,997	0	0	427,449
4,597,111	5,446	32,050	25,104	10	320,500	417,114
4,640,652	5,153	33,338	24,108	20	666,760	407,510
4,743,982	5,084	38,987	18,529	60	2,339,220	258,139
4,756,936	4,371	34,716	23,513	30	1,041,480	398,175
4,820,522	4,319	32,443	25,839	10	324,430	499,214
4,898,598	3,815	34,027	24,758	20	680,540	487,637
4,978,789	2,834	36,339	23,427	40	1,453,560	382,317
5,112,545	2,452	36,103	24,045	30	1,083,090	476,343
5,125,388	1,798	37,542	23,261	50	1,877,100	354,431
5,253,090	1,193	39,194	22,214	60	2,351,640	321,181
5,463,000	0	39,296	23,304	60	2,357,760	384,227
Criminal Enforcement; Low Fine; Elasticity of Supply = 0.33; Net Public Cost						
0	26,606	26,671	9,323	0	0	0
274,420	25,835	27,442	9,323	10	274,420	0
376,649	24,077	28,054	10,468	10	280,540	336,881
545,705	15,632	29,421	17,546	0	0	1,014,674
857,083	14,581	30,473	17,546	10	304,730	989,777
923,357	10,397	30,239	21,964	0	0	1,339,229
1,365,422	5,842	30,761	25,997	0	0	1,657,537
1,665,010	5,446	32,050	25,104	10	320,500	1,616,787
1,699,029	4,558	31,431	26,611	0	0	1,972,524
1,989,250	4,319	32,443	25,839	10	324,430	1,923,943
1,991,574	4,168	31,821	26,611	0	0	2,283,347
2,330,061	3,815	34,027	24,758	20	680,540	1,878,447

Table 6. Cost Effective Scenarios for Each Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
2,371,113	2,681	33,308	26,611	10	333,080	2,225,721
2,742,028	1,841	34,920	25,839	20	698,400	2,172,505
2,747,111	1,509	34,480	26,611	10	344,800	2,523,053
3,175,194	0	35,989	26,611	10	359,890	2,815,305
Criminal Enforcement; High Fine; Elasticity of Supply = 0.33; Net Public Cost						
-232,101	20,258	28,054	14,288	0	0	173,059
-210,399	15,632	29,421	17,546	0	0	258,570
-72,532	10,397	30,239	21,964	0	0	343,341
135,334	5,842	30,761	25,997	0	0	427,449
238,075	4,558	31,431	26,611	0	0	511,570
303,678	4,168	31,821	26,611	0	0	595,450
464,173	2,681	33,308	26,611	0	0	678,670
625,659	1,509	34,480	26,611	0	0	761,490
1,102,442	0	35,989	26,611	10	359,890	742,553
Regulatory Enforcement; Low Fine; Elasticity of Supply = 3.00; Public Cost						
0	26,606	26,671	9,323	0	0	0
161,405	22,255	29,877	10,468	0	0	161,405
322,809	14,905	35,256	12,439	0	0	322,809
484,214	7,129	42,891	12,580	0	0	484,214
645,619	1,253	48,106	13,241	0	0	645,619
807,023	0	49,359	13,241	0	0	807,023
Regulatory Enforcement; High Fine; Elasticity of Supply = 3.00; Public Cost						
0	26,606	26,671	9,323	0	0	0
40,193	22,255	29,877	10,468	0	0	40,193
80,387	14,905	35,256	12,439	0	0	80,387
120,580	7,129	42,891	12,580	0	0	120,580
160,774	1,253	48,106	13,241	0	0	160,774
200,967	0	49,359	13,241	0	0	200,967

Table 6. Cost Effective Scenarios for Each Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
Regulatory Enforcement; Low Fine; Elasticity of Supply = 3.00; Total Cost						
2,176,078	26,606	26,671	9,323	0	0	0
2,413,350	23,400	30,076	9,124	10	300,760	0
2,657,059	22,255	29,877	10,468	0	0	161,405
2,906,325	17,385	36,091	9,124	20	721,820	0
3,103,211	16,875	36,057	9,667	10	360,570	161,405
3,413,208	14,905	35,256	12,439	0	0	322,809
3,736,784	9,042	46,838	6,720	30	1,405,140	0
3,902,479	8,150	44,782	9,667	20	895,640	161,405
4,126,004	7,271	43,692	11,638	10	436,920	322,809
4,293,862	7,129	42,891	12,580	0	0	484,214
4,547,507	1,381	55,443	5,776	40	2,217,720	0
4,727,033	0	57,307	5,293	50	2,865,350	0
Regulatory Enforcement; High Fine; Elasticity of Supply = 3.00; Total Cost						
2,176,078	26,606	26,671	9,323	0	0	0
2,413,350	23,400	30,076	9,124	10	300,760	0
2,535,847	22,255	29,877	10,468	0	0	40,193
2,906,325	17,385	36,091	9,124	20	721,820	0
2,981,999	16,875	36,057	9,667	10	360,570	40,193
3,170,786	14,905	35,256	12,439	0	0	80,387
3,736,784	9,042	46,838	6,720	30	1,405,140	0
3,781,268	8,150	44,782	9,667	20	895,640	40,193
3,883,582	7,271	43,692	11,638	10	436,920	80,387
3,930,228	7,129	42,891	12,580	0	0	120,580
4,491,640	1,381	52,467	8,752	30	1,574,010	40,193
4,520,282	1,253	51,680	9,667	20	1,033,600	80,387
4,687,185	0	53,848	8,752	30	1,615,440	80,387
Regulatory Enforcement; Low Fine; Elasticity of Supply = 3.00; Net Public Cost						

Table 6. Cost Effective Scenarios for Each Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
-61,141	22,255	29,877	10,468	0	0	161,405
24,715	14,905	35,256	12,439	0	0	322,809
270,335	7,129	42,891	12,580	0	0	484,214
595,492	1,253	48,106	13,241	0	0	645,619
807,023	0	49,359	13,241	0	0	807,023
Regulatory Enforcement; High Fine; Elasticity of Supply = 3.00; Net Public Cost						
-217,707	14,905	35,256	12,439	0	0	80,387
-93,299	7,129	42,891	12,580	0	0	120,580
110,647	1,253	48,106	13,241	0	0	160,774
200,967	0	49,359	13,241	0	0	200,967
Regulatory Enforcement; Low Fine; Elasticity of Supply = 0.33; Public Cost						
0	26,606	26,671	9,323	0	0	0
161,405	24,690	27,442	10,468	0	0	161,405
322,809	20,258	28,054	14,288	0	0	322,809
484,214	15,632	29,421	17,546	0	0	484,214
645,619	10,397	30,239	21,964	0	0	645,619
807,023	5,842	30,761	25,997	0	0	807,023
968,428	4,558	31,431	26,611	0	0	968,428
1,129,832	4,168	31,821	26,611	0	0	1,129,832
1,291,237	2,681	33,308	26,611	0	0	1,291,237
1,452,642	1,509	34,480	26,611	0	0	1,452,642
1,812,531	0	35,989	26,611	10	359,890	1,452,642
Regulatory Enforcement; High Fine; Elasticity of Supply = 0.33; Public Cost						
0	26,606	26,671	9,323	0	0	0
40,193	24,690	27,442	10,468	0	0	40,193
80,387	20,258	28,054	14,288	0	0	80,387
120,580	15,632	29,421	17,546	0	0	120,580
160,774	10,397	30,239	21,964	0	0	160,774

Table 6. Cost Effective Scenarios for Each Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
200,967	5,842	30,761	25,997	0	0	200,967
241,160	4,558	31,431	26,611	0	0	241,160
281,354	4,168	31,821	26,611	0	0	281,354
321,547	2,681	33,308	26,611	0	0	321,547
361,741	1,509	34,480	26,611	0	0	361,741
721,629	0	35,989	26,611	10	359,890	361,741
Regulatory Enforcement; Low Fine; Elasticity of Supply = 0.33; Total Cost						
2,176,078	26,606	26,671	9,323	0	0	0
2,232,788	25,835	27,442	9,323	10	274,420	0
2,278,074	25,324	28,152	9,124	20	563,040	0
2,397,935	24,029	29,447	9,124	30	883,410	0
2,526,934	22,760	30,715	9,124	40	1,228,600	0
2,654,423	22,710	29,421	10,468	20	588,420	161,405
2,720,479	21,038	32,438	9,124	50	1,621,900	0
2,920,253	20,495	32,438	9,667	40	1,297,520	161,405
2,997,528	20,258	28,054	14,288	0	0	322,809
3,011,009	18,654	34,822	9,124	60	2,089,320	0
3,210,783	18,111	34,822	9,667	50	1,741,100	161,405
3,230,341	17,839	30,473	14,288	20	609,460	322,809
3,407,380	16,267	32,045	14,288	30	961,350	322,809
3,489,064	15,989	36,944	9,667	60	2,216,640	161,405
3,514,994	15,660	33,601	13,339	40	1,344,040	322,809
3,578,457	15,632	29,421	17,546	0	0	484,214
3,654,003	15,186	35,776	11,638	50	1,788,800	322,809
3,685,146	14,581	30,473	17,546	10	304,730	484,214
3,862,185	13,009	32,045	17,546	20	640,900	484,214
3,936,182	12,401	32,653	17,546	30	979,590	484,214
4,092,056	11,480	34,523	16,598	40	1,380,920	484,214

Table 6. Cost Effective Scenarios for Each Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
4,195,509	11,166	36,130	15,304	50	1,806,500	484,214
4,269,190	10,397	30,239	21,964	0	0	645,619
4,356,924	9,645	31,733	21,222	10	317,330	645,619
4,424,051	9,135	32,653	20,813	20	653,060	645,619
4,557,190	8,159	33,752	20,689	30	1,012,560	645,619
4,705,395	7,120	34,836	20,643	40	1,393,440	645,619
4,910,398	6,072	36,878	19,650	50	1,843,900	645,619
4,934,886	5,842	30,761	25,997	0	0	807,023
4,987,021	5,446	32,050	25,104	10	320,500	807,023
5,040,165	5,153	33,338	24,108	20	666,760	807,023
5,131,462	5,084	38,987	18,529	60	2,339,220	645,619
5,165,785	4,371	34,716	23,513	30	1,041,480	807,023
5,289,736	4,319	32,443	25,839	10	324,430	968,428
5,379,390	3,815	34,027	24,758	20	680,540	968,428
5,403,496	2,834	36,339	23,427	40	1,453,560	807,023
5,577,980	1,798	37,542	23,261	50	1,877,100	807,023
5,738,932	1,193	39,194	22,214	60	2,351,640	807,023
6,046,644	588	37,223	24,788	30	1,116,690	1,129,832
6,047,201	0	39,296	23,304	60	2,357,760	968,428
Regulatory Enforcement; High Fine; Elasticity of Supply = 0.33; Total Cost						
2,176,078	26,606	26,671	9,323	0	0	0
2,232,788	25,835	27,442	9,323	10	274,420	0
2,278,074	25,324	28,152	9,124	20	563,040	0
2,356,467	24,690	27,442	10,468	0	0	40,193
2,397,935	24,029	29,447	9,124	30	883,410	0
2,526,934	22,760	30,715	9,124	40	1,228,600	0
2,533,212	22,710	29,421	10,468	20	588,420	40,193
2,639,901	21,659	30,473	10,468	30	914,190	40,193

Table 6. Cost Effective Scenarios for Each Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
2,755,105	20,258	28,054	14,288	0	0	80,387
2,881,230	18,891	29,421	14,288	10	294,210	80,387
2,987,919	17,839	30,473	14,288	20	609,460	80,387
3,164,958	16,267	32,045	14,288	30	961,350	80,387
3,214,824	15,632	29,421	17,546	0	0	120,580
3,321,512	14,581	30,473	17,546	10	304,730	120,580
3,498,551	13,009	32,045	17,546	20	640,900	120,580
3,572,548	12,401	32,653	17,546	30	979,590	120,580
3,728,422	11,480	34,523	16,598	40	1,380,920	120,580
3,784,345	10,397	30,239	21,964	0	0	160,774
3,872,079	9,645	31,733	21,222	10	317,330	160,774
3,939,206	9,135	32,653	20,813	20	653,060	160,774
4,072,345	8,159	33,752	20,689	30	1,012,560	160,774
4,220,550	7,120	34,836	20,643	40	1,393,440	160,774
4,328,830	5,842	30,761	25,997	0	0	200,967
4,380,965	5,446	32,050	25,104	10	320,500	200,967
4,434,109	5,153	33,338	24,108	20	666,760	200,967
4,525,702	4,558	31,431	26,611	0	0	241,160
4,559,729	4,371	34,716	23,513	30	1,041,480	200,967
4,562,469	4,319	32,443	25,839	10	324,430	241,160
4,617,017	4,168	31,821	26,611	0	0	281,354
4,652,122	3,815	34,027	24,758	20	680,540	241,160
4,797,440	2,834	36,339	23,427	40	1,453,560	200,967
4,829,605	2,681	33,308	26,611	10	333,080	281,354
4,877,362	2,452	36,103	24,045	30	1,083,090	241,160
4,968,332	1,841	34,920	25,839	20	698,400	281,354
4,971,924	1,798	37,542	23,261	50	1,877,100	200,967
5,042,529	1,509	37,421	23,670	40	1,496,840	241,160

Table 6. Cost Effective Scenarios for Each Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
5,047,421	1,509	34,480	26,611	10	344,800	321,547
5,132,875	1,193	39,194	22,214	60	2,351,640	200,967
5,198,165	588	37,223	24,788	30	1,116,690	281,354
5,322,981	0	38,514	24,086	40	1,540,560	281,354
Regulatory Enforcement; Low Fine; Elasticity of Supply = 0.33; Net Public Cost						
-85,493	24,690	27,442	10,468	0	0	161,405
-82,351	20,258	28,054	14,288	0	0	322,809
15,245	15,632	29,421	17,546	0	0	484,214
351,520	14,581	30,473	17,546	10	304,730	484,214
514,908	5,842	30,761	25,997	0	0	807,023
694,933	4,558	31,431	26,611	0	0	968,428
838,060	4,168	31,821	26,611	0	0	1,129,832
1,076,740	2,681	33,308	26,611	0	0	1,291,237
1,316,811	1,509	34,480	26,611	0	0	1,452,642
1,812,531	0	35,989	26,611	10	359,890	1,452,642
Regulatory Enforcement; High Fine; Elasticity of Supply = 0.33; Net Public Cost						
-348,389	15,632	29,421	17,546	0	0	120,580
-255,099	10,397	30,239	21,964	0	0	160,774
-91,148	5,842	30,761	25,997	0	0	200,967
-32,335	4,558	31,431	26,611	0	0	241,160
-10,419	4,168	31,821	26,611	0	0	281,354
107,050	2,681	33,308	26,611	0	0	321,547
225,910	1,509	34,480	26,611	0	0	361,741
721,629	0	35,989	26,611	10	359,890	361,741

Table 7. Cost Effective Scenarios for Each Landfill Ban Assumption Set

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
Tons to Preferred Disposal Site						
0	35,731	26,869	0	0	0	0
282,110	34,389	28,211	0	10	282,110	0
640,038	30,598	32,002	0	20	640,038	0
1,091,977	26,201	36,399	0	30	1,091,977	0
1,639,252	19,737	42,863	0	30	1,285,880	353,372
2,139,971	14,559	48,041	0	30	1,441,230	698,741
2,620,169	10,660	51,940	0	40	2,077,617	542,552
3,042,328	6,691	55,909	0	40	2,236,364	805,964
3,468,664	2,483	60,117	0	40	2,404,664	1,064,000
3,822,066	0	62,600	0	40	2,504,001	1,318,065
No Landfilling; Criminal Enforcement; High Fine; Public Cost						
0	35,731	26,869	0	0	0	0
121,055	34,389	28,211	0	0	0	121,055
241,335	30,598	32,002	0	0	0	241,335
360,808	26,201	36,399	0	0	0	360,808
479,154	19,737	42,863	0	0	0	479,154
596,738	14,559	48,041	0	0	0	596,738
713,834	10,660	51,940	0	0	0	713,834
830,175	6,691	55,909	0	0	0	830,175
945,596	2,483	60,117	0	0	0	945,596
1,060,719	0	62,600	0	0	0	1,060,719
No Landfilling; Criminal Enforcement; Low Fine; Total Cost						
1,900,936	35,731	26,869	0	0	0	0
1,997,824	34,389	28,211	0	10	282,110	0
2,313,863	30,598	32,002	0	20	640,038	0
2,718,650	26,201	36,399	0	30	1,091,977	0
3,381,414	19,737	42,863	0	40	1,714,507	0
3,959,021	14,559	48,041	0	50	2,402,051	0

Table 7. Cost Effective Scenarios for Each Landfill Ban Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
4,433,927	10,660	51,940	0	60	3,116,425	0
5,112,062	6,691	55,909	0	60	3,354,547	153,558
5,856,001	2,483	60,117	0	60	3,606,995	303,688
6,383,097	0	62,600	0	60	3,756,001	451,125
No Landfilling; Criminal Enforcement; High Fine; Total Cost						
1,900,936	35,731	26,869	0	0	0	0
1,997,824	34,389	28,211	0	10	282,110	0
2,313,863	30,598	32,002	0	20	640,038	0
2,825,814	26,201	36,399	0	20	727,984	107,165
3,381,414	19,737	42,863	0	40	1,714,507	0
3,959,021	14,559	48,041	0	50	2,402,051	0
4,433,927	10,660	51,940	0	60	3,116,425	0
4,997,108	6,691	55,909	0	60	3,354,547	38,605
5,629,082	2,483	60,117	0	60	3,606,995	76,769
6,046,626	0	62,600	0	60	3,756,001	114,655
No Landfilling; Criminal Enforcement; Low Fine; Net Public Cost						
0	35,731	26,869	0	0	0	0
137,228	34,389	28,211	0	0	0	481,119
341,187	30,598	32,002	0	0	0	953,150
630,293	26,201	36,399	0	0	0	1,416,317
1,080,151	19,737	42,863	0	0	0	1,869,645
1,586,941	14,559	48,041	0	0	0	2,314,891
2,113,842	10,660	51,940	0	0	0	2,753,418
2,716,017	6,691	55,909	0	0	0	3,184,381
3,369,326	2,483	60,117	0	40	2,404,664	1,064,000
3,822,066	0	62,600	0	40	2,504,001	1,318,065
No Landfilling; Criminal Enforcement; High Fine; Net Public Cost						
-425,216	26,201	36,399	0	0	0	360,808
-310,340	19,737	42,863	0	0	0	479,154

Table 7. Cost Effective Scenarios for Each Landfill Ban Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
-131,213	14,559	48,041	0	0	0	596,738
74,258	10,660	51,940	0	0	0	713,834
361,811	6,691	55,909	0	0	0	830,175
746,922	2,483	60,117	0	0	0	945,596
1,060,719	0	62,600	0	0	0	1,060,719
Landfilling; Criminal Enforcement; Low Fine; Public Cost						
0	26,606	26,671	9,323	0	0	0
281,517	25,324	28,152	9,124	10	281,517	0
345,117	24,178	27,953	10,468	0	0	345,117
616,284	22,661	30,814	9,124	20	616,284	0
635,044	21,516	30,616	10,468	10	306,158	328,886
682,794	18,152	30,160	14,288	0	0	682,794
989,717	16,254	33,907	12,439	10	339,074	650,643
1,013,921	13,723	31,330	17,546	0	0	1,013,921
1,324,536	12,092	35,856	14,652	10	358,560	965,976
1,338,381	8,826	32,962	20,813	0	0	1,338,381
1,642,515	7,120	36,782	18,697	10	367,824	1,274,691
1,656,370	4,109	35,064	23,427	0	0	1,656,370
1,951,094	2,153	37,431	23,016	10	374,307	1,576,787
1,970,150	1,778	37,008	23,814	0	0	1,970,150
2,268,069	0	39,296	23,304	10	392,962	1,875,107
Landfilling; Criminal Enforcement; High Fine; Public Cost						
0	26,606	26,671	9,323	0	0	0
86,847	24,178	27,953	10,468	0	0	86,847
172,924	18,152	30,160	14,288	0	0	172,924
258,382	13,723	31,330	17,546	0	0	258,382
343,130	8,826	32,962	20,813	0	0	343,130
427,158	4,109	35,064	23,427	0	0	427,158

Table 7. Cost Effective Scenarios for Each Landfill Ban Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
510,979	1,778	37,008	23,814	0	0	510,979
594,395	0	38,786	23,814	0	0	594,395
Landfilling; Criminal Enforcement; Low Fine; Total Cost						
2,176,078	26,606	26,671	9,323	0	0	0
2,269,865	25,324	28,152	9,124	10	281,517	0
2,488,755	22,661	30,814	9,124	20	616,284	0
2,828,837	18,956	34,520	9,124	30	1,035,596	0
3,173,784	18,413	34,520	9,667	20	690,397	306,577
3,372,359	13,695	40,077	8,828	40	1,603,064	0
3,647,111	13,153	39,780	9,667	30	1,193,397	247,810
3,671,177	11,483	43,348	7,769	50	2,167,400	0
3,889,018	10,585	42,568	9,447	40	1,702,719	192,233
4,007,458	9,253	46,785	6,562	60	2,807,111	0
4,245,650	7,550	45,899	9,151	50	2,294,942	163,979
4,467,515	7,408	45,744	9,447	40	1,829,762	380,513
4,788,140	3,978	51,279	7,343	60	3,076,745	133,016
4,977,732	3,216	50,232	9,151	50	2,511,604	324,416
5,204,278	3,216	49,936	9,447	40	1,997,442	564,457
5,250,638	1,005	52,740	8,855	60	3,164,370	263,480
5,495,503	709	52,740	9,151	50	2,636,975	482,038
5,527,863	0	53,745	8,855	60	3,224,683	392,310
Landfilling; Criminal Enforcement; High Fine; Total Cost						
2,176,078	26,606	26,671	9,323	0	0	0
2,269,865	25,324	28,152	9,124	10	281,517	0
2,438,678	24,178	27,953	10,468	0	0	86,847
2,488,755	22,661	30,814	9,124	20	616,284	0
2,652,351	21,516	30,616	10,468	10	306,158	82,777
2,828,837	18,956	34,520	9,124	30	1,035,596	0

Table 7. Cost Effective Scenarios for Each Landfill Ban Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
2,944,374	18,413	34,520	9,667	20	690,397	77,168
3,011,544	18,152	30,160	14,288	0	0	172,924
3,191,441	16,254	33,907	12,439	10	339,074	164,840
3,372,359	13,695	40,077	8,828	40	1,603,064	0
3,461,627	13,153	39,780	9,667	30	1,193,397	62,325
3,565,579	12,567	38,196	11,836	20	763,928	153,592
3,671,108	12,092	35,856	14,652	10	358,560	246,291
3,671,177	11,483	43,348	7,769	50	2,167,400	0
3,745,148	10,585	42,568	9,447	40	1,702,719	48,362
3,829,697	10,392	42,348	9,859	30	1,270,445	124,216
3,920,413	9,996	40,278	12,327	20	805,554	229,609
4,007,458	9,253	46,785	6,562	60	2,807,111	0
4,075,377	8,826	32,962	20,813	0	0	343,130
4,122,894	7,550	45,899	9,151	50	2,294,942	41,222
4,183,324	7,408	45,744	9,447	40	1,829,762	96,321
4,261,396	7,120	36,782	18,697	10	367,824	327,022
4,502,785	5,498	42,605	14,497	20	852,095	304,879
4,679,499	4,109	35,064	23,427	0	0	427,158
4,688,536	3,978	51,279	7,343	60	3,076,745	33,412
4,735,316	3,216	50,232	9,151	50	2,511,604	82,000
4,838,300	3,091	48,077	11,432	30	1,442,325	246,478
4,900,317	2,153	37,431	23,016	10	374,307	406,973
5,048,106	1,778	37,008	23,814	0	0	510,979
5,053,654	1,005	52,740	8,855	60	3,164,370	66,496
5,111,470	907	43,695	17,999	20	873,893	379,401
5,135,955	709	52,740	9,151	50	2,636,975	122,490
5,212,769	559	52,594	9,447	40	2,103,740	190,865
5,235,022	0	53,745	8,855	60	3,224,683	99,469

Table 7. Cost Effective Scenarios for Each Landfill Ban Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
Landfilling; Criminal Enforcement; Low Fine; Net Public Cost						
0	26,606	26,671	9,323	0	0	0
103,333	24,178	27,953	10,468	0	0	345,117
319,748	18,152	30,160	14,288	0	0	682,794
602,220	13,723	31,330	17,546	0	0	1,013,921
961,774	12,092	35,856	14,652	10	358,560	965,976
985,346	8,826	32,962	20,813	0	0	1,338,381
1,357,701	7,120	36,782	18,697	10	367,824	1,274,691
1,450,940	4,109	35,064	23,427	0	0	1,656,370
1,843,444	2,153	37,431	23,016	10	374,307	1,576,787
1,863,497	1,778	37,008	23,814	0	0	1,970,150
2,268,069	0	39,296	23,304	10	392,962	1,875,107
Landfilling; Criminal Enforcement; High Fine; Net Public Cost						
-190,123	18,152	30,160	14,288	0	0	172,924
-153,319	13,723	31,330	17,546	0	0	258,382
-9,905	8,826	32,962	20,813	0	0	343,130
221,727	4,109	35,064	23,427	0	0	427,158
404,326	1,778	37,008	23,814	0	0	510,979
594,395	0	38,786	23,814	0	0	594,395
No Landfilling; Regulatory Enforcement; Low Fine; Public Cost						
0	35,731	26,869	0	0	0	0
161,405	34,389	28,211	0	0	0	161,405
322,809	30,598	32,002	0	0	0	322,809
484,214	26,201	36,399	0	0	0	484,214
645,619	19,737	42,863	0	0	0	645,619
807,023	14,559	48,041	0	0	0	807,023
968,428	10,660	51,940	0	0	0	968,428
1,129,832	6,691	55,909	0	0	0	1,129,832

Table 7. Cost Effective Scenarios for Each Landfill Ban Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
1,291,237	2,483	60,117	0	0	0	1,291,237
1,452,642	0	62,600	0	0	0	1,452,642
No Landfilling; Regulatory Enforcement; High Fine; Public Cost						
0	35,731	26,869	0	0	0	0
40,193	34,389	28,211	0	0	0	40,193
80,387	30,598	32,002	0	0	0	80,387
120,580	26,201	36,399	0	0	0	120,580
160,774	19,737	42,863	0	0	0	160,774
200,967	14,559	48,041	0	0	0	200,967
241,160	10,660	51,940	0	0	0	241,160
281,354	6,691	55,909	0	0	0	281,354
321,547	2,483	60,117	0	0	0	321,547
361,741	0	62,600	0	0	0	361,741
No Landfilling; Regulatory Enforcement; Low Fine; Total Cost						
1,900,936	35,731	26,869	0	0	0	0
1,997,824	34,389	28,211	0	10	282,110	0
2,313,863	30,598	32,002	0	20	640,038	0
2,718,650	26,201	36,399	0	30	1,091,977	0
3,381,414	19,737	42,863	0	40	1,714,507	0
4,120,425	14,559	48,041	0	40	1,921,640	161,405
4,433,927	10,660	51,940	0	60	3,116,425	0
5,281,312	6,691	55,909	0	50	2,795,456	322,809
6,036,526	2,483	60,117	0	50	3,005,830	484,214
6,416,185	0	62,600	0	60	3,756,001	484,214
No Landfilling; Regulatory Enforcement; High Fine; Total Cost						
1,900,936	35,731	26,869	0	0	0	0
1,997,824	34,389	28,211	0	10	282,110	0
2,313,863	30,598	32,002	0	20	640,038	0

Table 7. Cost Effective Scenarios for Each Landfill Ban Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
2,718,650	26,201	36,399	0	30	1,091,977	0
3,381,414	19,737	42,863	0	40	1,714,507	0
3,959,021	14,559	48,041	0	50	2,402,051	0
4,433,927	10,660	51,940	0	60	3,116,425	0
4,998,697	6,691	55,909	0	60	3,354,547	40,193
5,632,700	2,483	60,117	0	60	3,606,995	80,387
6,052,552	0	62,600	0	60	3,756,001	120,580
No Landfilling; Regulatory Enforcement; Low Fine; Net Public Cost						
-301,810	26,201	36,399	0	0	0	484,214
-143,875	19,737	42,863	0	0	0	645,619
79,073	14,559	48,041	0	0	0	807,023
328,852	10,660	51,940	0	0	0	968,428
661,469	6,691	55,909	0	0	0	1,129,832
1,092,563	2,483	60,117	0	0	0	1,291,237
1,452,642	0	62,600	0	0	0	1,452,642
No Landfilling; Regulatory Enforcement; High Fine; Net Public Cost						
-665,444	26,201	36,399	0	0	0	120,580
-628,720	19,737	42,863	0	0	0	160,774
-526,984	14,559	48,041	0	0	0	200,967
-398,416	10,660	51,940	0	0	0	241,160
-187,010	6,691	55,909	0	0	0	281,354
122,873	2,483	60,117	0	0	0	321,547
361,741	0	62,600	0	0	0	361,741
Landfilling; Regulatory Enforcement; Low Fine; Public Cost						
0	26,606	26,671	9,323	0	0	0
161,405	24,178	27,953	10,468	0	0	161,405
322,809	18,152	30,160	14,288	0	0	322,809
484,214	13,723	31,330	17,546	0	0	484,214

Table 7. Cost Effective Scenarios for Each Landfill Ban Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
645,619	8,826	32,962	20,813	0	0	645,619
807,023	4,109	35,064	23,427	0	0	807,023
968,428	1,778	37,008	23,814	0	0	968,428
1,129,832	0	38,786	23,814	0	0	1,129,832
Landfilling; Regulatory Enforcement; High Fine; Public Cost						
0	26,606	26,671	9,323	0	0	0
40,193	24,178	27,953	10,468	0	0	40,193
80,387	18,152	30,160	14,288	0	0	80,387
120,580	13,723	31,330	17,546	0	0	120,580
160,774	8,826	32,962	20,813	0	0	160,774
200,967	4,109	35,064	23,427	0	0	200,967
241,160	1,778	37,008	23,814	0	0	241,160
321,547	0	38,786	23,814	0	0	321,547
Landfilling; Regulatory Enforcement; Low Fine; Total Cost						
2,176,078	26,606	26,671	9,323	0	0	0
2,269,865	25,324	28,152	9,124	10	281,517	0
2,488,755	22,661	30,814	9,124	20	616,284	0
2,730,979	21,516	30,616	10,468	10	306,158	161,405
2,828,837	18,956	34,520	9,124	30	1,035,596	0
3,028,611	18,413	34,520	9,667	20	690,397	161,405
3,161,430	18,152	30,160	14,288	0	0	322,809
3,349,411	16,254	33,907	12,439	10	339,074	322,809
3,372,359	13,695	40,077	8,828	40	1,603,064	0
3,560,706	13,153	39,780	9,667	30	1,193,397	161,405
3,671,177	11,483	43,348	7,769	50	2,167,400	0
3,858,191	10,585	42,568	9,447	40	1,702,719	161,405
4,007,458	9,253	46,785	6,562	60	2,807,111	0
4,243,077	7,550	45,899	9,151	50	2,294,942	161,405

Table 7. Cost Effective Scenarios for Each Landfill Ban Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
4,409,812	7,408	45,744	9,447	40	1,829,762	322,809
4,562,847	7,324	45,275	10,001	30	1,358,257	484,214
4,579,993	7,120	36,782	18,697	10	367,824	645,619
4,816,529	3,978	51,279	7,343	60	3,076,745	161,405
4,976,126	3,216	50,232	9,151	50	2,511,604	322,809
5,237,441	3,091	48,077	11,432	30	1,442,325	645,619
5,300,366	2,153	37,431	23,016	10	374,307	807,023
5,309,967	1,005	52,740	8,855	60	3,164,370	322,809
5,497,679	709	52,740	9,151	50	2,636,975	484,214
5,619,767	0	53,745	8,855	60	3,224,683	484,214
Landfilling; Regulatory Enforcement; High Fine; Total Cost						
2,176,078	26,606	26,671	9,323	0	0	0
2,269,865	25,324	28,152	9,124	10	281,517	0
2,392,025	24,178	27,953	10,468	0	0	40,193
2,488,755	22,661	30,814	9,124	20	616,284	0
2,609,767	21,516	30,616	10,468	10	306,158	40,193
2,828,837	18,956	34,520	9,124	30	1,035,596	0
2,907,400	18,413	34,520	9,667	20	690,397	40,193
2,919,007	18,152	30,160	14,288	0	0	80,387
3,106,988	16,254	33,907	12,439	10	339,074	80,387
3,361,193	13,723	31,330	17,546	0	0	120,580
3,372,359	13,695	40,077	8,828	40	1,603,064	0
3,439,495	13,153	39,780	9,667	30	1,193,397	40,193
3,492,374	12,567	38,196	11,836	20	763,928	80,387
3,545,397	12,092	35,856	14,652	10	358,560	120,580
3,671,177	11,483	43,348	7,769	50	2,167,400	0
3,736,979	10,585	42,568	9,447	40	1,702,719	40,193
3,785,868	10,392	42,348	9,859	30	1,270,445	80,387

Table 7. Cost Effective Scenarios for Each Landfill Ban Assumption Set, continued.

Cost Objective ($)	Tons Disposed Illegally	Tons to Preferred Disposal Site	Tons Landfilled	Subsidy Per Ton ($)	Total Subsidy Expense ($)	Enforcement/ Audit Expense ($)
3,811,383	9,996	40,278	12,327	20	805,554	120,580
3,893,021	8,826	32,962	20,813	0	0	160,774
4,095,148	7,120	36,782	18,697	10	367,824	160,774
4,358,679	5,498	42,605	14,497	20	852,095	160,774
4,453,308	4,109	35,064	23,427	0	0	200,967
4,694,310	2,153	37,431	23,016	10	374,307	200,967
4,778,288	1,778	37,008	23,814	0	0	241,160
4,933,036	907	43,695	17,999	20	873,893	200,967
5,009,217	0	39,296	23,304	10	392,962	241,160
Landfilling; Regulatory Enforcement; Low Fine; Net Public Cost						
-80,380	24,178	27,953	10,468	0	0	161,405
-40,237	18,152	30,160	14,288	0	0	322,809
72,513	13,723	31,330	17,546	0	0	484,214
292,584	8,826	32,962	20,813	0	0	645,619
601,593	4,109	35,064	23,427	0	0	807,023
861,775	1,778	37,008	23,814	0	0	968,428
1,129,832	0	38,786	23,814	0	0	1,129,832
Landfilling; Regulatory Enforcement; High Fine; Net Public Cost						
-291,121	13,723	31,330	17,546	0	0	120,580
-192,261	8,826	32,962	20,813	0	0	160,774
-4,464	4,109	35,064	23,427	0	0	200,967
134,507	1,778	37,008	23,814	0	0	241,160
281,354	0	38,786	23,814	0	0	281,354

Table 8. Summary of Results for Normal Assumption Sets.

Assumption Set	Cost Range		Maximum Subsidy Per Ton		Average Subsidy Expenditure*	
	Crime	Regul.	Crime	Regul.	Crime	Regul.
(1) Total Cost; ES=3; Low Fine	2,176,078 4,716,188	2,176,078 4,727,033	40	50	75%	65%
(2) Total Cost; ES=3; High Fine	2,176,078 4,670,162	2,176,078 4,687,185	40	30	72%	71%
(3) Public Cost; ES=3; Low Fine	0 1,653,364	0 807,023	10	0	22%	0%
(4) Public Cost; ES=3; High Fine	0 426,409	0 200,967	0	0	0%	0%
(5) Net Public Cost; ES=3; Low Fine	-135,763 1,653,364	-61,141 807,023	0	0	0%	0%
(6) Net Public Cost; ES=3; High Fine	2,176,079 426,409	-207,707 200,967	0	0	0%	0%
(7) Total Cost; ES=0.33; Low Fine	2,176,078 6,554,956	2,176,078 6,074,201	60	60	66%	63%
(8) Total Cost; ES=0.33; High Fine	2,176,078 5,463,000	2,176,078 5,322,981	60	60	71%	68%
(9) Public Cost; ES=0.33; Low Fine	0 3,175,194	0 1,812,531	10	10	17%	2%
(10) Public Cost; ES=0.33; High Fine	0 1,102,442	0 721,629	10	10	3%	5%
(11) Net Public Cost; ES=0.33; Low Fine	0 3,175,194	-85,493 1,812,531	20	10	19%	6%
(12) Net Public Cost; ES=0.33; High Fine	-232,101 1,102,442	-384,389 721,629	10	10	4%	6%

* Average Subsidy Expenditure equals the average over all scenarios of subsidy expense divided by total public cost (subsidy plus enforcement). It shows the relative weight of the subsidies as a component of public expenditures.

Table 9. Summary of Results for Landfill versus No Landfill Assumption Sets

Assumption Set	Cost Range		Maximum Subsidy Per Ton		Average Subsidy Expenditure*	
	Crime	Regul.	Crime	Regul.	Crime	Regul.
(1) Total Cost; No Land; Low Fine	1,900,936 6,383,097	1,900,936 6,416,185	60	60	97%	95%
(2) Total Cost; No Land; High Fine	1,900,936 6,046,626	1,900,936 6,052,552	60	60	98%	99%
(3) Public Cost; No Land; Low Fine	0 3,822,066	0 1,452,642	40	0	81%	0%
(4) Public Cost; No Land; High Fine	0 1,060,719	0 361,741	0	0	0%	0%
(5) Net Public Cost; No Land; Low Fine	0 3,822,066	-301,810 1,452,642	40	0	15%	0%
(6) Net Public Cost; No Land; High Fine	-425,216 1,060,719	-665,444 361,741	0	0	0%	0%
(7) Total Cost; Land; Low Fine	2,176,078 5,527,863	2,176,078 5,619,767	60	60	91%	79%
(8) Total Cost; Land; High Fine	2,176,078 5,235,022	2,176,078 5,009,217	60	50	74%	67%
(9) Public Cost; Land; Low Fine	0 2,268,069	0 1,129,832	20	0	26%	0%
(10) Public Cost; Land; High Fine	0 594,395	0 321,547	0	0	0%	0%
(11) Net Public Cost; Land; Low Fine	0 2,268,069	-80,380 1,129,832	10	0	9%	0%
(12) Net Public Cost; Land; High Fine	-190,123 594,395	-291,121 281,354	0	0	0%	0%

* Average Subsidy Expenditure equals the average over all scenarios of subsidy expense divided by total public cost (subsidy plus enforcement). It shows the relative weight of the subsidies as a component of public expenditures.

Before the results are discussed, the reader should be reminded that all of these results are case specific, and cannot be generalized to other types of solid waste or to other scrap tire markets. It should be remembered that the premise under which the model was developed is that the choice of policy tool--enforcement or subsidies--is waste and industry specific. Therefore, each solid waste management situation must be analyzed individually.

Also, it should be remembered that each scenario run was developed out of the basecase, which included a subjective cost of illegal disposal equal to $67.00 per ton. Therefore, in each scenario, even those for which no additional enforcement is called for--enforcement/audit costs = zero-- the results assume that each solid waste generator and hauler feels they pay some cost when they dispose of tires illegally.

4.2 Effect Of Assumptions On The Model Results

4.2.1 Criminal Versus Regulatory Enforcement

In order to determine the relative effectiveness of criminal and regulatory enforcement, Table 8 must be examined. For each assumption set, (1) through (12), we can determine which enforcement mechanism is least expensive. It must be remembered, however, that Table 8 is only a summary of Table 6. Therefore, the cost ranges given only include the cost to do nothing and the cost to effect total legal disposal.[6] However, an examination of Table 6 will show that the results described below are almost universal, regardless of the level of legal disposal targeted.

In each case, except (1) and (2), the regulatory mechanism results in a lower cost to deter illegal disposal. In the case of (1) and (2), which deal with total cost, an elasticity of supply =3, and low and high fine, respectively, the percentage difference between the total cost to insure legal disposal through regulation rather than criminalization is 0.2 percent and 0.03 percent. With regard to (7) and (8), which target total cost, an elasticity of supply =0.33, and low and high fine, respectively, the percentage difference, this time in favor of regulation are 8 percent and 2.6 percent. In each case, the difference is so small, that it is fair to say that when concerned with minimizing total cost, there is no reason to choose one enforcement mechanism over another.

In each of the other cases, the cost of regulatory enforcement is significantly less then the cost of criminal enforcement. Therefore, when concerned with public cost, or net public cost, regulatory enforcement is the most cost effective enforcement mechanism regardless of fine level or elasticity of supply.

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[6] In the case of net public costs, the least cost solution may be to take some enforcement action, since this can result in lower (negative) costs than doing nothing.

4.2.2 Enforcement Versus Subsidies

In order to determine the relative effectiveness of enforcement versus subsidies, we turn our attention to the "Maximum Subsidy Per Ton" and "Average Subsidy Expenditure" columns of Table 8. As one glances down the Maximum Subsidy Per Ton Columns, it is clear that in assumption sets (1), (2), (7), and (8), scenarios exist which use subsidies per ton of $40, $50, and $60 per ton, both under the criminal and regulatory enforcement mechanisms. All the other assumption sets have scenarios with subsidies per ton of between $0 and 20 per ton. In the "Average Subsidy Expenditure" column, which shows the relative weight of subsidy expenditures to total public costs--enforcement costs plus subsidy costs, assumption sets (1), (2), (7) and (8) have average subsidy expenditures among their scenarios of between 63 percent and 75 percent for both enforcement mechanisms. The other assumption sets have average subsidy expenditures of between 0 percent and 22 percent.

It is clear that when concerned with total cost, as is the case in assumption sets (1), (2), (7), and (8), subsidies will be a major policy tool, while enforcement will remain quite modest. In the case of minimizing public costs or net public costs, subsidies will be used sparingly, and enforcement will be the major policy tool.

4.2.3 Low Fines Versus High Fines

When investigating the effect of fine level on costs and policy selection, it is necessary to do six pair-wise comparisons of assumption sets. One must compare (1) and (2); (3) and (4); (5) and (6); (7) and (8); (9) and (10); and (11) and (12). In every case, the cost to effect legal waste disposal is lower when a high fine is present. However, the choice of enforcement mechanism is not sensitive to the fine level. Also, the maximum subsidy per ton is fairly static, as it remains constant or decreases slightly with higher fine levels. The average subsidy expenditure is fairly constant, as it decreases or increases slightly under the higher fine level. Therefore, although a higher fine level will decrease cost under each assumption set, it will not affect the policy tools, i.e. the choice of enforcement mechanism or the relative importance of subsidies or enforcement.

4.2.4 The Effect Of The Elasticity Of Supply

Again, in order to determine the effect of the elasticity of supply, it is necessary to do six pair-wise comparisons between: (1) and (7); (2) and (8); (3) and (9); (4) and (10); (5) and (11); and (6) and (12). In each case, the cost to reach a given level of legal disposal is higher when the elasticity of supply is 0.33, regardless of the cost objective, enforcement mechanism or fine level. The maximum subsidy level increases or remains the same in each case. In the case of total cost, the maximum subsidy rises from levels of between $30 and $50 per ton when the elasticity equals 3.0 to $60 per ton in all cases when the elasticity equals 0.33. With respect to public costs and net public cost, the maximum subsidies rise from levels of $0 to $10 per ton when the elasticity is equal to 3.0, to levels of $10 to $20 per ton when the elasticity is equal to 0.33.

The average subsidy expenditure, with regard to total cost, ranges from 65 percent to 75 percent when the elasticity of supply is 3.0, and from 63 percent to 71 percent when the elasticity is equal to 0.33. With regard to public costs and net public costs, the average subsidy expenditure ranges from 0 percent to 22 percent when the elasticity is 3.00, and from 2 percent to 19 percent when the elasticity is 0.33. As these figures show, while the cost under any assumption set is higher when the supply curve is inelastic (0.33), the choice of policy tool does not change with the elasticity of supply, except for a slightly higher per ton subsidy when the elasticity is inelastic.

4.2.5 Landfilling Versus A Landfill Ban

Table 9 shows how the model results differ if a landfill ban is in effect. It should be remembered that all the assumption sets assume an elasticity of supply of unity. By comparing lines (1) and (7), (2) and (8), (3) and (9), (4) and (10); (5) and (11), and (6) and (12), it can be seen that a landfill ban increases the cost of disposal under each assumption set. However, the landfill ban does not change any of the above mentioned policy findings. Subsidies still dominate when minimizing total costs is the objective, and regulatory enforcement still dominates when gross and net public costs are to be minimized. The only exception to this is with regard to public costs, when the fine level is low and a landfill ban is in effect. In this case the average subsidy expenditure under criminalization is 81 percent.

4.3 Results Summary And Analysis

4.3.1 Summary Of Results

The results of this simulation procedure can be summarized as follows. Regulation is a more public-cost effective and net-public-cost effective enforcement mechanism than criminalization, With regard to total-cost effectiveness, no evidence exists to choose one mechanism over the other. Subsidies are more total-cost effective than enforcement, while enforcement is more public-cost effective and net-public-cost effective subsidies. Fine levels and the elasticity of supply are major determinants of the costs of effecting legal disposal, and it would be helpful to know these parameters for budget purposes. However, except for small increases in the use of subsidies in inelastic supply environments, these assumptions did not change the choice of policy instruments which are cost effective.

Also, another point which radiates from the analysis is that if, for policy or legal reasons, the type of enforcement was fixed, given a criminalization mechanism, more emphasis would be placed on subsidies than would be the case if regulation was in place. Finally, a landfilling ban resulted in higher costs under each assumption set, but the only policy landfill ban only significantly effected the enforcement - subsidy mix under one assumption set.

4.3.2 Analysis Of Results

The results show that the use of subsidies is in general the cost-effective solution, regardless of the enforcement mechanism, fine level, or elasticity of substitution, when the agency is trying to minimize the total cost of effecting legal disposal. This result is intuitive. When the government subsidizes legal disposal, it is using money, collected from the populus, to partially pay for the cost of disposal. The total disposal cost, at each level of legal disposal, remains the same regardless if the cost is borne by consumers directly, through higher tipping fees, or borne by consumers indirectly, through a tax and subsidy program administered by the government. In other words, the use of subsidies does not add to the total cost of disposal, subsidies are offset by lower tipping fees paid by scrap tire generators. Enforcement, either criminal or regulatory, does add to the total cost of reaching each level of legal disposal. The cost of actual disposal remains constant at each level--the total tipping fees plus transportation cost paid by scrap tire generators.

Enforcement costs are simple additions to the cost of disposal. Therefore, when minimizing the total cost of disposal, in order to reach a higher level of legal disposal, the agency should simply increase the tire tax and provide higher per ton subsidies to scrap tire disposers. Enforcement in this scenario will play a small ancillary role.

Under an agency budget constraint scenario, where the agency cannot raise the tire tax easily, the policy question changes. The question posed is no longer "how can we achieve a given level of legal disposal at the lowest total cost" but rather, "how can we achieve a given level of legal disposal while using as little of our budget dollars as possible." The answer to this question is to leverage scarce budget dollars and to push the cost of disposal onto the scrap tire generators directly.

This can be seen in the model results when the objective is to minimize public expenditures, gross or net fine revenue. In both cases, the predominant cost effective solution is to use public expenditures on enforcement, and provide an incentive for scrap tire generators to dispose of the scrap tires legally at their expense. This is true for both enforcement mechanisms--criminal and regulatory, and without regard to fine level or the elasticity of supply.

Although the fine level doesn't effect the predominant policy mechanism--subsidy or enforcement, a lower fine will cause a relatively greater use of subsidies, and a higher fine will cause a relatively greater use of enforcement. This makes sense, because a higher fine level makes each enforcement dollar spent more effective in modifying peoples' behavior.

The fine level and elasticity of supply are both important data for the decision maker to have, because they both effect the cost of achieving levels of legal disposal. As noted above, they don't significantly change the choice of policy tool, but can affect significantly the budget levels necessary to achieve different legal disposal goals. In order to effectively predict the cost of any plan to increase legal disposal, it is necessary to consider the fine level, as well as to estimate the elasticity of supply.

Finally, by banning the landfilling of scrap tires, policy makers will make the cost--total, public and net public--of achieving a level of legal disposal higher under all scenarios. This makes a great deal of sense, because it makes a previously available, relatively less expensive, legal disposal option, now illegal. Therefore, it will take a greater amount of private disposal expenditure, transportation cost, enforcement expenditure, and subsidies, to reach the same level of legal disposal. By constraining the previous least cost disposal option--by making landfilling unacceptable-- the objective function of the scrap tire market must, and does, increase.

In the next chapter the results presented in this chapter will be fit into a policy context. By providing a history of the author's involvement in the development of Virginia's scrap tire regulations, it will be shown how these results could have aided the development of a cost effective policy.

Chapter 5. Policy Applications And Limits

5.1 Introduction

In Chapters one through four the following was accomplished. First, an examination of a waste typology and waste disposal enforcement options was presented. Second, a simulation model was developed to examine the cost effectiveness of three management options, regulatory enforcement, criminal enforcement, and a tax-subsidy arrangement, with respect to solid waste disposal. Third, this model was applied to the scrap tire management problem in Virginia, and the results of this case study were presented. The question now must be asked, how does this modeling exercise fit into the policy development process? This is the question that will be addressed in this chapter.

This task will be accomplished in a two-fold process. First, a brief history of scrap tire policy development in Virginia will be provided (a detailed history can be found in Appendix B). This history will place special emphasis on the author's role as an economic advisor within this process. After this history is laid out, it will be called upon to illustrate how the policy development process could have been improved if the results of the modeling exercise were used as input into the process.

5.2 Scrap Tire Policy Development In Virginia

5.2.1 Policy Backdrop

In 1989 the Virginia legislature published the Report of the Joint Subcommittee Studying Alternatives for Improving Waste Volume Reduction and Recycling Efforts (House Doc No. 60, 1989). The report noted that according to testimony presented to the subcommittee, over 117.5 million scrap tires were currently in dumps around the commonwealth, and 47 of these dumps contained over 500,000 tires. These large dumps, according to the testimony, were slated for clean-up. It is of interest at this point to mention that after a very thorough survey of actual tire disposal sites, by the Virginia Department of Environmental Quality in 1993, only 18 million scrap tires were estimated to be littering the landscape, about 15 percent of the original estimate. One of the problems encountered throughout the policy development process was gaining agreement on the size of the actual problem.

At the Joint Subcommittee meeting, tire recyclers testified that in order to spur collection and recycling efforts, incentives would have to offered. They supported the idea of a $1.00 per tire tax on all new tires sold, with revenues going to defer disposal costs of scrap tires. The tire retailers, although concerned with the administrative costs associated with collecting the tax, did not oppose the idea outright. As part of the report, the Joint Subcommittee proposed legislation which read "the department (Department of Waste Management) shall develop and implement a plan for the management and transportation of all waste tires in the commonwealth. The costs of implementing such a plan, as well as the costs of any program created by the Department pursuant to such a plan shall be paid for out of the Waste Tire Trust Fund (10.1-1422.1)." They also added "There is hereby levied and imposed upon every retailer of tires in the commonwealth, in addition to all other taxes and fees of every kind now imposed by law, a tax of one dollar for each new tire sold by the retailer (58.1-641)." The proposed legislation, under section 58.1-642, allowed the tire retailers to retain 15 percent of the tire tax revenues to cover their administrative costs. Section 58.1-643 set up the Waste Tire Trust Fund, which protected the funds from being reverted to the general fund, and used only for scrap tire management.

The 1989 session of the General Assembly passed the legislation, however several important modifications were made. First, the tire tax was lowered to 50 cents per tire. Second, the retailers were only allowed to retain five percent of the tire tax revenues to cover their expenses. Finally, the law was to take effect January 1, 1990 and sunset, unless re-authorized, on December 31, 1994 (House Bill 1745).

5.2.2 The Department Of Waste Management's First Approach

Between the time that the legislation was passed in 1989, and August 1990, the Department of Waste Management (DWM) had assembled a nineteen member "Used Tire Advisory Committee" made up of tire dealers, scrap tire disposal industry representatives, and local government officials. The advisory committee, in their August 1990 report, stated that "the main reason for the tire problem, nationally as well as in the Commonwealth, is the lack of significant markets for used tires and tire products, and it emphasized the importance of market development (p.1)." By September 1990, the advisory committee had endorsed DWM's plan to set up state wide collection centers at eighteen Department of Correction (DOC) field units. Inmate labor was to be used to reduce handling and transfer costs.

By October 1991, DWM was finalizing their plan to offer a comprehensive state-run disposal system. DWM also planned to contract with haulers and designated processors, though a bidding process, and provide these services to tire disposers free of charge as well.

In November 1991, DWM took the next step in the development of their program by publishing a request for proposals (RFP) for the recycling/disposal of scrap tires. The RFP provided that the scrap tires will be delivered to the disposal plants by a state hired hauler by the tractor trailer load. The disposal plant would then bill the state for the cost of disposal, according to rates set forth in their contract. The proposals were to be returned to the department by January 31, 1992.

In January 1992, Leonard Shabman and the author, Virginia Polytechnic Institute and State University (Virginia Tech), and Richard Collins, Institute for Environmental Negotiations (IEN) at the University of Virginia, were asked to provide an overview of the "New Environmentalism" i.e., the use of market incentives with regard to waste management, to the entire staff of DWM. Without a clear mandate as to what economic advise was most appropriate, Virginia Tech decided to review the scrap tire management plan as it currently stood, to see where their assistance would be most beneficial. It was clear that no calculation of the cost of the program, including collection, hauling, and recycling/disposal, had been done, and therefore, the magnitude of the needed tire tax was unknown. Using the best information available, it was estimated that the tire tax would have to be $1.42 per tire to run the program that DWM was planning. On top of this, the analysis showed that even though the state was providing collection, hauling, and disposal, free of charge, this did not guarantee compliance on the part of the tire haulers, and thus some type of deposit-refund, as is done with car batteries, may be appropriate. Therefore, DWM may wish to institute a tire tax of $3.00, and a refund, upon return of the scrap tire, of somewhere around $1.50. This presentation was given on March 12, 1992.

However, DWM felt that it was politically unfeasible to raise the tire tax beyond the current 50 cents per tire level. This was especially true because the waste tire trust fund was becoming a political embarrassment, as it was growing at a rate of over $2 million a year and very little expenditures were being made.

5.2.3 A Regulatory Approach?

In response to DWM's concerns, Virginia Tech decided to rethink, in a hurry--one day to be exact, DWM's plan, and how market forces could be used to lower the tax requirement. The key to the proposal was simple. A voucher system would be used to track scrap tires from their point of origin, tire retailers, through tire haulers, and finally to an authorized disposal site. The tire haulers would not be paid by the retailers until they returned a copy of the voucher with proof of delivery to an authorized disposal site.

The disposal site would then send the voucher to DWM for payment for disposal services rendered according to the terms of their contract.

This "cash on delivery," or COD, system provided the following advantages: collection and hauling was no longer funded by the state, no increase in the tire tax was needed, tire haulers no longer had an incentive to dispose of tires illegally, the current RFP process could continue and thus not cause political embarrassment, and the plan had low administrative costs for DWM. The one regulatory reform that would be needed is some way to punish the retailers if any of their tires did not reach a legal disposal site. This is very similar to the "regulatory" approach modeled in this research.

In a high level memo within DWM, dated March 26, 1992, it was made clear that DWM was happy with the COD plan. They expressed keen interest in "the power and use of a three signature form," utilizing the current scrap tire transport system (haulers and dealers) rather than supplementing it with a centralized state collection and transportation system, and "no state ownership of the tires at any point of tire handling or recycling/disposal process."

In June 1992, IEN sent a memo to DWM, which Virginia Tech reviewed. This memo suggested that the RFP process be abandoned for several reasons. First, the RFP presupposed that the state would deliver scrap tires to the disposal sites that won the bidding process. This was no longer considered feasible, and thus changed the terms of the contract. Second, the state did not have enough funds to pay the cost of disposal for the current flow of tires. Third, the RFP subsidy program would distort the current market for scrap tires where it existed, and could drive currently operating disposal firms out of business. The memo finished by proposing our alternative COD voucher plan, with enforcement against those who did not follow the rules of the plan, as well as possible subsidies to any disposal firm taking Virginia scrap tires, as a better alternative to the quickly failing RFP process.

By the September 15, 1992 meeting of the STMC, DWM's official position had changed. A senior DWM official, outlined the departments philosophy as: 1)A tire tax of $0.50 will not be sufficient to handle the waste tire problems in Virginia, 2) DWM does not want to be the waste manager for the State of Virginia. The Virginia law requires the state to develop a plan for the handling of scrap tires, but does not contemplate the state becoming the owner and manager of waste tires, and 3) DWM has learned that the private sector is tackling many of the waste tire issues. DWM would prefer to see economic incentives employed to resolve the tire problem whenever possible rather than to develop an extensive on-going regulatory system. Also, at this meeting, DWM made a commitment to wrap up the RFP process, already long past its deadline, within one month, and to have a comprehensive scrap tire management program developed within three and one-half months.

In December 1992, DWM issued their Internal Management Operating Program Plan for the Virginia Waste Tire Program: 1993-1994 (VDWM, 1992a). First of all, the RFP process was concluded with no bids being accepted. The plan called for a regional approach to current flow management. Each of the five regions in the state were evaluated with regard to their current disposal capacity. In two of the regions no indigenous capacity was present, and the plan called for providing processing services on a demonstration basis. In one region, a local government sponsored system was in place, and the plan called for the upgrading of equipment and services to capture all current flow. In the other two regions, it was determined that capacity was sufficient, and no program funds were appropriated. In addition to these efforts, the plan called for training of local officials, public information outreach, and classroom curriculum for children. This program called for a phased in approach over the two years, 1993 and 1994.

5.2.4 A New Law And A New Planning Challenge

In their 1993 session, the Virginia legislature amended the Virginia Code section 10.1-1422 to do two things. First, the sunset provision on the tire tax was removed. Second, the law allowed for the "partial reimbursement for the end users of waste tires."

The Department of Waste Management now found itself reorganized as the Division of Waste Management within the newly formed Department of Environmental Quality (DEQ). The DEQ had the responsibility for developing the regulations to advance section 10.1-1422. As part of Virginia's administrative process act, DEQ was required to take a participatory approach to drafting the regulations, and therefore formed a public advisory committee known as End User Reimbursement Advisory Committee (EURAC) as well as held an introductory public meeting.

IEN was contracted by DEQ to facilitate the regulatory development process. Noting the necessity of bringing economic analysis of the scrap tire market into the discussion, IEN subcontracted Virginia Tech to provide this analysis.

The first EURAC meeting was held on October 13, 1993. The EURAC was composed of 20 members. These members represented tire dealers, industry interested in using tire derived fuel, tire recyclers, regional public solid waste authorities, Virginia Department of Transportation, regional recycling concerns, citizen groups, environmental groups, and planning districts. The first agenda item was the department's review of the current scrap tire management program.

Next, Virginia Tech presented an overview of the economic analysis which they had conducted with regard to the scrap tire market, and the economic disincentives which exist for tire haulers to dispose of tires properly. They stressed that an enforcement option, including a voucher system, can achieve the same market enhancing outcomes for waste tires as can partial reimbursement. If tires could be tracked at a low cost from source to point of disposal, and a penalty existed for illegal disposal, the market would change in such a way that tire haulers would act in their own best interest and dispose of tires legally. Virginia Tech's presentation summed up by stating that in order to encourage legal disposal, the department can lower the tipping fee through subsidies, raise the expected cost of illegal disposal through enforcement, or lower transportation costs by providing capital grants to firms who locate in low capacity areas. Each of these are viable options to be considered, separately, as well as parts of a broader program design.

On February 9, 1994 the EURAC met again. DEQ informed the members that it was DEQ's opinion that they don't have the authority to regulate haulers. They stated that this statutory restriction is not superseded by the new tire legislation. Thus, if DEQ is correct, statutory authority would be needed to require a tire tracking system as recommended by Virginia Tech. Also, at the meeting, a DEQ representative demonstrated DEQ's response to the EURAC's desire for a tracking system--voluntary waste tire certification. He maintained that if tire dealers were to voluntarily employ the waste tire certification form, effective control over current flow could be established. The key elements of the plan are that tire dealers voluntarily provide tire haulers with the certification form and haulers only receive payment when the form, certified by the waste tire processors, is returned to the dealers. Also, because the system is voluntary, no statutory authority was needed.

However, the EURAC members had concerns about the voluntary system. They felt: haulers would not consent to delayed payments; the "good" tire dealers would be penalized with higher costs, while the "bad" tire dealers would continue to evade the law; there was no clear enforcement power with the existing law and process; and it would produce excess paperwork for everyone.

The EURAC members, unsatisfied with DEQ's voluntary alternative, requested that the Attorney General's opinion be sought on the issue of scrap tire regulation authority. There was general agreement, that without some form of control over haulers, no effective waste tire program could be established in Virginia. It was agreed that at the next meeting, both the opinion, and the alternatives consistent with that opinion, would be considered.

At the next EURAC meeting, on March 8, 1994, DEQ notified the members that they determined that DEQ lacked statutory authority to license or regulate haulers. Also, retailers of tires are not liable, under current Virginia waste law, for illegal disposal activities of the haulers they hire. Civil liability is unlikely also.

The rest of the EURAC meeting dealt with a working copy of regulations developed by DEQ. The EURAC members were walked through the proposed regulations. The proposed regulations provided for a tiered subsidy to endusers, in which a higher subsidy was given for uses which were deemed preferred. Category I uses, energy production, were to be subsidized at a rate of $20.00 per ton. Category II uses, pyrolysis and civil engineering, were to be subsidized at a rate of $22.50 per ton. Finally, Category III uses, recycled scrap tires, were to be subsidized at $25.00 per ton.

Also, the subsidy amount was limited to the "out-of-pocket" expenses of the enduser. This clause in the proposed regulations meant that all endusers would be subsidized only to the point that they would be indifferent between using scrap tires or some other material. In other words, they would have no incentive to use scrap tires. Not only would determining a true cost of use for each enduser be arduous, but this, combined with the regulatory requirement that any person supplying scrap tires to the enduser who applies for the subsidy may be audited, almost assures that very little participation will result. Therefore, the DEQ plan for requiring tracking of tires which receive the subsidy will have little effect, because so few tires will receive the subsidy--people will opt out of the program.

On June 16, 1994 the EURAC held its final meeting. A set of draft regulations was produced by DEQ which attempted to institute a partial reimbursement program. The regulations, in large part due to the enabling legislation's wording, were very cumbersome. First, the program offered maximum reimbursement rates of between $15.00 and $32.00 per ton, depending on the use. Also, the subsidy was capped at the lower of the maximum reimbursement rate or either: 90 percent of the purchase price of the tires or chips if the tires or chips were purchased, or 90 percent of the cost of use of the tires or chips if the tires or chips were not purchased. Cost of use was defined as "the equipment, leasehold improvements, buildings, land, engineering, transportation, operating, taxes, interest, and depreciation or replacement costs, of using waste tires incurred by the enduser after deducting any tipping fee received by the enduser." Hence, in order to receive reimbursement, the enduser might have to undertake a painstaking financial analysis, and DEQ had to review this analysis. Also, this type of reimbursement schedule favors high cost users, and thus reduces the total number of subsidized waste tires.

Second, the regulations, by law, capped the total subsidy to 75 percent of the previous year's tire tax revenue. Therefore, it remained a real possibility that firms would use scrap tires, and not get reimbursed. This uncertainty could lead to reduced participation in the program.

Finally, the regulations provided for no enforcement within the waste tire program. Therefore, the only enforcement would be criminal enforcement against tire haulers, and the amount of effort used in apprehending illegal disposers would be at the discretion of the local law enforcement officials and their budgets.

In October 1994, DEQ put together their final proposed regulations and presented them to the Virginia Waste Management Board. The Waste Management Board claimed an exemption from the Administrative Process act in accordance with the Code of Virginia (9-6.14:4.1 B 4), which exempts regulations relating to grants of state or federal funds or property. This exemption, which they can claim because they are simply giving grants or subsidies, allowed them to by-pass any public comment requirements, and the regulations became effective December 20, 1994 (VR 672-60-1).

5.2.5 The Final Scrap Tire Program

The final regulations were identical to the proposed regulations which were presented to the EURAC at the last meeting, except for two points. First, a single maximum subsidy of $30.00 per ton was approved for any use--no hierarchy was imposed. Second, full reimbursement of the purchase price, or cost of use, up to the maximum of $30.00, was given instead of 90 percent.

In addition to the regulations, the DEQ also instituted a voluntary tire hauler registration program. The DEQ registers any hauler who does not have any outstanding compliance or enforcement actions with DEQ or the locality in which they are based. DEQ then provides this list to anyone who requests it. However, registration is not required to haul tires, and using a registered hauler is not required to receive subsidies. The system is wholly voluntary. Also, by using a registered hauler, the tire generator does not relieve himself of any liability for improperly dumped tires. As of April 1995, 30 haulers received DEQ certification.

5.3 Empirical Information And The Policy Process

5.3.1 A Note On The Model's Predictive Ability

In the first quarter of 1995, DEQ approved requests for reimbursement from 8 endusers for a total of 9,560 tons of scrap tires. In the second quarter they received 10 requests for a total of 9,870 tons of scrap tires. This amount annualizes to 38,860 tons.

The model predicted that with a $30.00 per ton subsidy, and no enforcement, 46,838 tons would be subsidized if the elasticity of supply was 3.00, 34,520 with an elasticity of supply of 1.00, and 29,447 with an elasticity of supply of 0.33. Although the model was developed and run with 1992 prices and quantities, the fact that these real world 1995 results fall within the range predicted by the model lends credibility to the model's robustness.

According to the model, at a subsidy of $30.00 per ton and no enforcement, if the DEQ was interested in minimizing total costs, this would be a cost-effective plan regardless of enforcement approach, elasticity of supply, or fine level. This plan will use up in subsidy expense $1,165,800.00 per year. This is 52 percent of the annual tire tax revenues.

This validation of the model shows that if the model had been available during the policy development process, it could have provided accurate information to the policy makers. The question of how useful the information might have been will be taken up in the next section

5.3.2 Incorporating Empirical Analysis Into The Policy Process

In chapter one, the premise was offered that the choice between criminal enforcement, regulatory enforcement, and subsidies, is an empirical one which is industry, or waste specific. As this chapter has shown, throughout the development of

Virginia's scrap tire program, a continual question was raised as to whether enforcement or subsidies were a more cost effective means of controlling illegal scrap tire disposal. At first, Virginia Tech espoused a subsidy program, whereby the subsidies went toward paying for both transport and disposal of the scrap tires. This was in accord with the DEQ's first approach to the problem. When Virginia Tech estimated the necessary subsidy to be around $1.50 per tire, the DEQ, realizing that it could not justify raising the tire tax, revised its plan to only subsidize disposal. Realizing that subsidizing disposal at a maximum rate of $0.37 per tire--75 percent of the tire tax, would not effect a great deal of additional legal disposal, Virginia Tech backed away from subsidies and recommended a regulatory enforcement approach--the voucher system.

The reality of the situation is that both DEQ's approach, and Virginia Tech's recommendation, were based on very little empirical knowledge. At the time of the initial proposals, even the extent of the problem--the number of tires stockpiled and annual increase in the stockpiles--was not known. However, as one compares the results of the model, with Virginia Tech's policy recommendations, it can be seen that they are in accord. Under the non-budget-constrained scenario, Virginia Tech agreed with DEQ's subsidy program, and gave no thought to enforcement. Virginia Tech's proposal was simply to raise the subsidy, and the tire tax, to a level they felt would be sufficient to effect complete legal disposal of scrap tires. When DEQ made it clear that the tire tax could not be raised, and thus subsidies had to be capped at about $0.37 per tire, Virginia Tech believed that this subsidy level would be insufficient to effect a significant level of legal disposal. Therefore, Virginia Tech began to think of ways to leverage the scarce budget dollars. The way to do this, they decided, was to use the available funds to institute a regulatory enforcement program, and make scrap tire generators responsible for their scrap tires until the point of final disposal. This line of thought is in clear agreement with the model's results.

Although it is encouraging to know that Virginia Tech was "right," it is at the same time troubling to know how wrong their policy advice could have been. The structure of the model itself assures that the choice of policy tool--criminal enforcement, regulatory enforcement, or subsidy--is dependent on the initial scrap tire market conditions and the cost of enforcement. No information was available with regard to how much of a subsidy it would require to effect different levels of legal disposal, or how much a regulatory approach would cost. If regulation had been more expensive, or the structure of the scrap tire market a little different, for example, if large quantities of tires originated very close to disposal plants, then subsidies may have been the dominant policy tool even in the budget constrained environment.

At best, it could be argued that Virginia Tech had an intuitive sense of the scrap tire market, and the cost of a voucher type regulatory system. However, DEQ chose to disregard Virginia Tech's intuition and institute a subsidy program. The problem is, it is very difficult to convince others based on one's intuition. This is where the power of the model comes into play.

At several points in time, Virginia Tech had the opportunity to provide their opinion to both the DEQ and the industry/citizen advisory boards with regard to how they felt the scrap tire problem in Virginia could be best managed. Each time, Virginia Tech's ideas were well received, yet no better received then DEQ's subsidy proposal. Virginia Tech was able to convince those involved in the policy development process of the logic behind regulatory enforcement; the fact that every market based environmental policy must include enforcement of the rules of the market. However, Virginia Tech was unable to convince them that one could induce a greater amount of legal scrap tire disposal by making the scrap tire generator responsible for, and willing to, legally dispose of her tires, by instituting an enforcement program. In other words, DEQ and the EURAC members understood that both subsidies and enforcement would alleviate the scrap tire problem, but they had no reason to believe that one could do so at a lower cost.

The model's results, if available, would have provided the needed empirical evidence to substantiate Virginia Tech's recommendations. Therefore, through the presentation of the empirical evidence resulting from the model developed in this research, a cost-efficient solution to the scrap tire management problem might have been reached. However, there are limitations to the use of this type of modeling in the policy arena, and these shall be discussed below.

5.4 Limitations Of The Model In The Policy Arena

5.4.1 Time And Data Requirements

Policy analysts are aware of the need for timely and accurate information to support the policy formation process. The modeling exercise presented in this research took three years to complete, including development time, data collection time, and data analysis time. Therefore, it is clear that this type of effort does not lend itself to policy analysis. This is evidenced by the fact that the results of this analysis were not available when decisions were made with regard to Virginia's scrap tire policy.

However, the time required to complete this study included model development time and data collection time which could be significantly shortened or eliminated in future studies. If a data base could be developed which updated enforcement costs information, and if waste specific generation and disposal data could also be recorded, the model could most likely be modified, and results available, within three to six months. This fits the timeline of many policy studies.

5.4.2 Model Acceptance

5.4.2.1 Agreement On The Model's Accuracy And Appropriateness

Any simulation model is built, by necessity, on the assumptions of the model builder. These assumptions can be a source of disagreement among those involved in policy decisions. If the assumptions are not agreed to by those who have the ability to accept or reject the model results, it is quite possible that the model will be labeled "inappropriate" or the model's results will be dismissed as "unrealistic."

Therefore it is important to have participants in the policy process agree on the assumptions and parameters of the model in the beginning. This can be accomplished by allowing them to assist in the model development. If agreement can not be reached on the model structure or a parameter, then the model can be run in different configurations, and the sensitivity of the results to these disagreements can be determined. This was done with regard to the elasticity of supply in this research. If the sensitivity analysis shows no significant effect on the models results, then the initial disagreement is moot. If however, the results are sensitive to the disagreed upon model attribute, the model's acceptability, and thus usefulness, may be hindered.

5.4.2.2 Legal Constraint Or Political Objection To The Model's Findings

It is possible that the recommendations which flow from the model's results will not be implemented. The first reason is that the current legal structure may not allow the recommendations to be followed. Although legal constraints can be included in the model, such as the landfill ban was included in this research, legal opinions may not surface until after the analysis is complete. For example, in the case of Virginia's scrap tires, the Attorney General's office decided very late in the policy development process that the DEQ does not have the right to require tire dealers to keep disposal records. This eliminated the possibility of a regulatory enforcement approach as modeled. Therefore, in order to make useful recommendations about regulatory enforcement, the model would have to be modified to include a legal regulatory enforcement mechanism and re-analyzed.

Even if the model is consistent with current law, the policy makers may decide that the recommendations which the model proposes are politically unfeasible. This was the case with regard to the Virginia Scrap Tire Management Plan when the subsidy program would have required raising the tire tax. The political situation, including the fact that the waste tire trust fund was building at a rate of $2 million a year, with little expenditures, made requesting a tax increase from the General Assembly unacceptable. In this situation, the model could still be helpful, since the results are cost-effective solution sets, and the model will give the best budget-constrained solutions. However, the policy analyst must be sensitive to the political climate, because even the mention of a politically unfeasible solution can discredit the analyst and the modeling procedure as well. This almost happened to Virginia Tech when they suggested an increase in the tire tax.

5.5 Summary

The policy development history presented in this chapter illustrated the need for, and lack of, empirical evidence in the scrap tire management debate which the author was involved in. It was shown that the results of this research could have aided the development of a cost effective scrap tire management policy. However, it was also noted that the simple existence of the model's results may not have guaranteed they would be instrumental in policy design. In order for the results of the modeling procedure to be useful to policy makers, they need to be timely, be based upon agreed upon assumptions, be consistent with the existing legal and institutional structure, and be sensitive to the current political climate.

Chapter 6. Conclusions

6.1 Summary Of Research Findings

The objective of this research was to fill a void in the economics literature related to solid waste disposal and enforcement. Through an examination of the economics and law literature, namely Shavell's recent work, it was determined that the choice of a cost effective enforcement mechanism should not be a theoretical or ideological decision, but rather an empirical decision. In other words, the least cost means of achieving different levels of legal solid waste disposal is not universal, but dependent on the many attributes of the current solid waste disposal situation and the costs of alternative enforcement mechanisms or other policy tools.

Following this logic, this research centered upon the development of a solid waste disposal market simulation model. This model incorporated current conditions of the solid waste disposal market, the cost of regulatory enforcement, and the cost of criminal enforcement. It also allowed for sensitivity analysis of the effect of certain parameters on the results. Finally, the model allowed for different objective functions which may be important to policy makers depending on their budget situation: the minimization of total costs, the minimization of gross public costs, and the minimization of public costs net any fine revenue.

The model was applied to the development of a policy aimed at solving Virginia's scrap tire disposal problem. The policy options considered were criminal enforcement, regulatory enforcement, and subsidies. The necessary data were collected concerning the current level of scrap tire generation, legal and illegal disposal options and locations, the cost of transporting the scrap tires, and the cost of criminal and regulatory enforcement. The results of the modeling exercise indicated that in every case criminal enforcement was more expensive than regulatory enforcement. With regard to the question of what the role of enforcement versus subsidies should be, the most important indicator was the objective function.

If the policy makers were concerned with total costs, and were not budget constrained, then subsidies were found to dominate. If however, officials were concerned with gross or net public costs, due to a budget constraint, then enforcement dominated.

The model was analyzed under several configurations of elasticity of supply, fine level, and with a landfill ban in effect. The model predicted that the elasticity of supply, fine level, and legality of landfilling, in almost every case, did not affect the choice of policy tool. However, an inelastic supply function, low fine level, or a landfill ban does raise the cost of achieving legal disposal.

In addition to the model results, another important result of the case study was the policy implications gained through the author's involvement in the development of Virginia's scrap tire management regulations. This experience showed that the model, although accurate, would only be helpful under certain conditions. First, the model must be able to provide timely input into the policy development process. This means that data must be continually updated with respect to enforcement costs, and data concerning the current solid waste disposal situation must be available. Second, participants in the policy development process must agree to the model's assumptions and structure. Third, The model must be constrained to include only legal options, and the analyst must be sensitive to interpreting the model's results to suggest a politically unfeasible policy recommendation.

6.2 Applicability Of Research Findings To Other Situations

The model developed in chapter two is flexible enough to be applied to a large range of solid waste disposal problems, for example, used oil disposal, hazardous waste disposal, animal waste disposal, or human sludge disposal. The model can also be changed to include different policy tools, such as a deposit-refund system. The power of the simulation lies in the straight forward structure of the non-linear programming model--simply minimizing the disposer's costs while including the expected fine as part of that cost. The manner in which the expected fine is reached, and the cost of doing so, is then calculated separately. This allows the analysts to tackle the two problems independently.

Of course, as mentioned above, the application of the model to other solid waste scenarios will require the collection of a broad range of data, a task which is both expensive and timely.

6.3 Proposed Future Research: Automating The Model

The analysis presented began in January 1993 and was completed in October 1995, a total of 34 months. This is a great deal of time. However, the results of this research lay the ground work for a new means of looking at effecting legal solid waste disposal, and thus the time was well spent. The reasons for this long time frame, besides the significant time collecting data discussed above, are two-fold. First, the conceptual model needed to be developed, as this had never been done. Although the conceptual model will need to be adjusted for each policy question, this is a minor task. Second, the simulation was done very piece-meal, using GAMS mathematical programming language, SAS statistical analysis software, LOTUS spreadsheet software, and AMIPRO word-processing software. This approach, although necessary to develop the prototype simulation model, resulted in numerous transfers of data between these programs, all in different formats. Also, each step had to done manually.

It would be necessary before this modeling exercise could be applied to many solid waste disposal problems to automate the simulation procedure, from beginning to end, using a single piece of software. This would serve the solid waste disposal policy development process well, and is a next step for this research.

6.4 Final Comments

Although the model can determine the least cost approach to reaching a level of legal disposal, it would be inappropriate to hold that single solution above all others. Small data errors, or errors in the model's structure could show one solution to dominate another, when indeed, the opposite is true. Falling into this trap should, and can, be avoided. The analyst should rather look to the model for general guidance and themes. For example, in the case of Virginia's scrap tires, regulation dominates criminal enforcement, and the role of subsidies and enforcement depends on the objective function. These are powerful results, which can guide policy toward a least cost solution, if not to one.

Finally, although the model developed here is a sophisticated means to determine least cost solutions to solid waste disposal problems, it can be even more powerful as a means to demonstrate, both to policy makers as well as to other economists, the need to consider the cost of enforcement when developing policy. Too often research has been done which prescribes certain policy tools, for example, marketable permits, subsidies, or command and control measures, without specific information on enforcement costs or other transaction costs being considered. Thankfully, this trend is changing. An example of which is Stavins recent research which found that transactions costs make the advantage of tradable permit systems over government regulation, or taxing, less certain. This research adds to this recent literature which demonstrates that the relative strength of different policy tools is an empirical question, and one that can only be answered correctly if all transactions costs, including enforcement costs, are included in the analysis.

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Appendix A. Cost Function Estimation

A.1 Police Cost Function

The output measure for police services, or deterrence and apprehension services, is the number of arrests made. Arrest data were obtained for each county and independent city in Virginia for calendar years 1986 through 1993 (Virginia Department of State Police, 1986-1993). The arrest data was broken down into 29 offense types as specified under the Virginia Uniform Crime Reporting Program. The offenses are: murder, manslaughter, forcible rape, robbery, aggravated assault, burglary, larceny, motor vehicle theft, arson, other assaults, forgery and counterfeiting, fraud, embezzlement, stolen property (buy, sell, possession), vandalism, weapons possession, prostitution and commercial vice, sex offenses, narcotic sales, narcotic possession, gambling, offenses against the family, driving under the influence, liquor laws, public drunkenness, disorderly conduct, curfew and loitering, runaways and juveniles apprehended, and others. Since cost and price data were available on a fiscal year basis, the output data was converted to fiscal years by taking the average of the two calendar years making up the fiscal year. In order to estimate the police cost function, it was necessary to reduce the dimensions of the analysis by aggregating across outputs. Three outputs were defined. Y_1 equaled the sum of: murder, manslaughter, forcible rape, and aggravated assault. Y_2 equaled the sum of: robbery, burglary, larceny, motor vehicle theft, and arson. Finally, Y_3 equaled the sum of all the other offense types.

Expenditure data for most of Virginia's county, city and town police and sheriff departments were obtained for fiscal years 1987 through 1993 (Virginia Auditor of Public Accounts, 1987-1993). In all 1201 observations were available. This expenditure data included personnel expenses, fringe benefits, contractual costs, internal transfers, capital expenditures, and rental expenditures. Input quantity data, the number of police (P) and civilian (C) employees in each department, was also obtained for each department over the fiscal years 1987 to 1993 (Virginia Department of State Police, 1986 - 1993).

Since the output data was collected on a county and city basis, the input data had to be aggregated to the same basis. After this was completed, the price of police employees and civilian employees was determined for each county and city. Since no direct data was available on these salaries, several assumptions were made. First, civilian employees were assumed to be equal to the average "secretary salary" in Virginia and

Northern Virginia, as determined by the Virginia Department of Personnel and Training (1986a-1992a; 1986b-1992b). After subtracting civilian personnel expenses, from total personnel expenses, the remainder is police personnel expenses. The average police salary was then calculated by dividing police personnel expenses by the number of police officers in each county or city. The price of the civilian (P_C) and police labor (P_P) inputs were calculated by multiplying the salaries by a fringe factor. The fringe factor is equal to (fringe expenses / personnel expenses) +1.

Several small departments do not report their expenditures to the Virginia Auditor of Public Accounts, and thus it was not possible to calculate a salary for police. In these cases, the price for those localities' police officers were set equal to the average police salary in the rest of the county, and the county's total personnel and fringe expenditures were adjusted accordingly.

In order to calculate the annual capital expenditures, some further assumptions were needed. First, the capital expenditures obtained are on a cash flow basis, and thus are not annualized. In order to come up with an annualized expenditure, the average capital expenditure for each county or city, over the fiscal years 1987 to 1993, was used. Each locality in the sample had at least four years worth of capital expenditure data, and therefore, the average capital expenditure is a good estimate of the size of the annualized capital expenditure. In addition to the average capital expenditure amount, the total capital expenditure for each observation included the contract, other, and rental expenses. The quantity of capital (K) for each observation was obtained by dividing the total capital expenditure by the price of capital (P_K). The following prices (P_K) were used: 2.0 (FY 1987), 2.06 (FY 1988), 2.12 (FY 1989), 2.17 (FY 1990), 2.30 (FY 1991), 2.40 (FY 1992), 2.44 (FY 1993). The prices were developed using a Virginia specific price index derived from personal income data. It is important to note that the capital expenditures for some counties and cities are biased downward, because no capital is included for those small departments which do not report their expenditures to the Virginia Auditor of Public Accounts. However, this bias should be quite small. As evidence of this, the capital associated with 50,688 police person years is included in the analysis, while the capital associated with 1,324 police person years is omitted. Assuming a constant police labor-capital mix, the capital expenditures are only biased downward 2.5 percent. Instead of adjusting the capital expenditure upward, and imposing some type of Leontiff technology, it was decided to simply recognize the small bias in the data.

There were 888 county and city observations for which all the necessary input and output data was available. Since the prices of the labor inputs (P_P and P_C) were calculated from secondary data sources, including the secretary proxy for civilian salary, it was necessary to remove those observations which resulted in clearly poor price estimates. Ninety-two observations were removed because the price of the police input was less than the price of the civilian input. Twenty-one observations were removed because the price of the police input was unreasonably high, over $65,000. This left 765 observations in the sample. However two 1993 observations were returned to the sample because it would be necessary to predict the increase in cost in those counties as part of the larger study, Thus 767 observations were used in the estimation of the police cost function.

For each fiscal year, the following table shows the number of observations, the average civilian labor input price, and the annual police labor input price. The standard deviations are in parentheses.

Table A-1. Police and Civilian Employee Prices (Salary + Fringe Benefits)

Fiscal Year	Observations	Price Police (S.D.)	Price Civilian (S.D.)
1987	99	$28,911 (8,889)	$19,450 (982)
1988	113	$29,655 (7,776)	$19,881 (923)
1989	101	$31,557 (8,932)	$20,821 (1,480)
1990	117	$32,317 (8,292)	$21,686 (1,183)
1991	110	$33,934 (8,329)	$22,821 (1,113)
1992	109	$33,856 (7,916)	$23,090 (1,104)
1993	118	$35,041 (9,737)	$23,203 (1,161)

Since each court produces more than one output, we can write its transformation function as:

$$(A1) \qquad F(Y_1, Y_2; Y_3, X_P, X_C, X_K; MULTI) = 0$$

where Y_1 , Y_2 , Y_3 are the number of arrests, X_P, X_C, and X_K are the levels of inputs, and MULTI represents a locality with more than one law enforcement agency. Assuming that the police are cost minimizers, and (A1) satisfies the usual regularity conditions, duality theory ensures that for each transformation function, there exists a dual cost function (Diewert, 1971). The cost function can be written as:

$$(A2) \qquad C = g(Y_1, Y_2, Y_3; W_P, W_C, W_K : MULTI)$$

where W_P, W_C, and W_K are input prices.

In order to estimate the cost function (A2), a functional form must be specified. The following translog form was chosen because it is flexible enough to portray all measures of interest; i.e. the functional value, first order derivatives, and second order derivative, independently without imposing prior constraints on or across these measures. The cost function is now written as:

$$(A3) \quad \ln(C) = A_O + \sum_i A_i \ln(Y_i) + \sum_j B_j W_j + \frac{1}{2}[\sum_i \sum_s Z_{is} \ln(Y_i) \ln(Y_s) + \sum_j \sum_l D_{jl}$$

$$\ln(W_j) \ln(W_l)] + \sum_i \sum_j E_{ij} \ln(Y_i) \ln(W_j) + M \times MULTI$$

where A_O, A_i, B_j, Z_{il}, D_{jl}, E_{ij}, and M are the parameters to be estimated. Using Shephard's lemma, the following four share equations can be obtained (A4).

(A4) $\partial C / \partial W_j = W_j X_j / C = S_j = B_j + \sum_l D_{jl} \ln(W_l) + \sum_j E_{ij} \ln(Y_i)$

The adding up property of the share equations ($\Sigma S_J = 1$) and the properties of neo-classical production theory require the following linear restrictions to be imposed on the model:

(A5) $\sum_j B_j = 1; \quad \sum_j D_{jl} = 0; \quad \sum_j E_{ij} = 0; \quad D_{jl} = D_{lj}; \quad Z_{is} = Z_{si}$

The cost equation (A3) and three of the four share equations (A4), with the parameter restrictions in (A5) make up the system that was estimated Additive disturbance terms were added to the cost equation and each of the share equations. The resulting disturbance vector is assumed independently and identically multivariate normally distributed with mean vector zero and constant nonsingular covariance matrix. Efficient parameter estimates are obtained using iterative seemingly unrelated regression. Before the estimation, some of the data was scaled in order to reduce parameter instability. The following data scaling was done, which of course in no way changes the resulting estimates.

Y_2 = (Number of Arrests Type I1) / 6
Y_3 = (Number of Arrests Type III) / 38.5
W_P = (Price of Annual Police Labor Input) / 1000
W_C = (Price of Annual Civilian Labor Input) / 1000

The following table shows the estimated parameter values, standard errors, and t-ratios. Parameters denoted P, C, and K, represent police labor, civilian labor, and capital inputs respectively. Parameters denoted 1,2, and 3 represent arrest type 1, arrest type2, and arrest type 3 respectively. M is the parameter on the multi-force dummy variable. All of the first order coefficients that are statistically significant at the 0.05 level of significance are positive. This is a necessary condition for a globally well behaved function. It is also important to notice that the dummy variable is highly significant and positive, showing that costs, ceteris paribus, are higher in multi-force localities.

Table A-2. Police Cost Function Parameter Estimates

Parameter	Estimate	St. Error	T Ratio	
A_0	9.09	0.13	72.14	*
A_1	0.01	0.05	0.18	
A_2	-0.13	0.08	-1.63	
A_3	0.58	0.09	6.69	*
B_P	0.62	0.02	27.15	*
B_C	-0.03	0.07	-0.43	
B_K	0.41	0.07	5.87	*
Z_{11}	0.08	0.04	2.13	*
Z_{22}	0.06	0.07	0.08	
Z_{33}	-0.22	0.09	-2.49	*
Z_{12}	-0.07	0.04	-1.61	
Z_{13}	0.02	0.04	0.48	
Z_{23}	0.14	0.07	1.94	**
D_{PP}	0.05	0.01	3.41	*
D_{CC}	0.14	0.04	3.61	*
D_{KK}	-0.13	0.04	-3.03	*
D_{PC}	-0.03	0.01	-2.10	*
D_{PK}	-0.02	0.01	-2.29	*
D_{CK}	-0.11	0.03	-3.31	*
E_{P1}	-0.01	0	-1.41	
E_{P2}	-0.02	0.01	-3.57	*
E_{P3}	0.06	0.01	7.94	*
E_{C1}	0	0	0.59	
E_{C2}	0	0.01	0.28	
E_{C3}	-0.02	0.01	-3.51	*
E_{K1}	0	0	1.41	
E_{K2}	0.02	0	5.45	*
E_{K3}	-0.03	0	-7.50	*
M	0.19	0.03	7.17	*

* Significant at 0.05 level. ** Significant at 0.10 level

The R^2 for the cost function, the police labor cost share equation, and the civilian labor cost share equation were 0.9372, 0.1946, and 0.0922 respectively. Eigenvector-eigenvalue analysis found no multicollinierity problem which might cause the parameters to be unstable.

In order to assure that the cost function was well behaved over the relevant range of output, each observation was checked by raising each output level by 900 in intervals of 300. In both the case of (Y_1) and (Y_3) cost increased at a decreasing rate, as output increased at each of the 767 data points. In the case of (Y2), the function showed negative additional costs, and thus was not well behaved, at 37 of the 767 observations-- 4.8 percent of the observations. For fiscal year 1993 observations, which will be the base for the scrap tire enforcement cost modeling, 6 of the 188 observations, or 3.19 percent, showed negative additional costs as (Y2) was increased. Although the function is clearly not globally well behaved, these low number of anomalies provide confidence in the model for predicting how costs increase with output. Finally, a White test for heteroskedaticity found no violation of the homoskedaticity assumption in the cost function.

A.2 Magistrate Cost Function

The office of magistrate traces its development through centuries of English and American history. In Virginia, many of the functions now performed by magistrates were once performed by elected justices of the peace, before that office was phased out in 1974. Magistrates are charged with providing an independent, unbiased review of complaints brought by police officers, sheriffs, deputies, and citizens. Magistrates, however, are not law enforcement officials, but rather, they act as a buffer between law enforcement and society (Supreme Court of Virginia, 1991).

The functions of the magistrate are to: issue arrest warrants, search warrants, admit a person to bail or commit to jail, issue court summonses including subpoenas, issue civil warrants, and issue temporary detention orders. Each time a magistrate considers such an action, a "transaction" is said to have occurred. The transaction is said to occur regardless of the magistrate's decision. Therefore, the number of transactions per year is the output used in the magistrate cost function estimation. For each magistrate district, of which there are 32, the number of transactions, as well as the number of magistrates and their salaries, were obtained. Also, the non-salary expenses for each district were obtained. This information was obtained for calendar years 1987 through 1992, thus the sample consists of 192 observations. (Supreme Court of Virginia 1987-1992).

Individual magistrate salaries were not available, but a salary schedule for each year was obtained. Magistrates are grouped into the following classes: magistrate 1 (Mag1) , magistrate 2 (Mag2), magistrate 3 (Mag3), magistrate 4 (Mag4), magistrate 5 (Mag5), magistrate 6 (Mag6), chief magistrate 1 (ChMag1), and chief magistrate 2 (ChMag2). It was assumed that each magistrate earned the median salary for their class.

Each district has either a chief magistrate 1 or chief magistrate 2, and any combination of the others. Also, a fringe benefit "factor" was calculated for each year, and each magistrate salary level was multiplied by the appropriate fringe factor to calculate the total price per magistrate position. The annual fringe factor simple equaled (1 + (Total Fringe Benefit Expenditures / Total Magistrate Salary Expenditures)).

In order to reduce the dimentionality of the estimation, two classes of magistrate were formed, Magistrate A (MagA) and Magistrate B (MagB). MagA included: Mag1, Mag2, Mag3, ChMag1 and ChMag2. MagB included: Mag4, Mag5, and Mag6. In order to aggregate these inputs, it was necessary to assume that the cost function is both separable in factor prices and output, or in other words it is weakly homothetically separable (Chambers). This assumption allows the cost function to be written as:

$$\text{(A6)} \quad C = \left(Y, C^A\left(W_1, W_2, W_3, W_{C1}, W_{C2}\right), C^B\left(W_4, W_5, W_6\right)\right)$$

where (W_i) are the prices of the magistrates, (Y) is the level of output--transactions, and C^A and C^B are unknown aggregator functions. Tornquist-Theil price indices, which are exact for homothetically separable technologies, were used as the aggregator functions C^A and C^B (Diewart, 1976). The form of the price index is:

$$\text{(A7)} \quad C(P_i) / C(P_B) = \prod_{n=1}^{N} \left[P_n^i / P_n^B\right]^{\left[S_n^i + S_n^B\right]}$$

where (N) is the number of inputs being aggregated, ($P^B{}_n$) is the price of the nth input in the base observation, ($P^i{}_n$) is the price of the nth input in the ith observation, ($S^i{}_n$) is the share of the aggregated cost of the nth input in the ith observation, and ($S^B{}_n$) is the share of the aggregated cost of the nth input in the base observation. The base observation was magistrate district one in 1987, hence the price of MagA and MagB were set equal to 1 for this observation and index values were calculated according to (A7) for the other 191 observations.

Other, non-personnel related, expenses were given a unit price of $2.00 in 1987 and were adjusted upwards for each year by a Virginia specific inflation factor based on per capita income information. The prices were: $2.06 (1988), $2.21 (1989), $2.29 (1990), $2.36 (1991) and $2.45 (1992). The number of "units" of other expense were calculated simply by dividing the expenditure amount by the price. Also, in order to reduce parameter instability the level of transactions was divided by its minimum, 1845. Finally, a dummy variable was used to distinguish between "large" and "small" districts. This was done by arbitrarily dividing those districts with 16 or fewer magistrates from those with more. The first group were considered small.

In order to estimate the cost function, a functional form had to be specified. The translog functional form was chosen for its flexibility--that is, its ability to portray all measures of interest without restricting across measures (Chambers). Hence the cost function estimated was:

$$(A8)\ \ln(C) = A_O + A_y + \sum_j B_j\, W_j + \frac{1}{2}\left[A_{yy} ln(Y)^2 + \sum_j \sum_l D_{jl}\, \ln(W_j)\ln(W_l) \right] + \sum_j E_{jy}\, \ln(Y)$$
$$+ R \times \text{Small}$$

where A_0, A_y, R, A_{yy}, all the B_j, all the D_{jl}, and all the E_{jy}, are the parameters to be estimated. The W are input prices, Y is output, and "Small" is the dummy variable.

The assumption of cost minimization, along with Sheppard's lemma, allow for cost share equations to be specified for each input. These are:

$$(A9)\quad \partial C / \partial W_j = W_j\, X_j / C = S_j = B_j + \sum_l D_{jl}\, \ln(W_l) + E_{jy}\, \ln(Y)$$

The adding up property of the share equations ($\Sigma\, S_J = 1$) and the properties of neo-classical production theory require the following linear restrictions to be imposed on the model:

$$(A10)\qquad \sum_j B_j = 1;\quad \sum_j D_{jl} = 0;\quad \sum_j E_{jy} = 0;\quad D_{jl} = D_{lj}$$

The cost equation (A8) and two of the three share equations (A9) were estimated. Additive disturbance terms were added to the cost equation and each of the share equations. The resulting disturbance vector is assumed independently and identically multivariate normally distributed with mean vector zero and constant nonsingular covariance matrix. Efficient parameter estimates are obtained using iterative seemingly unrelated regression. The results of the regression can be found in Table A. Parameters labeled A and B represent Magistrate type A and B respectively. O represents "other" inputs. Y represents the output measure--transactions. R is the parameter for the dummy variable--rural.

Table A-3. Magistrate Cost Function Parameter Estimates.

Parameter	Estimate	Standard Error	T Ratio
A_o	8.17	0.43	19.15 *
A_y	0.46	0.19	2.49 *
A_{yy}	-0.11	0.03	-3.70 *
B_A	0.78	0.3	2.59 *
B_B	0.97	0.14	7.02 *
B_O	-0.76	0.31	-2.47 *
D_{AA}	0.62	0.2	3.09 *
D_{BB}	-0.43	0.06	-6.66 *
D_{OO}	-0.72	0.21	-3.40 *
D_{AB}	-0.46	0.06	-7.89 *
D_{AO}	-0.16	0.18	-0.91
D_{BO}	0.89	0.07	13.14 *
E_{AY}	-0.2	0.04	-5.76 *
E_{BY}	0.47	0.05	9.17 *
E_{OY}	-0.27	0.06	-4.14 *
R	-0.42	0.03	-14.78 *

* Significant at 0.05 level.

As can be seen in the above table, all but one of the parameters is significant at the 0.05 level. Also, most of the signs are as expected, with the exception of the parameter on price of "other" inputs. The R^2 of the cost function, Mag A share equation, and Mag B share equation was 0.60, 0.43, and 0.22 respectively. In order to check that the cost function was increasing in output over the necessary range of the simulation, each data point had the number of hearings raised by 900 at 300 level increments. For each observation, costs increased at a decreasing rate, consistent with a well behaved cost function. The cost function was tested to see if it met the homoskedasticity assumption.

A.3 District Court Cost Function

In Virginia, the District Court system is comprised of three types of courts: general district courts (GD), juvenile and domestic relations courts (J&DR), and combined courts. GD courts have primary jurisdiction over civil suits involving amounts of money up to $10,000, all traffic cases, and criminal cases involving a possible penalty of no more than one year in jail or a fine up to $1000, or both. Also, the general district court holds preliminary hearings in felony cases. The J&DR courts have primary jurisdiction over cases involving delinquents, juvenile traffic violations, children in need of services, abused children, adults accused of crimes against members of their own family, child custody cases, and court ordered rehabilitation. Combined courts have jurisdiction over all of the above cases (Supreme Court of Virginia, 1990-1991). In the case of separate GD and J&DR courts, each will have its own staff and data were available on the expenditures by both courts. In the case of the combined courts, although their is a distinction between GD judges and J&DR judges, all clerks work on both types of cases, and expenditure data is collected in such a way that it is not separable by function.

Therefore, in order to estimate a single cost function for both district court types--combined, and not combined, each GD court was paired with its partner J&DR court as a single observation. In order to distinguish between these courts, and those that truly are combined courts, a dummy variable was used. This will be discussed in more detail below.

In order to estimate the cost function for district court outputs, or hearings, data was collected from each of the 125 Virginia district courts, on a annual basis, from fiscal year 1990 to fiscal year 1993. All data used in the estimation of the district court cost function was provided by the Supreme Court of Virginia (1989-1993). Of the 500 observations, 17 were removed from the data set because certain data for the observation was missing or obviously incorrect. This left 483 usable observations. Data were collected on the number of hearings held, of which there are 19 different hearing types. These hearings types are: GD courts-- criminal misdemeanors, criminal felonies, criminal capias, traffic infractions, traffic misdemeanors, traffic felonies, traffic capias, civil general hearings, civil garnishments, civil motions for judgments, and J&DR--juvenille delinquency, juvenile custody, juvenile status, juvenile traffic, domestic misdemeanor, domestic felony, domestic capias, domestic civil support, and domestic criminal support. For the purposes of the cost function estimation, the hearing types were aggregated into two types, type one, all GD hearings (Y_1), and type two, all J&DR hearings (Y_2). Any further disaggregation resulted in high degrees of multicolliniarity and parameter instability.

In addition to the output data--number of hearings-- data were collected on judge salaries and positions, personnel expenditures, fringe expenditures, substitute judge expenditures and rates, and clerk positions. It was not possible to obtain detailed clerk salary information for each court, however, working backward from the other information obtained, it was possible to determine an average clerk salary for each court. By adding a fringe factor--FICA, retirement contribution, life insurance contribution, and health plan contribution-- to both the judge and clerk salaries, it was possible to determine the price for each of these inputs: J&DR judges (W_J), GD judges (W_G), and clerks (W_C). The rate for substitute judges per day (W_S) was also obtained. By dividing the substitute judge expenditures by the daily rate, the number of days substitutes were utilized per court (X_S) was obtained. As mentioned above, the number of J&DR judgeships (X_J), GD judgeships (X_G), and clerks (X_C), per court is known (Senechal, 1994)

Since each court produces more than one output, we can write its transformation function as:

$$(A11) \qquad F(Y_1, Y_2; X_j, X_G, X_C, X_S; COMB) = 0$$

where Y_1 and Y_2 are the number of hearings, X_J, X_G, X_C, and X_S are the levels of inputs, and COMB represents the court is a combined court. Assuming that the courts are cost minimizers, and (A11) satisfies the usual regularity conditions, duality theory ensures that for each transformation function, there exists a dual cost function (Diewert, 1971). The cost function can be written as:

$$(A12) \qquad C = g(Y_1, Y_2; W_J, W_G, W_C, W_S : COMB)$$

where W_J, W_G, W_C, and W_S are input prices.

In order to estimate the cost function (A12), a functional form must be specified. The following translog form was chosen because it is flexible enough to portray all measures of interest; i.e. the functional value, first order derivatives, and second order derivative, independently without imposing prior constraints on or across these measures. The cost function is now written as:

$$(A13) \quad \ln(C) = A_O + \sum_i A_i \ln(Y_i) + \sum_j B_j W_j + \frac{1}{2}[\sum_i \sum_s Z_{is} \ln(Y_i)\ln(Y_s) + \sum_j \sum_l D_{jl} \ln(W_j)\ln(W_l)] + \sum_i \sum_j E_{ij} \ln(Y_i)\ln(W_j) + CB \times COMB$$

where A_O, A_i, B_j, Z_{il}, D_{jl}, E_{ij}, and CB are the parameters to be estimated. Using Shephard's lemma, the following four share equations can be obtained (A14).

(A14) $\quad \partial C / \partial W_j = W_j X_j / C = S_j = B_j + \sum_{l} D_{jl} \ln(W_l) + \sum_{j} E_{ij} \ln(Y_i)$

The adding up property of the share equations ($\Sigma S_J = 1$) and the properties of neo-classical production theory require the following linear restrictions to be imposed on the model:

(A15) $\quad \sum_{j} B_j = 1; \quad \sum_{j} D_{jl} = 0; \quad \sum_{j} E_{ij} = 0; \quad D_{jl} = D_{lj}; \quad Z_{is} = Z_{si}$

In addition to these theory-based restrictions, an additional set of restrictions was imposed on the model. Since, J&DR judges only hold type 2 hearings, and GD judges only hold type 1 hearings, the interactions between the price of J&DR judges (W_J) and the number of type 1 hearings (Y_1), as well as the interaction between the price of GD judges (W_G) and the number of type 2 hearings (Y_2) must be set equal to zero. Also the interaction between the two prices (W_J, W_G) should be set equal zero .Thus, the following restrictions were imposed on the model:

(6) $\quad E_{1J} = E_{2G} = D_{JG} = 0$

The cost equation (A13) and three of the four share equations (A14), with the parameter restrictions in (A15) and (A16) make up the system that was estimated Additive disturbance terms were added to the cost equation and each of the share equations. The resulting disturbance vector is assumed independently and identically multivariate normally distributed with mean vector zero and constant nonsingular covariance matrix. Efficient parameter estimates are obtained using iterative seemingly unrelated regression. Before the estimation, some of the data was scaled in order to reduce parameter instability. The following data scaling was done, which of course in no way changes the resulting estimates.

Y_1 = (Type 1 Hearings) /840
Y_2 = (Type 2 Hearings) / 180
W_J = (Price of J&DR Judge) / 20000
W_G = (Price of GD Judge) / 20000
W_C = (Price of Clerk) / 4000
W_S = (Price of Substitute Judge) / 50

The following table shows the estimated parameter values, standard errors, and t-ratios. Parameters denoted G,J,C,S, represent general district judge, juvenile and domestic relations judge, clerk, and substitute judge inputs respectively. Parameters denoted 1,2 represent hearing type 1 (general court) and 2 (juvenile and domestic relations court) respectively. C is the parameter on the combined court dummy variable. Most of the parameters are significant and carry their expected signs. All of the first order coefficients are positive, and all but one is statistically significant at the 0.05 level. It is also important to notice that the dummy variable is highly significant and negative, showing that costs, ceteris paribus, are lower in combined courts.

Table A-4. District Court Cost Function Estimates

Parameter	Estimate	Standard Error	t-ratio
A_0	9.79	0.06	163.59 *
A_1	0.15	0.05	3.14 *
A_2	0.14	0.06	2.42 *
B_J	0.16	0.12	1.34
B_G	0.06	0.02	2.87 *
B_C	0.01	0	3.36 *
B_S	0.78	0.11	7.00 *
Z_{11}	0.21	0.05	4.55 *
Z_{22}	0.11	0.05	2.13 *
Z_{12}	-0.08	0.05	-1.81 **
D_{JJ}	-0.04	0.21	-0.21
D_{GG}	0.06	0.03	1.62
D_{CC}	0	0	13.02 *
D_{SS}	0.12	0.19	0.06
D_{JC}	0.04	0	10.81 *
D_{GC}	-0.04	0	-15.13 *
D_{JS}	0	0.2	0.23
D_{GS}	-0.02	0.03	-0.46
D_{CS}	0	0	-0.18
E_{1G}	0	0	-5.91 *
E_{2J}	0.01	0	1.90 **
E_{1C}	0	0	6.25 *
E_{2C}	0	0	-1.22
E_{1S}	0	0	5.67 *
E_{2S}	0.01	0	1.89 **
C	-0.3	0.02	-17.29 *

* Significant at 0.05 level
** Significant at 0.10 level

The R^2 for the cost function, the J&DR judge cost share equation, the GD judge cost share equation, and the clerk cost share equation, were 0.9637, -0.0762, 0.0855, and 0.3165 respectively. The negative R^2 is made possible by the ITSUR estimation procedure. Eigenvector-eigenvalue analysis found no multicollinierity problem which might cause the parameters to be unstable.

In order to assure that the cost function was well behaved over the relevant range of output, each observation was checked by raising (Y_1) by 900 in intervals of 300. In each case, costs increased with output at a decreasing rate, consistent with a well behaved cost function.

It should be noted that a White test for heteroskedaticity found a violation of the homoskedaticity assumption, and thus the standard errors of the parameters may be biased downward. However, since the parameters remained unbiased, they are still reliable for predicting how costs increase as Y_1 increases. Therefore, no effort was made to correct the violated assumption.

Appendix B. Case Study History

B.1 Background

In 1989 the Virginia legislature published the Report of the Joint Subcommittee Studying Alternatives for Improving Waste Volume Reduction and Recycling Efforts (House Doc No. 60, 1989). The report noted that according to testimony presented to the subcommittee, over 117.5 million scrap tires were currently in dumps around the commonwealth, and 47 of these dumps contained over 500,000 tires. These large dumps, according to the testimony, were slated for clean-up. It is of interest at this point to mention that after a very thorough survey of actual tire disposal sites, only 18 million scrap tires were estimated to be littering the landscape, about 15 percent of the original estimate. One of the problems encountered throughout the policy development process was gaining agreement on the size of the actual problem.

At the Joint Subcommittee meeting, tire recyclers testified that in order to spur collection and recycling efforts, incentives would have to offered. They supported the idea of a $1.00 per tire tax on all new tires sold, with revenues going to defer disposal costs of scrap tires. The tire retailers, although concerned with the administrative costs associated with collecting the tax, did not oppose the idea outright. As part of the report, the Joint Subcommittee proposed legislation which read "the department (Department of Waste Management) shall develop and implement a plan for the management and transportation of all waste tires in the commonwealth. The costs of implementing such a plan, as well as the costs of any program created by the Department pursuant to such a plan shall be paid for out of the Waste Tire Trust Fund (10.1-1422.1)." They also added "There is hereby levied and imposed upon every retailer of tires in the commonwealth, in addition to all other taxes and fees of every kind now imposed by law, a tax of one dollar for each new tire sold by the retailer (58.1-641)." The proposed legislation, under section 58.1-642, allowed the tire retailers to retain 15 percent of the tire tax revenues to cover their administrative costs. Section 58.1-643 set up the Waste Tire Trust Fund, which protected the funds from being reverted to the general fund, and used only for scrap tire management.

The 1989 session of the General Assembly passed the legislation, however several important modifications were made. First, the tire tax was lowered to 50 cents per tire. Second, the retailers were only allowed to retain five percent of the tire tax revenues to cover their expenses. Finally, the law was to take effect January 1, 1990 and sunset, unless reauthorized, on December 31, 1994 (House Bill 1745).

B.2 The Department Of Waste Management's First Approach

In August of 1989, the Department published the report entitled Virginia Strategy for Used Tires: Background Document. The report surveyed the exiting technological potential for tire disposal as well as the problems of improper scrap tire disposal. More importantly, however, the report recognized that the scrap tire disposal problem was at least in part due to what was termed the "used tire generation process:"

> "Recalling that most used tires are discarded at readily identifiable locations, such as retail tire dealers, auto service stations, automotive fleet operators, and junk yards, it can be seen that an effective managementt/control process can be relatively straightforward through registration, licensing, and enforcement. Nearly all used tires going to dumps or landfills are brought there by "tire jockeys," haulers who for a price remove the tires collected at the locations mentioned above...With the help of local governments, law enforcement agencies, and major trade associations...all of whom are on record favoring control strategies and resource recovery, state government should be able to influence it to the ends of safe storage and resource recovery (Robbinson, pp. 4-5).

It is important to note, that this perspective, that scrap tire disposal is an illegal disposal problem which requires enforcement, which will later be the one I recommend to the department, is lost almost as soon as it was written; replaced by a desire on the part of the department to develop a state run collection, transport, and disposal program.

Between the time that the legislation was passed in 1989, and August 1990, the department had assembled a nineteen member "Used Tire Advisory Committee" made up of tire dealers, scrap tire disposal industry representatives, and local government officials. The advisory committee, in their August 1990 report, stated that "the main reason for the tire problem, nationally as well as in the Commonwealth, is the lack of significant markets for used tires and tire products, and it emphasized the importance of market development (p.1)." By September 1990, the advisory committee had endorsed the department's plan to set up state wide collection centers at eighteen Department of Correction (DOC) field units. Inmate labor was to be used to reduce handling and transfer costs.

By October 1991, the department was finalizing their plan to offer a comprehensive state-run disposal system. Now, not only were DOC sites being considered, but Department of Transportation (VDOT) sites were as well. The sites were to accept tires without charge--i.e no tipping fee. It was estimated that each site would have start-up costs between $25,000 and $50,000, and could handle upwards of 1000 tires per day. The department also planned to contract with haulers and designated processors, though a bidding process, and provide these services to tire disposers free of charge as well. In summarizing their plan, the department wrote "the scrap tire management program begins operation with a stated goal of promoting a market driven tire recycling/disposal process. There has been little work nationally in providing such a sweeping program for handling tires without directly entering the disposal business (VDWM,1991)." This statement caught my attention. If the state is setting up collection centers on state lands, and paying for the hauling and disposal of the scrap tires, through a government bid process, is this a market based approach? That is like saying if the federal government pays Lockheed to build a fighter jet, then it isn't part of a government defense program. This logic is clearly faulty, yet instructive, because it shows that there is a fundamental misunderstanding of what "market based" environmental policy is all about--the use of incentives, be they monetary or otherwise, to get people to meet an environmental goal, because due to the policy it is now in their own best interest to do so.

In November 1991, the department took the next step in the development of their program by publishing a request for proposals (RFP) for the recycling/disposal of scrap tires. The RFP provided that the scrap tires will be delivered to the disposal plants by a state hired hauler by the tractor trailer load. The disposal plant would then bill the state for the cost of disposal, according to rates set forth in their contract. The proposals were to be returned to the department by January 31, 1992.

In January 1992, Leonard Shabman, Virginia Polytechnic Institute and State University; and Richard Collins, Institute for Environmental Negotiations (IEN) at the

University of Virginia, were asked to provide an overview of the "New Environmentalism" i.e., the use of market incentives with regard to waste management, to the entire staff of the department. By chance, the only funding source available was the waste tire fund, therefore, another deliverable on their contract was to give economic advice to the scrap tire management staff.

Without a clear mandate as to what economic advise was most appropriate, Shabman and I decided to review the scrap tire management plan as it currently stood, to see where our assistance would be most beneficial. It was clear that no calculation of the cost of the program, including collection, hauling, and recycling/disposal, had been done, and therefore, the magnitude of the needed tire tax was unknown. Using the best information available we estimated that the tire tax would have to be $1.42 per tire to run the program that the department was planning. On top of this, we pointed out that even though the state was providing collection, hauling, and disposal, free of charge, this did not guarantee compliance on the part of the tire haulers, and thus some type of deposit-refund, as is done with car batteries, may be appropriate. Therefore, the department may wish to institute a tire tax of $3.00, and a refund, upon return of the scrap tire, of somewhere around $1.50. This presentation was given on March 12, 1992.

To our surprise, our analysis met with some apprehension. The department felt that it was politically unfeasible to raise the tire tax beyond the current 50 cents per tire level. This was especially true because the waste tire trust fund was becoming a political embarrassment, as it was growing at a rate of over $2 million a year and very little expenditures were being made. Although they did not argue with our calculations, and agreed that the $1.42 per tire was the cost of moving a scrap tire from the point of origin to proper disposal, they didn't wish to accept our advice. It seemed the costs of their system surprised them--they had put a great deal of political capital in to this plan, and now realized that they could not afford it. Not only this, but the department had already received responses from their RFP and needed to act upon the bids from recyclers/disposers.

B.3 New Plan For Scrap Tire Management

In response to their concerns, Shabman and I decided to rethink, in a hurry--one day to be exact, the departments plan, and how market forces could be used to lower the tax requirement. In a March 13, 1995 memo, we outlined our plan to (IEN), who later shared it with the department. The key to the proposal was simple. A voucher system would be used to track scrap tires from their point of origin, tire retailers, through tire haulers, and finally to an authorized disposal site. The tire haulers would not be paid by the retailers until they returned a copy of the voucher with proof of delivery to an authorized disposal site. The disposal site would then send the voucher to the department for payment for disposal services rendered according to the terms of their contract.

This "cash on delivery," or COD, system provided the following advantages: collection and hauling was no longer funded by the state, no increase in the tire tax was needed, tire haulers no longer had an incentive to dispose of tires illegally, the current RFP process could continue and thus not cause political embarrassment, and the plan has low administrative costs for the department. The one regulatory reform that would be needed is some way to punish the retailers if any of their tires did not reach a legal disposal site.

In a high level memo within the department, dated March 26, 1992, it was made clear that the department was happy with the COD plan. They expressed keen interest in "the power and use of a three signature form," utilizing the current scrap tire transport system (haulers and dealers) rather than supplementing it with a centralized state collection and transportation system, and "no state ownership of the tires at any point of tire handling or recycling/disposal process." They did however have one major problem with the COD plan, as they stated they were interested in "utilizing market forces, not additional regulations, to drive each part of the process." It is interesting, as a matter of advice to other policy economists, to hear how the memo ended "I believe that Rich (Collins) now knows what we want in the market place analysis or our redesigned program, and his report will recognize the same." Somehow, the fact that we did a cost analysis of their unfeasible program made it "our" program, and the fact that we presented them with an alternative they accepted, made it "their" redesigned program. Although this may seem trivial, it is actually important. As the policy development process continued, being associated with good ideas gained us favor and the ability to advance positive outcomes, while the opposite was true of being associated with bad ideas.

On May 28, 1992, Shabman and I sent a memo to the department which summarized our best thinking to date with regard to the tire program. The memo maintained the COD voucher, allowed for an initial acceptance of bids from tire recyclers/disposers, and a payment to these tire utilizers from tire tax receipts. The memo stressed however, that the state program should not put current tire utilizers at a disadvantage. They should be paid their historical tipping fee, or allowed to bid in an extended RFP process. We also noted that after capacity is jump started, no more subsidies should be needed, and the COD voucher system should continue to provide for legal disposal of tires. Finally, we stressed the need for enforcement actions, or even just the threat of action, against those haulers or dealers who fail to dispose of their tires properly.

In June 1992, IEN sent a memo to the department, which Shabman and I reviewed. This memo suggested that the RFP process be abandoned for several reasons. First, the RFP presupposed that the state would deliver scrap tires to the disposal sites that won the bidding process. This was no longer considered feasible, and thus changed the terms of the contract. Second, the state did not have enough funds to pay the cost of disposal for the current flow of tires. Third, the RFP subsidy program would distort the current market for scrap tires where it existed, and could drive currently operating disposal firms out of business. The memo finished by proposing our alternative COD voucher plan, with enforcement against those who did not follow the rules of the plan, as well as possible subsidies to any disposal firm taking Virginia scrap tires, as a better alternative to the quickly failing RFP process.

Up through July 1992, it seemed to us as though our advice to the Department was going unnoticed. However, during a series of meetings in July, the Scrap Tire Management Committee (STMC), which was set up within the department to evaluate the tire utilizer bids, began to examine the possibility of "subsidizing any valid tire reuse or recycling (STMC minutes July 20, 1992)." A brief dated July 1992 outlined their thinking with regard to this idea, and although favorable, they felt that the Virginia Procurement Act may need to be amended in order to subsidize firms without a bidding process. They write:

> "this is a true market driven tire disposal system. The pre-disposal subsidy is weighted to the groups that recycle or reuse the tire in some way. The state is not dictating location and does not set up a system that competes with private industries. The pre-disposal fee is set based on the RFPs. If it is too low the processor will have to charge an additional fee to the tire owners. Some other group will find a cheaper process and undercut the processors that are charging the extra fee. If the fee is too high, there will be more groups that come forward to claim their share."

By the September 15, 1992 meeting of the STMC, the department's official position had changed. A senior DWM official outlined the departments philosophy as: 1)A tire tax of $0.50 will not be sufficient to handle the waste tire problems in Virginia, 2) DWM does not want to be the waste manager for the State of Virginia. The Virginia law requires the state to develop a plan for the handling of scrap tires, but does not contemplate the state becoming the owner and manager of waste tires, and 3) DWM has learned that the private sector is tackling many of the waste tire issues. The DWM would prefer to see economic incentives employed to resolve the tire problem whenever possible rather than to develop an extensive on-going regulatory system. Also, at this meeting, the department made a commitment to wrap up the RFP process, already long past its deadline, within one month, and to have a comprehensive scrap tire management program developed within three and one-half months.

In December 1992, the department issued their Internal Management Operating Program Plan for the Virginia Waste Tire Program: 1993-1994 (VDWM 1992). First of all, the RFP process was concluded with no bids being accepted. The plan called for a regional approach to current flow management. Each of the five regions in the state were evaluated with regard to their current disposal capacity. In two of the regions no indigenous capacity was present, and the plan called for providing processing services on a demonstration basis. In one region, a local government sponsored system was in place, and the plan called for the upgrading of equipment and services to capture all current flow. In the other two regions, it was determined that capacity was sufficient, and no program funds were appropriated. In addition to these efforts, the plan called for training of local officials, public information outreach, and classroom curriculum for children. This program called for a phased in approach over the two years, 1993 and 1994.

B.4 A New Law And Planning Challenge

In their 1993 session, the Virginia legislature amended the Virginia Code section 10.1-1422 to do two things. First, the sunset provision on the tire tax was removed. Second, the law allowed for the "partial reimbursement for the end users of waste tires." Section 10.1-1422.4 reads:

> Partial reimbursement for waste tires; eligibility; promulgation of regulations--A. The intent of the partial reimbursement of costs under this section is to promote the use of waste tires by enhancing markets for waste tires or chips or similar material.
> B. Any person who (i) purchases waste tires generated in Virginia and who uses the tire chips or similar materials for resource recovery or other appropriate uses as established by regulation may apply for reimbursement for the cost of purchasing the tires or chips or similar materials or (ii) uses but does not purchase waste tires or chips or similar materials for resource recovery or other appropriate uses as established by regulation may apply for a reimbursement of part of the costs of such use.
> C. To be eligible for the reimbursement (i) the waste tire or chips or similar materials shall be generated in Virginia and (ii) the user of the waste tires shall be the end user of the waste tire or chips or similar materials. The end user does not have to be located in Virginia.
> D. Reimbursements from the Waste Tire Trust Fund shall be made quarterly. Any costs reimbursed under this section shall not exceed seventy-five percent of the previous year's collections as certified by the Department of Taxation.
> E. The board shall promulgate regulations to carry out the provisions of this section. The regulations shall include, but are not limited to:
> 1. Defining the types of uses eligible for partial reimbursement;
> 2. Establishing procedures for applying for and processing of reimbursements; and;
> 3. Establishing the amount of reimbursement.

The Department of Waste Management now found itself reorganized as the Division of Waste Management within the newly formed Department of Environmental Quality (DEQ). The DEQ had the responsibility for developing the regulations to advance section 10.1-1422. As part of Virginia's administrative process act, DEQ was required to take a participatory approach to drafting the regulations, and therefore formed a public advisory committee known as End User Reimbursement Advisory Committee (EURAC) as well as held an introductory public meeting.

IEN was contracted by DEQ to facilitate the regulatory development process. Noting the necessity of bringing economic analysis of the scrap tire market into the discussion, IEN subcontracted Shabman and I to provide this analysis.

During the period between July 1993 and September 1993, Shabman and I wrote a paper entitled "Making Market Based Environmental Policy: The Example of Scrap Tire Management" for submission to the Southern Economic Association meetings (Shabman and Stedge, 1993). This paper was an extension and elaboration on a theme we had been trying to convey to DEQ, that a subsidy to end users or enforcement against illegal dumping were both market based strategies. We summarized the paper by writing:

> "it is important, as the promotion of market based policy becomes more acceptable, that economists seize the opportunity to explain the true logic of these systems. After all, the goal of market based environmental policy is to correct current market price signals in order to reach an environmental goal. The economist needs to consider all methods of accomplishing this goal, including the re-alignment of current property rights and liability (through enforcement) inherent in the market."

This paper, although not new in the advise we had offered to DEQ, made the choice between enforcement and subsidies much clearer in our own minds, and it is this dichotomy that we stressed in our continual consulting relationship with DEQ. At this point, without any empirical evidence, we felt that the COD voucher system, and the enforcement effort required to allow it to function, was a more cost effective means to stop illegal scrap tire disposal then subsidizing disposal.

A open public meeting was held on August 18, 1993, and was attended by about 25 interested persons. The public meeting made it quite clear that DEQ considered the scrap tire problem to be one of limited disposal capacity, and thus the need to have "market development." Despite our continued insistence, DEQ did not see the problem as one of illegal dumping caused by the perverse economic incentives inherent in the scrap tire market.

The first EURAC meeting was held on October 13, 1993. The EURAC was composed of 20 members. These members represented tire dealers, industry interested in using tire derived fuel, tire recyclers, regional public solid waste authorities, VDOT, regional recycling concerns, citizen groups, environmental groups, and planning districts. The first agenda item was the department's review of the current scrap tire management program.

Next, Shabman presented an overview of the economic analysis which he and the author had conducted with regard to the scrap tire market, and the economic disincentives which exist for tire haulers to dispose of tires properly. Shabman stressed that an enforcement option, including a voucher system, can achieve the same market enhancing outcomes for waste tires as can partial reimbursement. If tires could be tracked at a low cost from source to point of disposal, and a penalty existed for illegal disposal, the market would change in such a way that tire haulers would act in their own best interest and dispose of tires legally. Shabman's presentation summed up by stating that in order to encourage legal disposal, the department can lower the tipping fee through subsidies, raise the expected cost of illegal disposal through enforcement, or lower transportation costs by providing capital grants to firms who locate in low capacity areas. Each of these are viable options to be considered, separately, as well as parts of a broader program design.

On October 28, IEN sent a memo to DEQ responding to their concern that Shabman and I played to great a role at the first EURAC meeting, and that Shabman's advice shed doubt on the wisdom of a subsidy program. This was the first indication that DEQ's objective was to move fast, and to start spending money from the politically embarrassing tire trust fund, which has been growing steadily since its conception. DEQ's lack of interest in the advise of experts showed that he was under some pressure to reach the above objective, and had a lesser interest in developing regulations which effectively solved the scrap tire problem.

As requested by the EURAC members, before their second meeting, IEN put together a glossary of terms to standardize terminology for the rest of the debate, and distributed the glossary to all the EURAC members. The definition of enforcement used in the glossary was a critical mistake, and plagued Shabman and I in our efforts to facilitate the development of a market based policy. It read:

> "In waste tire discussions 'enforcement' means a process of using a regulatory process to attain waste tire objectives as distinct from market processes. The enforcement and market process can be employed to support each other, or one process can be emphasized over the other (emphasis in original)."

This definition set the stage for what later would become a misled debate, over a market based approach versus an enforcement approach. The debate was misled because any market based approach needs some type of enforcement of the market rules. Although emphasis, in terms of funds or energy, can be placed on subsidies or enforcement, as this research showed, that emphasis should be based on empirical evidence and not on political ideology. As will be shown later in this chapter, this was not the case.

The nest EURAC meeting was not held until January 14, 1994, three months after the first meeting, due to contractual problems between DEQ and IEN. At this meeting, I presented an economic analysis of scrap tire management programs in general, and then examined two programs in detail, Oregon and Minnesota. I started out with a review of the generic scrap tire market, emphasizing the leakage occurs when the hauler leaves the dealer with the tires and the payment, and that there are three ways to decrease illegal dumping: lower tipping fees through subsidies, lower transportation costs by increasing the number of disposal sites, and increase the expected fine by increasing the fine level and/or the probability of being fined. I also noted that there was already sufficient "funds in the system" to pay for the disposal of scrap tires, since the dealer pays the hauler a significant disposal fee, usually collected from the consumer. The problem is the hauler is leaking tires, and capturing illegal profits.

The Minnesota plan was quite successful, in fact, according to Minnesota state officials, 96 percent of the current flow was being disposed of properly, while none was being landfilled due to a statewide ban. Also, 1.3 million stockpiled tires were being cleaned up each year. The Minnesota plan required tire dealers to keep records of the amount of waste tires generated and the name of the tire hauler who took the tires. Tire haulers are required to be permitted, and they must keep records of where they received tires, where they disposed of tires, and how many tires were handled. Waste tire processors are permitted as well. In addition, they are required to keep track of how many scrap tires they process, and the origin of the tires. The current flow in Minnesota is thus directed to legal disposal sites by use of a tracking system, and the threat of an audit and penalty. Almost all of the state's funds, $2 million, are used for stockpile clean-ups. The Oregon plan was very similar to the Minnesota plan. The only real difference is that Oregon began the program with subsidies to waste tire processors in addition to the tracking system. These subsidies were later phased out.

After the January 14, 1994 meeting, Shabman and I felt confident that they had made a strong argument for the implementation of a tracking system in Virginia, rather than using the tire tax revenues for partial reimbursement of endusers. It seemed a strong argument, considering that both Minnesota and Oregon had successful tracking systems in place. Also, it should be noted, that the Virginia law which allowed for partial reimbursement of endusers was copied from Oregon's law. However, Virginia only copied one section of the law, and neglected the parts authorizing the tracking and enforcement provisions. Thus, Virginia borrowed the one section of the Oregon law which Oregon saw fit to phase out. When I made this point known to the EURAC member's, they seemed enthusiastic about the use of a tracking system.

On January 24, 1995, Shabman and I submitted to IEN an eight page report entitled "Scrap Tire Management Brief." In this report, we outlined in the most clear and concise manner, to date, their vision of Virginia's scrap tire program. It was their hope that the brief would solidify the EURAC members' understanding that enforcement was necessary to promote legal scrap tire disposal, and also, that by not providing subsidies to endusers, tire tax funds would be available for stockpile clean-up. The text of the brief follows:

The Creation of Stockpiles

Over 240 million waste tires are generated every year in the United States. In 1992, 27 percent of the waste tires were recycled as retreads, reused in some other form (i.e. fishing reefs) or were burned as an energy source. The remaining tires are scrap. In the past, scrap tires were disposed of in landfills along with other solid waste. However, due to the tires' volume, shape, and unique ability to capture methane gas and rise in a landfill and break the daily cover, many communities recently have banned scrap tires from landfills. As a result, about 73% of the used tires, over 175 million tires, now are scrap that are being "stockpiled" each year.

Consider the situation in our state -- Virginia. Currently, Virginia residents generate about four million waste tires per year. The Virginia Division of Waste management estimates that half of these are disposed of in dispersed stockpiles through-out the state, adding two million tires per year to the existing stockpile of 18 million tires. With the number of automobiles in the state growing, the size of the state's stockpiles should double in less than 10 years .

Stockpiles are quite diverse in size and nature. One in Ohio contains 30 million tires, but many are small piles of illegally dumped tires often not exceeding a few thousand tires. For example, in Virginia a significant percentage are in very few piles. Simply as a tire-pile, the environmental effects are limited to breeding pests such as rats and mosquitoes. The more serious environmental problem is the risk of fire. Tire-piles have a propensity to ignite, creating air pollution as well as an oily and toxic runoff to streams and ground water. Piles can be managed to minimize their environ-mental risk but this is the exception. Virginia has a tire fire occur frequently.

Alternatives to Stockpiles

To reduce the current flow to stockpiles new uses for the scrap tires need to be found. At present the most promising uses appear to be rubberized asphalt, crumb rubber products (i.e., park benches and floor mats), civil engineering applications (i.e. reefs and highway crash barriers), and energy production . A short term solution to the pest breeding problems and fire risk is to shred the tires and store the shreds (monofilling).

Of these alternative uses, the EPA, as well as the tire industry's Scrap Tire Management Council, supports energy production as having the greatest potential to utilize large volumes of tires at lowest cost. Whole tires may be used as a fuel, but it is more common to shred the tires into chips and at the same time remove the wire from the steel belts. Whether burned in dedicated boilers or in boilers where tires are used as a supplemental fuel, scrap tires can be incinerated in compliance with even the most strict air emission regulations.

However, the price of obtaining a BTU from coal or fuel oil versus the cost from burning tires (including shredding costs) makes tire derived fuel a more costly energy source. Therefore, for boilers to be willing to burn tires they demand a payment for each tire they burn. In effect, even at the energy plant site, scrap tires have a negative price. This negative price is analogous to the "tipping" fee a waste hauler pays when they take trash to a landfill.

Understanding the Used Tire Market

In the past, landfills accepted tires at no charge or with only a minimal tipping fee. Meanwhile retail tire stores accumulated used tires in direct proportion to the number of new tires they sold. Some could be resold as used tires, some were purchased for retreading, but the majority of the tires were simply a waste product of the tire business. This meant that a secondary, and often informal business developed in used tire hauling. These tire haulers (often termed "tire jockeys" to represent the informal nature of the business) would collect waste tires from the retail tire stores in return for a payment adequate to cover the cost to haul the tires to the local landfill and pay the small tipping fee.

As long as local landfills accepted tires, the number of tire derived fuel plants (or other uses for scrap tires) were limited. The tipping fee these plants could charge had to be less than the modest charge at local landfills. More importantly, the fuel plants needed a large volume of tires, so they had to draw tires to the plant from a large region. This meant that the transportation costs for the tire hauler to the regional plant were typically higher than to the local landfill. As a result, the economic feasibility of investing in tire derived fuel plants was limited to a few areas with a high concentration of tires. The scrap tire market did little to encourage alternatives to landfilling.

These same market forces explain the recent rapid growth of legal and illegal stockpiles. First, the unwillingness of landfills to accept scrap tires came suddenly with new US EPA regulations on landfill design. Because these design requirements sharply increased the cost of replacement landfills, communities began to ban large volume items such as tires or radically raised tipping fees. When this occurred few alternative facilities that were willing to take tires at any price were in place. An even more critical factor leading to the growth of stockpiles is the organization of the market for scrap tire hauling.

The current market for scrap tires encourages leakage of tires between the tire retailers who collect used tires and the endusers of used tires. Consider how this occurs. First, the tire dealerships have little incentive to be concerned about the fate of the scrap tires once they have made payment to the tire hauler to haul them away from their store. Second, once tires are on the hauler's truck, every mile the hauler drives is a reduction in the net return he can earn on the payment received from the tire retailer. The hauler wants to minimize the sum of the transportation costs and the tipping fee at the point of delivery, say to a tire-derived fuel plant. These costs can be minimized by driving a shorter distance and by finding places that will accept tires at the lowest tipping fee. The lowest tipping fee might include illegal dumping (that is a zero fee), but more often there is some landowner in the area who is willing to take the tires and "stockpile them" for a small fee. Hence, this rational market behavior is the explanation for the growing stockpiles.

Many tire haulers dispose of their tires properly, however the existence of stockpiles is evidence that illegal disposal is being conducted by some haulers. Tire haulers will dispose of their tires legally, only as long as the costs of legal disposal are less than or equal to the costs of illegal disposal. The cost of legal disposal includes the transportation cost to the legal disposal site plus the tipping fee paid to the disposal firm, less any subsidy paid by the state. The cost of illegal disposal includes the transportation cost to some illegal disposal site plus a tipping fee paid to the illegitimate disposal site (if one is paid at all), plus some expected fine. The expected fine is some fine level set by the state multiplied by the probability of incurring the fine. Thus, the state has several policy options available to it in order to decrease the number of illegally dumped tires--institute a subsidy, raise the expected fine by increasing the enforcement effort, or both.

Most states have laws that provide for the enforcement of a property owner's right not to have waste tires dumped on his/her land unknowingly, and also restrict the property right of landowners who wish to stockpile tires. These laws also provide for financial penalties against those who violate these rules. However, the vast number of waste tire generators, haulers and legal as well as illegal disposal sites, makes the enforcement of these laws expensive under the current legal regime. The state may be able to reduce the cost of enforcement by altering the legal and regulatory structure inherent in the current scrap tire market. The next section will describe the possible actions that can be imposed. This includes a tax and enduser subsidy approach which has been adopted by many states, as well as a plan that allows for increasing enforcement.

State Responses

State governments have acted to address the stockpile problem by a combination of taxes, subsidies, and regulation. Because there is a recognition that the waste tires have some economic value, states have been inclined to search for a market based solution to the stockpile problem. This typically is defined as stimulating the demand for scrap tires by a "tax and subsidize" program. Some states hope that by subsidizing scrap tire utilizers directly, the tipping fee these utilizers charge the tire haulers will fall, thus lowering the economic incentive for the tire haulers to dispose of the scrap tires improperly. Also, they feel that the presence of the subsidies will guarantee the utilizers a more certain cash flow and encourage entry into the waste tire processing industry, thus increasing waste tire disposal capacity.

About twenty states now provide grants to tire utilizers in return for taking the waste tires. These include start-up grants, per tire subsidies and low interest loans. These sub-sidies are being paid from tire-tax revenue. Twenty-nine states have enacted legislation that provides for a tax on tire usage in order to fund scrap tire programs; these include: 22 have a tax on new tire sales that ranges from $0.50 to $2.00, two have a per tire disposal fee that ranges from $0.25 to $1.00, five have a surcharge on vehicle registration that ranges from $0.50 to $4.00 per vehicle, and one state charges a permit fee for tire storage sites .

Many state governments also have enacted regulations on tire storage and hauling. Storage (stock-piling) regulations have been enacted by 26 states. These regulations include: permitting, size limits, fencing requirements, fire lane requirements, mosquito control, and financial responsibility.

Haulers now are regulated by 18 states. These regulations require haulers to be registered, and the more aggressive legislation requires haulers to keep records of the number of tires hauled and the receivers' name. Two states, Oregon and Minnesota, have a cradle-to-grave tracking system in place, while permitting tire disposal firms and scrap tire haulers.

Toward A Market Alternative

In 1989, Virginia enacted legislation that established a $0.50 tax on each new tire purchased. At that time the Virginia Division of Waste Management (DWM) began to develop a "market- based" scrap tire management plan, following the tax-subsidy approach of other plans throughout the country. The state would collect taxes paid on the sale of new tires and would use the revenues to make payments to tire utilization plants that take Virginia waste tires. In addition the tax receipts would be used to set up a system of state run collection centers where tires could be dropped off at no charge. Finally, the state planned to contract with haulers to move the collected tires to the waste tire utilizers who were subsidized through the state program.

One alternative management plan is to place some responsibility for improperly disposed tires on the tire retailers, while keeping the existing market for scrap tire hauling and utilization intact. Placing this responsibility on the tire retailers may seem to miss the point, since it has been suggested that the leakage in the used tire market occurs during the transportation between the dealers and the endusers. Therefore, it may seem more appropriate to monitor the used tire haulers, since it is their behavior that needs to be altered. However, it really doesn't matter who the initial liability is assigned to, as long as the liability is enforceable.

Under this alternative, the liability continues to rest with the tire dealer until he/she trades the liability with an enduser (tire derived fuel plant etc.) who is willing to take the tires in return for some fee. Due to the relative informality of the used tire hauling industry, as compared to the retail tire business, enforcement will be less costly if the liability is not allowed to be transferred to the tire haulers. Most importantly, given the power relationship that exists in the tire disposal industry (tire retailers choose which tire haulers to do business with), the tire retailers have the ability to change the tire haulers' behavior. With the liability of illegally disposed waste tires resting with them, they will also have the incentive to change the haulers' behavior.

Enforcement

The simplest enforcement mechanism is to have the tire dealers document that the number of new tires they sold was approximately equal to the number of used tires they had hauled to certified disposal sites. The logic is that most purchasers of new tires leave their used tires with the tire retailers. The flow of scrap tires from each dealer is established through a voucher system. The tire dealers would be provided with a multi-part form on which they record the amount of tires taken by the hauler. The tire dealer retains one copy of the form. The hauler takes the tires to the tire utilizer named on the form, along with the two remaining copies of the completed voucher. Once the scrap tires are delivered, the tire utilizer documents, on the voucher, that they have received the tires from the hauler. The tire hauler takes the two copies back to the tire dealer that shows that the tires were taken to an approved site. The tire dealer keeps one copy and provides the state with one copy as proof of proper disposal. A strong possibility exists that this voucher system could be paperless, and all records can be kept electronically. All parties would interact with a central computer using a touch-tone telephone.

The total sales of new tires for each dealer are documented with the records of tire tax collections which dealers file with the Virginia Department of Taxation. Failure to be able to document the equality of these two flows (tires sold and tires disposed of properly) would subject the dealer to a financial penalty for each scrap tire unaccounted for. Since most retailers have no interest in illegal disposal, penalties should be lowered, or forgiven, for the first violation. The first violation can serve as a signal for retailers to look for a more responsible hauler.

Some of the tire dealers may express concern that customers will choose to take the used tires with them to avoid the disposal charge that the retailers would have to charge to recover there costs (the mark-up on tires is reported to be quite small). Then the customers would dispose of the tire in an unacceptable manner, but the dealer would be liable for the missing tire. One solution is to set the tire tax at (for example) $5.00. That is, the tire tax would be higher than any likely disposal fee that might be charged. If the used tire is left with the dealer, $4.50 of the tax is forgiven so the actual tax paid on a tire left with the dealer stays at $.50. This tax rebate at the point of sale of a new tire is what is now done in most states when a new car battery is purchased. If a used battery is left no disposal fee is paid on the new battery. A fee on the new battery is paid if no used one is turned in. A person who still wants the used tire, must be expecting to put it to some valued use and not simply be seeking to avoid the disposal charge, because the tax is more than that charge.

As a part of the tax auditing program the following logic would apply. Vouchers for used tires delivered to an approved disposal point would equal new tire sales, if all used tires were left with the dealer. Therefore the difference between new tire sales and used tire vouchers will equal the tires not left at the dealer (some allowance for slippage must be considered). As a result the tax collections from any dealer should equal ($.50 * vouchers) + $5.00 (new tire sales - vouchers). Random audits could be used to assure that the voucher system is working as intended.

Changing Hauler Behavior
The system described above, in coordination with the enforcement mechanism of the voucher system, provides an incentive for the tire retailers to assure that all waste tires they generate are disposed of properly. The question now surfaces, how can the tire dealers limit their

liability exposure by insuring that tire haulers take the waste tires to certified disposal sites? This decision should be left to the retailers, because they know what actions would work best for their firm. They may wish to hire someone they know well and trust, invest in their own hauling capacity, or create some institutional rules that would provide incentive for the tire haulers to behave properly. One such set of rules would be the "collect on delivery" or "COD" system. This institutional framework is described below because it is not as intuitive as the other options, and it allows the tire retailers to limit their liability while leaving the current tire hauling industry intact.

The "COD" rules are quite straight forward. The tire retailer withholds payment to the tire hauler until the tire hauler returns the voucher signed by the tire enduser, thus proving that the tires were disposed of properly. At the time the scrap tires are picked-up the tire hauler would be expected to estimate the cost of the transportation to a certified utilization site, the tipping fee at the site, and a mark-up for hauler profit. The sum of these costs would be the price for hauling which is quoted to the tire dealer. As a result the hauler's price quote is the total disposal cost for scrap tires. The hauler's price quote establishes the cost of disposal that would then be added to the price of a new tire, making the new tire price have an element of the polluter pays principle. In fact, some kind of disposal fee (in addition to the state tire tax) is often currently collected when a new tire is sold. The COD system assures that market forces are used to establish a charge that is adequate to cover costs of acceptable disposal.

As one product of this competitive market process, it is likely that the tire hauling industry would change over time. One would expect entrepreneurs to set up central collection points and collect small loads for consolidation to larger loads to minimize transportation costs. Over time, total scrap tire disposal cost is minimized by competition among haulers and by competition among certified utilizers. Also, one would expect new, lower cost, scrap tire endusers to enter the market, thus lowering the market tipping fee. However, this competitive market process is retarded by several barriers to entry facing firms who wish to enter the scrap tire utilization industry. These barriers are: a certain flow of scrap tires, the high capital costs required to start-up, and the costly regulatory and permitting requirements, such as test-burns. The above proposal will stop the leakage of scrap tires, and will cause all scrap tires to be competitively bid for in the market. Therefore, the certain flow of scrap tires is accomplished. The waste tire trust fund could be used to off-set some of these start-up costs, and thus increase the capacity for scrap tire management in the region.

The Tire Trust Fund

The state currently collects about $2 million annually through its 50 cent tire tax. These funds should be allocated to three program areas in such a way as to stop the leakage of current flow tires, and to start the clean-up of stockpiled tires. The allocation of funds should be to three program areas: stockpile clean-up, lowering barriers to entry of new capacity, and the tracking of current flow.

Funds should be used to clean up stockpiles in a similar fashion as they are now. Those piles which the DWM has targeted as the most threatening should be addressed first. This program should receive about one quarter of each years tax receipts.

Two areas need to be addressed in order to remove the barriers to entry in the tire disposal industry. First, there needs to be a DWM "environmental compliance assistance program." This program, consisting of one or two staff positions, would help entrepreneurs expedite all permit processes within the Department of Environmental Quality.

The second barrier to entry is the high level of capital required to enter the scrap tire disposal industry. The DWM can use the tire tax revenues to give grants or make loans to new or expanding processors. The following guidelines should be followed when allocating these funds. First, only projects which will expand capacity are eligible for these funds. Second, support in the form of low interest loans should be made to facilitate capacity increasing capital improvements. Interest rates may be varied to encour-age new end use capacity in under-served areas of the state or for new capacity which dedicates tires to an environmentally preferred use. Third, grants, up to approxim-ately $50,000, should be given to fund the testing of new technologies--for example--test burns. These grants can be made on a cost share basis, with the private funds being reimbursed if the test is successful. In total, these programs to remove barriers to entry should receive about half of the available tire funds.

The last, but perhaps most important use of funds, is the development of a tracking system for current flow tires and enforcement against illegal tire disposal. Enforcement costs should be quite low, because the tracking system will reduce any chance that illegal behavior will go undetected.

The tracking system and enforcement effort should receive the last quarter of the available funds.

On February 9, 1994 the EURAC met again. DEQ informed the member's that it was their opinion that they don't have the authority to regulate haulers. They stated that this statutory restriction is not superseded by the new tire legislation. Thus, if DEQ is correct, statutory authority would be needed to require a tire tracking system as recommended in the above Scrap Tire Management Brief. Also, at the meeting DEQ demonstrated their response to the EURAC's desire for a tracking system--voluntary waste tire certification. They maintained that if tire dealers were to voluntarily employ the waste tire certification form, effective control over current flow could be established. The key elements of the plan are that: tire dealers voluntarily provide tire haulers with the certification form and haulers only receive payment when the form, certified by the waste tire processors, is returned to the dealers. Also, because the system is voluntary, no statutory authority was needed. The system, besides its voluntary nature, is similar to the tracking system proposed in the brief.

However, the EURAC members had concerns about the voluntary system. They felt: haulers would not consent to delayed payments; the "good" tire dealers would be penalized with higher costs, while the "bad" tire dealers would continue to evade the law; there was no clear enforcement power with the existing law and process; and it would produce excess paperwork for everyone.

The EURAC members, unsatisfied with the DEQ's voluntary alternative, requested that the Attorney General's opinion be sought on the issue of scrap tire regulation authority. There was general agreement, that without some form of control over haulers, no effective waste tire program could be established in Virginia. It was agreed that at the next meeting, both the opinion, and the alternatives consistent with that opinion, would be considered.

At the next EURAC meeting, on March 8, 1995, DEQ notified the members that they determined that DEQ lacked statutory authority to license or regulate haulers. Also, retailers of tires are not liable, under current Virginia waste law, for illegal disposal activities of the haulers they hire. Civil liability is unlikely also.

The rest of the EURAC meeting dealt with a working copy of regulations developed by DEQ. The EURAC members were walked through the proposed regulations. The proposed regulations provided for a tiered subsidy to endusers, in which a higher subsidy was given for uses which were deemed preferred. Category I uses, energy production, were to be subsidized at a rate of $20.00 per ton. Category II uses, pyrolysis and civil engineering, were to be subsidized at a rate of $22.50 per ton. Finally, Category III uses, recycled scrap tires, were to be subsidized at $25.00 per ton.

Also, the subsidy amount was limited to the "out-of-pocket" expenses of the enduser. This clause in the proposed regulations meant that all endusers would be subsidized only to the point that they would be indifferent between using scrap tires or some other material. In other words, they would have no incentive to use scrap tires. Not only would determining a true cost of use for each enduser be arduous, but this, combined with the regulatory requirement that any person supplying scrap tires to the enduser who applies for the subsidy may be audited, almost assures that very little participation will result. Therefore, the DEQ plan for requiring tracking of tires which receive the subsidy will have little effect, because so few tires will receive the subsidy--people will opt out of the program. The EURAC members saw the above flaws in the proposed regulations, as well as one more. There was considerable debate, the above issues aside, if the $20.00 to $25.00 per ton subsidies were enough to make scrap tire disposal companies profitable. In response to this concern IEN asked a group of "business" people to meet separately, and try to give estimates of how much tipping fees would have to be to make different scrap tire disposal firm's profitable. IEN asked me to join this group to facilitate its work.

A consultant to a firm interested in entering the scrap tire disposal business, but not a member of EURAC, headed up what he coined the "EURAC Economic Subcommittee." The group, which included myself, three endusers, and two tire dealers met on March 29, 1994 for a one day meeting in Richmond, VA. Prior to the meeting, I distributed to the group the "Scrap Tire Management Brief" discussed above. During the meeting, the group solidified around the ideas in the Brief. The following paragraphs are taken from a memo I sent to the consultant on April 4, 1995, providing my summery account of the meeting. As agreed at the end of the meeting, this summery was to be used to prepare a findings paper for the EURAC. The memo follows:

1. The group came to a quick consensus that the scrap tire management problem in Virginia is a result of illegal actions on the part of some tire haulers. When faced with the decision to dispose of scrap tires legally or illegally, these haulers will compare the cost of each and will choose the least expensive option....Therefore, in order to encourage a hauler to choose legal disposal, the state needs to decrease the transportation cost to a legal disposal site, decrease the tipping fee associated with legal disposal, or increase the expected fine faced by the hauler.

2. In order to decrease the transportation cost to legal disposal sites, as well as lower the tipping fee charged by legal disposal sites over the long run, more processing plants need to come on line within Virginia. However, several barriers to entry exist. These are: the capital costs involved in retrofitting or building a new plant, the expensive permitting process faced by endusers of TDF, and the lack of a guaranteed flow of scrap tires. If these barriers could be breached, the number of processors and endusers within Virginia could increase, and the transportation costs and tipping fees could be lowered. The committee recommended the following ways to do this:

A. No per tire subsidies should be given to endusers of scrap tires. Rather, DEQ should use the existing waste tire fund, and future revenues, to help fund the start-up costs associated with bringing new capacity on-line within the state. This would include: matching capital grants, loans to be repaid in kind (by taking a certain number of Virginia tires over a certain time period), matching permitting grants (to help pay for test burns and legal fees), as well as the establishment of an environmental compliance assistance office within DEQ to facilitate the permitting process. It was the opinion of the group that DEQ has the statutory authority to make partial reimbursement in these forms. The group agreed that the choice of who should receive assistance should be based upon their ability to take a large quantity of tires, while charging a low price for their disposal. Also, location can be taken into consideration. By subsidizing high cost, low quantity processors--a possible result of following an environmental hierarchy--the total amount of new capacity will be lowered. This would result in the continual illegal disposal of scrap tires on the landscape, the worst environmental scenario.

B. In order to guarantee a consistent flow of tires, DEQ will have to monitor the flow of tires from tire retailers to processors to endusers. Although the group understood that the leakage of tires occurs as a result of the haulers decision, the group felt it would be better to monitor the tires' disposition by making tire retailers responsible for the fate of the tires. Tire retailers have the power to change the haulers' behavior, and by placing the responsibility on the retailer, they would also now have the incentive to do so. Retailers can insure the proper disposal of tires by withholding payment to the hauler until proof of delivery is made, hiring only haulers they trust, or investing in their own hauling capacity. The choice will be theirs.

C. <u>The group sees the enforcement of illegal disposal as a partnership between DEQ and tire retailers.</u> DEQ's tracking system would be used to provide support to the retailers by notifying a dealer if a load of tires from their establishment did not reach its legal destination. Such notification would help the dealer better choose a trustworthy hauler. DEQ would only have to take an enforcement action against a dealer if they continue to make no effort to insure the proper disposal of their scrap tires after being informed by DEQ of the improper disposal of tires--an event the group found to be very unlikely. The group believed that this tracking and enforcement system may be possible under current statutory authority, because it is a volunteer partnership with industry.

Ten days later, I received a memo from the consultant addressed to all the members of the group. It stated the following:

Recommendations of EURAC subcommittee for polices and regulation of waste tires:

1. Certification of processors and end users of scrap tires. Certification based on verifiable recycling or waste to energy enduse.

2. Either regulate or encourage tire retailers to use a voucher (or similar) system of payment to tire haulers assuming haulers are paid after scrap tires are delivered to a certified processor or enduser

3. Prohibit landfilling of tires, whole, or processed.

4. Establish grant programs to encourage new users of scrap tires or expanding existing capacity. Grants to be reimbursed by end use of scrap tires at rate of $35.00 per ton.

5. Approve reimbursement rate of $35.00/ton for all end uses of waste tires recycled or waste to energy.

6. No arbitrary limit of reimbursement to single end users.

The memo ended asking that we each review the their draft recommendations and respond. He noted that he planned on distributing the recommendations not only to EURAC, as originally charged, but also to the Secretary of Natural Resources and state legislators.

It is clear that the consultant rethought his position after the meeting, and drafted a set of recommendations which were his and not what the group had agreed to. These recommendations included a subsidy rate of $35.00 per ton, in direct opposition to the group's decision that subsidies were not appropriate. Also, he proposed banning landfilling, a move that would divert more tires toward both illegal and other legal disposal. It is my opinion that he rethought the group's consensus position, and believed that his recommendations would be better for his clients. Thus he attempted to make his recommendations seem as if they were proposed by the group.

Not only that, but he also intended to circumvent the public participation process which spawned the EURAC, and go directly to the Secretary. On April 14, 1995, I drafted a memo to the consultant stating my objections to the draft recommendations, as they were not what the group had agreed on. I also informed him that it was inappropriate for the me to be a signatory, as I was at the meeting to facilitate and provide technical assistance. Finally, it was noted that before this information was distributed, IEN should be consulted since they are facilitating the regulatory development process. After the April 14 memo, and after I spoke with him several times by telephone, he held the group's recommendations hostage, and on May 12, 1994 the consultant drafted a memo, supposedly from the "Ad Hoc Waste Tire Economic Committee," including myself, to DEQ. The memo stated his original recommendations, without any concern for my protests.

On May 19, 1994, IEN met with DEQ and a political appointee of the Secretary of Natural Resources. The Secretary was unhappy to hear of the sub-committee's involvement, since the consultant was not appointed by her to be a member of EURAC. She was concerned that his involvement might jeopardize the regulatory development process. The political appointee was sent in to streamline the process, and to make sure that it followed a path consistent with the ideology of the new Republican Allen administration. IEN agreed that the distinction between the subcommittee and EURAC needed to be highlighted at the next EURAC meeting.

The political appointee also required that the Waste Tire Certification (WTC) form which DEQ was going to use to verify subsidy eligibility, and use as a volunteer monitoring system, would not be required to receive the subsidy. He felt that the administrative costs would be too great. Finally, DEQ decided that they needed a better definition of "cost of use," since the law required that partial reimbursement be limited to the cost of use of scrap tires.

On June 16, 1995 the EURAC held its final meeting. A set of draft regulations was produced by DEQ which attempted to institute a partial reimbursement program. The regulations, in large part due to the enabling legislation's wording, were very cumbersome. First, the program offered maximum reimbursement rates of between $15.00 and $32.00 per ton, depending on the use. Also, the subsidy was capped at the lower of the maximum reimbursement rate or either: 90 percent of the purchase price of the tires or chips if the tires or chips were purchased, or 90 percent of the cost of use of the tires or chips if the tires or chips were not purchased. Cost of use was defined as "the equipment, leasehold improvements, buildings, land, engineering, transportation, operating, taxes, interest, and depreciation or replacement costs, of using waste tires incurred by the enduser after deducting any tipping fee received by the enduser." Hence, in order to receive reimbursement, the enduser might have to undertake a painstaking financial analysis, and DEQ had to review this analysis. Also, this type of reimbursement schedule favors high cost users, and thus reduces the total number of subsidized waste tires.

Second, the regulations, by law, capped the total subsidy to 75 percent of the previous years tire tax revenue. Therefore, it remained a real possibility that firms would use scrap tires, and not get reimbursed. This uncertainty could lead to a reduction of participation in the program.

Finally, the regulations provided for no enforcement within the waste tire program. Therefore, the only enforcement would be criminal enforcement against tire haulers, and the amount of effort used in apprehending illegal disposers would be at the discretion of the local law enforcement officials and their budgets.

B.5 The Final Scrap Tire Program

In October 1994, DEQ put together their final proposed regulations and presented them to the Virginia Waste Management Board. The Waste Management Board claimed an exemption from the Administrative Process act in accordance with the Code of Virginia (9-6.14:4.1 B 4), which exempts regulations relating to grants of state or federal funds or property. This exemption, which they can claim because they are simply giving grants or subsidies, allowed them to by-pass any public comment requirements, and the regulations became effective December 20, 1994 (VR 672-60-1).

The final regulations were identical to the proposed regulations which were presented to the EURAC at the last meeting, except for two points. First, a single maximum subsidy of $30.00 per ton was approved for any use--no hierarchy was imposed. Second, full reimbursement of the purchase price, or cost of use, up to the maximum of $30.00, was given instead of 90 percent.

In addition to the regulations, the DEQ also instituted a voluntary tire hauler registration program. The DEQ registers any hauler who does not have any outstanding compliance or enforcement actions with DEQ or the locality in which they are based. DEQ then provides this list to anyone who requests it. However, registration is not required to haul tires, and using a registered hauler is not required to receive subsidies. The system is wholly voluntary. Also, by using a registered hauler, the tire generator does not relieve himself of any liability for improperly dumped tires. As of April 1995, 30 haulers received DEQ certification.

Vita

Gerald D. Stedge was born, on March 30, 1967, and raised, in Nanuet, New York. He graduated in 1985 from Nanuet High School. In 1989, he graduated magna cum laude from Plymouth State College in Plymouth, New Hampshire, where he studied Applied Economics. In 1990, he enrolled in the Department of Resource Economics and Development at the University of New Hampshire in Durham. He studied under Professor John M. Halstead, and completed his thesis, entitled "Bag Based Curbside Recycling: An Economic Analysis of an Alternative Recycling System," in 1991. Also, in 1991, he began studying under Professors Leonard Shabman and Daniel Taylor in the Department of Agricultural and Applied Economics at Virginia Polytechnic Institute and State University. Currently, he is employed as a Research Economist by the U.S. Army Corps of Engineers Institute for Water Resources, in Alexandria, Virginia.

Gerald D. Stedge