Essays on Economics, Government and the Environment

by

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ABSTRACT

This dissertation explores the economic consequences of government environmental policy at the federal, state, and local levels. It focuses on two issues that have generated considerable debate since public concern for the environment first emerged as an important political issue in the late 1960s: government management of federal lands in the western United States and municipal solid waste management. In both of these areas policy decisions have been criticized as being driven primarily by political concerns with little attention paid to economic factors. In each of the three essays presented here I analyze the economic impact of specific government policies that have been challenged as inefficient. In Chapter 2, I examine the effects of government investment in public-rangeland improvements, grazing fees, and bureaucratic management control on the level of investment in public-rangeland improvements by private ranchers who make use of the federal grazing lands. Chapter 3 examines the political economy of the adoption of curbside recycling programs by municipalities. In Chapter 4, I study the impact of the abolition of flow control statutes -- requirements that all solid waste generated within a given jurisdiction be disposed of at a designated facility -- on the distribution of rents among private firms in different segments of the solid waste management industry. The unifying theme in this thesis is the relationship between environmental policy and economics.

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To my husband and my parents

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Chapter 1

1 Introduction and Summary

This dissertation explores the economic consequences of government environmental policy at the federal, state, and local levels. It focuses on two issues that have generated considerable debate since public concern for the environment first emerged as an important political issue in the late 1960s: government management of federal lands in the western United States and municipal solid waste management. In both of these areas policy decisions have been criticized as being driven primarily by political concerns with little attention paid to economic factors. In each of the three essays presented here I analyze the economic impact of specific government policies that have been challenged as inefficient.

The role of the government in and the economic consequences of actions taken to address environmental concerns are central to the controversy over federal management of the public western rangelands. United States government policy allows for the use of these lands by private ranchers for the grazing of commercial cattle. This practice has been criticized for threatening the environmental health of the range and there is an ongoing debate about the effect of federal policies on the quality of stewardship provided by private ranchers. Range improvement investments are projects designed to organize foraging activity in ways that improve range condition and increase cattle productivity while averting the detrimental environmental effects of location-concentrated grazing. Since private and government investment

in public-rangeland improvements can be either substitutes or complements in production, private investment can be affected either negatively or positively by government investment. The effect of grazing fees for public-land forage on private stewardship is also much-debated. Some observers claim that low grazing fees encourage over-grazing, which worsens the condition of the rangelands. Others argue that low grazing fees increase private investment which improves rangeland condition. Finally, it is argued that higher levels of government management control on these privately-used, government-owned properties reduce private incentives for good stewardship.

The first essay examines the effects of government investment in public-rangeland improvements, grazing fees, and bureaucratic control on the level of private investment in public-rangeland improvements. The analysis presented here is the first empirical study to address the relationship between public and private investment in public-rangeland improvements and the impact of the level of the grazing fee on private investment. Using an original data set on private and public state-level aggregate investment in public-rangeland improvements, I employ two-stage least squares estimation to address the endogeneity of government investment. I also take into account the possible non-stationarity of the time-series data, heteroscedasticity, and cross-sectional correlation. Results suggest that government investment in public-rangeland improvements encourages rancher investment in public-rangeland improvements. Increased grazing fees have a significant negative effect on rancher investment as does increased federal management control over the public rangelands. Partial correlation coefficients indicate that a ten percent increase in government investment raises rancher investment by nine percent and a ten percent increase in grazing fees would decrease rancher investment by thirteen percent. The

coefficient on the dummy variable for the Federal Land Policy and Management Act, which signaled an important augmentation in the degree of federal management control over the public lands, suggests an approximate thirty percent decrease in private investment.

The remaining two essays in this dissertation address the government's role in solid waste management in general and the economic consequences of local and state policies regarding the adoption of municipal curbside recycling programs and flow control ordinances in particular. Flow controls are requirements that all solid waste generated within a given jurisdiction be disposed of at a designated facility. Both municipal curbside recycling programs and flow control ordinances were initiated in the 1970s and grew in popularity as concerns about a solid waste disposal crisis mounted during the 1980s. Recycling programs, viewed as a more environmentally sound alternative to discarding waste, were also a means of lessening demand for increasingly costly disposal services. Flow controls, seen as crucial to the planning abilities of government officials responsible for long-term solid waste management, were a means of financing the construction of multi-million dollar waste-to-energy facilities with municipal bond issues.

The second essay examines the political economy of the adoption of curbside recycling programs by municipalities. Since the collection and processing costs generally exceed the revenue generated by the sale of recyclable materials, recycling programs are often criticized as a luxury that cash-strapped municipalities can ill-afford. Nevertheless, between 1990 and 1992, the number of these programs in the United States doubled. The key economic consideration for program adoption is not the profitability of the stand-alone recycling program, but the overall budgetary impact of the program on total solid waste management costs including

the avoided costs of waste disposal. The central political factor affecting program adoption is the level of community concern for the environment. Using an original data set on the economic and political characteristics of eighty towns in Massachusetts, I examine the relative importance of these two considerations in municipalities' decisions to adopt curbside recycling programs. On average, the Massachusetts communities that had recycling programs saved $62,000 annually on total solid waste management costs, while those that did not avoided a $78,000 increase in their annual solid waste management budget.

By developing a cost function for curbside recycling programs and applying a Heckman correction procedure, I address the sample selection problem which arises because not all municipalities recycle. I estimate a probit equation in which the dependent variable is the existence of a municipal curbside recycling program. Among the explanatory variables are the cost of the recycling program, the avoided costs of refuse disposal, and the level of household membership in an environmental organization that advocates recycling. The results demonstrate that both economic and political factors have significant effects on whether a municipality adopts a recycling program. A $1000 savings on overall solid waste management costs increases the probability of adoption by 0.11 and a percentage point increase in the proportion of the community with membership in environmental interest groups raises the probability of adoption by 0.04. The study implies that both environmentally-motivated political participation and pressure on municipal budgets from solid waste management costs have a significant influence on the likelihood of adoption of curbside recycling programs.

The third and final essay studies the impact of the abolition of flow control statutes on the distribution of rents among private firms in different segments of the solid waste management

industry. These state-endorsed local ordinances were primarily used to finance construction of waste-to-energy plants by ensuring long-term supplies of waste sufficient for high capacity utilization rates that would generate sufficient disposal fee and energy revenue to meet debt service payments on municipal bonds. The number of these facilities in the United States increased ten-fold between 1980 and 1990. This was a time when federal legislation such as the Resource Conservation and Recovery Act had placed local governments at the forefront of efforts to manage a response to declining landfill capacity and the health risks posed by landfills. Flow controls were challenged in court by waste hauling firms, which argued that the statutes forced them to face monopoly providers of waste disposal services, and by landfill concerns, which argued that flow controls deprived them of disposal fees on waste that would otherwise be disposed of at their facilities. The resulting battle for control of market share in the $30 billion a year solid waste industry pitted waste-to-energy companies (and municipalities) against hauling and landfill firms and, when the solid waste disposal crisis failed to materialize, became the most significant industry issue of the early 1990s.

The analysis presented here examines the effect of the U.S. Supreme Court's May 1994 ruling that flow control laws are unconstitutional on the solid waste industry. I employ event study methodology to examine the effects of this decision on the expected profits of seven waste-to-energy companies and thirteen hauling/landfill firms. With efficient asset markets, movements in equity share prices of publicly-traded firms should reflect revisions in expected profits when new information about the status of flow control becomes available. Using 284 daily stock returns, I estimate a capital-asset pricing model to measure the expected returns for the securities in each industry group, controlling for differences in leveraging across firms,

conglomerates, and other factors. The "abnormal" return associated with the Supreme Court's decision is the residual from this seemingly unrelated regressions model. The model is estimated constraining all firms within an industry sector to have the same event response, as well as allowing event responses to be parameterized as a function of an individual company characteristic. The analysis is also extended back in time using 210 weekly returns to address the possibility that lower court cases were the true harbingers of flow control's demise. Contrary to expectations based on the public positions of the industry participants involved in the intense debate over the legitimacy of flow controls, large standard errors lead to a failure to reject the null hypothesis that flow controls had no significant effect on the expected profits of solid waste management firms.

Chapter 2

2 Private Investment In Public Rangelands

2.1 Introduction

A key question in the current national debate about federal management of the public rangelands is how policies, especially government investment in public rangelands, grazing fees, and the degree of bureaucratic control, affect the quality of stewardship by private ranchers who make use of the public rangelands. The Department of the Interior recently proposed amending regulations that govern the Bureau of Land Management's administration of livestock grazing on public rangelands.[1] The five major categories of proposed management actions were (1) the grazing fee and associated incentives, (2) effective public participation in rangeland management by all interested parties, (3) administrative practices, (4) range improvement and water rights, and (5) resource management requirements, including standards and guidelines [Federal Register 1994].

There has been much controversy about the effects of these policy changes on the level of rancher investment in public rangelands. According to the General Accounting Office, higher levels of federal funding for range improvements on grazing units in the Experimental

[1] In August 1993, the Department of the Interior first put forward for comment proposed rules designed to "carry out a rangeland management program to improve ecological conditions while providing for sustainable development" [U.S. Department of the Interior 1993]. Revised rules were published for comment in the Federal Register on March 4, 1994. The 103rd Congress adjourned without passing any rangeland reform legislation.

Stewardship Program, in which improvements in public-range conditions were promoted through incentives and rewards to ranchers demonstrating good stewardship, have not been matched by rancher contributions [GAO 1988]. Some have argued that low grazing fees encourage overgrazing -- in fact, the Bureau of Land Management (BLM) sets an upper limit on the number of animals permitted on public rangelands -- while others assert that low fees encourage private investment in rangeland improvements.[2] Finally, it has been shown that appraisal values for grazing permits are higher on public lands subject to less bureaucratic control [Fowler and Gray 1980], suggesting that incentives for good stewardship decline with increased federal management control.[3] Notwithstanding these debates, there has been no previous empirical study on either the relationship between public and private investment in public-rangeland improvements or the impact of the level of the grazing fee on private investment.

This chapter focuses on a public good that provides a wide variety of benefits to society -- the condition of the public rangelands. Rangeland condition is important for wildlife and endangered species habitat, watershed protection, soil stability, water quality, outdoor recreation, and ecological diversity. Public-rangeland improvement projects are funded by the government and by private ranchers that hold exclusive grazing privileges on designated sections of public lands interspersed with their privately-held property.[4] Given the preference of livestock to

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[2] In 1978, the year the Public Rangelands Improvement Act passed, a Congressional document [U.S. Congress 1978] stated that a lower grazing fee would contribute to improved range condition by encouraging private investment. The report also noted that "many groups and individuals concerned with the improvement of the range" did not agree with this assessment, believing that low fees encouraged overuse.

[3] See also Hess [1992] and Libecap [1981].

[4] As discussed in more detail below, ranchers hold a quasi-private property right with respect to their exclusive grazing privileges on their allotment of public-land. Public-land grazing privileges depend upon private ownership (continued...)

graze around water sources, projects such as development of water resources, fencing, brush control and reseeding, improve livestock distribution and thus increase the lands' productive capacity and protect sensitive areas from overuse. This improved resource management benefits habitat for wildlife such as elk, antelope, migratory birds and fish, as well as the 95 species listed as endangered or threatened on the rangelands in the 10 western-most contiguous states [Horning 1994, U.S. Department of Interior FWS 1993]. Watersheds secured by improved groundcover prevent severe storms from causing flash floods that destroy lives and property. Healthy riparian areas remove sediment from water flows, hold water in stream-banks to provide a higher water table and a more stable stream flow, and help dissipate the energy of flood waters.[5] Rangelands are also used for many recreational purposes such as hunting, fishing, camping, picnicking, winter sports and scenic beauty [Gardner 1991, Horning 1994].

This study analyzes the determinants of private investment in public-rangeland improvements, focusing on government investment, the level of the grazing fee faced by public-land ranchers, and the degree of management control exercised by the federal government. The remainder of the chapter is divided into five sections. Section 2.2 provides background information on public-land management, range improvements, and the grazing fee. I focus on the changing philosophy of, and principal actors in, public-land management over time. The nature and impact of range improvement projects, and the institutional framework for investment by both government agencies and public-land ranchers are discussed. Summary data on

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[4](...continued)
of certain "base properties" and while the law does not allow for a private market in public-land grazing permits, the permit is transferable to the purchaser upon sale of the base property.

[5] Riparian areas are heavily vegetated areas along the banks of rivers and streams and around springs, wet meadows, lakes and ponds.

investment by both sources over time are presented. This section ends with a discussion of the grazing fee, providing information about the level of the fee over time and how it is determined.

Section 2.3 considers whether government and private investment in public-rangeland improvements are substitutes or complements in livestock production. This section also discusses how the grazing fee, changes in the degree of federal management control, and other factors, influence rancher investment. In sections 2.4 and 2.5, I present the empirical specification and estimation method, as well as the data used to test the effects of these different factors on rancher investment. I provide summary information on the 1969-1992 state-level investment data used in the empirical model and address simultaneity, spurious regression problems, heteroscedasticity, and cross-sectional correlation.

Section 2.6 presents empirical results. I find that rancher investment in public-rangeland improvements is positively influenced by government investment. Increases in the level of the grazing fee have a significant negative effect on rancher investment as does the loss of private management control resulting from legislation passed in the mid-1970s. The partial correlation coefficients indicate that a 10 percent increase in government investment increases public-land rancher investment by 9 percent and a 10 percent increase in the level of the grazing fee decreases public-land rancher investment by 13 percent. The final section considers the implications of these findings for the effects of proposed changes in Bureau of Land Management (BLM) regulations on the quality of stewardship provided by public-land ranchers and discusses directions for future research.

2.2 Background

2.2.1 Public Rangelands

The lands discussed in this chapter are managed today by the BLM, formed in 1946 by the merger of the General Land Office and the Grazing Service. The General Land Office was created within the Department of the Treasury in 1812 to handle sales and grants of public lands which began with the earliest days of the Confederation and continued through the nineteenth century. At that time, government policy was to dispose of the public lands as quickly as possible and in so doing, obtain much-needed revenue as well as encourage settlement of the west. Public lands were sold to individual homesteaders for crop cultivation and to land speculators. Railroads and states were granted ownership of public lands, as were soldiers and veterans of the Revolutionary and Civil Wars. In 1849, the General Land Office was transferred to the newly established Department of Interior [Clawson and Held 1957].

In spite of these dispersal policies, a full two-thirds of the territory in states west of the 100th meridian remained in the public domain at the turn of the century. In 1916, the Stockraising Homestead Act kindled new interest in homesteading. Previous homestead acts were inappropriately based on Jeffersonian agrarianism and farming experiences in the eastern states. The small acreage tracts made available for crop-raising were ill-suited to the arid lands of the west. The Stockraising Homestead Act was one of the first to recognize ranching as a legitimate use of the public domain in the west. It provided for grazing use by expanding homestead tracts to 640 acres, thus securing one of the two critical inputs for range grazing by domestic livestock -- large tracts of land. The second was access to water. Homesteaders began

to claim only those sections of land that allowed them to control scarce water supplies.[6] This made it unprofitable for others to obtain the surrounding lands and secured their free use by existing settlers. The open range encouraged overgrazing and the condition of the public lands deteriorated [Culhane 1981].

The Taylor Grazing Act of 1934 asserted temporary government jurisdiction over as-yet-unsold rangelands, ending the era of the open range and setting up a framework for both government and private investment in projects that would improve the condition of the public lands. The Secretary of Interior was instructed to "make provision for the protection, administration, regulation, and improvement" of the public range and the Grazing Service was established to administer the provisions of the act. The basis for present-day public-land management and range improvement expenditures is contained in three key sections of the act. First, Section 3 authorized private ranchers with a history of prior use to lease the forage within newly established grazing districts for a specified fee per animal unit month (AUM) [USCA 1986].[7] By statute, one quarter of the revenue collected in the form of grazing fees was allocated to federal expenditure on range improvement projects [USCCS 1947]. Second, Section 4 granted public-land ranchers permission to construct "fences, wells, reservoirs, and other improvements necessary to the care and management of the permitted livestock." Third, Section

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[6] Control of water on arid rangelands served to enforce holdings. Groups of cattlemen that pooled their herds to jointly reinforce land claims generally determined the number of animals allowable from each member on the basis of water ownership. From Taylor [1886]:

> It will be seen that the ownership of watering places gives tenure to the contiguous range. This fact is recognized by western cattlemen, and the question as to the number of cattle individual owners are permitted to hold under regulations of various local associations, is determined by questions of water frontage.

[7] An AUM is defined as the amount of forage needed to support one cow or five sheep (all over six months of age) for a period of one month [Department of Interior 1969-1992].

9 stated that the Secretary of Interior would provide "for cooperation with local associations of stockmen ... interested in the use of the grazing districts [USCA 1986]." This section inaugurated organized rancher involvement in all aspects of public-land management.

Farrington Carpenter, the first director of the Grazing Service, was a Republican rancher with an aversion to bureaucracy. This was reflected in the fact that most of his employees did not have comprehensive maps marking the location of the federal rangelands. He relied upon local ranchers elected to district advisory boards to make the major decisions implementing the Taylor Act. In 1939 when Carpenter was replaced by Richard Rutledge, a forester and grazing specialist, ranchers were quick to recognize the threat to their intimate relationship with the Grazing Service. Senator McCarran of Nevada piloted the livestock industry's resistance to Rutledge, holding back proposed grazing fee increases and supporting reductions in the Service's budget in order to force recognition of the ranchers' right to control grazing district policy. In 1946, a thoroughly routed Grazing Service was combined with the General Land Office to form the new BLM [Culhane 1981].

Marion Clawson, BLM director from 1948 to 1953, advocated establishing appropriate grazing fees and professionally determining range carrying capacity, but neither fee increases nor reductions in AUMs to capacity levels could be accomplished without a fierce battle from public-land ranchers. BLM professionals were at a disadvantage with respect to the livestock industry because the Taylor Act did not provide a solid basis for conservation management. The BLM strategy for changing this situation was to advocate adoption of a multiple-use mandate for range management. The Classification and Multiple Use Act of 1964 introduced such a mandate and initiated the idea of permanently retaining the public range under federal ownership. The

Act was only temporary however and it expired in 1970 [Culhane 1981].

The Federal Land Policy and Management Act of 1976 (FLPMA) finally granted the BLM statutory status as a permanent federal agency called upon to manage the public domain under the principles of multiple use and sustained yield. It terminated statutory authorizations for public-land disposal and greatly enhanced BLM control and regulation of grazing on the federal range. Congress took the position that "the installation of range improvements could ... lead to substantial betterment of forage conditions with resulting benefits to wildlife, watershed protection, and livestock production." FLPMA increased to fifty percent the proportion of grazing-fee revenue to be used for BLM range improvement projects. One half of these funds would be returned to the districts of origin and the other half would be distributed as directed by the Secretary of the Interior [USC 1989].

The BLM currently manages 147 million acres in the 10 western-most contiguous states excluding Washington -- an area about the size of Texas. Figure 2-1 depicts the general location of these lands.[8] Each of these ten states has a BLM office responsible for supervisory functions of a policy, planning, and compliance nature. Primary responsibility for BLM land management is held by managers of the fifty-one grazing districts. They are assisted by the staffs of 142 resource area offices. The districts contain approximately 22,000 grazing allotments used by 19,000 livestock permittees [GAO 1993a].[9] While the majority of ranchers using BLM lands are small- to medium-sized family operations, about 37 percent of all BLM

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[8] Note in Figure 2-1 that private land, state land, and land managed by other federal agencies are intermingled with the lands administered by the BLM. Within grazing districts, the proportion of land under BLM jurisdiction ranges from about 90% in parts of Nevada and Utah to only 25% in areas such as eastern Montana. BLM lands in these ten states account for 85% of the land under BLM jurisdiction in the contiguous United States.

[9] BLM allotments average 11.5 square miles [GAO 1992].

AUMs are assigned to the 500 largest permittees. These ranchers represent only 2.7 percent of BLM permittees [GAO 1992].

When the permit system was initiated grazing privileges were awarded on the basis of the applicant's control of "base properties" -- defined as either private land having the capability to produce sufficient feed for authorized livestock during periods of the year that public-land grazing is prohibited, or private waters suitable for consumption and available to the authorized livestock grazing on public lands. Only in the "water-base states" of Arizona and New Mexico are base property requirements solely in terms of water [PLLRC 1970].[10] Public rangeland is used in a complementary grazing rotation with private grazing and haying land [U.S. Departments of Agriculture and Interior 1992].[11] Dependence upon public-land forage is substantial, approximately 4.3 million cattle and sheep graze at least part of the year on BLM-administered lands. One-third of all the beef-cattle produced in the western states grazes on public lands [GAO 1988].

2.2.2 Rangeland Improvements

Investment in public-rangeland improvements by government agencies and public-land

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[10] Water rights must be obtained directly from the state. Private citizens can hold title to water rights on public lands [Conversation with Dan Rathbun, BLM Rangeland Resources Division, Washington D.C. 1994]. State base property requirements for grazing privileges are outlined in Public Lands Law Review Commission [1970].

[11] Alternatives to public grazing, such as private grazing or use of supplementary feeds, are considerably more costly [Gardner 1991].

ranchers is shown in Figure 2-2 for the period 1969 to 1992.[12] Range improvements are designed to control patterns of livestock grazing, improve production of forage, change vegetative composition, and provide water in order to stabilize soil and water conditions -- this helps preserve riparian areas, increase groundcover for watershed protection, and maintain habitat for livestock and wildlife [CFR 1993]. These goals may be accomplished, for example, through development of water supplies, fence-building, seeding, and brush control. Water developments, such as springs, ponds, tanks, wells and distribution lines, and fencing, constructed from logs, wire, brush or rocks, are the principal means of controlling areas of use by livestock for range rehabilitation purposes.

Range improvement techniques have a gradual impact on range conditions. It is projected, for example, that implementation of these techniques on private rangelands would result in a 0.7 percent annual increase in rangeland productivity over the period 1987-2040 [Gardner 1991]. BLM lands may respond even more slowly to range improvement practices because they are the lowest in productive potential [Box 1976].[13] The degree to which these improvements enhance the different services provided by rangelands depends, in part, upon rangeland management. For example, range scientists have pointed out that watering points developed for livestock play a crucial role in supporting many wildlife populations. Carefully controlled grazing can improve wildlife habitat and riparian areas, and increase vegetation

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[12] The strong upward jump in government investment follows the passage of the Federal Land Policy Management Act of 1976 and the Public Rangelands Improvement Act of 1978 and reflects increased discretionary allocations of funds for stewardship programs and associated range improvements.

[13] These lands have been referred to as "the lands nobody wanted." Given the initial federal policy of public-land disposal, the most productive and most desirable lands were claimed under the homestead laws or granted to veterans, the states, and the railroads.

diversity and productivity. Brush control can improve wildlife habitat, soil stability and aesthetics, in addition to augmenting forage for livestock use [Holecheck 1993, Barnes et. al. 1991].[14]

Real annual investment in rangeland improvements by government agencies and private ranchers averaged $15 million in 1991 dollars during the 1969-1992 period. Investment by government agencies accounts for 81 percent of the total during this period and focuses on projects that maximize multiple-use benefits. The BLM is responsible for 94 percent of government investment. The remaining 6 percent comes from other federal agencies such as the U.S. Fish and Wildlife Service, state departments of fish, game and wildlife, and county governments. BLM range improvement funds are derived from two sources -- grazing fees and other funds appropriated by the U.S. Congress [U.S. Department of the Interior 1969-1992, U.S. Departments of Agriculture and Interior 1992]. As described above, beginning with the Taylor Grazing Act, Congress has always legislated that a proportion of grazing-fee revenue be used to finance BLM range improvement projects. The appropriation of other moneys is discretionary, as illustrated by the following two examples. First, the Vale Project was initiated in 1962 by two influential members of the Oregon Congressional Delegation, Senator Wayne Morse and Congressman Al Ullman. They supported the appropriation of $10 million over an 11-year period from 1963 to 1974 to improve vegetation for consumption by livestock and wildlife, and groundcover for wildlife habitat, soil stability, and water-quality enhancement. On

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[14] The Natural Resources Defense Council contests this view. Using data on BLM investments charged to one of three management categories (grazing, wildlife, or watershed) for fiscal years 1980 to 1990, they claim that "96.5% of the (BLM) range betterment funds that can be accounted for on a project-specific basis were spent chiefly to benefit livestock [Wald 1993]." The forced characterization of different types of projects as exclusively benefitting one type of rangeland use has been challenged by a recent GAO report [GAO 1993] and by BLM staff with field experience.

the Vale grazing district in Oregon, 72,000 miles of fencing, 1,600 water developments, and 460 miles of water pipelines were installed. In addition, brush was controlled on 560,000 acres and 267,000 acres were reseeded [Muhn and Stewart 1988].[15] Second, the Public Rangelands Improvement Act of 1978 (PRIA) made available for appropriation over the period 1980-1999 $365 million for rangeland improvements to benefit "livestock, wildlife habitat, recreation, forage, and water and soil conservation [USC 1989]."[16] Discretionary appropriations account for 29 percent of BLM investment in range improvements during the 1969-1992 period.

Rancher investment in public-rangeland improvements accounts for 19 percent of the total during the 1969-1992 period. Ranchers will undertake range improvement projects for which the marginal benefit to livestock production exceeds the marginal cost in present value terms. Improved resource conditions that result from such projects benefit livestock operations through enhanced grazing forage. The amount of AUMs available to the public-land rancher is limited by the grazing permit and this administratively-determined constraint remains essentially unchanged.[17] Ranchers can apply to the BLM for non-use of permitted AUMs and did so at an average annual rate of 15 percent of total allowable AUMs during periods for which data is available. Even at maximum permitted stocking capacity however, enhanced forage enables animals to achieve higher weight gains in shorter periods of time.

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[15] Available data on average annual BLM investment in rangeland improvements in Oregon suggests that the Vale project was responsible for a 60% increase in BLM funding.

[16] BLM investment in range improvements averaged $12.5 million in 1991 dollars during 1969-1979. The funds available under PRIA alone average $18.5 million per year in nominal terms.

[17] Enforcement of allowable AUMs is achieved through monitoring by area resource office personnel, sometimes with the assistance of public-land ranchers on neighboring allotments [Zechiel 1994]. In addition to current penalty fees of $9.70 per AUM for unauthorized livestock, compared to a fee of $1.98 per AUM for authorized livestock, violation of permit terms can lead to revocation of the grazing privilege [Hardy 1994].

The right to a certain number of public-land AUMs is conveyed through 10-year permits which carry a "preference right of renewal" for the holder. The BLM reserves the right to temporarily adjust the permit to "protect or conserve the public lands affected" and to revoke the permit for violation of its terms or in the event that the land is transferred from BLM administrative responsibility [PLLRC 1970]. The number of permitted animals, as well as seasons and maximum annual period of use, are determined by BLM officials. While accurate assessments of resource conditions are a key element in the determination of carrying capacity, a 1988 GAO study concluded that 66 percent of BLM grazing allotments did not have established monitoring and evaluation schemes. Of those allotments with such plans, 16 percent were over ten years old and not sufficiently current to properly manage the allotments. As a result of insufficient data on range conditions, appropriate adjustments in authorized livestock grazing levels are frequently not scheduled [GAO 1988]. Staff at resource area offices confirm that the number of AUMs allowed by a given permit are rarely adjusted [Zechiel 1994, McGuinness 1994].

2.2.3 Grazing Fees

Permittees have paid an annual fee per AUM to graze their livestock on public lands ever since the Taylor Grazing Act of 1934. The real level of the fiscal-year fee from 1941 to 1990 is shown in Figure 2-3. The level of the grazing fee reflects the political struggle for management control between public-land ranchers and the federal government [Libecap 1981]. Regardless of the ostensible basis for setting the fee -- be it "reasonableness", the cost of public

agency administration, the ability of ranchers to pay, fair market forage value, or a combination of these -- its level has mirrored the relative political power of the livestock industry.

The Taylor Act required only that the fee be "reasonable" and, given the prevailing poor economic conditions, it was initially set at the nominal level of $0.06 per AUM for the grazing-fee year 1936.[18] It remained at this level until 1947 in spite of a 1941 Grazing Service study that concluded the fee was considerably below that charged on private and state lands, and only one-sixth that charged for grazing on national forest lands [USC 1986, U.S. Departments of Agriculture and Interior 1992]. The House Appropriations Committee favored a fee increase that would allow the Grazing Service to cover its expenses with fee revenues, but western senators and the Senate Subcommittee on Public Lands and Survey sided with public-land ranchers and opposed a fee increase. In 1946, aware that public-land ranchers were willing to accept slightly higher fees, the Secretary of the Interior appointed California rancher Rex Nicholson to study the issue. Based on his estimates of administrative costs, which were too low, Nicholson recommended increasing the nominal 1947 fee to $0.08 per AUM where it remained for the next three years.

In 1951 BLM Director Marion Clawson persuaded ranchers to accept a fee of $0.12 per AUM in order to cover administrative costs. The fee remained at that level for four years. In 1955, BLM Director Edward Woozley suggested that the range management program be funded largely through appropriations, but maintained that ranchers should pay part of the cost if they were able. In principle, the new grazing fee was to vary with average western livestock prices but even in the first year of the program the resulting $0.18 fee was considered too high. The

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[18] The grazing-fee year runs from March 1st to February 28th (or 29th) of the following year.

fee was arbitrarily set at $0.15 for the grazing-fee years 1955 and 1956. Increases were delayed because of drought conditions until 1958, when the fee was raised to $0.19. After climbing to $0.22 per AUM in 1959 and 1960, the fee fell again to $0.19 during 1961 and 1962. In 1962, Secretary of the Interior Udall informed permittees that grazing fees were under review and that pressure for increased fees was rising from Congress and the Executive Branch. Despite opposition from ranchers, the fee was set at $0.30 during 1963-1965 and $0.33 during 1966-1968 [Muhn and Stewart 1988].

In response to criticism that fees were below market value, the BLM sponsored a project to estimate the fair market value of public-land grazing [Muhn and Stewart 1988]. The Western Livestock Grazing Survey analyzed the cost of private-land AUMs and took into account the disparity between the per-acre productivity of private and public lands [U.S. Departments of Agriculture and Interior 1992, Culhane 1981]. The livestock industry contended that the proposed increase to $1.23 per AUM was unreasonable because ranchers incurred the cost of the federal grazing permit when they purchased ranches from previous owners -- because grazing permits were transferred along with ownership of base properties, the capitalized value of the permit was incorporated in the cost of the base property [Culhane 1981].[19] The contribution of public-land grazing permits to the market value of western ranches is empirically well-established. Torell and Doll [1991] use data on ranch sale prices in New Mexico during the 1979-1988 period to demonstrate that increased grazing fees reduce the value of grazing permits; they estimate that a fee increase of $1.00 per AUM results in a $30.00 per AUM decline in

[19] The law does not allow for a separate, private market in public-land grazing permits.

ranch sale price.[20] Employing arguments of this nature, ranchers gained one concession from Congress -- the fee increase would be phased in through equal installments over a ten year period beginning in 1969, taking into account inflation and changes in the market value of private-land forage [Muhn and Stewart 1988, U.S. Departments of Agriculture and Interior 1992].

Four moratoriums on the scheduled fee increases, resulting from Congressional or Executive actions, prolonged the implementation schedule. The first of the incremental adjustments brought the fee to $0.44 per AUM in 1969. After a moratorium in 1970, the fee was raised to $0.64 per AUM in 1971 [U.S. Departments of Agriculture and Interior 1992]. The 1972 fee increase was limited to three percent in response to President Nixon's Economic Stabilization Program [Muhn and Stewart 1988]. The next adjustment was applied in 1973, when the fee reached $0.78. At this time the goal for achieving fair market value was postponed from 1978 to 1980. In 1974 the fee was raised to $1.00 per AUM and in 1975, in spite of the third moratorium on the scheduled increase, the President instructed that the schedule be maintained to reach fair market value by 1980. In 1976, the fee was raised to $1.51 per AUM and it stayed at this level until 1978 due to the fourth moratorium which was embodied in the Federal Land Policy and Management Act (FLPMA) signed October 21, 1976 [U.S. Departments of Agriculture and Interior 1992].

In FLPMA, Congress stated that the federal government should "receive fair market value of the use of the public lands and their resources unless otherwise provided by statute." The public land agencies were required to study the grazing fee issue, taking into consideration

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[20] The implied capitalization rate is 3.35%

"the costs of production, ... differences in forage values, and other factors which relate to the reasonableness of the fees." Their report was submitted to Congress on October 21, 1977 and the provisions of the Public Rangelands Improvement Act of 1978 (PRIA) provided a response [U.S. Departments of Agriculture and Interior 1992].

The sharp rise in the fee over the 1970s mirrors the rising strength of the environmental movement. Earth Day, April 22, 1970 marked the beginning of what was called the "environmental decade." The National Environmental Policy Act (NEPA) required agencies to prepare detailed environmental impact statements on "major federal actions significantly affecting the quality of the human environment." Public-land agency employees cite NEPA as a pivotal event in the transition to new agency awareness of environmentalism [Culhane 1981]. According to Libecap [1981] rising fees were visible evidence of the erosion of tenure arrangements the livestock industry held over the public rangelands.

The federal government's increasing role in public land management prompted the Sagebrush Rebellion of 1979, in which the Nevada legislature passed a resolution calling for state ownership of BLM public lands. Within a year Arizona, New Mexico, Utah and Wyoming had passed similar legislation. The rebellion quickly dissipated with the election of Ronald Reagan to the presidency in 1980. During the presidential campaign Reagan said, "Count me in as a Sagebrush Rebel." According to historian Phillip Foss, Secretary of the Interior James Watts' "good neighbor" policy helped to diffuse the rebellion -- traditional public land users were assured that they would have continued presence on the public lands and be included with other interests in the development of land use plans [Muhn and Stewart 1988].

The decline of the fee in real terms during the Reagan administration reflected the

renewed power of the livestock industry in matters of public-land management. Under the Public Rangelands Improvement Act (PRIA), Congress determined that "to prevent economic disruption and harm to the western livestock industry, it is in the public interest to charge a fee for livestock grazing ... which is based on a formula reflecting annual changes in the cost of production (and beef prices)." The grazing fee formula retained the Western Livestock Grazing Survey base value of $1.23 and adjusted it by the annual changes in a series of indexes measuring the value of grazing forage on private lands, prices received by ranchers for livestock, and the costs of livestock production.[21] Annual changes in fees are not to exceed 25 percent. Originally, this method of determining fees was to be in place from 1979 to 1985, at which time the system would be re-evaluated [USC 1989]. The public lands agencies submitted an evaluation report in 1986 but did not expressly recommend an alternative fee schedule. No action on the fee schedule was taken by Congress. As a result, Executive Order 12458 extended the PRIA determination method indefinitely pending action by Congress, and added a required minimum fee of $1.35 [U.S. Departments of Agriculture and Interior 1992].

2.3 Government and Private Investment: Substitutes or Complements?

Private ranchers invest in public-rangeland improvements to increase livestock production. Most range improvement projects are undertaken to improve livestock distribution in order to increase the lands' productive capacity and improve cattle weight, while protecting

[21] Recall that the Western Livestock Grazing Survey base fee of $1.23 took into account the disparity between the per-acre productivity of private and public lands.

sensitive areas, such as riparian areas and wildlife habitat, from overuse. Livestock tend to graze around water sources, thus range improvements such as development of alternative watering areas and fencing facilitate better resource management. Unless she values non-livestock uses of the public range including wildlife habitat, watershed protection and recreation, the profit-maximizing rancher will only be interested in funding those range-improvement projects for which the marginal benefit to livestock production exceeds the marginal cost. For example, by improving the timing of livestock grazing on different parts of the allotment, a pasture fence might generate a sufficiently large increase in forage production to justify its cost. Since a range improvement affects range productivity only on the allotment where it is made, investment decisions are independent across ranchers.

Government investment in public-rangeland improvements is primarily determined by the discretionary allocation of grazing-fee revenue and Congressional appropriations as described above. Thus, the rancher's cost of a unit of government investment is determined by tax rates and is zero at the margin; in addition, the rancher takes the level of government investment as given.

The effect of changes in government investment in public-rangeland improvements, $\mathbb{G}$, on rancher investment, $\mathbb{R}$, depends upon whether the two types of investment are substitutes or complements in livestock production. If $\mathbb{R}$ and $\mathbb{G}$ are substitutes, an increase in $\mathbb{G}$ will cause a decline in the level of $\mathbb{R}$. If $\mathbb{R}$ and $\mathbb{G}$ are complements, an increase in $\mathbb{G}$ will cause an increase in the level of $\mathbb{R}$. The marginal benefit of rancher investment may well be increased by government investment. For example, in order to protect a riparian area for water quality, flood control and fishery purposes, the BLM may direct cattle away from the overgrazed area

by drilling a well or developing a natural spring to provide an alternative water source [GAO 1988]. Once the government's investment has been undertaken, the rancher's rate of return on water pumps, pipelines, and troughs to disburse water for increased livestock distribution on the allotment may justify additional private investment. The potential complementarity between R and G encourages public-land ranchers to bring such projects to the attention of BLM resource area managers.[22]

In principle there are four possible relationships between private and government investment in range improvement projects. In two of these relationships, the rancher's investment decision is unaltered by the government's (politically-motivated) decision whether or not to invest. In the other two however, the government's investment decision does influence the rancher's investment decision [See Table].

	Government Decision	
	Invest	Do Not Invest
Investment Project (1)	Rancher Invests	Ranchers Invests
Investment Project (2)	Rancher Does Not Invest	Rancher Does Not Invest
Investment Project (3)	Rancher Does Not Invest	Ranchers Invests
Investment Project (4)	Ranchers Invests	Rancher Does Not Invest

[22] In fact, the majority of range improvement projects are initially identified by public land ranchers who have intimate knowledge of the resource quality on their allotments [McGuinness 1994, Vanzandt 1994, Zechiel 1994]. The BLM's limited staff resources make it much more difficult for the government to identify necessary range improvements. The BLM has only 142 resource area offices responsible for 147 million acres of land on 22,000 allotments [GAO 1993].

In the case of Project (1), the benefits of private investment exceed the costs regardless of whether or not the government also invests in a range improvement project. In the case of Project (2), the costs of private investment exceed the benefits regardless of the government's investment decision. In the case of Project (3), the rancher invests only if the government does not. One example of this is the government investing in projects that would otherwise be undertaken by private investors. Another example is when investment by the government causes the rancher's cost of a given range improvement project to exceed the private benefits of the project. In the case of Project (4), the benefits of private investment exceed the costs only when the government also invests in a range improvement project. The empirical results based on state-level investment data do not tell us which case is relevant for any particular investment decision, but can provide some rough guidance on aggregate patterns.

For illustrative purposes, let us consider Case (4) in more detail. Suppose a rancher must make decisions about the following investments: drilling a well to develop a new water source, installing pipelines and water troughs, or undertaking both projects to distribute the water obtained from the well. Let the rancher's cost of establishing the well on an under-utilized area of the allotment be C^R_w. The cost of water pipelines and troughs in the vicinity of the well is C^R_p. The value to the rancher of just the well is V^R_w, the value of just the pipelines and troughs is V^R_p, and the value of both projects is V^R_{p+w}. Suppose that

$$V^R_p < C^R_p$$

$$V^R_w < C^R_w$$

$$C^R_p + C^R_w > V^R_{p+w} > C^R_p, C^R_w$$

The value derived from each of the projects alone is insufficient to justify rancher investment.

Similarly the joint cost of the two projects exceeds the rancher's yield from investing in both the well and the installation of the pipelines and troughs. In other words, in the absence of government investment, the rancher will not invest at all. However, if one project is provided, the value to the rancher of having both is sufficient to justify her investment in the other. Government provision of the well, for example, will stimulate rancher investment in the pipelines and water troughs.[23]

Rancher investment is also influenced by the level of the grazing fee, F. Given that investments are financed by net income from livestock sales and borrowing, higher fees exert negative pressure on private investment in range improvements by reducing available net income, tightening credit availability, and reflecting increased BLM management control. First, by reducing net income, increases in the fee diminish the supply of internal funds for rancher investment. Cash poor ranchers typically install less-costly range-improvement projects while the government often undertakes major projects of a more permanent nature; in many cases, capital constrained ranchers contribute labor resources while the government provides materials for the project [McGuinness 1994, Vanzandt 1994, Obermiller 1994]. Second, by reducing the value of the grazing permit, which is the most important source of collateral for operating loans, higher fees make borrowing more difficult for ranchers [Myers 1994]. As discussed above, when private ranches or base-properties are sold, the right to the corresponding public-land grazing permit is transferred to the new owner; the ranch sales price includes the appraisal value of the grazing permit and increases in grazing fees have been shown to diminish the market

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[23] The government will be willing to invest in the well because the social benefit derived from the project exceeds the government's cost. Social benefits take into account factors such as watershed and riparian area protection, wildlife habitat, and recreation. Further, because the government represents a high volume purchaser of range improvements, it may face lower costs than the rancher, i.e. $C^{G}_{w} < C^{R}_{w}$.

value of these permits [Torell and Doll 1991]. Third, movements in the level of the grazing fee over time have reflected the relative political power of the livestock industry. The real fee rose dramatically in the 1970s, as heightened environmental concerns imposed greater management constraints on public-land ranchers, and fell in the 1980s during the "Sagebrush Rebel" Reagan years [Muhn and Stewart 1988]. The BLM reserves the right to adjust the amount of livestock permitted on public lands to protect or conserve the resource, as well as the right to cancel permits in order to devote the public lands to another public purpose [PLLRC 1970, Federal Register 1994]. Increased interest in managing the public lands for non-livestock purposes causes tenure uncertainty for ranchers, reducing their incentive to invest in range-improvement projects which do not yield sufficient short-term benefits. Given data on ranch sales prices since the 1970s, Gardner [1991] concludes that uncertainty about future range use caused buyers to discount the value of BLM grazing lands.

The passage of **FLPMA** in October 1976 heralded a period of increasing uncertainty about the use and tenure of public-land grazing permits. FLPMA signalled a fundamental change in the nature of federal land policy and decisively reduced the management power of public-land ranchers. The act eliminated the temporary status of federal control of the rangeland implied by the Taylor Grazing Act of 1934 and formally outlined permanent new powers of the BLM, greatly enhancing its control over grazing on the federal range for multiple use and sustained yield purposes [Hess 1992, Frederick and Sedjo 1991]. In addition to the emphasis placed on the need for range inventory information and grazing fee reviews, the BLM's management control was increased by a number FLPMA provisions. The Secretary of the In was allowed to offer short-term licenses instead of ten-year permits in the "interest of

sound land management." Allotment management plans, in which the BLM outlined stocking controls and general timetables for land rehabilitation, became mandatory. These responsibilities had previously been assumed by the powerful grazing advisory boards established in 1935 to obtain rancher cooperation in administering the Taylor Act. By 1936 these boards had a strong influence over almost every aspect of range management. A 1939 amendment to the Taylor Act required government consultation with the boards and gave Congressional support for the boards' role in grazing district management. State and national advisory boards received similar authorization under a 1949 amendment to the Taylor Act. The advisory boards, which had provided the framework for private management of BLM lands, lost their legal mandate as a result of FLPMA [Libecap 1981]. This fundamental shift in management power must also be taken into account when analyzing the level of rancher investment in public-rangeland improvements over time -- it is expected to exert a negative influence on rancher investment.[24]

2.4 Specification

The relationship between government and private investment in public-rangeland improvements, specifically, whether they are substitutes or complements in livestock production, depends upon project technology at the microeconomic level. A limitation of the empirical

[24] A variation on this argument has been made by Hess [1992]. He points out that private ownership of water rights by ranchers with water-based allotments necessitates the rancher's approval of water-based management activities on her allotment, particularly in light of the characteristic interdependence of private and public lands. Hess claims that this heightened degree of management control results in greater tenure security and thus, greater levels of rancher investment in public-rangeland improvements.

investigation of the factors affecting rancher investment is that only aggregate data are available. The state-level investment data used in this study were collected by BLM resource area offices and consolidated in the Range Improvement Project System (RIPS). RIPS records the annual level of investment in completed public-rangeland improvements by source of funds and project type. Table 2-1 summarizes investment by state and source over the 1969-1992 period. Total investment in public-rangeland improvements during this period averaged $15 million per year in 1991 dollars. Government agencies are responsible for 81 percent of total investment in public-rangeland improvements and the BLM provides the vast majority of these funds. While outlays of this magnitude are a small proportion of federal government spending, the following analysis yields important results regarding government resource management. Ranchers contribute the remaining 19 percent of total investment in public-rangeland improvements. Table 2-2 shows the proportion of investment directed to the two dominant project categories -- water developments and fencing. These are the principal means of controlling livestock distribution for rangeland rehabilitation purposes and account for 75 percent of total investment in rangeland improvements.

The basic equation to be estimated, with all relevant variables in logs, is

$$R_{it} = \beta_0 + \beta_1 G_{it} + \beta_2 F_t + \beta_3 FLPMA_t + \beta_4 BCPI_t + \beta_5 PPI_t + \beta_6 ITC_t + e_{it} \quad (2.1)$$

where **R** and **G** are rancher and government investment in public-rangeland improvements respectively, both normalized by million acres of BLM-administered land in the state and expressed in constant 1987 dollars. **F** is the grazing fee per AUM charged to public-land ranchers, expressed in 1987 cents and **FLPMA** is a dummy variable equal to one for years in which the Federal Land Policy and Management Act has been in force and zero otherwise.

BCPI and PPI are real price indices for beef cattle and for non-land inputs into western beef cattle production -- both are taken as given by individual ranchers and affect the availability of internal funds for financing range improvement projects.[25] Since increases in beef cattle prices or decreases in input prices raise net income, these two variables should exert positive and negative influences, respectively, on rancher investment. ITC is a dummy variable equal to one for years in which the federal investment tax credit was available and zero otherwise.[26] The ranchers' cost of a unit of $\mathbb{R}$ also depends on the tax treatment of private investment in public-rangeland improvements. The investment tax credit provision generally allowed individuals and firms to deduct as a credit against their tax ten percent of the amount of new investment with recovery periods of more than three years [Pechman 1987]. The credit, by reducing the rancher's cost of range improvement projects, increases the rate of return and is thus expected to have a positive effect on rancher investment. Nine state dummy variables are also included in the specification. The subscript i indexes the ten western-most contiguous states, excluding Washington. The subscript t indexes the years 1969-1992. The expected signs of the partial correlation coefficients are $\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 < 0$, $\beta_4 > 0$, $\beta_5 < 0$, and $\beta_6 > 0$.

2.5 Estimation

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[25] As discussed in more detail in section 2.6, the variable PPI includes the interest rate -- although this linear restriction is supported by econometric tests of the orthodox theory of investment as well as the effect of interest rates on investment under uncertainty, irreversibility and timing choice, results for both the restricted and unrestricted models will be presented.

[26] For a detailed explanation of the data used in the analysis, see Appendix A.

There are three key issues in estimation: the endogeneity of government investment, the possible non-stationarity of the time-series data, and heteroscedasticity and cross-sectional correlation. First, government and rancher investment may respond to the same unobservable influences. In other words, G may not be independent of the error term in Equation (2.1). I employ two-stage least squares to obtain consistent coefficient estimates. The instruments for government investment are the lagged grazing-fee revenue collected from each state, REV, and a lagged measure of each state's representation on key House committees, COMM. Both instruments are normalized by BLM-administered acres in the state.

As explained above, a fraction of grazing-fee revenue is earmarked by law, under either the Taylor Grazing Act or FLPMA, for government investment in rangeland improvements. The only guideline concerning the allocation of these funds was introduced under FLPMA in 1976. FLPMA authorized one-half of these earmarked funds "to be appropriated and made available for use in the district ... from which such moneys were derived." The other half is distributed according to the direction of the Secretary of Interior [USC 1989]. The Secretary generally returns these funds to the BLM state office from which they originated [U.S. Departments of Agriculture and Interior 1985]. At lower administrative levels, BLM personnel use their own informal and considerably varied priority systems for selecting range improvement projects [GAO 1988].

Discretionary appropriations by the U.S. Congress are another source of federal funds for investment in rangeland improvements.[27] To capture the relationship between

[27] There is a large literature analyzing the relationship between Congressional representation and the distribution of government-controlled economic benefits [Levitt and Poterba 1994].

Congressional representation and government investment in rangeland improvements, I focus on the number of each state's Congressional representatives with assignments on either the House Interior and Insular Affairs Committee or the House Appropriations Committee. Committee assignments in the House are more meaningful than those in the Senate because the Senate has fewer committees with more evenly divided jurisdictions and senators depend less upon committee memberships as avenues of participation -- they can propose amendments on the floor, filibuster, and even put "holds" on legislation. The House Interior and Insular Affairs Committee oversees the BLM's public-land management program. This committee has been referred to as a constituency committee -- one which attracts members for constituency-oriented reasons -- and candidates often make campaign promises to seek membership on constituency committees. The House Appropriations Committee is responsible for the BLM's budget. This committee is attractive to members seeking money for programs and projects in their districts because it has jurisdiction over spending [Smith and Deering 1984]. Government funding for rangeland improvements in a given state is likely to be higher the more representatives from the state's delegation have membership on these two committees.

The second issue in estimation is the possibility that the time series data are non-stationary [Appendix B]. In this case, conventional significance tests often lead to the rejection of the hypothesis of no relationship between variables when in fact there is none. It is frequently recommended that apparently non-stationary variables be differenced before estimating regressions. With the resulting stationary regressors, any t or F test has the usual limiting Gaussian or χ^2 distribution. It has been demonstrated that the Cochrane-Orcutt GLS regression, using the original variables in levels, is asymptotically equivalent to the differenced regression

[Hamilton 1994]. I take this approach in my analysis in order to avoid spurious regression results.

Third and finally, differences in the scale of the investment variables across the ten states would imply the presence of heteroscedasticity. I try to account for scale by normalizing all relevant variables by millions of acres of BLM-administered land in the state. However, the data may be heteroscedastic in other dimensions as well. In addition, state-level rangeland investment may be influenced by common national factors, so disturbances may be correlated across states. Lagrange multiplier tests for heteroscedasticity reject the null hypothesis of homoscedasticity for the specification in Equation (2.1) with state dummy variables included.[28] Lagrange multiplier tests fail to reject the null hypothesis of no cross-sectional correlation across states.[29]

2.6 Results

The empirical results strongly support the propositions that rancher and government

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[28] The test statistic is

$$LM = (T/2)\,\Sigma_i\,[(s_i^2/s^2)-1]^2$$

where $s^2 = (1/n)\Sigma_i\, s_i^2$ and T refers to the number of observations for each state i = 1...n. When computed at the pooled Cochrane-Orcutt FGLS estimates, the test statistic exceeds the 95% critical value from the chi-squared distribution with n degrees of freedom.

[29] The test statistic

$$LM = T\,\Sigma_{i=1}^{M}\,\Sigma_{j=1}^{i-1}\, r_{ij}^2$$

where r_{ij} is the correlation coefficient between the i^{th} and j^{th} residuals, is less than the 95% critical value from the chi-squared distribution with n(n-1)/2 degrees of freedom. Although the strictly appropriate basis for computing the correlations is the residuals from the iterated estimator in the groupwise heteroscedastic model, an asymptotically valid approximation to the test can be based on the FGLS residuals instead [Greene 1990].

investments in public-rangeland improvements are complements in livestock production, that grazing fee increases constitute financial constraints and represent diminished rancher management control, and that FLPMA has a significant negative effect on private investment in public rangelands. The coefficients in Equation (2.1) were first estimated using an ordinary least squares, Cochrane-Orcutt FGLS procedure with the pooled data, corrected for cross-sectional heteroscedasticity [Table 2-3]. Column (A) includes all of the independent variables in Equation (2.1). In columns (B) and (C), I first drop the investment tax credit and then the price index for inputs into western beef cattle production, both of which are not significant. The results presage those from the subsequent two-stage least squares estimation and are discussed more fully below in that context.[30] Government investment has a positive significant effect on rancher investment; the grazing fee and FLPMA have negative significant effects; and the beef cattle price index has a positive significant effect. Note that if G is correlated with the error term, we would expect its coefficient to be biased toward zero. Therefore, it is not surprising that the magnitude of the coefficient on G increases considerably once I instrument for government investment.

The results from the estimation of Equation (2.1) using a two-stage least squares, Cochrane-Orcutt FGLS procedure with the pooled data, corrected for cross-sectional heteroscedasticity are presented in Tables 2-4 and 2-5.[31] Table 2-4 shows that the

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[30] Lagged government investment did not have a significant effect on rancher investment when included as an explanatory variable in either analysis.

[31] The coefficient of determination for the second stage of two-stage least squares [Table 2-5] is defined:

$$R^2_{2SLS} = 1 - (\hat{\mu}'\hat{\mu} / \hat{R}'\hat{R})$$

(continued...)

instruments for G have positive partial correlation coefficients as expected.

In the final results [Table 2-5], the positive, significant coefficient on government investment indicates that, all else equal, an increase in government investment will cause an increase in rancher investment in public-rangeland improvements -- implying that $\mathbb{R}$ and $\mathbb{G}$ are complements in livestock production. This result is consistent with the fact that most range improvement projects are undertaken to improve livestock distribution for increased forage production and to protect sensitive areas from overuse. For example, while riparian areas account for only a small portion of the forage available on an allotment, they frequently represent a disproportionate amount of the forage consumed. The intensive foraging causes long-term damage to vegetation, fisheries, and the water source itself [GAO 1988]. Ranchers respond positively to government investment in rangeland improvements because they can extend the livestock-distribution and forage-production benefits of, for instance, a government-provided well, by investing in pipelines, water troughs or fencing. Similarly, improvements in rangeland condition from government brush-control projects can be aided by rancher reseeding. Government investment in rangeland improvements can increase the expected rate of return to private range-improvement projects which otherwise would not provide sufficient marginal benefits to livestock production to justify their marginal costs. The magnitude of the partial correlation coefficient suggests that a 10 percent increase in government investment increases rancher investment by about 9 percent.

The results confirm that an increase in the grazing fee causes a decline in rancher

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[31](...continued)
where $\hat{\mu} = \mathbf{R} - \hat{\mathbf{R}}$, from the second stage, and $\hat{\mathbf{R}}$ represents deviations from mean values. The R^2_{2SLS} so defined cannot exceed unity but it can be negative. It therefore does not have the usual interpretation of R^2 as the proportion of variance explained by the regression [Intriligator 1978].

investment in range improvements. Higher fees reduce net income available for projects and diminish the market value of public-land grazing permits, which cuts into rancher collateral for loans to finance investment projects. This result is consistent with the fact that rancher range-improvement projects are less capital-intensive than those undertaken by the government [Vanzandt 1994]. Higher fees also reflect erosion of the control that ranchers have over their use of the federal rangelands [Libecap 1981]. Grazing privileges held by ranchers are tenuous because the government is free to reallocate rangeland and alter use privileges to meet changing political conditions [Gardener 1991]. The partial correlation coefficient suggests that a 10 percent increase in the grazing fee causes a 13 percent reduction in private investment in public-rangeland improvements.

The negative, significant coefficient on the Federal Land Policy and Management Act dummy variable is consistent with the important reduction in the degree of rancher management control over the public lands that occurred in 1976. As discussed above, FLPMA signalled a fundamental change in the nature of federal land policy, decisively enhancing the BLM's control and regulation of grazing on the federal range. The approximate 30 percent decrease in rancher investment suggested by the partial correlation coefficient corroborates Fowler and Gray's [1980] finding that grazing permits on public lands subject to less bureaucratic control command higher appraisal values.

The positive, border-line significant coefficient on the beef cattle price index reflects the effect of increased revenue from livestock production on the level of rancher investment in public-rangeland improvements. However, the index of prices paid for inputs into western livestock production was not a significant determinant of rancher investment. Contrary to

expectations, the investment tax credit also had no significant influence on the level of rancher investment in public-rangeland improvements.

It is important to consider the possibility that there is an alternative explanation for the positive relationship between $\mathbb{G}$ and $\mathbb{R}$. Recall that only prior-year grazing-fee revenue has a significant effect on government investment in the first-stage results. Two factors could cause an increase in prior-year revenue: an increase in the prior-year grazing fee, or an increase in prior-year use of allowable public-land AUMs. First, we can dismiss the possibility that the positive coefficient is due to increases in the grazing fee causing increases in both $\mathbb{G}$ and $\mathbb{R}$ because the grazing fee ($\mathbb{F}$) has a negative, significant effect on $\mathbb{R}$. Second, it is possible that the economic environment for the livestock industry might increase public-land use by ranchers, leading to increased grazing-fee revenue and higher rancher investment. However, although positive demand shocks -- which would tend to be associated with increases in both the beef cattle price index and land use by ranchers -- are consistent with increases in both $\mathbb{G}$ and $\mathbb{R}$, it is unlikely that this drives the relationship because the beef cattle price index ($\mathbb{BCPI}$) is included in the specification. Positive supply shocks -- which would tend to be associated with a decrease in the beef cattle price index and an increase in land use by ranchers -- are also unlikely to be responsible for the positive relationship between $\mathbb{G}$ and $\mathbb{R}$ because the coefficient on $\mathbb{BCPI}$ is positive.[32] In sum, these alternative hypotheses do not appear to undermine the interpretation of the positive partial correlation coefficient on government investment as reflecting the complementarity of government and private investment in public-rangeland improvements.

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[32] As shown in Column (D) of Tables 2-4 and 2-5, the signs, magnitudes, and significance levels of the other coefficients do not change when the beef cattle price index (BCPI), which is plausibly endogenous to the story, is omitted from the specification.

The state-by-state estimation results are presented in Table 2-6. In each state, the signs of the coefficients on the variables of interest are as expected: the coefficient on government investment is positive and the coefficients on the grazing fee and the FLPMA dummy are negative. While on the whole, coefficient estimates are not significant, state-level estimation attests to the stability of the pooled results. Figure 2-4 shows the 95% confidence limits for the state coefficients on government investment and the grazing fee; in each case, overlapping confidence intervals coincide at coefficient values very similar to those estimated using the pooled sample.

The analysis outlined incorporates the interest rate as an element of the production inputs price index [Appendix A]. There are two reasons for relying on this linear restriction. First, econometric tests of the orthodox theory of investment generally find that interest rates are an insignificant, or perhaps weak, determinant of investment demand. This result is consistent with recent theoretical work showing that the effect of interest rates on investment is ambiguous due to uncertainty, irreversibility, and choice associated with the timing of investment [Dixit and Pindyck 1994]. Second, there is a high positive correlation between the real interest rate and the variable FLPMA, suggesting the possibility of estimation problems due to multicollinearity if both are directly included as explanatory variables.[33]

Table 2-7 presents the second-stage results without this linear restriction[34]

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[33] As an alternative, any significant parameter estimates for the production inputs price index resulting from the specification could be used to determine the effect of the interest rate on rancher investment, given the relationship between the production inputs price index and the interest rate.

[34] In the unrestricted model, the real interest rate (RIR) is no longer constrained to be an element of the production inputs price index variable, thus, the adjusted variable, PPIA, contains only the elements of the original PPI that are orthogonal to the real interest rate.

$$R_{it} = \beta_0 + \beta_1 \hat{G}_{it} + \beta_2 F_t + \beta_3 FLPMA_t + \beta_4 BCPI_t + \beta_5 PPIA_t + \beta_6 ITC_t + \beta_7 RIR_t + \varepsilon_{it}$$

There are two important observations to be made. First, the results are qualitatively similar to those obtained in the restricted version of the model.[35] The magnitude of the estimated coefficients differs however. For example, the estimated effect of a 10 percent change in government investment on rancher investment declines from 9 percent to 7 percent. The estimated decline in rancher investment from a 10 percent increase in the grazing fee falls to 8 percent from 13 percent.[36] Second, the coefficient on the real interest rate is positive and significant. While this is a puzzling result in the context of orthodox investment theory, where an increase in the interest rate decreases the expected present value of the profit stream thus decreasing investment, recent theoretical work on investment under uncertainty demonstrates a positive aspect of the relationship between interest rates and investment. This real options approach focuses on the fact that projects involving irreversible investment expenditures compete with themselves delayed in time. The decision to invest today must incorporate the forfeited value of keeping that particular investment option alive. Thus, an increase in interest rates not only decreases the value of investing, it also makes the future relatively less important and decreases the opportunity cost of exercising the option to invest. Capozza and Li [1994] demonstrate that some investment projects may be undertaken after an increase in interest rates that would not have been initiated at lower rates. This is due to a decline in the value of the option to invest, and in the corresponding reservation cash flow from the investment, associated

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35 As before, nine state dummy variables are included in the specification.

36 As was the case with the earlier specification, the state-level coefficients for government investment and the grazing fee, while on the whole not significant, are reasonably stable.

with the interest rate increase.

2.7 Conclusion

The empirical evidence suggests that recently proposed amendments to BLM regulations would have consequences for the quality of stewardship provided by public-land ranchers. First, provisions which allow BLM range-improvement funds to be used for planning, design, monitoring, and evaluation would tend to reduce the level of government investment in on-the-ground rangeland improvements, which would in turn decrease rancher investment. Second, a now-abandoned proposal to increase the grazing fee from $1.98 per AUM in 1994 to $2.75 per AUM in 1995, $3.50 per AUM in 1996, and $3.96 per AUM in 1997, with annual changes thereafter limited to 25 percent, would have tightened financing constraints for private ranchers and raised further doubts about the security of long-run returns from private investments. This study indicates that a 25 percent increase in the grazing fee, ceteris paribus, would cause a decline of about 33 percent in rancher investment in public-rangeland improvements. Third, provisions to further reduce rancher management control on public rangelands and eliminate private property rights to certain improvement projects would depress rancher investment. The most notable changes would provide for federal ownership of all future permanent improvements on public lands. In cases involving the development and registration of new rights to water on public land for livestock watering, such rights would be contingent upon their use in conjunction with grazing permits and would not convey any claim for compensation in the case of permit cancellation to devote the lands to another public purpose [Federal Register 1994].

Future research might more fully address the empirical question of whether government and private investments are substitutes or complements in livestock production, as well as the exact nature of the complementarity, by obtaining disaggregated investment data identifying projects on an allotment-by-allotment basis.[37] Disaggregated data might also be used in disentangling the financial effects of the fee on rancher investment from the impact of changes in tenure security associated with changing fees by drawing distinctions between allotments on the basis of ecological sensitivity.

[37] This information could also be used in assessing the optimality of government investment decisions by incorporating measures of non-grazing public resource values associated with each project.

Figure 2-1:

Public Lands administered by the Bureau of Land Management

PUBLIC LANDS IN THE WESTERN STATES

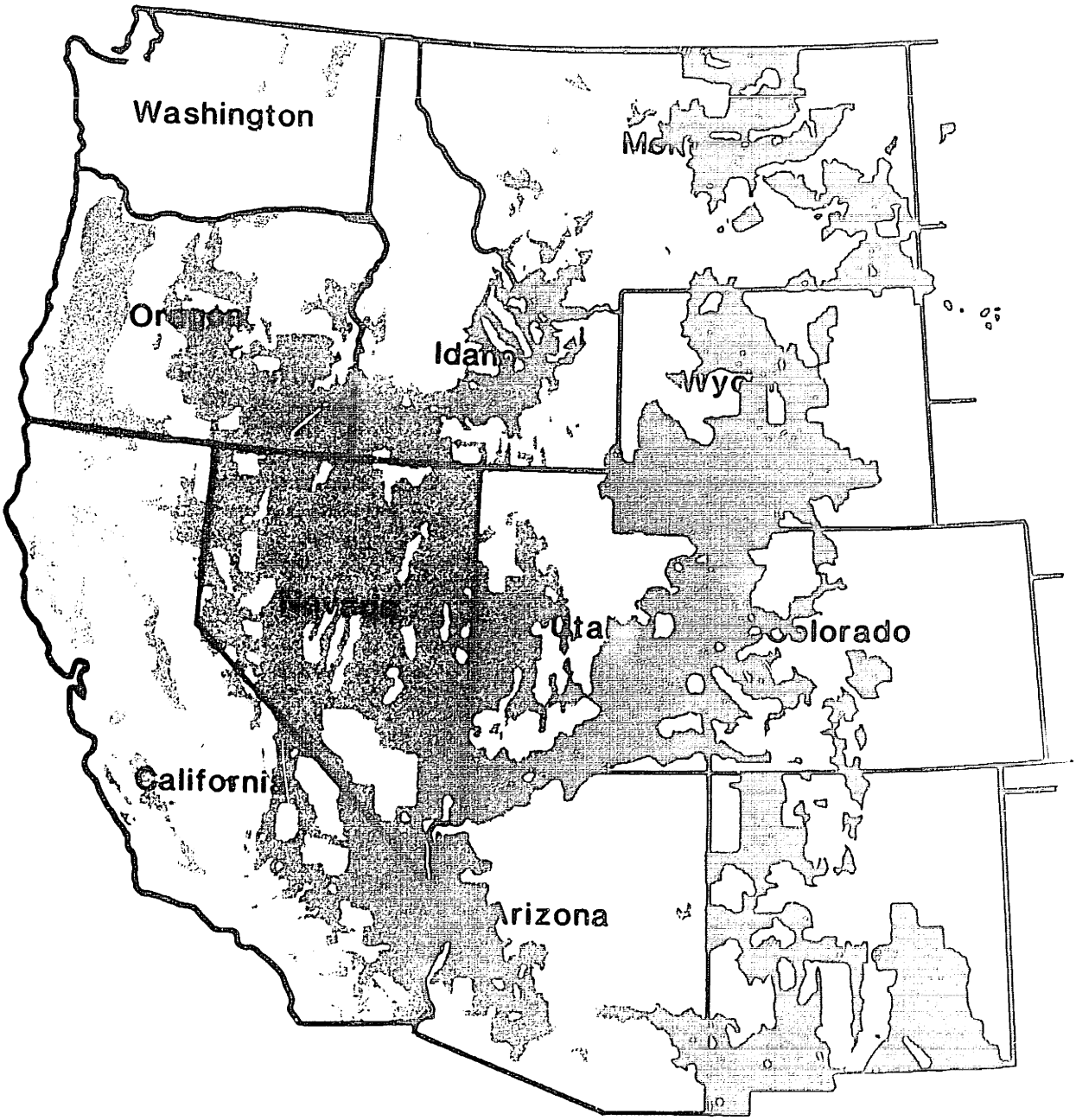
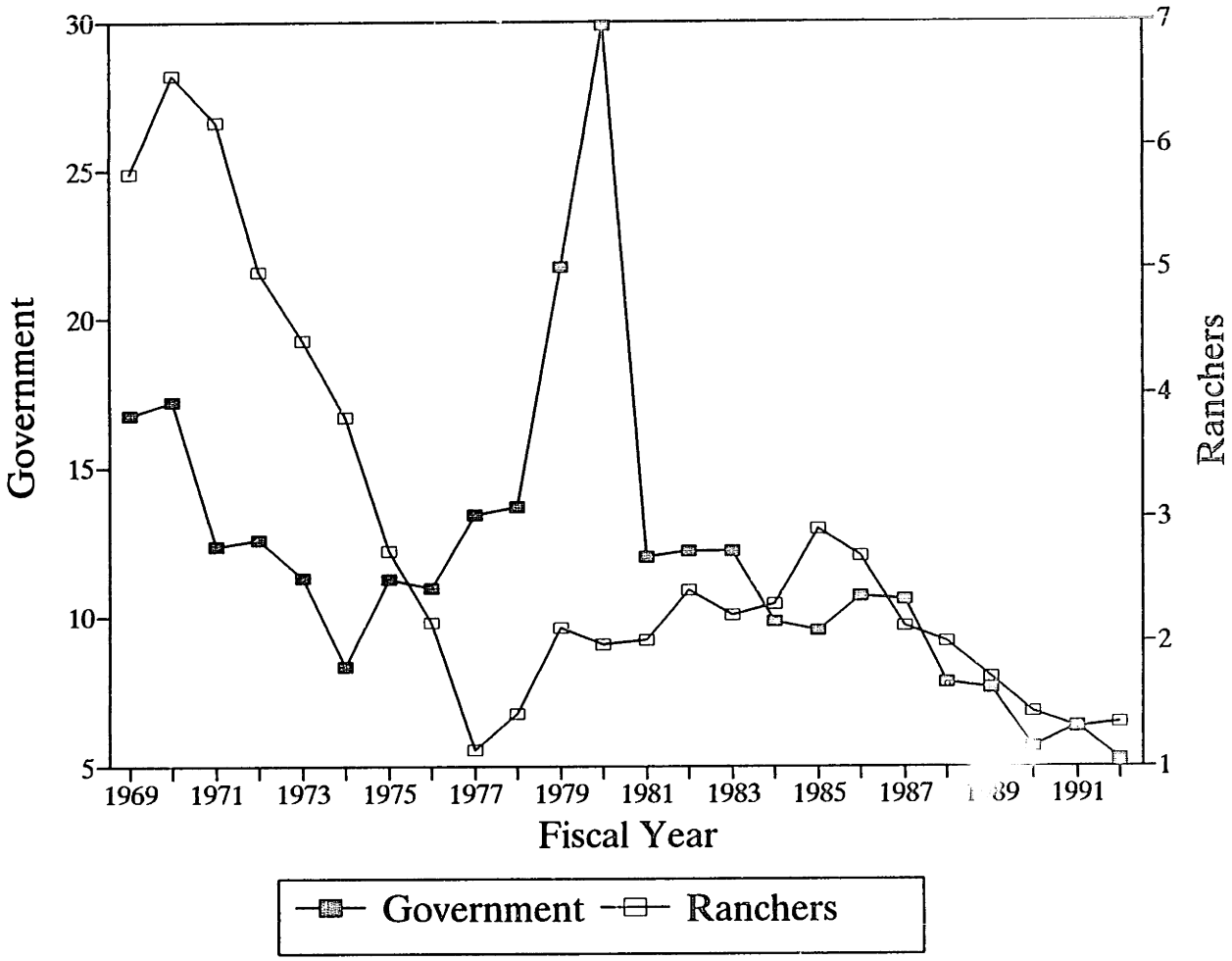
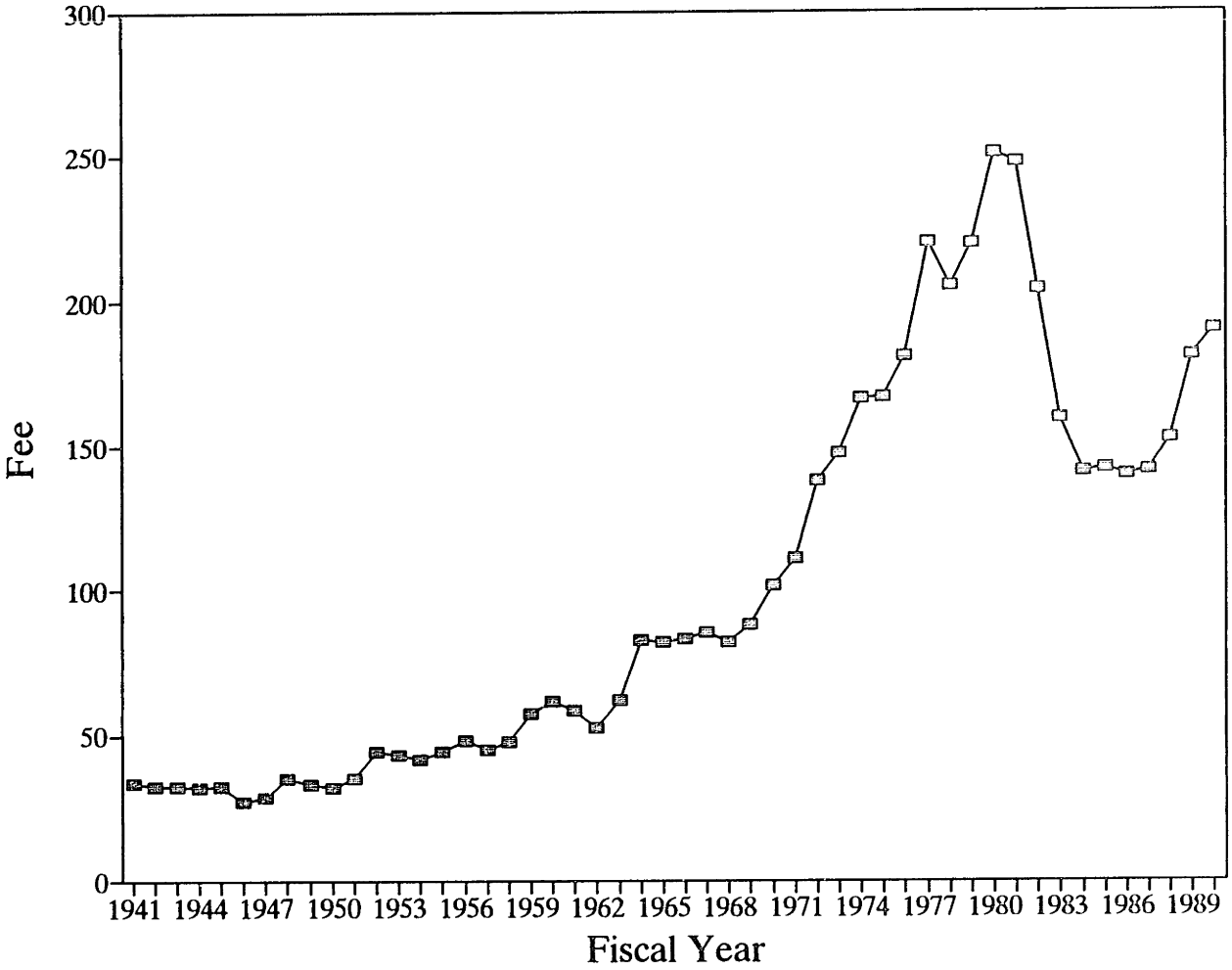


Figure 2-2: Improvement Investments
(Real 1991 $ Millions)



Source: RIPS/BLM,CEA 1994

Figure 2-3: Grazing Fee Per AUM
(Constant 1982 Cents)



Source: US Departments of Agriculture and the Interior 1992, CEA 1991

Figure 2-4: State Coefficient Estimates and Confidence Intervals
Government Investment and Grazing Fee

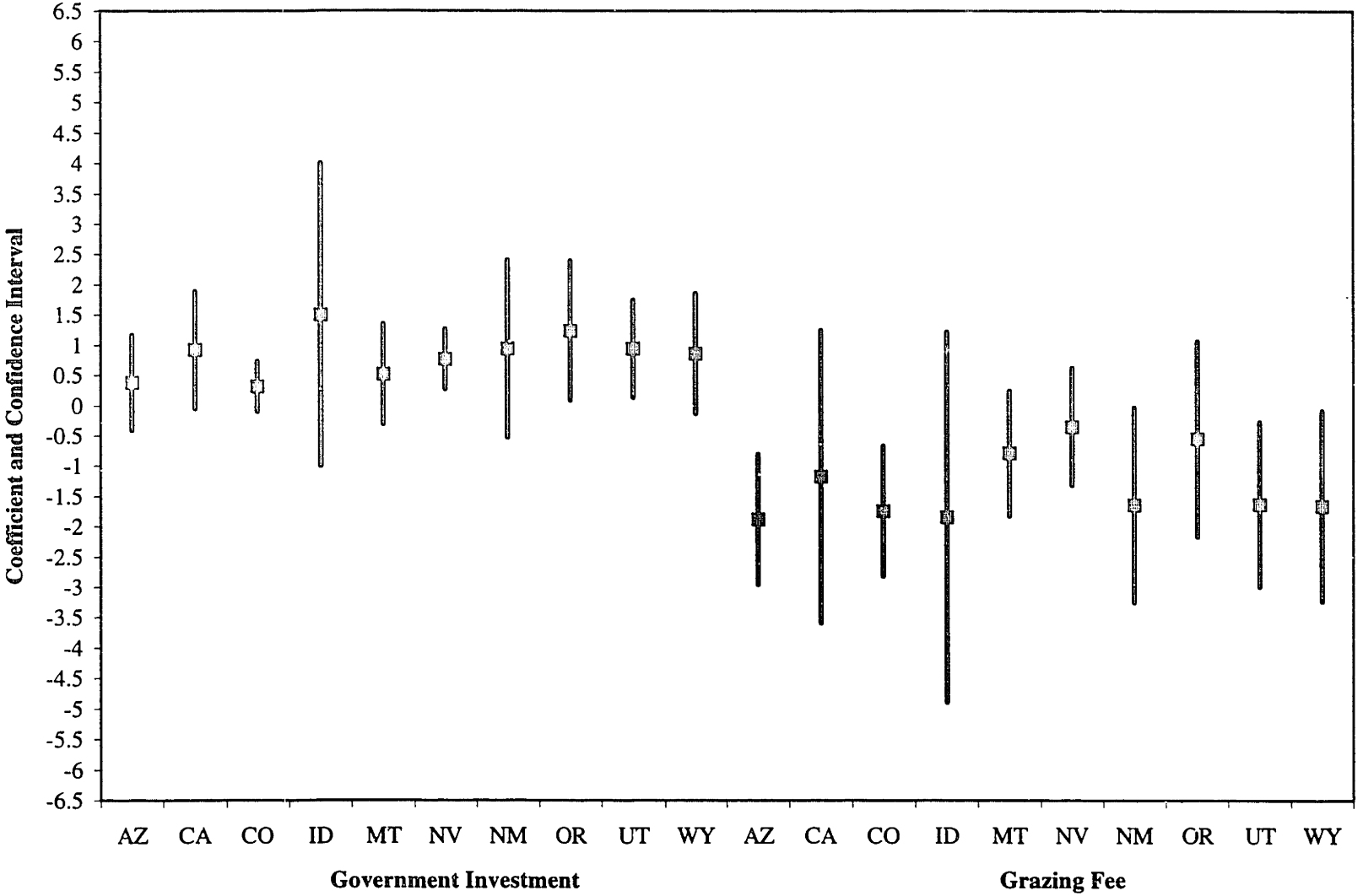


Table 2-1: Average Annual Investment in Rangeland Improvements 1969-1992[38]
($000 1991)

	Ranchers	BLM	Other Government	All Sources
Arizona	274	820	95	1170
California	69	452	114	635
Colorado	170	757	81	1008
Idaho	411	1902	52	2365
Montana	322	999	30	1351
Nevada	403	1676	121	2200
New Mexico	413	1045	35	1494
Oregon	194	1443	103	1741
Utah	267	1523	81	1871
Wyoming	299	682	65	1046
All States	2822	11280	777	14880
Percent of Total	19.0	75.8	5.2	100.0

[38] Implicit price deflator: Producers' Durable Equipment 1991=100 [CEA 1994].

Table 2-2: Investment by Source and Project Type 1969-1992
(% of Total Investment)

	Ranchers		BLM		Other Government	
	Water Developments	Fences	Water Developments	Fences	Water Developments	Fences
Arizona	70	23	69	17	51	16
California	40	40	29	32	31	43
Colorado	31	55	52	25	28	41
Idaho	34	45	32	25	45	31
Montana	59	34	62	23	42	43
Nevada	50	34	25	50	38	40
New Mexico	65	22	61	15	49	18
Oregon	39	40	41	23	47	30
Utah	44	35	38	16	46	23
Wyoming	42	51	60	28	58	29
Average	47	38	47	25	44	31

Table 2-3: Public Land Policy and Private Investment (OLS)[39]

Dependent Variable:
Rancher Investment in Public-Rangeland Improvements

	(A)	(B)	(C)
Constant	4.22 (2.09)	3.62 (1.86)	5.05 (1.25)
Government Investment	0.32 (0.06)	0.33 (0.06)	0.34 (0.05)
Grazing Fee	-1.35 (0.21)	-1.19 (0.16)	-1.21 (0.16)
FLPMA	-0.42 (0.12)	-0.47 (0.11)	-0.41 (0.09)
Beef Cattle Price Index	1.13 (0.27)	1.08 (0.26)	1.17 (0.24)
Production Inputs Price Index	0.34 (0.38)	0.36 (0.36)	----
Investment Tax Credit	0.12 (0.08)	----	----
R^2	0.98	0.98	0.98

(Standard errors in parentheses)

[39] State dummy variables are included.

Table 2-4: Public Land Policy and Private Investment (IV - First Stage)[40]

Dependent Variable: Government Investment

	(A)	(B)	(C)	(D)
INSTRUMENTS				
Grazing-Fee Revenue	1.06 (0.21)	1.11 (0.21)	1.11 (0.17)	1.13 (0.22)
Committee Membership	0.34 (0.62)	0.34 (0.62)	0.34 (0.62)	0.20 (0.63)
INCLUDED EXOGENOUS VARIABLES				
Constant	-2.69 (1.43)	-2.75 (1.37)	-2.72 (1.21)	-2.72 (1.18)
Grazing Fee	-0.93 (0.29)	-0.81 (0.27)	-0.83 (0.24)	-0.68 (0.29)
FLPMA	0.07 (0.13)	0.05 (0.13)	0.05 (0.09)	-0.17 (0.10)
Beef Cattle Price Index	0.85 (0.30)	0.77 (0.29)	0.77 (0.25)	----
Production Inputs Price Index	0.12 (0.42)	0.03 (0.41)	----	0.64 (0.39)
Investment Tax Credit	0.09 (0.09)	----	----	0.02 (0.09)
R^2	0.57	0.57	0.57	0.58

(Standard errors in parentheses)

[40] State dummy variables are included.

Table 2-5: Public Land Policy and Private Investment (IV - Second Stage) [41]

Dependent Variable:
Rancher Investment in Public-Rangeland Improvements

	(A)	(B)	(C)	(D)
β_0 Constant	3.90 (1.75)	3.89 (1.67)	3.17 (1.20)	3.34 (1.51)
β_1 Government Investment	0.95 (0.25)	0.94 (0.23)	0.85 (0.17)	0.96 (0.21)
β_2 Grazing Fee	-1.19 (0.28)	-1.30 (0.22)	-1.27 (0.20)	-1.10 (0.27)
β_3 FLPMA	-0.32 (0.15)	-0.29 (0.14)	-0.36 (0.10)	-0.48 (0.15)
β_4 Beef Cattle Price Index	0.54 (0.43)	0.63 (0.38)	0.61 (0.36)	----
β_5 Production Inputs Price Index	-0.31 (0.52)	-0.30 (0.48)	----	0.23 (0.60)
β_6 Investment Tax Credit	-0.06 (0.11)	----	----	-0.09 (0.10)
R^2_{2SLS}	0.98	0.98	0.98	0.97

(Corrected standard errors in parentheses)

[41] State dummy variables are included.

Table 2-6: Public Land Policy and Private Investment - State Results

Dependent Variable:
Rancher Investment in Public-Rangeland Improvements

	State				
	AZ	CA	CO	ID	MT
Constant	8.31 (3.05)	2.28 (6.98)	1.59 (2.52)	-2.47 (7.47)	1.79 (3.12)
Government Investment	0.38 (0.38)	0.92 (0.47)	0.32 (0.20)	1.50 (1.21)	0.52 (0.40)
Grazing Fee	-1.88 (0.52)	-1.17 (1.17)	-1.74 (0.52)	-1.84 (1.48)	-0.79 (0.50)
Beef Cattle Price Index	1.02 (0.90)	0.37 (1.51)	2.33 (0.53)	0.86 (1.56)	1.15 (0.84)
FLPMA	-0.27 (0.26)	-0.21 (0.58)	-0.44 (0.22)	-0.06 (0.59)	-0.26 (0.25)
R^2	0.67	0.41	0.80	0.71	0.58

	NV	NM	OR	UT	WY
Constant	-1.34 (2.91)	6.62 (4.63)	2.37 (4.88)	7.73 (4.14)	5.76 (4.60)
Government Investment	0.77 (0.24)	0.94 (0.71)	1.24 (0.56)	0.94 (0.39)	0.86 (0.48)
Grazing Fee	-0.35 (0.47)	-1.64 (0.78)	-0.55 (0.78)	-1.63 (0.66)	-1.66 (0.76)
Beef Cattle Price Index	0.78 (0.61)	0.10 (1.33)	-0.78 (1.62)	-0.19 (1.21)	0.45 (1.09)
FLPMA	-0.48 (0.24)	-0.14 (0.40)	-0.54 (0.38)	-0.60 (0.41)	-0.51 (0.35)
R^2	0.75	0.58	0.67	0.64	0.65

(Corrected standard errors in parentheses)

Table 2-7: Public Land Policy and Private Investment - Unrestricted Model[42]

$$R_{it} = \beta_0 + \beta_1 \hat{G}_{it} + \beta_2 F_t + \beta_3 FLPMA_t + \beta_4 BCPI_t + \beta_5 PPIA_t + \beta_6 ITC_t + \beta_7 RIR_t + \epsilon_{it}$$

Dependent Variable:
Rancher Investment in Public-Rangeland Improvements

	(A)	(B)	(C)
Constant	2.00 (1.54)	1.90 (i.62)	2.37 (1.49)
Government Investment	0.76 (0.25)	0.71 (0.18)	0.68 (0.17)
Grazing Fee	-0.72 (0.39)	-0.69 (0.29)	-0.85 (0.21)
FLPMA	-0.65 (0.19)	-0.72 (0.16)	-0.66 (0.13)
Beef Cattle Price Index	0.54 (0.35)	0.63 (0.36)	0.72 (0.32)
Adjusted Production Inputs Price Index	-0.18 (1.47)	----	----
Investment Tax Credit	-0.10 (0.10)	-0.08 (0.10)	----
Interest Rate	0.06 (0.03)	0.08 (0.03)	0.07 (0.02)
R^2_{2SLS}	0.98	0.98	0.98

(Corrected standard errors in parentheses)

[42] State dummy variables are included.

Chapter 3

3 On the Political Economy of Municipal Curbside Recycling Programs: Evidence From Massachusetts

3.1 Introduction

Between 1990 and 1992, the number of municipal curbside recycling programs in the United States doubled [Steuteville 1994]. Some have argued that recycling is an expensive luxury that cash-strapped municipalities can ill-afford. For example, Holusha [1993] asserts:

> "Most people feel good about recycling, convinced that they are helping save the planet, and their communities, by conserving resources and saving landfill space. What they're also doing, though, is taking money away from health care and other basic services."

David Gatton, Senior Environmental Adviser to the U.S. Conference of Mayors states:

> "Recycling ... costs money. Money that could go for schools is being absorbed by increasing disposal costs."

Critics of recycling point out that revenue from sales of recyclable materials is insufficient to cover collection and processing costs. A wide variety of organizations such as the National Solid Waste Management Association, Waste Management Incorporated, the Reason Foundation, and the Clean Washington Center estimate that the average net cost per ton of a curbside recycling program, i.e. the cost of collection and sorting (roughly $180) minus the revenue from sales of recyclables (roughly $50), is about $130 [Griffith 1992, Apotheker 1993, Steuteville

1993, Waste Management of North America 1992]. The result is a view of recycling well-illustrated by the statement of Jerry Taylor, Director of Natural Resource Studies at the Cato Institute:

> "Recycling programs are efficient when they are able to turn a profit, but most of these mandatory curbside programs aren't profitable. They're simply subsidizing the collection and processing of materials that should probably be buried or burned." [Allen 1992]

It is crucial to note however, that the profitability of a recycling program is not just the revenue from the sale of recyclables less the cost of collection and sorting.[43] There is also the "avoided cost" of refuse collection and disposal. As older landfills reach capacity, environmental regulations increase in stringency, and public opposition to the siting of new disposal facilities is increasingly well-organized, refuse disposal costs rise. Average tipping fees at municipal solid waste landfills increased by 17 percent between 1990 and 1992, reaching a high of $66 per ton in the Northeast region [Repa 1993].[44] Waste-to-energy facilities in the Northeast charged comparable tipping fees [Berenyi and Gould 1993a]. It is also important to note that recycling and refuse costs vary widely across communities [Apotheker 1993]. In sum, the correct basis for a fiscal evaluation of a curbside recycling program is the impact of the program on a community's total solid waste management costs.

In addition to this economic consideration, there may be a political rationale for municipal adoption of a curbside recycling program. Popular support for recycling rose substantially in the early 1990s. The fraction of Americans regularly sorting household trash

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[43] "Municipalities concerned about recycling costs may want to take another look. A study of recycling costs ... by the Institute for Local Self-Reliance finds that such programs can actually save tax dollars." [Kansas 1993]

[44] The Northeast region of the United States, which includes Massachusetts, has the highest tipping fees in the country.

for recycling rose from 24 percent in 1990 to 37 percent in 1991, and seven in ten Americans believed local governments were not doing enough to ensure that solid waste materials were recycled [The Roper Organization 1991]. The popularity of recycling among environmental interests implies that program adoption can yield political benefits to office-holders [West et. al. 1990]. Citizens concerned about the environment may pressure city governments to provide recycling programs.[45] As the mobilization of interest groups at the community level can have a decisive impact on municipal policy choices, a well-organized environmental lobby will increase the likelihood of adoption of a recycling program [Schumaker et. al. 1986].

Previous empirical research on municipal solid waste management focuses primarily on household behavior and most studies examine refuse programs. While some recent papers do deal directly with recycling, only one has addressed municipal decision-making. Studies by Wertz [1976], Jenkins [1991], and Hong et. al. [1993] examine the effects of prices for disposal services and income on household generation of solid waste. Modelling the interaction between household preferences, solid waste management options, and prices, Morris and Holthausen [1994] conclude that household response elasticities can vary widely over common price ranges and that relatively large household welfare gains may be obtained by adopting curbside recycling and unit pricing programs. Duggal et. al. [1991] examine the relationship between various household characteristics and the types and volumes of materials recycled. Judge and Becker [1993] compare marginal costs of increased household convenience of recycling programs to expected marginal increases in recyclables collected to determine the efficient level of

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[45] A recent survey found that 97% of all U.S. households participating in recycling activities did so because of concern for the environment [Boltz 1994].

convenience for a given recycling program. Keeler and Renkow [1994] model the municipal decision to build a waste-to-energy facility, demonstrating that desirability of incineration and optimal facility size depend on waste stream characteristics as well as underlying costs of various disposal options including waste-to-energy facilities, landfills, and recycling.

This chapter examines the political economy of a municipality's decision to adopt a curbside recycling program using an original data set on the economic and political characteristics of 80 towns in Massachusetts. The chapter makes three important contributions. First, the analysis corrects for the sample-selection bias present in many earlier studies that compare recycling and refuse costs only in towns with recycling programs. These costs are not necessarily relevant for towns that do not have recycling programs. Second, the study takes explicit account of the political rationale for the adoption of curbside recycling programs. Third, expectations of demand for future refuse disposal capacity are partly captured by identifying towns whose landfills are expected to close within four years.

The plan of the chapter is as follows. Section 3.2 provides background information on the economics of solid waste management in Massachusetts, including collection arrangements, disposal options for refuse, processing operations for recyclables, and secondary materials markets. Section 3.3 models the municipal decision regarding recycling program adoption as a function of the cost of the curbside recycling program, the avoided refuse cost, expected refuse disposal costs as represented by the perceived need to conserve existing landfill space, and the level of environmental activism in the community. The problem of estimating the model using a non-randomly selected sample, i.e. only those towns that have adopted curbside recycling programs, is addressed with the use of Heckman's correction for sample selection bias. Section

3.4 describes the data used in the analysis. I focus on the cost of the curbside recycling program and the avoided costs, or savings, achieved because of the reduced tonnage handled by the refuse program. I impute data on recycling program costs for municipalities that do not provide such services by using coefficients from the estimation of a recycling cost equation fit on the sub-sample of towns with recycling programs while correcting for sample selection bias. The analysis reveals that, on average, communities that recycle save $62,000 annually on total solid waste management costs while those that do not avoid a $78,000 increase in their annual solid waste management budget.

Section 3.5 presents empirical results. The probit analysis of municipal adoption of curbside recycling programs shows that both the impact of program adoption on the total solid waste management budget and the level of community membership in environmental interest groups are significant determinants of the existence of a curbside recycling program. The economic effect is attributable not to the cost of the recycling program itself, which has no significant effect on the probability of adoption, but to the avoided costs in refuse management. One might expect a rational decision-maker to treat the cost of a recycling program and the savings associated with avoided refuse costs in a symmetric manner when considering program adoption because both have the same effect on the municipal bottom line. A possible explanation for the difference in how these two costs are viewed is that media focus on rising disposal costs has heightened sensitivity to refuse program costs while popular support makes recycling costs a less sensitive issue. According to National Solid Waste Management Association polls, most Americans want to recycle and are willing to pay for it [Miller 1993]. Section 3.6 concludes and suggests directions for future research.

3.2 Background

Municipal governments typically assume financial and management responsibility for residential solid waste. The cost of municipal solid waste management generally ranks behind only education and police and fire protection in municipal budgets [Hershkowitz 1993]. These three services are also frequently identified as issues of serious concern among citizens. A recent poll by the Roper Organization [1991] asked respondents to rate their level of concern regarding seventeen different national issues -- 68 percent classified crime as a serious problem, 58 percent cited the quality of public school education, and 47 percent identified the disposal of solid waste. Three-quarters of Americans viewed solid waste disposal in their own communities as a serious problem in 1991, compared to just 58 percent three years earlier.

Residential solid waste services are provided either by municipal agencies or by private firms. Massachusetts ensures a competitive market in private waste services by requiring municipalities to publicly solicit bids for any private provision of a municipal service. The terms and conditions of the service to be provided must be described explicitly in the municipality's solicitation. Bids must be evaluated as submitted and terms are non-negotiable. The resulting contracts may cover periods of three or more years. The costs of the residential service are specified on an annual basis in one of the following ways: (1) the total annual contract cost covers the collection, transportation, and disposal (or delivery in the case of recyclables) of materials, or (2) the contract has two separate cost components -- total annual cost for collection and transportation of materials, and a per-ton tipping fee for disposal (or delivery). A community might also have two separate contracts, one addressing collection and

transportation, and the other addressing disposal (or delivery). For example, a contract with a private firm might specify total annual cost for collection and transportation of refuse to a waste-to-energy facility. A second contract, specifying a per-ton fee for refuse disposal, would exist between the municipality and the waste-to-energy plant.

Residential waste can be divided into two streams -- refuse and recyclable materials. Refuse disposal occurs at landfills or waste-to-energy facilities. In Massachusetts, landfills may be publicly- or privately-owned. Landfills owned and usually used exclusively by a single municipality do not identify a tipping fee for their own residential refuse, but data on landfill capital and operating costs are available. Landfills owned by several municipalities have either a tipping fee or an alternative cost-sharing arrangement. Private landfills owned by small firms engaged exclusively in disposal services accept refuse from different haulers upon payment of a tipping fee. Landfills owned by large, vertically-integrated disposal companies often accept refuse only from their own haulers.

All active waste-to-energy plants in Massachusetts are designed and operated by private firms.[46] Many municipalities enter into long-term contracts with these facilities for the disposal of residential waste. As revenue from the sale of electricity or steam generated from burning solid waste covers only part of operating and capital costs, waste-to-energy facilities charge a tipping fee for refuse disposal. Tipping fees are assessed on delivered tonnage and may also be charged for guaranteed-but-not-delivered tonnage. Some facilities reserve the right to

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[46] Municipalities may select full-service disposal contracts with "merchant" or privately-owned facilities, but waste-to-energy facilities are usually developed jointly by municipal governments and private firms. In this case, municipalities often finance projects on their own and commit to operating contracts for disposal services; alternatively, the municipality might contract with a firm to build a facility that will be owned and operated by the municipality [Marron 1993].

charge additional penalty fees for guaranteed-but-not-delivered tonnage in order to compensate for revenue lost due to reduced energy production.

Recyclable materials must be processed, i.e. sorted and have their contaminants eliminated, before they are supplied to end-users. Recyclables can be processed either at collection sites, by dealers who hand-sort loads of mixed recyclables, or by materials recovery facilities which accept high volumes of recyclables and use sophisticated capital equipment for processing. While materials recovery facilities produce recyclables in cleaner, larger loads that are considered more marketable, dealers provide processing close to the collection site and can more easily exploit relationships with local end-users to whom they want to supply recyclables. End-users are companies, including foundries and plastic and paper manufacturers, that substantially transform recyclable materials into new products.[47]

Markets for recyclables are regional and material-specific. For example, in August of 1990, prices received by collection agents ("processor prices") in the Northeast ranged from $660.00 per ton for aluminum beverage cans to - $2.00 per ton for newspaper.[48] During the same period, the processor price in the West for aluminum beverage cans was only $440.00, and the price for newspaper in the South Central region was as high as $10.00 [Recycling Times 1990]. Processor prices are highly correlated with prices paid by end-users ("end-user prices").

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[47] In some cases, recyclable materials compete with virgin inputs into production processes and may require different processing equipment than that used for virgin materials.

[48] The prices for these two items represent the boundaries of the range of market prices commanded by different recyclable materials. The northeast region includes Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont.

Materials with low or zero end-user prices may have negative processor prices.[49] Figures 3-1 a and b illustrate the relationship between processor and end-user prices in the Northeast region for newspaper and aluminum beverage cans. These figures also demonstrate the high variability of recyclable prices.

3.3 Program Adoption: Economics or Politics?

A municipality's choice regarding the adoption of a curbside recycling program depends on economic and political considerations. The relevant economic variables are the cost of the recycling program, the avoided refuse cost, and expectations of future refuse disposal cost related to anticipated demand for disposal capacity. The main political variable is the degree of interest group pressure in support of the adoption of the recycling program. The net utility of the political leadership of the municipality (henceforth, the mayor) from the adoption of the recycling program is a function of these economic and political variables,

$$U^* = \gamma' x + e \qquad (3.1)$$

where x is a vector containing the variables discussed above and e captures the non-economic, non-political factors that influence the mayor's utility and are assumed to have mean zero and a normal distribution.

If $U^* \geq 0$ the mayor adopts curbside recycling; if $U^* < 0$ there is no such program. Although U^* itself is unobservable, the sign of U^* is revealed by whether or not a municipality

[49] A study assessing materials recovery facility processing costs concludes tipping fees are necessary because revenue from end-user prices are not sufficient to cover operating costs [Weston 1992].

has adopted a curbside recycling program. This information is used to construct a discrete dependent variable, U, that takes on a value of one if the municipality provides curbside recycling services and zero otherwise. Thus,

$$\text{Prob}\,[U = 1] = \Phi(\beta' x)$$

where $\Phi(\beta' x)$ is the normal cumulative density function. The probability that a municipality provides curbside recycling services is

$$E[U] = 0[1 - \Phi(\beta' x)] + 1[\Phi(\beta' x)] = \Phi(\beta' x)$$

U is modeled according to Equation (3.2)

$$U = \alpha + \beta_1 \ln RECC + \beta_2 \ln REFC + \beta_3 \ln FREFC + \beta_4 \ln ENV + \varepsilon \quad (3.2)$$

where **RECC** is the cost of the curbside recycling program, **REFC** is avoided refuse cost, **FREFC** is a dummy variable that captures expectations of future refuse disposal costs in a simple way, and **ENV** is the level of community membership in environmental interest groups. The parameters of this equation are estimated by assuming epsilon is normally distributed -- this generates a standard probit specification.

One difficulty in the estimation of Equation (3.2) is that the variable **RECC** is only observable for towns that have a recycling program. Unfortunately, the cost of recycling programs in towns that have adopted them is not a reliable estimate of the cost of such programs in towns that have not. One possible reason for the lack of recycling programs is precisely that they may have cost relatively more. If only towns with recycling programs were used to estimate Equation (3.2), this non-randomly selected sample would yield a biased estimate of the behavioral relationship under investigation.

Heckman's [1979] approach controls for sample selection bias and is described in detail

in Appendix C. The basic strategy is to estimate a cost function for curbside recycling programs using the selected sub-sample of towns with recycling programs, while controlling for the expected bias. This produces consistent coefficient estimates which can then be used to impute recycling costs for towns without such programs. Given these imputed costs, full-sample estimation of Equation (3.2) is possible.

The cost of a recycling program depends on its size, the prices of the factors of production, and other town-specific characteristics. Consider a firm competing for a contract to collect recyclable materials at curbside and process them. Since previous studies of municipal refuse programs [Stevens 1978] have been unable to reject the hypothesis that the production function is homothetic and exhibits a constant elasticity of substitution not significantly different from one, the production function may be written as[50]

$$Y = \psi L^a K^b$$

where Y is the tonnage of recyclable materials collected and processed annually, ψ represents the state of technology and the joint effect of a set of fixed characteristics expected to change the intercept of the cost function across municipalities, L is labor, and K is capital. The firm's objective is to minimize the annual cost of collection and processing

$$\text{Min } \mathbf{RECC} = wL + rK \text{ subject to } Y = \psi L^a K^b$$

The first order conditions are $wL/a = rK/b$ and $Y = \psi L^a K^b$. Using the cost identity one obtains

$$L = a^*\mathbf{RECC} / w(a+b)$$

$$K = b^*\mathbf{RECC} / r(a+b)$$

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[50] The data collected for this study do not lend themselves to a separate analysis of the appropriate functional form for the production function.

Substituting these expressions into the production function and solving for total costs yields a log linear total cost function,

$$\ln RECC = \delta_0 + \delta_1 \ln w + \delta_2 \ln Y + \mu \qquad (3.3)$$

where

$$\delta_0 = (a+b)^{-1} [b \ln r - \ln \psi + a \ln(a+b) + b \ln(a+b) - a \ln a - b \ln b]$$

$$\delta_1 = a / (a+b)$$

$$\delta_2 = 1 / (a+b)$$

I assume that the price of capital, r, does not vary across municipalities. Both w and Y are expected to exert a positive influence on program costs. If there are economies of scale associated with program size, δ_2 will be less than one.

Through ψ, δ_0 captures the effects of various characteristics that are expected to change the intercept of the cost function across municipalities. These characteristics are the density of collection points (DENS), the distance to the delivery site (DIST), the mix of materials collected (PRICE), whether the service provider is a municipal agency or a private firm (MUNI), and the frequency of service (FREQ). Density (DENS), the ratio of the number of households to the residential land area, is determined by exogenous factors such as zoning laws, property lot size, and housing composition with respect to multi-family and single-family dwellings. In general, collection costs are expected to fall with the density of collection points. Distance to delivery site (DIST) is determined by materials recovery facility or dealer location -- this is in turn set by exogenous factors such as zoning, land costs, permitting ease, transport accessibility and end-user location. Collection costs are expected to rise with the distance to the delivery site. The net cost of a recycling program depends on revenue from the sale of recyclables, which depends

on the secondary market price of a particular basket of materials (PRICE). The types of materials collected are determined by receiving facilities and the prices of materials are given, since the amount of materials provided by each individual municipality is small relative to the market for recyclables. The higher these prices, the lower is the expected cost of the program.

The type of service provider (MUNI) may also influence program costs. Previous research has argued that municipal agencies are less efficient providers of solid waste management services than private firms.[51] For the towns in this study, use of a private company to provide refuse services indicates that recycling services will also be provided by private firms (except in the few cases where the state subsidizes recycling service provision by municipal employees). In contrast, the entrenched interests of municipal employees who already provide refuse services influence the mayor to use the same method of service provision for recycling programs. The legal requirements for the mayor to consider competitive bids for service provision only apply to situations in which it has been predetermined that a private contractor will be hired. Finally, while collection frequency is less exogenous, the psychology of program participation generally constrains frequency of pick-ups (FREQ) to a minimum of twenty-six per year [Steuteville et. al. 1994].[52] Collection costs are expected to rise with the frequency of service. As DENS, DIST and FREQ are expected to have a proportional effect

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[51] These studies are Kemper and Quigley [1976], Stevens [1978], Savas [1977], Savas [1981], McDavid [1985], and Domberger et. al. [1986].

[52] Due to the possibility that MUNI and FREQ are less exogenous, the estimation is performed both with and without these two variables in the definition of δ_0 shown in Equation (3.4) -- the corresponding results vary little [Tables 3-4 and 3-5, Columns (A) and (D)].

on RECC [Equation (3.3)], the appropriate specification is[53]

$$\delta_0 = \delta_0^* + \delta_3 \ln DENS + \delta_4 \ln DIST + \delta_5 PRICE + \delta_6 MUNI + \delta_7 \ln FREQ \quad (3.4)$$

3.4 Data

The sample for this study consists of observations on 80 towns in Massachusetts, 31 of which have recycling programs, for fiscal year 1992. The data for the independent variables of the recycling cost function are as follows. First, for all observations, the average hourly wage for drivers of medium-sized trucks in the metropolitan area in which the town is located (w) was obtained from the Bureau of Labor Statistics [1992]. According to the BLS definition, truckdrivers transport materials within a city or industrial area and may also load or unload materials with or without helpers. The definition of medium-sized trucks, 1.5 to 4 tons inclusive, corresponds to the range of vehicle sizes used in various recycling programs examined in previous recycling studies [Platt et. al. 1992]. Second, the annual tonnage of materials recycled (Y) was reported by towns with recycling programs and averaged 130 pounds per capita. The potential recyclable tonnage (Y) for the remainder of the sample was obtained by multiplying this figure by town population.

Third, density of collection points (DENS) is measured for each town by the ratio of the

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[53] For example, increasing the frequency of collection from once per week to twice per week is expected to exert a greater impact on costs than an increase from twice per week to three times per week, but an impact equal to that resulting from an increase from twice per week to four times per week [Stevens 1978].

number of households to the residential land area.[54] Fourth, the distance variable (DIST) is measured by road mileage from the municipality to either the reported delivery site or, for towns without programs, the nearest eligible delivery site.[55] Fifth, the per ton price of a town's basket of recyclable materials (PRICE) was calculated by weighting the types of materials the town reported collecting by the composition of the recovery stream from residential recycling programs in the United States [Table 3-1]. Processor prices in the Northeast region were obtained from *Recycling Times* [1988-1992]. Under the assumption of perfect foresight, I use the average of observed material prices from the reported start date of the curbside recycling program through fiscal year 1992.[56] The potential recyclables price index (PRICE) for the non-recycling towns was obtained by assuming program characteristics (types of materials collected and program start date) most common among the among the sub-sample of recycling towns. The frequency of combinations of materials collected within the sub-sample of towns with curbside recycling programs is shown in Table 3-2. Figure 3-2 shows the frequency

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[54] The ideal density measure is the number of pick-up locations per route mile, but this information is not available. The correlation coefficients among the alternatives described below are between .97 and .99:

(1) Population / Land Area
(2) Population / [Land Area * (R/T)]
(3) Number of Households / Land Area
(4) Number of Households / [Land Area *(R/T)]

where R = Residential Property Tax Valuation
T = Total Property Tax Valuation

The fourth measure is used in an effort to control for the possibility that the proportion of land area devoted to residential purposes differs across municipalities [Bureau of the Census 1990, Information Publications 1991].

[55] Transfer stations, locations near collection sites where materials are gathered over a period of time before being transported to the delivery site, allow larger payloads to be hauled by fewer employees. For the one town in the sample that uses a transfer station for recyclables, DIST is the mileage between the town and the transfer station.

[56] *Recycling Times* reports high and low material-specific prices for overlapping two-week periods beginning in December 1988. Processor prices are distinguished from end-user prices in most periods; for periods in which the two are not distinguished, the low reported price should reflect the processor price. The price index (PRICE) uses low reported processor prices. For eligible municipalities that deliver recyclables to the state materials recovery facility in Springfield and neither receive nor make payments for delivery, PRICE is assigned a value of zero.

distribution of program start dates within the sub-sample.

Sixth, since towns with recycling programs tended to have the same type of provider (MUNI) for both recycling and refuse services [See Box below], the potential type of recycling service provider (MUNI) for the non-recycling towns was assigned to be the same as the town's type of refuse service provider. MUNI is a dummy variable equal to one if recycling services are provided by municipal employees and zero otherwise. Finally, the frequency variable (FREQ) reflects the reported annual number of collections provided by the recycling program. The potential frequency (FREQ) for the non-recycling towns is that which is most commonly observed among the recycling towns as shown in Figure 3-3.

Number of Towns by Type of Service Provider[57]

		REFUSE	
		Private	Municipal
RECYCLING	Private	25	1
	Municipal	2	3

These data on the determinants of recycling program costs, and reported actual program

[57] Each of the five towns in the selected sub-sample using municipal employees to provide recycling services was subsidized by the state. Eligible towns willing to initiate curbside recycling programs and deliver materials to the state-owned materials recovery facility in Springfield received collection trucks from the state. Six towns in the sub-sample deliver materials to the Springfield materials recovery facility.

costs for recycling towns (RECC) were used in the Heckman correction procedure -- described above and in Appendix C -- to obtain consistent coefficient estimates, $\hat{\delta}_k$, for the cost function. Program costs for non-recycling towns, to be used in full-sample estimation of Equation (3.2), were imputed as

$$RECC = \hat{\delta}_0^* + \hat{\delta}_1 w + \hat{\delta}_2 \ln Y + \hat{\delta}_3 \ln DENS + \hat{\delta}_4 \ln DIST + \hat{\delta}_5 PRICE + \hat{\delta}_6 MUNI + \hat{\delta}_7 \ln FREQ$$

Data for the remaining independent variables in the probit Equation (3.2) are as follows. Avoided cost (REFC) is the difference between municipal refuse program costs in the presence and absence of a recycling program. For the sub-sample of recycling towns, I estimate 1992 refuse costs in the absence of a recycling program by computing the annual average growth rate in refuse costs prior to recycling program adoption and apply that rate (as necessary) to refuse costs for the year immediately preceding recycling program adoption.[58] For towns that have not adopted a recycling program, I estimate 1992 refuse costs in the presence of recycling by subtracting from actual 1992 refuse costs the product of the refuse disposal tipping fee and the annual tonnage of recyclables potentially collected (Y).[59]

Given public concern about future disposal costs, recycling programs are often promoted as a means of conserving existing landfill space. The influence of this factor on the program adoption decision is captured by the dummy variable, FREFC, that takes on the value one if the

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[58] In addition to data on refuse costs for 1992 (when recycling programs were in place), towns with such programs also provided annual refuse program costs for the three to five years prior to recycling program adoption.

[59] Per ton tipping fees were reported by municipalities and/or disposal facilities.

disposal facility used by the town is scheduled for closure prior to 1996 and zero otherwise.[60]

Finally, the political incentive for recycling program adoption (ENV) is measured by the proportion of households in the community with membership in a non-governmental organization that advocates action on issues of environmental concern.[61] Summary statistics for the four independent variables used in the probit estimation of program adoption are provided in Table 3-3 for both recycling and non-recycling towns.

3.5 Empirical Results

By examining the importance of both political and economic factors in municipalities' decisions regarding adoption of recycling programs, the empirical analysis provides unique evidence about whether or not curbside recycling delivers benefits beyond "comforting the soul" [Bailey 1995]. Data on the determinants of recycling program costs (RECC), avoided refuse costs (**REFC**), concerns about future refuse costs (**FREFC**), and the level of political support for recycling (**ENV**) was collected from 80 Massachusetts municipalities, 31 of which had curbside recycling programs. First, in estimating recycling program costs with data from the selected sub-sample of recycling towns, Heckman's correction for sample selection bias was employed by including the inverse of the Mills ratio -- obtained from the estimated parameters of a full-sample probit of recycling program adoption defined by replacing RECC in Equation (3.2) with the expression in Equations (3.3) and (3.4) -- as an independent variable. This is

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60 This information was provided by the Massachusetts Department of Environmental Protection.

61 Membership data was provided under an agreement of strict confidentiality.

explained in detail in Appendix C.[62] The resulting consistent coefficient estimates were then used to impute recycling program costs for towns in the sample that had not adopted such programs. Second, the probit Equation (3.2) was run using data on all observations.

3.5.1 Cost Function for Recycling

The cost function for curbside recycling programs is estimated using 1992 data from the sub-sample of recycling towns while correcting for sample selection bias [Table 3-4]. The ordinary least squares coefficients are consistent and the standard errors are taken as reasonable approximations of the true standard errors [Lee 1978]. As explained in Appendix C, the estimator of the population variance, $\hat{\sigma}_{\epsilon\epsilon}$ is downward biased. It is possible to obtain a consistent estimator of the population variance but an estimate of the asymptotic covariance matrix is needed in order to test hypotheses. In a finite sample there is no guarantee that the sample estimate of the asymptotic covariance matrix will be positive definite (a condition commonly not met in this model), and thus that the standard errors can be computed. In this case, one cannot be confident that the usual least squares standard errors are smaller than the correct values [Greene 1990].

The coefficient on the quantity of recyclable materials collected is positive and significant at the five percent level. The significance of quantity is consistent with earlier work by Kitchen [1976] and Stevens [1978], who found that quantity was the most important determinant of

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[62] This is similar, but not identical, to various selection bias correction methods used in labor economics. In this case parameters are identified by functional form.

curbside refuse program costs, and with statements by private providers of recycling services who say that a key factor in the development of their contract bids is proprietary data on diversion rates, i.e. the percentage of the waste stream directed to recycling. The fact that the magnitude of the coefficient is less than one suggests that there are economies of scale in curbside recycling programs.[63] Stevens [1978] and Dubin and Navarro [1988] also find scale economies in the provision of refuse services.[64]

Density is generally not a significant determinant of program costs.[65] Earlier studies of refuse collection also failed to detect economies of density. Hirsch [1965], Kemper and Quigley [1976], and Stevens [1978] find statistically insignificant parameter estimates on density measures. Dubin and Navarro [1988] conclude that these studies fail to find econometric evidence of economies of density because they do not give adequate consideration to market organization choice in their estimation. Specifically, they distinguish between laissez-faire private market arrangements with no exclusive territorial rights, and public or private monopolies serving given communities. Young [1972] in a related, though less-technical, paper suggests that, "once moderate collection densities are reached, the rate at which additional economies of density are achieved diminishes rapidly." It is likely that any economies of density associated with the curbside recycling programs in the present sample are already captured by the restriction of each service area to a sole service provider -- in no case are curbside service

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63 This estimate of scale economies is downward biased. Recall from Section 3-3 that the coefficient is equal to $1/(a+b)$. The estimate of $a+b$ in the analysis is a random variable $\tilde{r}$ with $E(\tilde{r})=\bar{r}$, but $E(1/\tilde{r}) > 1/E(\tilde{r})$.

64 Stevens finds evidence that scale economies are exhausted in cities with populations of more than 50,000.

65 When the tonnage variable (Y) -- generally the only significant variable -- is dropped, density (DENS) becomes significant [Column (C), Table 3-4]; however, this is due to the high correlation (.69) between density and tonnage of recyclables.

markets organized under strict competition where individual households enter into service contracts with one of any number of providers.

The coefficients on the wage, the distance to delivery site, and the municipal dummy all generally have the expected signs but are not significant. While the wage paid to collectors was found to be a significant determinant of program costs in the refuse collection studies of Kitchen [1976] and Stevens [1978], the wage data in this study refer to the metropolitan areas in which the towns are located and thus provide less municipality-specific variation. Kitchen [1976] also fails to identify distance to the delivery site as a significant determinant of collection costs. Refuse study results regarding the relative efficiency of public and private service providers are mixed -- Kitchen [1976] finds municipally-provided services significantly more expensive, Stevens [1978] distinguishes a difference in cost only in cities with population greater than 50,000, and Dubin and Navarro [1988] find no significant differences in refuse collection costs due to municipal service providers.

The coefficients on the price index and frequency variables are also not significant. One possible explanation for the high standard errors on the coefficients of these two variables is the lack of variation in the data. As explained above, the potential recyclables price index for the non-recycling towns was obtained by assuming program characteristics [Table 3-2 and Figure 3-2] most common among the among the sub-sample of recycling towns. Similarly, the most common value of frequency of collection among the sub-sample of recycling towns was assigned to those towns that did not have recycling programs [Figure 3-3].[66]

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[66] Frequency has been identified as a significant determinant of refuse collection costs in both Stevens [1978] and Dubin and Navarro [1988].

An F-test fails the reject the null hypothesis that all slope coefficients except tonnage of recyclables (Y) are equal to zero. The F-statistic is 0.81 -- well below the five percent critical value for F(6,24) of 2.51. Two Goldfeld-Quandt tests for heteroscedasticity associated with program size were also performed. I fail to reject the hypothesis of homoscedasticity. The test statistic does not exceed the five percent critical value when one-third of the 31 observations are dropped [Harvey 1974]

$$F(2,2) = s^2_{\ln(Y)>7.50} / s^2_{\ln(Y)<7.10} = 0.29 < 19$$

Due to the limited number of observations however, the power of the test is quite low. Degrees of freedom increase when only three observations are dropped, but this diminishes the test's power by reducing the difference in program size between the two groups

$$F(5,5) = s^2_{\ln(Y)>7.40} / s^2_{\ln(Y)<7.20} = 0.3 < 5.1$$

3.5.2 Municipal Adoption of Curbside Recycling

A probit of the municipal adoption of curbside recycling on the relevant economic and political variables is estimated. The results provide strong support for the view that both economic and political factors influence the municipality's decision [Table 3-5]. Specification (1) constrains the coefficients on avoided refuse costs (REFC) and recycling program costs (RECC) to be the same, while specification (2) relaxes this restriction.

The coefficients on the budgetary savings and environmental interest group variables in

specification (1) are both positive and significant at the five percent level.[67] In interpreting the magnitude of the coefficients, the marginal effects are given by:

$$\partial E[U] / \partial x = \phi(\beta' x)\beta$$

As the marginal effects depend on the values of the explanatory variables, it is customary to calculate them at the means of the regressors.[68] The marginal effect of changes in the budgetary impact of program adoption, calculated at mean values, is 0.07, indicating that a $1000 improvement in the budgetary impact of program adoption (1.6 percent at the mean) has a marginal effect on the probability of program adoption of 0.11. Calculated at mean values, a percentage point increase in the level of membership in environmental organizations has a marginal effect of .04 on the probability of municipal adoption of curbside recycling.

Although one would expect an economic agent concerned about the municipal budget's bottom line to treat the cost of a recycling program and the avoided refuse costs symmetrically, it is possible that the voting public perceives refuse and recyclables differently. Specifically, an environmentally-conscious public might be more willing to spend a dollar on recycling than on refuse disposal. For example, with growing publicity about rising disposal costs, due largely to public opposition to the siting of new waste disposal facilities, the percent of the population that cited solid waste disposal as a serious local problem increased from 58 percent in 1988 to 75 percent in 1991 [The Roper Organization 1991]. It has also been documented that the public

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67 The notion that people with high incomes are more likely to engage in conservation behavior, including recycling, is widespread and has been documented in several studies and reviews [Vining and Ebreo 1990]. When 1989 per capita income was used as an indicator of the level of community support for a curbside recycling program, the coefficient was not significant. Interestingly, in this sample, the correlation coefficient between 1989 per capita income and the level of membership in environmental interest groups (ENV) is .51.

68 The estimates that follow are computed for FREFC=0, i.e. for the case in which the community's current disposal site is not slated for closure prior to 1996.

values recycling activity for its perceived impact on energy and natural resource conservation [Vining and Ebreo 1990] and is willing to pay in order to be able to recycle [Miller 1993].

In order to test this hypothesis, the probit was re-estimated allowing for different coefficients on avoided refuse cost (REFC) and recycling cost (RECC) as shown in Table 3-5's specification (2). The cost of the recycling program itself generally does not affect the likelihood of adoption; however, the coefficient on avoided refuse costs is positive and significant.[69] Calculated at mean values, the marginal effect of changes in avoided refuse costs is 0.07, indicating that a $1000 increase in avoided refuse costs (2.2 percent at the mean) has a marginal effect on the probability of program adoption of 0.15.

Finally, expectations of future disposal costs, as represented by the indicator variable for whether a community's present disposal site was slated for closure prior to 1996 (FREFC), were not found to be a significant influence on the probability of program adoption. This result supports the hypothesis that conserving existing landfill space is not perceived as the primary benefit of recycling [Vining and Ebreo 1990]. Any such benefit may also be less important in Massachusetts due to the structure of the state's refuse disposal capacity -- of seven regions in the United States, the states of New England have the lowest rate of landfilling waste with only 35 percent of municipal solid waste landfilled.[70] Massachusetts itself is one of three states in the country that landfills less than 25 percent of its municipal solid waste [Steuteville and

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[69] The only case in which the coefficient on the cost of the recycling program is significant is the one in which the specification of the cost function includes density (DENS), but not tonnage of recyclables (Y).

[70] The regions are New England, Mid-Atlantic, Southern, Great Lakes, Midwestern, Rocky Mountain, and Western.

Goldstein 1993].[71] Massachusetts also ranks third among the states, behind Florida and New York, in waste-to-energy capacity, with its eight facilities capable of disposing 9700 tons of waste per day [EPA 1994, Glenn 1992]. Thus the need to conserve landfill space is mitigated by the large amount of capacity at alternative disposal sites.

3.6 Conclusion

This study models municipal solid waste management decisions to determine whether the adoption of curbside recycling programs is explained by budgetary concerns or by the environmental preferences of community residents. A probit analysis is employed, along with Heckman's correction for sample selection bias, to evaluate the impact of recycling costs, avoided refuse costs, expected future disposal costs, and community environmental preferences on recycling program adoption. The budgetary impact of adopting a recycling program has two immediate components -- the cost of the program itself and the avoided refuse costs. Much of the data on these costs were gathered for a sample of 80 towns in Massachusetts through interviews with municipal officials. Expectations about future disposal costs were addressed by including a dummy variable indicating whether or not the community's existing disposal site was slated for closure within four years. Community environmental preferences were measured by the proportion of households with membership in a non-governmental organization that advocates action on environmental issues. Results show that both budget concerns and the level of political support for curbside recycling are significant determinants of program adoption. Communities

[71] Within the sample used for this study, 28% of the municipalities landfilled their waste.

that have adopted curbside recycling programs save, on average, $62,000 on annual total solid waste management costs, while those that have no such program would have to spend an additional $78,000 annually to provide curbside recycling services. While the cost of the recycling program itself does not generally have a significant effect on the likelihood of program adoption, avoided refuse costs are a significant determinant of the probability of adoption.

These results indicate that the voting public is more willing to spend a dollar on recycling services than on refuse disposal, perhaps because of perceived environmental benefits such as energy and natural resource conservation, which suggests that the level of community support for recycling is not fully captured by the percentage of households in the town with membership in an environmental organization. As the results from the estimation of the cost function for curbside recycling indicate economies of scale but not economies of density for single-provider recycling services at the municipal level, adjacent municipalities may be able to save on curbside recycling costs by combining their programs to increase tonnages.

Future research might exploit both cross-sectional differences in municipal characteristics and changing disposal prices over time to further examine the relative importance of political and economic factors in determining the existence of municipal curbside recycling programs. Recent increases in refuse disposal capacity may lessen the level of public concern regarding local solid waste management.

Figure 3-1a: Newspaper (ONP) Price

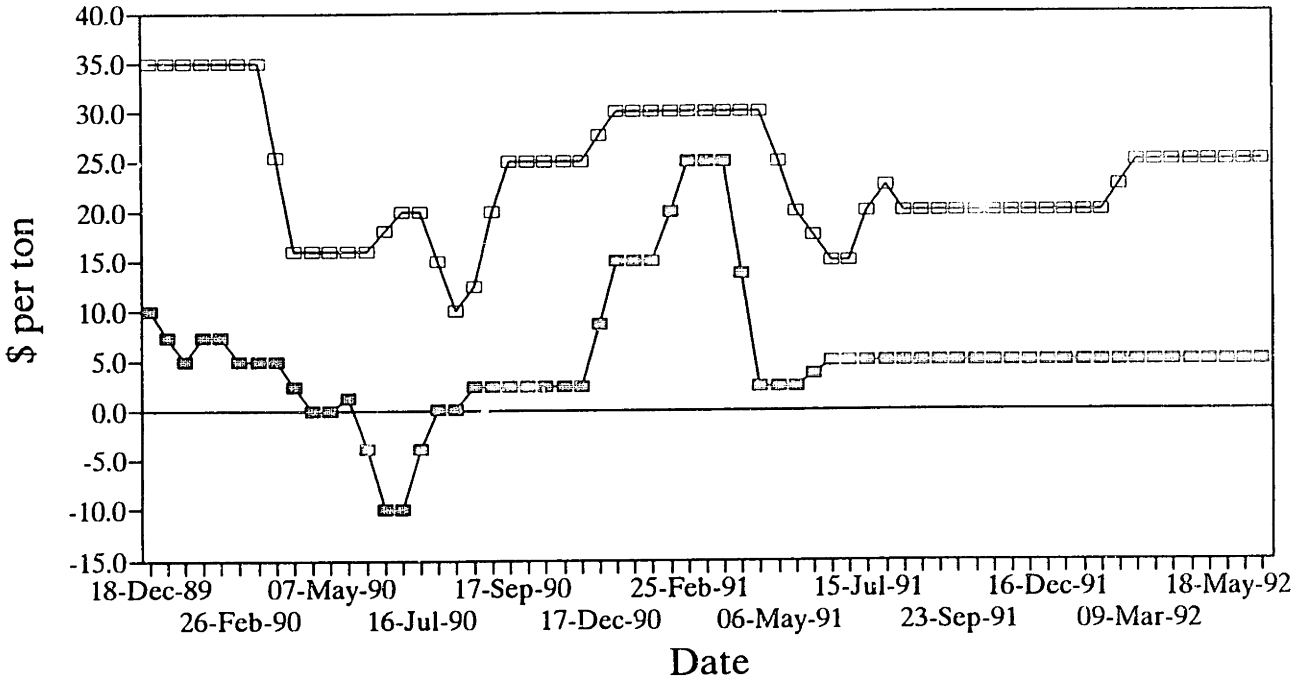
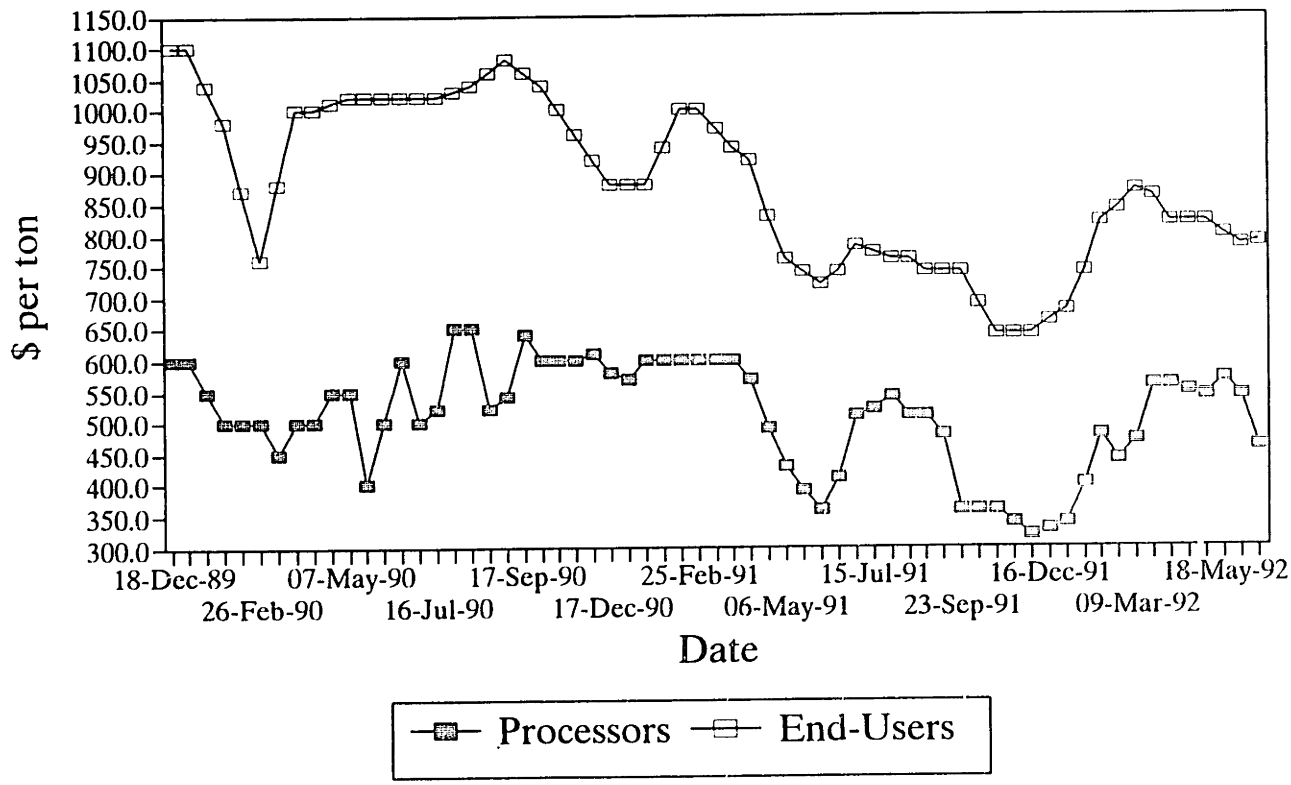


Figure 3-1b: Aluminum Cans (UBC) Price



Source: Recycling Times

Figure 3-2: Start Date for Recycling

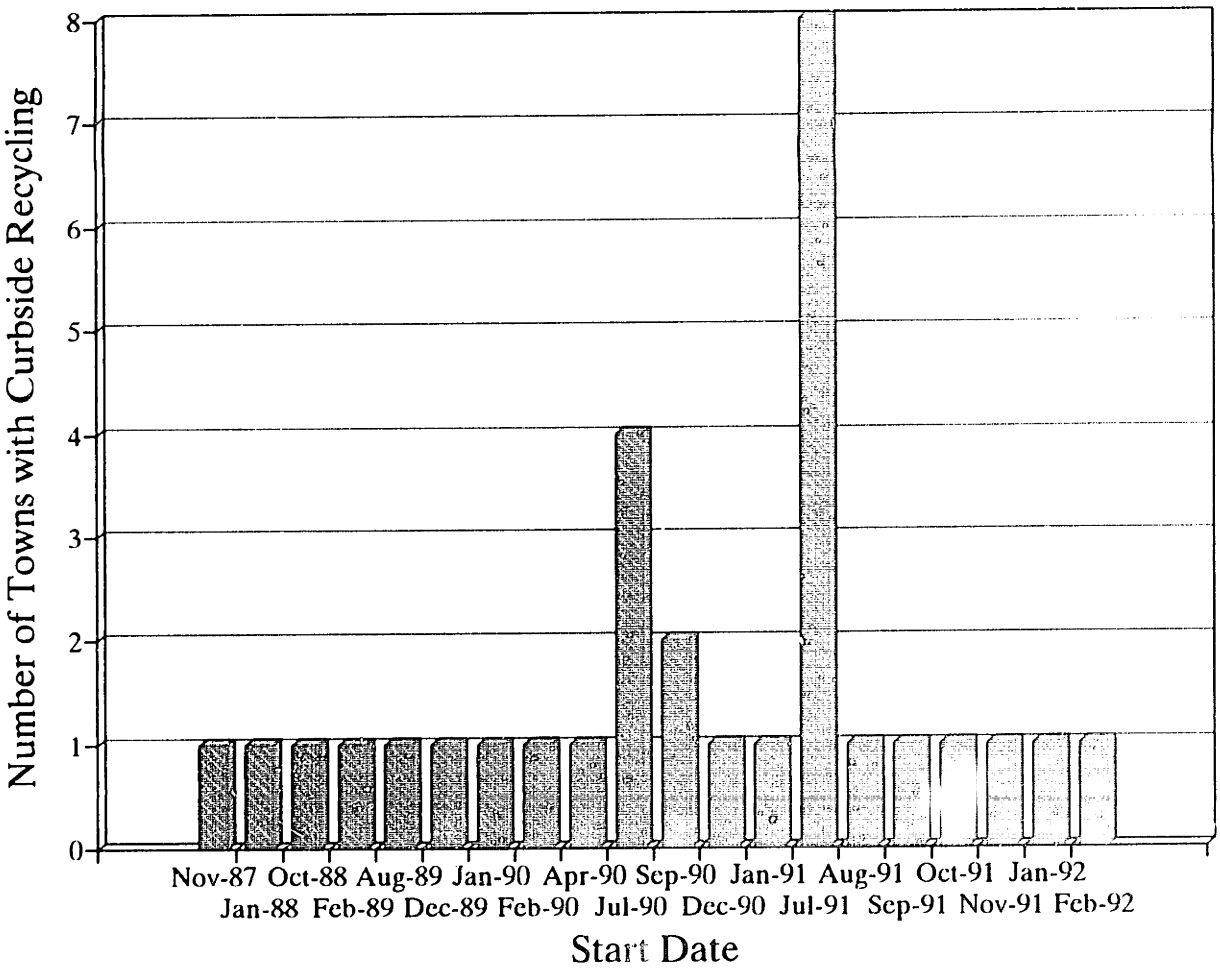


Figure 3-3: Collections per Year

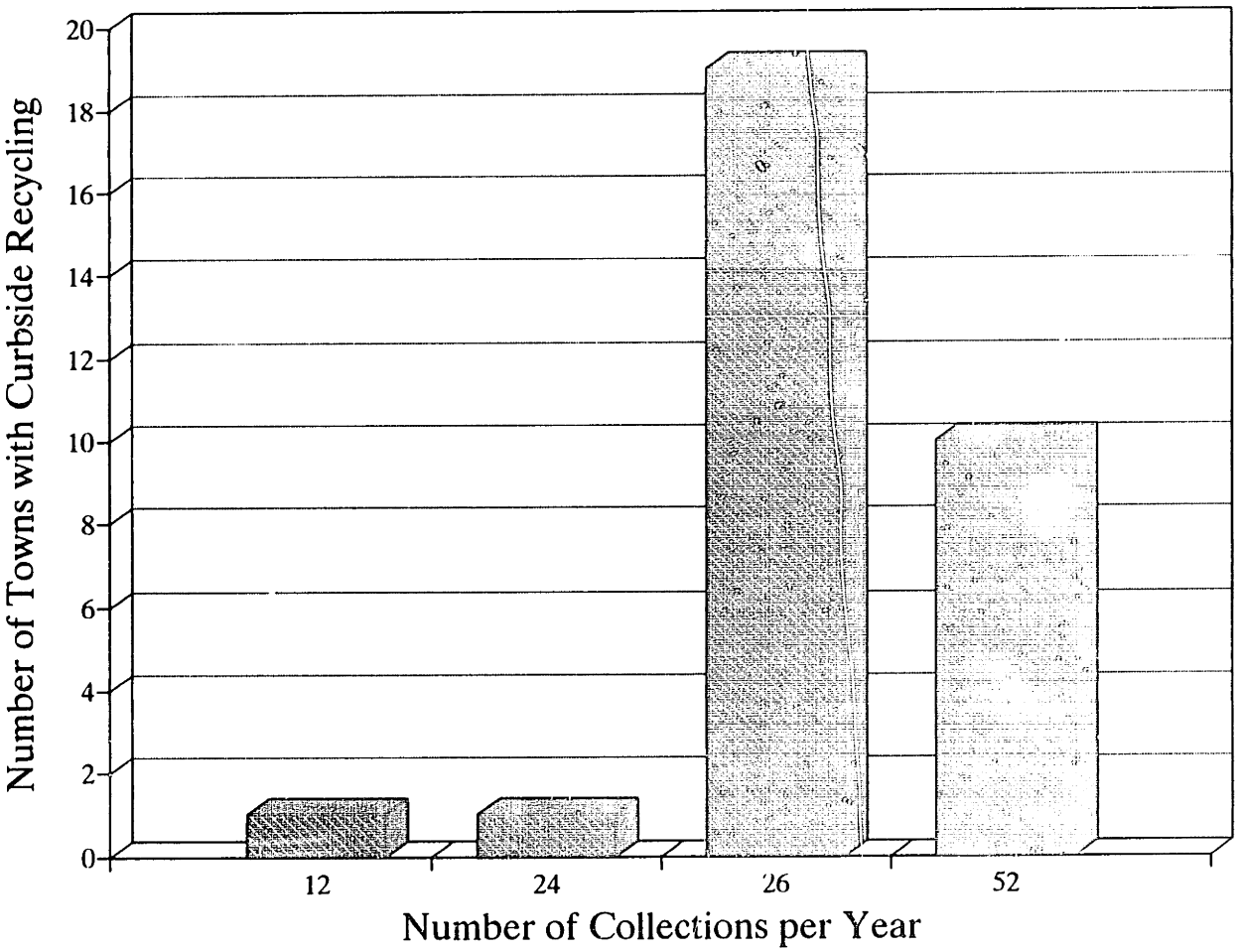


Table 3-1: Estimated Composition of Residential Recyclables[72]

Material	Proportion of Recovery Stream (Weight)
Newspaper (ONP)	0.20
Clear Glass	0.19
Cardboard (OCC)	0.15
Brown Glass	0.10
Green Glass	0.10
Ferrous Cans (Tin/Steel)	0.08
Ferrous Metals	0.06
Aluminum Cans (UBC)	0.04
High density polyethylene (HDPE)	0.04
Polyethylene terephthalate (PET)	0.03
Nonferrous Metals	0.01
TOTAL	1.00

[Denison 1990]

[72] Information on geographic variation in composition is not available.

Table 3-2: Recyclable Materials Collected in Towns With Curbside Programs

# of Towns	Material							
	Glass	News	Tin/ Steel	Alum.	#1 & #2 Plastic	Card-board	#2 Mix.	#2 Nat.
7	X	X	X	X	X			
5	X	X	X	X				
4	X	X	X	X	X	X		
4	X	X	X	X		X		
2	X	X	X	X			X	
2	X	X	X					
2	X	X	X			X		
1	X	X	X		X			
1	X	X	X			X	X	
1	X	X	X	X				X
1	X		X	X	X			
1	X	X						

Table 3-3: Summary Statistics

Statistic	Towns with Curbside Recycling	Towns without Curbside Recycling
Average **RECC**	$135,224	$133,369
Average **REFC**	$196,918	$ 55,831
Average **REFC-RECC**[73]	$ 61,694	-$ 77,538
Average **ENV**	4.76%	3.46%
Percent of Facility Closures by 1996 (**FREFC**)	10.00%	13.00%
Number of Observations	31	49

[73] If **REFC - RECC** > 0 (< 0), program adoption reduces (increases) total solid waste management costs.

Table 3-4: Cost of Curbside Recycling

$$\ln RECC_i = d_0^* + d_1 \ln w_i + d_2 \ln Y_i + d_3 \ln DENS_i + d_4 \ln DIST_i + d_5 PRICE_i + d_6 MUNI_i + d_7 \ln FREQ_i + d_8 I_i + \epsilon_i$$ [74]

	(A)	(B)	(C)	(D)
Constant	6.25 (8.85)	6.58 (8.55)	20.18 (9.53)	5.53 (7.32)
Wage	0.10 (2.83)	0.01 (2.73)	-4.10 (3.10)	0.09 (2.57)
Tons of Recyclables	0.76 (0.22)	0.82 (0.18)		0.72 (0.21)
Density	0.06 (0.15)		0.37 (0.15)	0.06 (0.13)
Distance to Delivery	0.08 (0.09)	0.09 (0.09)	0.01 (0.11)	0.08 (0.08)
Price Index for Recyclables	0.01 (0.01)	0.01 (0.01)	0.01 (0.02)	0.01 (0.01)
Municipal Dummy	0.11 (0.36)	0.10 (0.35)	0.40 (0.43)	
Frequency of Collection	-0.32 (0.47)	-0.36 (0.44)	-0.34 (0.57)	
Inverse Mills Ratio	-0.14 (0.35)	-0.17 (0.33)	-0.24 (0.42)	-0.23 (0.34)
R^2	0.67	0.67	0.48	0.67

Number of Observations: 31
(Standard errors in parentheses)

[74] The inverse of the Mill's ratio (I_i) is obtained from the estimated parameters of a full sample probit of recycling program adoption. The estimated equation is defined by substituting the expression for the natural log of **RECC** given in Equations (3.3) and (3.4) into Equation (3.2). This is shown in Equation (C.5) of the appendix.

Table 3-5: Municipal Adoption of Curbside Recycling Services[75]

(1) $U_i = \alpha + \beta_1 (\ln \mathbf{REFC}_i - \ln \mathbf{RECC}_i) + \beta_2 \ln \mathbf{FREFC}_i + \beta_3 \ln \mathbf{ENV}_i + \varepsilon_i$

(2) $U_i = \alpha + \beta_1 \ln \mathbf{RECC}_i + \beta_2 \ln \mathbf{REFC}_i + \beta_3 \ln \mathbf{FREFC}_i + \beta_4 \ln \mathbf{ENV}_i + \varepsilon_i$

	(A1)	(A2)	(B1)	(B2)	(C1)	(C2)	(D1)	(D2)
Constant	-0.60 (0.25)	-2.62 (2.62)	-0.59 (0.25)	-1.92 (2.63)	-0.57 (0.25)	2.77 (2.92)	-0.59 (0.25)	-1.89 (2.69)
Total Savings from Program Adopt.	0.18 (0.09)		0.19 (0.09)		0.25 (0.09)		0.19 (0.09)	
Cost of Recyc. Program		-0.02 (0.23)		-0.09 (0.23)		-0.52 (0.25)		-0.09 (0.24)
Avoided Refuse Costs		0.19 (0.10)		0.20 (0.10)		0.24 (0.09)		0.20 (0.10)
Landfill Closure	0.46 (0.46)	0.53 (0.47)	0.47 (0.46)	0.52 (0.47)	0.54 (0.46)	0.46 (0.47)	0.47 (0.46)	0.51 (0.47)
Env. Member	0.10 (0.05)	0.11 (0.05)	0.10 (0.05)	0.11 (0.05)	0.11 (0.05)	0.10 (0.05)	0.10 (0.05)	0.11 (0.05)

Number of Observations: 80
(Standard errors in parentheses)

[75] Column letters correspond to specifications in Table 3-4. Column numbers correspond to the equations shown here for the restricted (1) and unrestricted (2) versions of the model.

Chapter 4

4 Flow Control and Rent Capture in Solid Waste Management

4.1 Introduction

Flow control was the most significant waste management concern of the early 1990s. At issue in this $30 billion a year industry was the right of a local government to require that solid waste generated within, or sent to, its jurisdiction be disposed of at a specified facility. Since 1976 local governments enacted flow control ordinances primarily for the purpose of financing multimillion dollar waste-to-energy disposal plants. These ordinances were challenged in the courts by waste hauling firms, which argued that flow controls forced them to face a monopoly provider of waste disposal services, and by landfill concerns, which argued that flow controls deprived them of the tipping fees on waste that would otherwise be disposed of at their facilities. These challenges were rejected by courts throughout the United States during the late 1970s, the 1980s, and the early 1990s [Appendix D].

The stage for the controversy over flow control was set in the 1980s as the threat of declining landfill capacity, concerns about the health risks of landfills, and rising energy prices fostered a boom in investment in waste-to-energy (WTE) facilities. There was a ten-fold increase in the number of WTE facilities operating in the United States between 1980 and 1990

and flow control played its most significant role in the financing of these facilities. Municipalities in as many as thirty-five states supported large capital investments in the construction and operation of WTE facilities by issuing billions of dollars worth of municipal bonds supported by flow control statutes. The Environmental Protection Agency reports that 45 percent of the WTE facilities in the country, representing 58 percent of total WTE throughput, are supported by flow control ordinances.[76]

The end of the "garbage crisis" ignited an increasingly rancorous battle for market share in the multibillion dollar waste industry. The positions of the opposing parties -- local governments and WTE companies on the one hand and hauling and landfill firms on the other -- were spelled out in the lobbying efforts of representative associations and elaborated upon in specially organized conferences and the trade press. The Solid Waste Association of North America, a group of municipal trash officials, launched a precautionary telephone and mail campaign directed at members of Congress in support of flow control and scheduled its own flow control forum in the U.S. Capitol Building. The head of the association warned, "If we lose flow control, ... contracts (between cities and WTE operators) are null and void, (and the more than $10 billion of bonds outstanding that back WTE projects are) belly up." The vast majority of WTE facilities are operated, and many are owned, by firms such as Ogden Corporation -- a company strongly in favor of flow control. In contrast, the determination of hauling and landfill firms to hammer away persistently at flow control in the courts was characterized by the legal counsel for the National Solid Wastes Management Association saying,

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[76] An additional 28 percent of facilities (representing 31 percent of total WTE throughput) receive waste guaranteed by contracts. These contractual arrangements may also be supported by some form of municipal control over waste disposition.

"Hell no, we won't flow," as well as a legal fundraising event that raised over $100,000 from haulers in one evening. Representatives of large hauling and landfill companies, such as Attwoods, made their position clear in public hearings, stating that flow control constitutes monopolistic regulation that artificially raises prices. The president and CEO of Mid-American Waste labeled flow control, "un-natural, un-American, and un-constitutional."

Legal challenges to flow control intensified following growth in the WTE industry. From its inception throughout the 1980s, flow control was challenged, unsuccessfully, in only six court cases. Yet, between 1990 and 1993 ten new challenges were resolved by the courts -- some finding against the right of the local government to impose flow control [Appendices D and E]. These contradictory rulings in the lower courts in the early 1990s introduced judicial uncertainty over the constitutionality of flow control and caused the U.S. Supreme Court to step in. In August 1993 the Court agreed to hear *C&A Carbone, Inc. v. Town of Clarkstown, New York* during its 1993-94 session, a case which had been decided in favor of flow control in the lower courts.[77] On May 16, 1994, in spite of anticipation that the ruling would be narrow in scope and apply exclusively to the particulars of the case, the Supreme Court rendered a broad decision in favor of the plaintiff and struck down flow control laws nation-wide by declaring them unconstitutional.

This chapter addresses a question raised by the heated and public struggle over flow control that was eventually decided by the Supreme Court's ruling in *Carbone*: Did flow control create monopoly rents and, if so, what was the effect of the Court's decision on the distribution

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[77] Lower court case citation: *Town of Clarkstown v. C&A Carbone, Inc.* 587 N.Y.S.2d 681 (N.Y. App. Div.) cert. granted,_ S.Ct. _, 1993 WL 58536, 61 USLW 3621 (U.S.N.Y., May 24, 1993).

of those rents among the different players in the solid waste management industry? We might expect the *Carbone* decision to increase expected profits in hauling to the extent that flow control forced haulers to dispose of waste at specified WTE facilities, and landfilling, the major alternative to WTE facilities, and to decrease the expected profits of WTE firms. These effects might be mitigated by two factors. First, if entry into hauling and landfilling is relatively easy, then any super-normal profits in these activities would be bid away quickly by new entrants and the effect on the expected profits of existing firms would be smaller. Second, if super-normal profits of WTE plants are at least partly captured by local governments for the financing of additional integrated solid waste management services such as curbside recycling and household hazardous waste collection, then the *Carbone* decision would have a relatively smaller negative effect on the expected profits of these firms. These factors give rise to four possible situations, as depicted in Figure 4-1.

The reactions of the concerned parties to the *Carbone* decision suggests that many industry observers and participants thought that the lower, right-hand box was the relevant one. The decision was labeled by the press covering the industry as "devastating" for municipalities' bond issues and for companies that own waste-to-energy plants. At the North American Waste-to-Energy Conference of 1994, the industry press observed that WTE companies were "reeling" in the aftermath of the decision, expressing dismay at the outcome and holding out little hope for legislative relief. The perceived plight of the WTE industry was characterized by Congressman Bill Richardson's statement, "There is no question that with flow control there will be more waste incinerators built. Without it, there will be fewer." Market participants on the other side of the issue were celebratory. The National Solid Wastes Management Association

stated that the overturn of flow control laws nation-wide would have "a tremendous (positive) impact on our industry." Reports in both the popular press and the trade press indicated that hauling companies and landfills anticipated significant benefits from the ruling.

This chapter examines the view that the repeal of flow control decreased expected profits in the WTE industry and increased expected earnings for waste hauling and landfill concerns. I use event study methodology to test the competing hypotheses suggested by Figure 4-1. With efficient asset markets, movements in equity share prices of publicly traded WTE and hauling/landfill firms should reflect revisions in expected profits when new information about the status of flow control first becomes available. Using data on daily share returns of thirteen hauling/landfill firms and seven WTE firms from the beginning of 1993 through the period of the Supreme Court's *Carbone* decision, I estimate a capital asset pricing model to measure the expected returns for the securities in each industry group, controlling for differences in leveraging across firms, conglomerates, and other factors. The "abnormal" return associated with the *Carbone* decision is the residual from this seemingly unrelated regressions model. The model is estimated constraining all firms within an industry sector to have the same event response, as well as allowing event responses to be parameterized as a function of an individual company characteristic. The analysis is also extended back to the end of 1990 using weekly returns on the shares of eleven hauling/landfill firms and seven WTE firms in order to address the possibility that the lower court cases were the true harbingers of the downfall of flow control.

The remainder of the chapter is divided into four sections. Section 4.2 describes the structure of and recent developments in the solid waste management industry. Background

information on the major industry players and their market share is presented, including the proportions of the waste stream handled by landfill firms, WTE firms, and hauling firms. This section also provides information on the types of service contracts typical in each industry segment and the participants' attitudes regarding flow controls. It concludes with a brief history of the legal status of flow controls over time. Section 4.3 discusses the empirical methodology and the data. A brief review of event study methodology is presented, including a discussion of event window choice and the implications for standards for statistical significance. The empirical model -- an expanded capital asset pricing model -- is delineated and a detailed discussion of relevant events is provided. This section concludes with the presentation of summary statistics on the data used in the analysis. Section 4.4 presents the empirical results. In both the daily and weekly analyses, I fail to reject the null hypothesis that the *Carbone* ruling, as well as previous court rulings striking down flow control laws, had no impact on the share values of either the WTE or the hauling/landfill firms. Contrary to expectations based on the public positions of industry participants involved in the intense debate over the legitimacy of flow controls, the null hypothesis that the industry's ability to rely upon, or avoid, flow controls had no effect on the expected profits of solid waste management firms is not rejected owing to large standard errors. The final section concludes.

4.2 Background

Solid waste management is a $30 billion a year industry and the major market participants are landfill firms, WTE facility companies, and hauling businesses. Landfill

companies are in direct competition with the WTE industry for provision of solid waste disposal services. Landfills handle approximately 59.5 percent of municipal solid waste disposal in the United States. Large private landfills owned by publicly-held companies account for an estimated 30 percent of the landfill market, while smaller, independently-owned private landfills account for 25 percent. Government-owned landfills make up the remaining 45 percent. Large private landfills have capacities of up to 2000 tons per day. Small private landfills and government landfills have capacities of less than 500 tons per day and an average disposal rate of less than 100 tons per day. Table 4-1 lists the country's largest landfill companies and provides information on their total disposal capacity. Where applicable, the company under which the firm is publicly traded is listed.

Landfill development and expansion involves substantial capital requirements but, unlike WTE facilities, capital costs are not all incurred up front -- landfills operate in cells, opening one section as another is closed so that capital expenditures are spread over the entire life of the facility. Major contracts for landfill disposal of municipal solid waste generally have terms of three to six years, in contrast with the twenty-year commitments common in the WTE industry. Landfill firms have demonstrated their ability to raise investment capital through issuance of common stock and debt, and through retained earnings, to expand landfill capacity nation-wide without site-specific flow control guarantees [EPA 1995].

WTE plants handle approximately 16.0 percent of municipal solid waste disposal in the United States, recovering heat from waste combustion to produce either steam or electricity.[78]

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[78] The remaining 24.5 percent of municipal solid waste, i.e. the amount handled neither by landfills nor by WTEs, is either recycled (20.0 percent) or composted (4.5 percent).

Most of this incineration, 47 percent, takes place in the Northeast while WTE plants in the South, Midwest, and West are responsible for 28 percent, 16 percent, and 9 percent of municipal solid waste combustion respectively. There are three types of facilities: (1) Mass Burn -- These installations burn unprocessed municipal solid waste; recyclables may or may not be removed prior to combustion. (2) Refuse Derived Fuel -- These facilities pre-process incoming waste to remove noncombustibles and prepare a more homogeneous fuel product. Refuse is usually shredded to reduce particle size for burning in semi-suspension or suspension-fired furnaces. (3) Modular Mass Burn -- These plants employ one or more small-scale combustion units to process lesser quantities of waste. The average modular facility has 15 percent of the design capacity of the average mass burn facility. Operational mass burn and refuse-derived fuel facilities represent 72 percent of all WTE facilities and 98 percent of WTE throughput [EPA 1995]. Table 4-2 lists the primary WTE project vendors and developers and provides information on market share according to total design capacity. Where applicable, the company under which the firm is publicly-traded is listed.

The average initial capital investment for the two most prevalent types of WTE facilities, mass burn and refuse-derived fuel, was $82 million in 1992. These facilities are normally financed over 20-year periods. Privately-owned WTEs are typically financed with municipal debt, portions of which are tax-exempt. Equity investment covers parts of the project not eligible for tax-exempt financing. Publicly-owned WTEs are financed with a mixture of tax-exempt and taxable municipal debt. In both cases, the debt is usually structured as non-recourse revenue bonds, i.e. bonds for which repayment depends on revenues generated [Marron 1993].

Owners and operators of WTE facilities thus want to ensure adequate, long-term supplies

of waste and function at high capacity utilization rates to generate sufficient tipping fee and energy revenue to meet debt service payments.[79] Among currently-operating WTE facilities, nearly half are explicitly associated with flow controls. Of these, 38 percent are privately owned and operated; an additional 38 percent are publicly owned and privately operated and the remaining 24 percent are publicly owned and operated. An additional 30 percent of WTE facilities have contract guarantee mechanisms that may be supported by some form of municipal control over waste disposition including a flow control ordinance. Of these, 67.5 percent are privately owned and operated; 15 percent are publicly owned and privately operated, and the remaining 17.5 percent are publicly owned and operated [EPA 1995]. Flow control has been viewed as a mechanism through which governments can fulfill legislatively imposed responsibilities to plan for long term availability of appropriate solid waste management facilities -- tax-free financing has been instrumental in encouraging the build-up in WTE capacity. Flow control's most significant role has been played in the financing of WTE facilities.[80] Municipalities in as many as thirty-five states have supported large capital investments in the construction and operation of WTEs by issuing billions of dollars worth of municipal bonds supported by such statutes [Ewel 1993, Greenhouse 1994].[81] During the years of the disposal crisis, between 1980 and 1990, there was a ten-fold increase in the number of WTE facilities

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[79] The Environmental Protection Agency reports that debt service accounts for more than 60 percent of net WTE costs.

[80] Flow controls have also been important, although less so, in the recycling sector for the financing of high technology materials recovery facilities. There is no evidence that flow controls have played an important role in financing new or expanded landfills or composting facilities.

[81] Thirty-five States, the District of Columbia, and the Virgin Islands explicitly authorize the use of flow controls. Four additional states authorize flow controls indirectly through mechanisms such as home rule authority or the local solid waste management planning process [EPA 1995].

operating in the United States [EPA 1995].

The third group of key participants in municipal solid waste management are waste haulers. Municipal solid waste is generated by residential, commercial and industrial sources.[82] Private waste haulers are involved in 60 percent of residential solid waste collection services, 77 percent of commercial collection services, and 86 percent of industrial collection services [Good et. al. 1991]. Table 4-3 lists the largest publicly-traded municipal solid waste hauling companies and their 1993 revenues. Comparing this with Table 4-1 reveals that publicly-held waste management firms are mostly vertically integrated -- all firms listed are involved in both hauling and landfilling. Comparing Table 4-3 with Table 4-2 however reveals that few firms, namely WMX Technologies and Browning-Ferris Industries, participate in both hauling and combustion. Tables 4-1, 4-2, and 4-3 show that WMX and BFI have large operations in all three aspects of solid waste disposal -- landfilling, WTE, and hauling. The empirical analysis will take advantage of this fact.

Privately-provided collection services take place under contracts, franchise agreements or subscriptions. Under contract collection, the local government hires a private firm to collect refuse and pays the firm directly; collection is mandatory for all specified types of generators in the area covered by the contract. Lengths of contracts range from two to ten years, with three years being the most common contract length. In a franchise arrangement, the local government awards a private firm the exclusive right to collect refuse from all specified types of generators in a given area. These arrangements differ from contracts in that the firm must

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82 The Environmental Protection Agency's definition of municipal solid waste includes, "wastes such as durable goods, nondurable goods, containers and packaging, food scraps, yard trimmings, and miscellaneous inorganic wastes from residential, commercial, institutional, and industrial sources [EPA 1995]."

bill and collect payments directly from the generators. A subscription system is one in which several firms, generally licensed by the municipality, compete for business in the same area to collect and dispose of refuse generated by individual customers who pay the firm directly. Publicly-provided collection services take the form of direct local government provision of collection services using the public work force and intergovernmental contracts [Millar 1983 and Good et. al. 1991].[83]

The large build-up of WTE disposal capacity was a significant change in the solid waste industry during the 1980s. This was the decade of the solid waste "crisis," an anticipated national shortage of disposal capacity based on older landfills reaching capacity or closing due to stricter environmental standards as well as opposition to the siting of new landfills due to perceived health risks. These developments signaled great potential for the WTE industry which offered reliable long-term availability of solid waste disposal capacity and avoidance of health risks caused by contamination of soil and water from buried trash. In addition, at a time of rising energy prices, the facilities provided an alternative source of power.

The municipal commitment to flow controls, and the WTE industry, was predicated on the waste disposal crisis and federal legislation that placed local governments at the forefront of efforts to manage the crisis. The Resource Conservation and Recovery Act of 1976 (RCRA) encouraged the development of state solid waste management plans and in so doing, specifically

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[83] Geographic data on public and private collection activity are available only for residential collection. Private firms are heavily involved in residential collection services in the Midwest, Northeast and Western regions of the country where over 70 percent of the communities have privately-provided services. Among these, approximately 40 percent of the municipalities in the Midwest and Northeast regions use contract arrangements while the remaining 30 percent use subscriptions. In contrast, communities in the West rely most heavily on franchise arrangements. Municipalities in the South are more likely to use government-provided residential solid waste collection; only 40 percent involve private firms in collection operations.

encouraged sub-state regions to develop comprehensive waste management plans [OTA 1989, SWANA 1993]. RCRA ensured that local governments would not be "prohibited from negotiating and entering into long-term contracts for the supply of solid waste to (WTE) facilities (or) from entering into long-term contracts for the operation of such facilities." Further, the act allowed planning which might require all discarded materials to be transported to a particular location [Memishi 1994].[84]

However, contrary to the expectations of the 1980s, the solid waste disposal crisis never materialized. A shortage in landfill capacity ultimately failed to develop. Growing recycling and composting markets led to reductions in demand for disposal. Increasingly competitive waste transport markets and advances in compacting technology fostered reductions in the cost of carrying large loads long distances by truck or rail [Bailey 1993a]. This facilitated access to newly expanded landfills and new large regional landfills. As capacity limits were reached and environmental standards were raised during the 1980s, the number of landfills declined but total landfill capacity did not [EPA 1995].[85]

The dissipation of the garbage crisis left industry participants in a bitter battle for control of the multibillion dollar waste management business.[86] Although the bulk of waste was still

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[84] The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (Superfund) reiterates the principle of local officials' responsibility for waste management activities in that it does not exempt municipalities from financial liability for adverse consequences of waste management even when performed by private companies under contract with the government.

[85] Estimates of the number of municipal solid waste landfills in the United States were made by the National Solid Wastes Management Association, Biocycle Magazine, the Environmental Protection Agency, and the Government Accounting Office.

[86] The WTE industry faced two additional challenges. First, while concerns about the health risks of landfills were being addressed in federal legislation, misgivings about the safety of combustion facilities with respect to ash residue and air emissions became an increasingly visible issue [OTA 1989]. Second, the trend toward rising energy prices subsided.

managed by landfills, WTE facilities had increased their share of the disposal market.[87] The landfill market also saw a steady increase in price competition as recessionary declines in waste generation spurred competitors to accept lower profit margins in order to maintain market share, and older landfills reduced prices in order to fill existing capacity and shut down permanently before having to comply with revised environmental protection regulations [Chambers Development Company 1992, Browning-Ferris Industries 1993]. In the hauling industry, firms experienced downward pressure on profits as increased resources were demanded for providing lower margin recycling services. Numerous local and regional hauling markets had also seen the entry of additional well-capitalized firms, often through the acquisition of a small local hauler, and these vertically-integrated firms were poised to capitalize on their new investments in large regional landfills [Miner 1993]. Together, these developments stimulated renewed interest and fervor in the battle over the legitimacy of flow controls.

For the fourteen years between the time that the country's first flow control ordinance was passed in 1976 to the beginning of the 1990s, only six legal challenges to flow controls made their way through the courts. As documented in Appendix D, during this time the judiciary unanimously upheld flow control laws. The first of these court challenges is an instructive model for outlining the controversy. In 1976 the City of Akron, Ohio passed a flow control ordinance to finance a $46 million WTE plant. The ordinance required waste haulers to agree to deliver all waste to the new WTE facility as a condition for obtaining operating licenses. The guaranteed waste supply, given related revenues from both tipping fees and power generation, supported the issue of millions of dollars in revenue bonds. The city also entered

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[87] Growing amounts of recycling and composting further reduced demand for disposal services.

into a contract with a private WTE firm that supervised construction, operated the plant on a five year renewable term, and claimed a proportion of project revenues. The ordinance was unsuccessfully challenged in federal court in 1979 by waste hauling and landfill concerns arguing, respectively, that flow control forced them to face a monopoly provider of waste disposal services and deprived them of the tipping fees on waste that would otherwise be disposed of at their facilities [Kim 1993, Federal Supplement 1979].

The renewed dedication to the fight in the 1990s was exhibited by a dramatic increase in the number of legal challenges -- in the few years between 1990 and 1993 the lower courts faced ten new flow control cases. Unlike before, these cases were not resolved uniformly. Six were decided in favor of flow control and four struck down the challenged ordinances [Appendices D and E].[88] This judicial uncertainty over the constitutionality of flow control is illustrated by the following two cases: *Waste Stream Management, Inc. v. St. Lawrence County* and *DeVito Trucking, Inc. v. Rhode Island Solid Waste Management Corporation.* In the first case, *Waste Stream*, the plaintiff was a commercial waste collector who challenged a county ordinance requiring all waste to be taken to designated facilities. The state court of appeals held that the ordinance was valid because state law explicitly authorized its enactment. Moreover, the plaintiff failed to show that this statutory authority was unconstitutional beyond a reasonable doubt. In the second case, *DeVito*, the plaintiff was a hauling company that made half of its income by hauling solid waste from Rhode Island to other states. The federal district court of Rhode Island granted a preliminary injunction enjoining the enforcement of the state's

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88 Appendix D lists five of the cases decided in favor of flow control, the sixth, which would be appealed to the U.S. Supreme Court and overturned as discussed below, is listed in Appendix E.

flow control law. The district court's decision was upheld by the First Circuit Court of Appeals. The court condemned the statute as a protectionist measure designed to serve the financial interests of the state's disposal facility and found that it likely violated the Commerce Clause of the Constitution [Kim 1993].

The uncertain status of flow control laws was finally resolved by the decision of the U.S. Supreme Court in *C&A Carbone, Inc. v. Town of Clarkstown, New York.* Court and industry observers predicted that the direct impact of the case would be limited to Clarkstown's ordinance, explaining that the Supreme Court usually does not write its decisions beyond the facts presented. Thus, given the uniqueness of Clarkstown's flow control ordinance, even if the Supreme Court were to hold the law unconstitutional, the ruling would not necessarily apply to other state or local government flow control provisions [Environment Reporter 1993, Solid Waste Digest October 1993b]. However, on May 16, 1994, in a surprise ruling that was considerably broader than expected, the Supreme Court went much further than merely overturning the lower court's approval of Clarkstown's flow control ordinance [Memishi 1994]. By including extraneous and theoretical comments, called dictum, in the written opinion, the Court rendered a sweeping decision that invalidated all flow control measures by declaring them unconstitutional [Solid Waste Report 1994a].

4.3 Methodology and Data

The Supreme Court's *Carbone* decision is a natural candidate for event-study analysis. Under the assumption of efficient asset markets, firms' stocks are priced to yield a normal rate

of return with adjustments made for their risk characteristics. I use the empirical version of Sharpe's [1964] capital asset pricing model, as modified by Rose [1985], to measure the expected returns for shares in both hauling/landfill firms and WTE companies.[89] Essentially, the abnormal returns associated with the Supreme Court's decision are estimated by controlling for market-wide shifts in stock returns, as well as additional factors related to firms' returns, and calculating residual returns at the time of the ruling. Share price movements are used to infer the revision to expected future profits of different types of participants in the solid waste management industry.

Let $i \in \{1,\ldots,I\}$ index firms, $t \in \{1,\ldots,T\}$ index trading dates and $k \in \{1,\ldots,K\}$ index announcements.[90] Assume the return on shares in firm i at time t (R_{it}) is generated by the following stochastic process:

$$(R_{it}-R_{ft}) = \alpha_i + \beta_i (R_{mt}-R_{ft}) + \gamma_i X_{it} + \sum_k \delta_k \frac{PRO_i}{1-DEBT_i} D_{kt} + e_{it} \qquad (4.1)$$

where

$$R_{it} = \frac{P_{it}-P_{i,t-1}+d_{it}}{P_{i,t-1}} \qquad P_{it} = \textit{Share price} \qquad d_{it} = \textit{Dividend}$$

$$R_{mt} = \textit{Return on the market portfolio}$$

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89 This is called an empirical version because the original version from which it is derived is not testable without modification. Theoretical versions are stated in terms of unconditional expectations of firm share returns and the market return, which are not observed. Empirical versions are stated in terms of the conditional expectation of the firm share return given the actual value of the market return, i.e. observed quantities [Snyder 1991].

90 Note, as described in the introduction, for the daily returns analysis, K=1.

R_{ft}= Risk-free rate of interest

X_{it}= Additional Explanatory Variable

D_{kt}=Indicator variable for event k: 1 if event k occurs at time t

PRO_i= Proportion of book assets attributable to relevant business

1-$DEBT_i$= Share of equity in firm book value

e_{it} = Serially uncorrelated random error term

Since hauling/landfill firms and WTE firms are expected to react differently to changes in the status of flow control, the two market segments are estimated separately. Within each sector, the disturbance terms (ϵ_{it}) in Equation (4.1) are potentially contemporaneously correlated across firms, so the Seemingly Unrelated Regressions (SUR) technique is used.

The model is first estimated using 284 observations on daily return data for two periods -- December 31, 1992 to December 31, 1993 and April 4, 1994 to June 7, 1994 -- focusing the analysis on the Supreme Court's *Carbone* decision of May 16, 1994.[91] As described above, the ruling of May 16, 1994 striking down flow control laws nation-wide as unconstitutional was widely unanticipated by industry and Court observers. First, prior to the uncertainty caused by contradictory decisions rendered by the lower courts during the early 1990s, the judiciary had unanimously upheld flow control laws for fourteen years. Second, and perhaps more importantly, regardless of the inclination of the Court's decision, most expected it would be

[91] Due to data availability the time span is not continuous but this will not affect the validity of the estimation.

narrow in scope and apply exclusively to the particulars of the *Carbone* case. Instead, the Court ruled on the universal validity of flow control laws [Solid Waste Digest 1993b and 1993c, Environment Reporter 1993, Memishi 1994].

I then extend the analysis back in time using 210 observations on weekly return data -- from December 21, 1990 to December 31, 1994 -- covering the entire period over which flow control laws experienced judicial disfavor to determine whether prior court cases bore significant news content regarding the demise of flow control. Flow control ordinances were viewed unfavorably in eight decisions from six court cases in the early 1990s [Appendix E]. Two of these decisions were rendered by the Supreme Court and, although they were similar in the breadth of their rulings, only *Carbone* dealt specifically with flow control.[92] The earlier ruling strictly concerned interstate waste transport -- an issue that has been referred to as "the flip side of flow control." It has been argued however, that this decision striking down state-imposed waste import restrictions provided the foundation for subsequent legal upsets for flow control [Aquino 1993, Solid Waste Digest 1993a]. The remaining six decisions were rendered by the lower courts -- district courts and circuit courts -- and dealt specifically with flow control legislation.[93]

Following Rose [1985] three adjustments are made in applying the basic capital asset

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92 The impact of a Supreme Court ruling, as described above in the background section, depends upon the manner in which the decision is rendered.

93 The United States is divided into 91 federal judicial districts. Decisions from district courts are binding in that jurisdiction for "like" cases. In states with multiple districts, whether or not a decision from one district court is binding within another of that state's districts is arguable. There are eleven federal judicial circuits. Circuit decisions are binding in that circuit and may be argued as persuasive in others. Thus, circuit court decisions on flow control are more likely to have a discernable impact upon the solid waste management industry than district court rulings.

pricing model to the data. First, I control for differences in leveraging across firms by dividing the event indicator variables for each firm by the share of equity in total firm value ($1\text{-}DEBT_i$).[94] Second, I control for the effect of conglomerates, i.e. firms with irrelevant subsidiaries, by weighting the indicator variable for each firm by the proportion of total corporate book assets attributed to relevant waste-management operations (PRO_i).[95] Third, to address the problem of fit which is characteristic of event studies, I include energy price expectations, an industry performance index, and the first lag of firm returns relative to the risk-free rate of interest as additional explanatory variables (X_{it}):

$$\gamma_i X_{it} = \gamma_{1i} OILFUT_t + \gamma_{2i} INDPERF_t + \gamma_{3i} (R_{i,t-1} - R_{f,t-1}) \qquad (4.2)$$

I control for changing oil price expectations using returns on crude oil futures ($OILFUT_t$) because energy prices affect haulers negatively by increasing transport costs and WTE facilities positively by making alternative forms of energy generation more valuable. The industry performance index ($INDPERF_t$) is an asset-weighted average of R_{it} - R_{ft} for the solid waste industry leaders, WMX Technologies and Browning-Ferris Industries, which have interests on both sides of the flow control issue. They are the two largest firms in the hauling/landfill business [Tables 4-1 and 4-3] and rank second and third in the WTE industry [Table 4-2].

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[94] A change in firm value can be decomposed into the change in debt and the change in equity:

$$\Delta F = \Delta D + \Delta E$$

Solving for $\Delta E/E$ yields $e = (F/E)\,\Gamma f$, where $\Gamma = 1 - \Delta D/\Delta F$. If debt is not revalued, any proportional change in firm value is magnified, appearing as a relatively large proportionate change in equity value. In practice, debt changes less in value than equity in response to an event since equity owners are the residual claimants of the firm's profits. Asquith and Wizman [1990] show that even in the case of a leveraged buyout, a potentially disastrous event for bondholders since the probability of a default increases with the firm's leverage, the average abnormal return on bonds is -2.0 percent. One would therefore expect that Γ is not significantly different from one for many event studies [Snyder 1991].

[95] This variable is also used, where necessary, to adjust for the percent of assets attributed to operations in the United States.

Empirical results are reported both with and without the industry performance index. In the latter case, WMX and BFI are included in the sample of firms used for estimating abnormal returns associated with court rulings. Finally, I include firm lagged returns ($R_{i,t-1} - R_{f,t-1}$) because of the empirical model's reliance upon conditional expectations. Let y_{it}, the abnormal return estimated in event studies, be defined as:

$$y_{it} \equiv R_{it} - E_t (R_{it})$$

where $E_t (R_{it}) = E (R_{it} \mid \phi_{t-1}, W_t)$, i.e. the expected value of the firm's return at time t conditional on the information set at time $t-1$ and the observable variables at time t. A standard rule of conditional expectations yields:

$$E_t (R_{it}) = \frac{E_t (P_{it}) - P_{i,t-1}}{P_{i,t-1}} \qquad (4.3)$$

The fact critical for Equation (4.3) to hold is that, since $P_{i,t-1}$ is contained in ϕ_{t-1}, the expectation is implicitly taken conditional on $P_{i,t-1}$. Including lagged returns as a right-hand side variable ensures that this equation is valid by forcing $P_{i,t-1}$ to be part of the conditioning set [Snyder 1991].[96]

It is standard practice in event studies, which focus on announcements for which the timing and extent of pre-event news leakage varies, to examine event windows of varying length prior to the event date. This is done by modifying the length of the period during which the indicator variable, D_{it}, is set equal to one. This practice alters standards for statistical significance -- in the absence of an event, the probability of obtaining a Z-statistic greater than

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[96] The efficient-markets hypothesis implies that past return and price should not contribute to the explanatory power of a capital-market model. With daily data, though, the problem of asynchronous trading may induce serial correlation [Brown and Warner 1985].

1.96 in absolute value on one of the several event windows examined is greater than five percent. Thus adopting the standard critical value for a two-tailed test will overstate the statistical significance of the results [Corrado 1993].

The nature of the event examined in this study, a Supreme Court decision, limits event window uncertainty. The primary question is whether the event date is the day the decision is rendered, or the date of publication of a Wall Street Journal or New York Times announcement of the decision. If the ruling was released before the close of trading and the newspaper article was published the following day, one would expect no reaction (on average) on the day of publication. Taking publication as the event date and considering the two-day window that includes the date of the ruling is not an ideal solution -- if the true event date is the ruling date and the effect on the day of publication is in fact zero, the return needed on the true event date to get statistical significance will be relatively high.

This study employs a procedure developed by Salinger [1994] that treats the two days more equally.[97] The test allows for uncertainty about both the end of the event window and the length. Let $t = 0$ be the publication date. The test statistic is the maximum of all Z-statistics for windows ending at either $t = 0$ or $t = -1$ and beginning between the earliest date to be considered and time zero inclusive. In the present study, because there is no leakage of information regarding Supreme Court decisions, the earliest date to be considered is the date of the Court's ruling. The adjusted critical value for the standard five percent significance level is 2.32 for a two-tailed test when the start of the search window is $t = -1$ [Salinger 1994].

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[97] Note that for the analysis of weekly return data, which extends back to end-1990 to incorporate all decisions striking down flow controls, event responses are measured over the week in which both the ruling and the publication date occur. For cases in which the ruling was delivered on a Friday, a two-week event period is considered.

The model is first estimated constraining all firms within an industry sector, hauling/landfill or WTE, to have the same event response as shown in Equation (4.1) -- the homogeneous response model. Then, by parameterizing event responses as a function of a company characteristic, the model is estimated allowing for unique responses across companies within an industry sector -- the heterogeneous response model. Imposing this additional structure on the systems exploits differences across firms in their exposure to the effects of the repeal of flow control. The revised estimation is represented by Equations (4.4) and (4.5) below:

$$(R_{it}-R_{ft}) = \alpha_i + \beta_i (R_{mt}-R_{ft}) + \gamma_i X_{it} + \sum_k \delta_{ik} \frac{PRO_i}{1-DEBT_i} D_{kt}(\theta, Z_i) + e_{it} \qquad (4.4)$$

$$D_{kt}(\theta, Z_i) = \theta_1 + \theta_2 Z_i \qquad (4.5)$$

where D is a taken to be a linear function of the vector of parameters to be estimated (θ) and the vector of characteristics for firm i. In this case, Z_i is a scalar equal to percent of revenue derived from hauling for hauling/landfill firms and average capacity of company facilities for WTE firms. First, hauling/landfill firms differ in the degree to which their business focuses on collection versus disposal. Firms for which collection is a relatively more important source of revenue are likely to benefit less from the ruling because they are affected by flow-control-determined disposal costs only to the extent that they have not had the opportunity to incorporate them in negotiated contracts -- as explained above, three year terms are typical of hauling contracts. Firms for which disposal is a relatively more important source of revenue are likely to benefit more from the abolition of flow controls, which are capable of blocking demand for their services from a number of different sources. Second, average WTE throughput for plants

explicitly associated with flow controls is 3.0 times the average throughput for WTE plants without flow controls [EPA 1995].[98] Thus, companies with higher average capacity are likely to be more severely affected by the abolition of flow controls.

Data on firm returns (R_{it}) were obtained from the Center for Research in Security Prices and Standard & Poor's Daily Stock Price Record.[99] The market return (R_{mt}), also obtained from the Daily Stock Price Record, is derived from daily data on Standard & Poor's 500 Composite Stock Price Index. The risk-free rate of return (R_{ft}) is the net yield on the 30 Day Treasury Bill derived from daily data quoted in the Washington Post and weekly data provided by the Federal Reserve Board. Returns on one-year oil futures ($OILFUT_t$) were derived from price data quoted in the Wall Street Journal for light, sweet crude. Summary statistics for these variables are presented in Table 4-4 for the time periods in both the daily and weekly analyses. Finally, the proportion of total corporate book assets attributable to business relevant to this study (PRO_i), the share of equity in firm value ($1\text{-}DEBT_i$), and the percent of revenue derived from hauling, were obtained from Standard & Poor's COMPUSTAT. The average capacity of WTE company facilities was obtained from the Environmental Protection Agency's Municipal Solid Waste Factbook. This information is summarized in Table 4-5 for all firms in the estimation sample.[100] Note that for hauling/landfill firms, waste operations potentially

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98 In addition, average WTE throughput for plants likely to be associated with flow controls is 2.4 times the average throughput for WTE plants without flow controls.

99 Firms are included in the study based on the availability of the necessary data.

100 Recall from above that due to their status in the industry and interests on both sides of the flow control issue -- hauling/landfill and WTE -- WMX and BFI are used in the construction of the industry performance index ($INDPERF_t$). Estimation is performed both with and without $INDPERF_t$. In the latter case, WMX and BFI are included in the sample of firms used for estimating abnormal returns associated with the court rulings.

affected by flow control rules are quite important. The proportion of book assets attributable to relevant business is 100 percent for nine of the thirteen companies, and for three of the remaining firms it exceeds 50 percent. The situation is quite different for WTE firms. For only one of the seven firms in the sample do WTE operations represent a substantial proportion of book assets.[101] For the remaining six WTE firms, the relevant business is represented by less than 16 percent of book assets. This poses greater challenges for finding significant effects of flow control rulings on WTE firms.

4.4 Results

This study examines the question of whether or not flow controls created monopoly rents. If such rents did exist, the analysis seeks to identify the effect of the abolition of flow control on the distribution of those rents among the different sectors of the solid waste management industry. The null hypotheses are that the court rulings had no effect on the expected profits of either hauling/landfill firms or WTE companies -- because entry into hauling/landfill is relatively easy and local governments capture much of the super-normal profits afforded WTE facilities by flow controls. Each of the alternative hypotheses predict some significant effect of the repeal of flow control on the expected profits of either hauling/landfill firms (positive), WTE firms (negative), or both [Figure 4-1]. Event study methodology is employed using SUR estimation of an expanded capital asset pricing model. Daily data for hauling/landfill firm and

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[101] BFI could not be included in the estimation sample because data on the proportion of total corporate book assets attributable to the relevant business (PRO_i) was not available for WTE operations.

WTE firm returns are used in examining the impact on expected profits of the Supreme Court's *Carbone* decision which overthrew flow control laws nation-wide. Weekly data are used to analyze the impact of the series of court rulings that found disfavor with flow control ordinances.

Using the daily data, the system estimates for the industry groups for both the homogeneous and heterogeneous response models are presented in Table 4-6.[102] With one exception, the coefficients on all right-hand side variables (omitted from the Table) demonstrate significant effects on firm share prices at the five percent level. The coefficient on oil futures is the expected sign and significant at the ten percent level for hauling/landfill firms, but is not significant in the WTE system estimates. The explanatory power of energy futures in the determination of WTE share prices may be limited by the manner in which the Public Utility Regulatory Policy Act of 1978 (PURPA) has been implemented in a number of different states. PURPA, passed in response to the fluctuating energy prices of the late 1970s, created a new class of nonutility generators (which included WTEs) from which utilities are required to buy power at their own incremental or avoided cost of production [EIA 1993]. Avoided costs have often been determined based on early 1980s projections that oil prices would skyrocket; thus, affected WTE facilities have guaranteed markets for energy generation at prices already well-above market levels [Bailey 1993a].[103]

The null hypothesis that the Supreme Court's overturning of flow control laws had no

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[102] Due to the wide range of primary lines of business exhibited by WTE firms [Table 4-5] the industry performance index variable has been dropped from the WTE specifications.

[103] The WTE event responses reported are robust to a specification that does not include oil futures as an explanatory variable.

effect on the stock market returns of either hauling/landfill firms or WTE firms is not rejected by the individual firm estimation -- in which the event coefficients are not significant and signs are not consistent across firm type. The improved efficiency from system estimation does nothing to alter this result [Table 4-6]. The signs on the event coefficients in the homogeneous response model are consistent with the alternative hypotheses that the stock market returns of hauling/landfill firms rose and that those of WTE firms fell. However, the magnitudes of the reactions -- less than .9 percent -- are smaller than their corresponding standard errors. The view that hauling/landfill firms would benefit relatively more from the ruling the lower the percentage of company revenues derived from hauling, and that WTE companies would be hurt relatively less by the decision the lower their facilities' average capacity receives no empirical support here, as coefficients on the response effects attributable to these firm characteristics are insignificant in the heterogeneous response model. Owing to large standard errors the results fail to reject the null hypothesis that the market did not anticipate substantial changes in profits as a result of the *Carbone* decision.

Using the weekly data, the system estimates are presented in Table 4-7. The weekly data allow the examination of the market responses to all eight court decisions overturning flow control ordinances.[104] Echoing the daily results, the coefficients on all right-hand side variables (not reported), with the exception of oil futures, indicate significant effects on hauling/landfill firm share prices at the five percent level. The WTE estimation results are

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104 I assume throughout the paper that the classic capital asset pricing model coefficient on the market portfolio return variable is constant for each firm over the entire sample period, rather than allowing it to differ before and after the event(s). The effect of the estimated coefficient in explaining returns on individual stocks depends upon the product of this coefficient and the return on the market portfolio. Since the expected weekly return on the market portfolio is .17 percent, the results should be robust to even large variations in this coefficient [Rose 1985].

robust to specifications without the independent variables that fail to achieve standard significance levels: the first lag of firm returns relative to the risk-free interest rate and oil futures.

As in the daily analysis, the null hypothesis that the court rulings of the early 1990s undermining flow control ordinances had no effect on the stock market returns of either hauling/landfill firms or WTE firms is not rejected by the individual firm estimation. The estimated coefficients for each of the eight event dummy variables are not significant for firms in either industry sector nor are the signs for any one coefficient consistent across firms.[105] The efficiency gains associated with SUR estimation of the two market sector systems do not change this result. Coefficient signs are not consistent across events and all of the responses are small, under 1.6 percent, with large standard errors -- none of the decisions are indicated to have had a significant effect on firm returns. Under these circumstances, it is perhaps not surprising that the cumulative responses to all events overturning flow controls are both substantively and statistically insignificant at -1.8 percent with a standard error of 4.4 percent for hauling/landfill firms and 2.5 percent with a standard error of 3.9 percent for WTE firms -- they also have unexpected signs.[106] Although the cumulative response is strictly defined as the effect of each event conditional on the occurrence of the previous events, the difference

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[105] The one exception is the coefficient on the ruling of the 8th Circuit (February 18, 1993) in the case of the landfill/hauling firm Mid-American Waste -- the market response, while significant, does not have the expected sign.

[106] These are the results for the model that includes the industry performance index as a right-hand side variable for hauling/landfill firms. The empirical results when WMX and BFI are included in the estimation sample are -0.2 percent with a standard error of 4.1 percent for hauling/landfill firms and 2.7 percent with a standard error of 3.9 percent for WTE firms.

between this calculation and using the simple sum of event coefficients is negligible. I use the latter calculation here to simplify the computation of standard errors [Rose 1985].

Thus, all estimation results -- those using daily data to focus on the Supreme Court's flow control decision, as well as those using weekly data in order to assess the impact of each judicial step in the dismantling of flow controls -- have large standard errors and fail to reject the null hypothesis that the repeal of flow control had no impact on the anticipated profits of firms in the waste management industry.

4.5 Conclusion

Did flow control create monopoly rents and, if so, what was the effect of its abolition on the distribution of those rents among the different players in the solid waste management industry? The obsession of the industry with the legitimacy of flow control laws was manifest in the virulent legal and public controversy that raged throughout the early 1990s. While hauling/landfill firms argued that flow controls forced them to face a monopoly provider of waste disposal services and deprived them of the tipping fees on waste that would otherwise be disposed of at their facilities, waste-to-energy firms asserted that flow control was a critical tool in helping local governments to fulfill the federal mandate to provide long-term, reliable solid waste management services and avert solid waste disposal crises. When the Supreme Court's surprisingly broad *Carbone* decision unequivocally resolved uncertainty about the constitutionality of flow control, the reactions of industry observers and participants strongly suggested that profits in hauling and landfilling (the major alternative to waste-to-energy

facilities) would increase and that the profits of waste-to-energy firms would decrease.

Notwithstanding the intensity of the debate and industry reactions to the Supreme Court's decision, the large standard errors in this study lead to failure to reject the null hypothesis that flow controls did not have significant effects on the expected profits of either hauling/landfill firms or waste-to-energy firms. Rejection of the null is consistent with relatively easy entry into waste hauling and landfilling and the capture by local governments of any super-normal profits in waste-to-energy due to flow control. In fact, the 100 largest municipal solid waste collection companies account for only about half of total industry revenue, the remainder being spread among thousands of small "mom-and-pop" hauling operations [Aquino 1994]. Also, studies have found that distance traveled to the disposal site is not a significant determinant of collection and disposal contract costs [Kitchen 1976, Tawil 1994]. Recent improvements in compaction technology for municipal solid waste have even further reduced truck and rail transport costs [McCarthy 1993, Bailey 1993a, Woods 1994].

At the same time, it is true that tipping fees per ton of refuse at waste-to-energy facilities have on average exceeded those at landfill disposal sites [Figure 4-2]. However, evidence from public hearings suggests that local governments have used revenues generated by flow controls to support integrated solid waste management systems, i.e. to provide services such as curbside recycling, household hazardous waste collection, solid waste planning, source reduction programs, public awareness programs and even, in some instances, Superfund cleanup [EPA 1995]. Other evidence that the viability of waste-to-energy facilities has not been threatened by the repeal of flow control is provided by the ratings of revenue bonds issued to finance these facilities: of its 57 ratings on approximately $4.6 billion of unenhanced solid waste/waste-to-

energy debt, Standard & Poor's downgraded only two as a direct result of the Supreme Court's ruling [Creditweek Municipal 1995].

Owing to large standard errors, I fail to reject the null hypothesis that waste-to-energy firms and hauling/landfill firms were not significantly affected by the repeal of flow control. Rejection of the null is consistent with the view that while the abolition of flow control may increase the demand for hauling/landfilling, new entrants would bid away any super-normal profits that might emerge. It is also consistent with the possibility that, though tipping fees at waste-to-energy facilities may fall on average relative to those at landfills, local governments could be the true losers, having lost a potential mechanism for generating and capturing rents. Future research could examine the reaction of local governments to the elimination of flow control, focusing on the provision of related solid waste services and the extent to which alternative funding mechanisms have been found.

Figure 4-1: The Possible Effects of the Repeal of Flow Control On Expected Profits

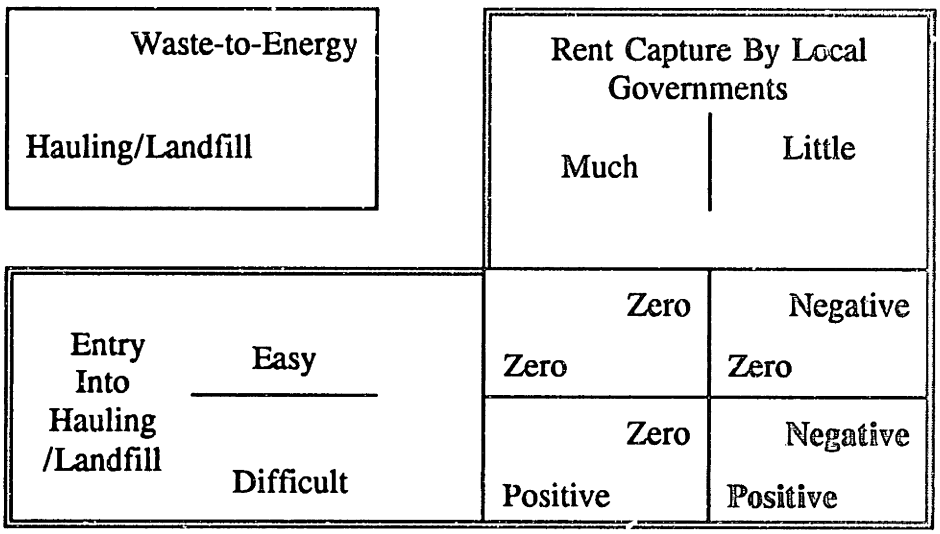
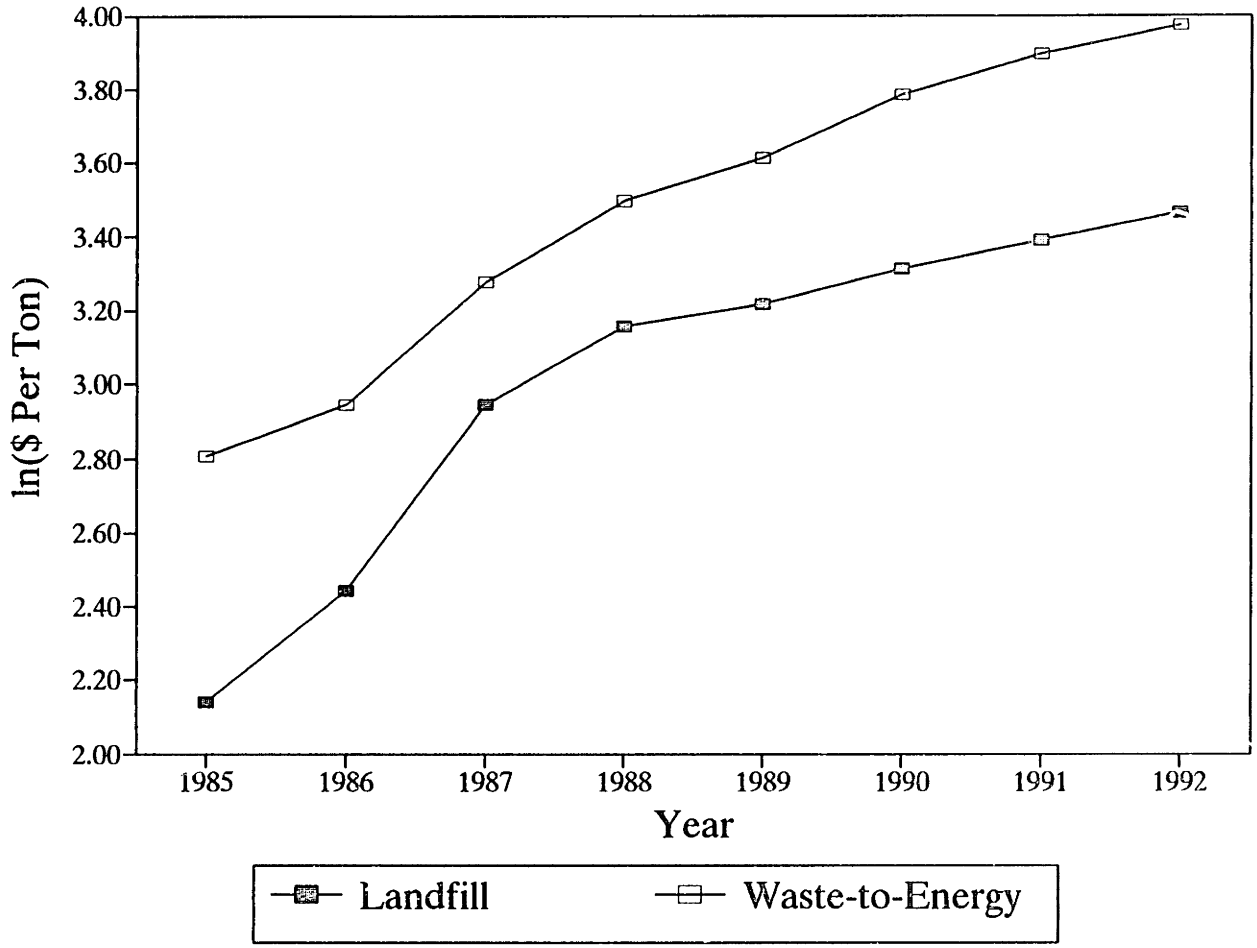


Figure 4-2: National Average Fees
Landfill and Waste-to-Energy Facilties



Source: Environmental Protection Agency [1994]

Table 4-1: Landfill Firms [107]

Firm	Disposal Capacity (Thousands of Tons Per Year)	Publicly Traded
WMX Technologies, Inc.	25,900	WMX Technologies, Inc.
Browning-Ferris Industries	19,300	Browning-Ferris Industries
Laidlaw Waste Systems, Inc.	5,100	Laidlaw, Inc.
Mid-American Waste Systems	4,100	Mid-American Waste Systems
Chambers Development Company	2,900	Chambers Development Company
Republic Waste Industries	1,600	Republic Waste Industries
Norcal Waste Systems, Inc.	1,500	NA
Sanifill, Inc.	1,400	Sanifill, Inc.
USA Waste Services, Inc.	1,200	USA Waste Services, Inc.
Western Waste Industries	800	Western Waste Industries
Eastern Environmental Services	400	Eastern Environmental Services
American Waste Services, Inc.	300	American Waste Services, Inc.
Attwoods plc	200	Attwoods plc

Source: EPA 1995, Aquino and Jones 1994, Standard & Poor's 1995b

[107] Major landfill firms.

Table 4-2: Waste-to-Energy Firms

Firm	Market Share	Publicly-Traded
Ogden Martin Systems, Inc.	28.9%	Ogden Corporation
Wheelabrator Technologies	21.7%	WMX Technologies, Inc.
American Ref-Fuel, Inc.	7.7%	Browning-Ferris Industries Air Products and Chemicals
Montenay Power Corporation	4.7%	NA
Westinghouse Resource Energy Systems	4.1%	Westinghouse Electric
Foster Wheeler Energy Systems, Inc.	3.0%	Foster Wheeler Corporation
NRG Resources	2.3%	Northern States Power
Energy ANSWERS Corporation	1.9%	NA
Consumat Systems, Inc.	1.6%	Consumat
Babcock & Wilcox	1.5%	NA
Additional Firms: Quadrant Company CMS Generation Flour Daniel 31 Other Firms	22.6%	 Otter Tail Power Company CMS Energy Corporation Fluor Corporation NA

Source: Berenyi and Gould 1993b, Standard & Poor's 1995b

Table 4-3: Hauling Firms

Firm	Revenues 1993 ($M)
WMX Technologies, Inc.	9,135.6
Browning-Ferris Industries	3,494.9
Laidlaw Waste Systems, Inc.	1,993.3
Attwoods plc	410.0
Chambers Development Company	288.5
Western Waste Industries	231.2
Mid-American Waste Systems	166.9
Sanifill, Inc.	121.3
Republic Waste Industries	102.7
American Waste Services, Inc.	87.3
USA Waste Services, Inc.	78.1
United Waste Systems, Inc.	77.5
Allied Waste Industries	54.4
Eastern Environmental Services [108]	14.3
Transamerican Waste Industries	11.5

Source: Aquino and Jones 1994, Standard & Poor's 1995b, Miner 1993

[108] Revenues are 1992.

Table 4-4: Summary Statistics Market Return, Risk Free Rate, Oil Futures
(Percent)

Variable	Daily 12/31/92 to 6/7/94				Weekly 12/21/90 to 12/30/94			
	Mean	Var	Min	Max	Mean	Var	Min	Max
Market Return	0.03	0.00	-2.40	1.93	0.17	0.02	-3.41	5.39
Risk Free Rate	0.01	0.00	0.01	0.01	0.07	0.00	0.05	0.11
Oil Futures	-0.04	0.01	-4.55	3.72	-0.06	0.05	-13.26	5.64

Table 4-5: Descriptive Statistics on Firms in [illegible] ample

Firm	PRO[109]	1-DEBT	Proportion of Revenue From Hauling	Facility Average Capacity (100 Tons/ Day)
HAULING/LANDFILL FIRMS				
Attwoods	0.53	0.71	0.67	NA
Chambers (A&B)	1.00	0.45	0.39	NA
Western	1.00	0.66	0.86	NA
Mid-American	1.00	0.48	0.77	NA
Sanifill	1.00	0.63	0.14	NA
Republic	0.66	0.81	0.22	NA
USA Waste	1.00	0.42	0.39	NA
United	1.00	0.68	0.49	NA
Allied	1.00	0.60	0.76	NA
Eastern	1.00	0.81	0.57	NA
WMX	0.42	0.58	0.77	15.02
Browning-Ferris	0.78	0.73	0.70	17.30
WASTE-TO-ENERGY FIRMS				
Ogden	0.75	0.40	NA	11.89
Westinghouse	0.04	0.76	NA	9.40
Foster Wheeler	0.15	0.73	NA	6.31
Northern States	0.05	0.71	NA	9.67
Otter Tail	0.08	0.69	NA	1.00
CMS Energy	0.07	0.55	NA	2.25
WMX	0.19	0.58	0.77	15.02
Browning-Ferris	NA	0.73	0.70	17.30

109 With the exception of Ogden, the WTE industry does not represent the primary line of business for the sample of "WTE firms." This poses greater challenges for finding significant effects of flow control rulings on these firms. Note also that the industry performance variable (*INDPERF*), constructed from the returns of the waste industry leaders -- WMX and BFI, does not bear a clear theoretical relationship to the returns on the sample of "WTE firms" and therefore, as noted, it is not included in the estimation for this industry group.

Table 4-6: Supreme Court Flow Control Decision (SUR)[110]

Event	Hauling/Landfill		Waste-to-Energy	
	(1a)	(1b)	(2a)	(2b)
Homogeneous Response	.001 (.006)	.003 (.006)	-.008 (.008)	-.008 (.008)
Heterogeneous Response				
Event Mean Response	-.009 (.013)	-.009 (.012)	.086 (.091)	.067 (.087)
Response Effect of Firm Characteristic	.021 (.024)	.024 (.022)	-.008 (.008)	-.006 (.007)
Number of Firms	11	13	6	7
Number of Daily Returns	284	284	284	284

(Standard errors in parentheses)

[110] Column (1a) includes the industry performance index as an explanatory variable. Column (2a) also includes only those firms with an interest in a single side of the flow control debate in the estimation sample. In contrast, Column (1b) includes WMX and BFI in the estimation sample and thus has no industry performance index on the right-hand side. Column (2b) includes WMX in the estimation sample.

Table 4-7: Multiple Events Overturning Flow Control (SUR) [111]

Event	Hauling/Landfill Firms		Waste-to-Energy Firms	
	(1a)	(1b)	(2a)	(2b)
District (RI) 7/22/91	.000 (.016)	.000 (.015)	.005 (.014)	.005 (.014)
Circuit (1st) 11/18/91	.005 (.016)	.003 (.015)	-.002 (.015)	-.001 (.014)
District (MN) 2/14/92	-.002 (.011)	-.001 (.011)	.015 (.010)	.013 (.010)
Circuit (8th) 2/18/93	-.005 (.016)	-.006 (.015)	-.011 (.014)	-.011 (.014)
Supreme Court Interstate Waste 6/1/92	.003 (.016)	.012 (.015)	.006 (.014)	.008 (.014)
District (NC) 6/19/92	.001 (.011)	.011 (.011)	.001 (.010)	.003 (.010)
District (AL) 3/8/93	-.006 (.016)	-.006 (.015)	-.001 (.014)	.001 (.014)
Supreme Court Flow Control 5/16/94	-.014 (.016)	-.016 (.015)	.012 (.014)	.009 (.014)
Cumulative Effects	-.018 (.044)	-.002 (.041)	.025 (.039)	.027 (.039)
Number of Firms Number of Weekly Returns	9 210	11 210	6 210	7 210

(Standard errors in parentheses)

[111] The results from the homogeneous response model are presented here in the interest of parsimony. They do not differ substantially from those obtained from the heterogenous response model. Column (1b) includes WMX and BFI in the estimation sample. Column (2b) includes WMX in the estimation sample.

Appendix A

A Chapter 2 Data

Rancher Investment, R_{it}:

Log of fiscal-year t, real dollar investment in public-rangeland improvements in state i by public-land ranchers, normalized by million acres of BLM land in the state. Nominal investment data were obtained from the BLM's Range Improvement Project System and the implicit price deflator for Producers' Durable Equipment (1987=100) [CEA 1994] was used. BLM acreage was obtained from U.S. Department of Interior BLM [1969-1992].

Government Investment, G_{it}:

Log of fiscal-year t, real dollar investment in public-rangeland improvements in state i by government agencies, normalized by million acres of BLM land in the state. Nominal data were obtained from the BLM's Range Improvement Project System and the implicit price deflator for Producers' Durable Equipment (1987=100) [CEA 1994] was used. BLM acreage was obtained from U.S. Department of Interior BLM [1969-1992].

Grazing Fee, F_t:

Log of fiscal-year t, real cents grazing fee per AUM. Nominal fiscal-year t grazing fee per AUM was derived from the schedule of grazing fees published on the basis of the grazing-fee year [U.S. Departments of Agriculture and Interior 1992]. The grazing-fee year (GFY) runs from March 1 to February 28 (or 29) of the following year. Using the simplifying assumption that public-land grazing use is evenly distributed throughout the year, F_t is a months-weighted average of the relevant GFY fees using the implicit price deflator for Producers' Durable Equipment (1987=100) [CEA 1994].

Federal Land Policy and Management Act, $FLPMA_t$:

Dummy variable equal to one for fiscal years in which FLPMA has been in force and zero otherwise. FLPMA was signed by the President on October 21, 1976 [Muhn and Stewart 1988].

Beef Cattle Price Index, $BCPI_t$:

Fiscal-year index of real national beef cattle prices based on data collected by the National Agricultural Statistics Service. $BCPI_t$ is a months-weighted average of the nominal calendar year index published by the Department of Interior [U.S. Departments of Agriculture and Interior 1992] using the implicit price deflator for Producers' Durable Equipment (1987=100) [CEA 1994].

Prices Paid Index, PPI_t:

Fiscal-year index of real prices for inputs into western beef cattle production. Components of the index were selected from the National Index of Prices Paid by Farmers and weighted based on the cost of production budget for cow-calf operations in the western region. Examples of these components are fertilizer and chemicals, trucks and machinery, building and fencing materials, and farm services such as veterinary services, wages, and interest rates. PPI_t is a months-weighted average of the nominal index (based on November through October of the data year) published by the Department of Interior [U.S. Departments of Agriculture and Interior 1992] using the implicit price deflator for Producers' Durable Equipment (1987=100) [CEA 1994].

Real Interest Rate, RIR_t:

Rate on the 10 Year U.S. Treasury Security minus a three year (t-1, t, t+1) moving average of the change in the natural log of the implicit price deflator for GDP [CEA 1994].

Investment Tax Credit, ITC_t:

Dummy variable equal to one for fiscal years in which the federal investment tax credit was available and zero otherwise. The investment tax credit was first enacted January 1, 1962 and was in effect through December 31, 1985 with the exception of the periods October 10, 1966 to March 9, 1967 and April 19, 1969 to August 15, 1971 [Pechman 1987]. The dummy variable was assigned a value of one for fiscal years in which the credit was in place for 9 or more months.

Grazing Revenue, $REV_{i,t-1}$:

Log of fiscal-year t-1 real grazing-fee revenue collected from state i, normalized by million acres of BLM land in the state. Nominal revenue data and BLM acreage were

obtained from U.S. Department of Interior BLM [1969-1992]. The implicit price deflator for Producers' Durable Equipment (1987=100) [CEA 1994] was used.

House Committee Representation, $COMM_{i,t-1}$:

Number of Congressional representatives from state i with assignments on the House Interior and Insular Affairs Committee or the House Appropriations Committee in fiscal year t-1, normalized by million acres of BLM land in the state. Data on committee assignments were obtained from Congressional Quarterly [1968-1992], U.S. Government [1971], and Francis and Trammell [1992]. BLM acreage was obtained from U.S. Department of Interior BLM [1969-1992].

Appendix B

B Chapter 2 Unit Root Tests

Augmented Dickey-Fuller Model [Hamilton 1994]

Use of conventional significance tests for regressions involving non-stationary data often leads to rejection of the hypothesis of no relationship when, in fact, there is none [Granger and Newbold 1974].[112] Thus, in the regression $y_t = x'_t\beta + u_t$ for which elements of y_t and x_t might be non-stationary, OLS is likely to produce spurious results.[113] In order to determine whether the data used in this study are integrated, I perform an augmented Dickey-Fuller test for each of the quantitative variables in the analysis.[114]

The asymptotic distributions and rates of convergence for the estimated coefficients of unit root processes differ from those for stationary processes. The asymptotic distributions for unit root processes can be described in terms of functionals on Brownian motion. Hamilton derives the asymptotic distribution of the estimated coefficient for a first-order autoregression when the true process is a random walk. This distribution depends on whether a constant or time-trend is included in the estimated regression and whether the true random walk is characterized by non-zero drift. The derivation can be extended to cover unit root processes whose differences exhibit general serial correlation and the results used to develop the following

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[112] A data series is covariance stationary when neither the mean, μ_t, nor the autocovariances, γ_{jt}, depend on the date, t:

$E(y_t) = \mu$ for all t.

$Cov(y_t, y_{t-j}) = \gamma_j$ for all t and any j. Note $\gamma_j = \gamma_{-j}$.

In non-stationary series, the mean and the variance depend on time and tend to differ more from a given value as time progresses. Such a series is said to exhibit a trend if this movement is predominantly in one direction. Examples of non-stationary series are:

Trend-stationary process $y_t = \alpha + \delta_t + \Psi(L)\epsilon_t$

Unit Root process $\Delta y_t = \delta + \Psi(L)\epsilon_t$ where $\Psi(1) \neq 0$

[113] Unless some value of β exists for which $u_t = y_t - x'_t\beta$ is integrated of order zero (i.e. u_t is a stationary process).

[114] A process that is integrated of order one, for example $y_t \sim I(1)$, has only one root of the autoregressive polynomial equal to unity and the rest are inside the unit circle.

test for unit roots:

Estimate the regression

$$y_t = \zeta_1 \Delta y_{t-1} + \zeta_2 \Delta y_{t-2} + \ldots + \zeta_{p-1} \Delta y_{t-p+1} + \alpha + \rho y_{t-1} + \delta t + \varepsilon_t$$

This specification controls for serial correlation by including higher order autoregressive terms in the regression. The null hypothesis is that the data were really generated by a unit root autoregression, i.e. that the variable follows the process above with α any value, $\rho = 1$ and $\delta = 0$. Although the t-statistic for ρ is calculated in the usual way, it does not have a limiting Gaussian distribution when the true process is characterized by $\rho = 1$. Using the appropriate limiting distribution, the critical value for the OLS t test of $\rho = 1$, for a sample size of 25, is -3.6. In this study, 24 years of data are available. A t statistic greater than the critical value of -3.6 indicates a unit root, or failure to reject the null hypothesis at the 5% level [Table B-1].

As shown in Table B-1, in most cases, the test fails to reject the null hypothesis that there is a unit root. However, the interpretation of these tests has been called into question. Most importantly, for any unit root process there exists a stationary process that is impossible to distinguish from the unit root representation for any given sample size T. Conversely, for any stationary process and a given sample size T, there exists a unit root process that will be impossible to distinguish from the stationary representation [Hamilton 1994].[115]

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[115] Other objections to unit root tests have been raised. For example, the null hypothesis (the series has a unit root) is only rejected when the weight of evidence is against it. Using a Bayesian approach, in which the null and alternative hypotheses are on a level playing field, DeJong and Whiteman [1991] analyzed the data in Nelson and Plosser's classic 1982 article on unit roots in macroeconomic time series and found that, in fact, only two of the series tested actually contained unit roots. It has also been shown that when tests are conducted using the null hypothesis that the series is stationary, the results often contradict those of the classic unit root tests [Kahn and Ogaki 1990, Park and Choi 1988, Bierens 1990, Kwiatkowski et. al. 1990].

Table B-1: t Statistics for Unit Root Tests

$$(\hat{\rho}-1)/\hat{\sigma}_{\hat{\rho}}$$

	R	G	F	BCPI	PPI
AZ	-1.84	-2.78	-2.60	-2.75	-2.25
CA	-3.58	-1.68	-2.60	-2.75	-2.25
CO	-2.24	-2.22	-2.60	-2.75	-2.25
ID	-2.16	-2.32	-2.60	-2.75	-2.25
MT	-2.86	-1.97	-2.60	-2.75	-2.25
NV	-3.85	-2.14	-2.60	-2.75	-2.25
NM	-2.57	-3.20	-2.60	-2.75	-2.25
OR	-3.14	-2.87	-2.60	-2.75	-2.25
UT	-2.59	-2.37	-2.60	-2.75	-2.25
WY	-2.02	-2.57	-2.60	-2.75	-2.25

Appendix C

C Chapter 3 Heckman Correction for Sample Selection Bias

The expected bias associated with estimation of the cost function using the sub-sample of towns with recycling programs can be estimated using a re-specified probit equation in which the variable **RECC** of Equation (3.2) is replaced by explanatory variables for recycling program costs. The parameters from full-sample estimation of this re-specified probit are used to construct the measure of the bias -- the inverse Mills ratio. This ratio is then included as a separate explanatory variable in the estimation of the cost function using the sub-sample of towns with recycling programs in order to obtain consistent coefficient estimates. These coefficients are used to impute program costs for non-recycling towns. Equation (3.2) can thus be estimated using the full sample of recycling and non-recycling towns. The procedure is explained in detail below.

The net benefit to the mayor from providing curbside recycling services is U_i^*.[116] If $U_i^* \geq 0$, a curbside recycling program is adopted; if $U_i^* < 0$, there is no curbside recycling program.

$$U_i^* = \gamma_0 + \gamma_1 \ln RECC_i + \gamma_2 \ln REFC_i + \gamma_3 FREFC_i + \gamma_4 ENV_i + e_i \qquad (C.1)$$

Suppose for the moment that U_i^* is observable. Recycling program cost ($RECC_i$) is unobserved for towns that do not have a curbside recycling program. Equation (C.1) cannot be reliably estimated using only the sub-sample of towns for which $RECC_i$ is observed. The cost function

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[116] U^*: Net utility to mayor from provision of curbside recycling services

RECC:	Cost of providing curbside recycling services.
REFC:	Avoided refuse costs attributable to curbside recycling services.
FREFC:	1 if disposal facility used by the community is scheduled to close by 1996, 0 otherwise.
ENV:	Level of community household membership in environmental organizations.

for curbside recycling services is[117]

$$\ln RECC_i = \delta_0^* + \delta_1 \ln w_i + \delta_2 \ln Y_i + \delta_3 \ln DENS_i + \delta_4 \ln DIST_i + \delta_5 PRICE_i$$

$$+ \delta_6 MUNI_i + \delta_7 \ln FREQ_i + \mu_i \qquad (C.2)$$

The regression function for the sub-sample of recycling towns ($U_i^* \geq 0$) is given by

$$E(\ln \text{RECC} \mid w,Y,DENS,DIST,PRICE,MUNI,FREQ,U_i^* \geq 0) =$$
$$d_0^* + d_1 \ln w_i + d_2 \ln Y_i + d_3 \ln DENS_i + d_4 \ln DIST_i + d_5 PRICE_i + d_6 MUNI_i + d_7 \ln FREQ_i + E(\mu_i \mid U_i^* \geq 0)$$

The sample selection bias, $E(\mu_i \mid U_i^* \geq 0)$, can be defined in terms of Equation (C.1)

$$E[\mu_i \mid U_i^* \geq 0] = E[\mu_i \mid e_i \geq -(\gamma_0 + \gamma_1 \ln RECC_i + \gamma_2 \ln REFC_i + \gamma_3 FREFC_i + \gamma_4 ENV_i)] \qquad (C.3)$$

It is assumed that $f(\mu,e)$ is a bivariate normal density, thus, from Equation (C.3) using a well-known result,

$$E[\mu_i \mid e_i \geq -(\gamma_0 + \gamma_1 \ln RECC_i + \gamma_2 \ln REFC_i + \gamma_3 FREFC_i + \gamma_4 ENV_i)] = \sigma_{\mu,e} / (\sigma_{ee})^{1/2} * I_i$$

where

$$I_i \equiv \phi(Z_i) / [1 - \Phi(Z_i)]$$
$$Z_i \equiv -(\gamma_0 + \gamma_1 \ln RECC_i + \gamma_2 \ln REFC_i + \gamma_3 FREFC_i + \gamma_4 ENV_i) / (\sigma_{ee})^{1/2}$$

I_i is the inverse Mills ratio; ϕ and Φ are the density and distribution function for a standard normal variable.

Assuming $(\sigma_{ee})^{1/2} = 1$, the conditional regression function for the sub-sample of recycling towns is

$$\ln RECC_i = d_0^* + d_1 \ln w_i + d_2 \ln Y_i + d_3 \ln DENS_i + d_4 \ln DIST_i + d_5 PRICE_i$$

The least squares estimators of the coefficients in Equation (C.4) are unbiased and can be used to impute the value of recycling program costs for municipalities which do not have recycling

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w:	Wage of recycling service providers.
Y:	Tons of recyclables collected annually.
DENS:	Household density in residential area.
DIST:	Distance from municipality to delivery site for recyclables.
PRICE:	Price index for recyclables
MUNI:	1 if recycling services are provided by a municipal agency and 0 otherwise.
FREQ:	Frequency of recyclables collection.
I:	Inverse Mills ratio.

$$+ d_6 MUNI_i + d_7 \ln FREQ_i + d_8 I_i + e_i \qquad (C.4)$$

programs, i.e. municipalities for which $U_i^* < 0$.[118] This provides the data needed to construct the full statistical model for normal population disturbances.

Unfortunately, the variable I in Equation (C.4) is unknown and must be estimated. Given the discrete dependent variable approach taken here, the procedure for estimating I is as follows. Estimate the parameters of the probability that $U_i^* \geq 0$ using a probit analysis on the full sample of towns, i.e. those with and without recycling programs, of the form

$$U_i = \zeta_0 + \zeta_1 \ln w_i + \zeta_2 \ln Y_i + \zeta_3 \ln DENS_i + \zeta_4 \ln DIST_i + \zeta_5 PRICE_i$$

$$+ \zeta_6 MUNI_i + \zeta_7 \ln FREQ_i + \zeta_8 REFC_i + \zeta_9 FREFC_i + \zeta_{10} ENV_i + v_i \qquad (C.5)$$

where U_i is one if the municipality provides curbside recycling services and zero otherwise, and v_i is an error term. This approach mirrors the probit Equation (3.2) in which we are interested, but because of the lack of data on $RECC_i$ for towns that do not provide curbside recycling, information on the regressors in Equation (C.2) is used instead.

Using the estimated parameters from Equation (C.5) the estimate of I

$$\hat{I} = \phi(-\hat{\zeta}'x_i) / [1 - \Phi(-\hat{\zeta}'x_i)]$$

---

[118] The standard least squares estimator of the *population* variance ($\hat{\sigma}_{\epsilon\epsilon}$) is downward biased:

$$\hat{\epsilon}'\hat{\epsilon}/(n\text{-}K) = \sigma_{\mu\mu} - \sigma_{\mu\mu}\kappa^2 [1/(n\text{-}K)\, \Sigma(\hat{I}_i^2 - \hat{I}_i\hat{Z}_i)$$

where

$$\kappa = \sigma_{\mu,e}/\sigma_\mu \sigma_e \quad \text{and} \quad 0 < \Sigma(\hat{I}_i^2 - \hat{I}_i\hat{Z}_i) < 1.$$

This expressic is derived using a well known result for the second moment of the incidentally truncated bivariate normal distribution. Using this expression, it is possible to obtain a consistent estimator of the population variance.

However, an estimate of the asymptotic covariance matrix, $[d', d_8]$, is needed in order to test hypotheses. The expression for the second moment of the incidentally truncated bivariate normal distribution implies heteroscedasticity of the form

$$\text{Var}[\epsilon_i] = \sigma_{\mu\mu}[1 - \kappa^2 (\hat{I}_i^2 - \hat{I}_i\hat{Z}_i)].$$

Unfortunately, in a finite sample, there is no guarantee that the sample estimate of the asymptotic covariance matrix (using the appropriate form of the variance of ordinary least squares in a heteroscedastic model) will be positive definite, and thus that the true standard errors can be computed. This is a common outcome in this model; if in fact they cannot be computed, one cannot be confident that the usual least squares estimates are smaller than the true values [Greene 1990].

can be calculated. This estimate is used in Equation (C.4) fit on the sub-sample of 31 towns that have adopted curbside recycling. The resulting consistent coefficients are then used to impute recycling program costs for municipalities that do not have programs. Finally the probit Equation (3.2):

$$U = \alpha + \beta_1 \ln RECC + \beta_2 \ln REFC + \beta_3 \ln FREFC + \beta_4 \ln ENV + \varepsilon \quad (2.2)$$

can be reliably estimated, using the data developed, for the full sample of recycling and non-recycling municipalities.

Appendix D

D Chapter 4 Cases Upholding Flow Control

Year	Case
1983	*Central Iowa Refuse Systems, Inc. v. Des Moines Metro Solid Waste Agency* 715 F.2d 419 (8th Cir.) The owner of a private landfill challenged the flow control ordinances passed by fifteen Iowa cities.
1984	*Hybud Equipment Corp. v. Akron* 742 F.2d 949 (6th Cir.) A commercial hauler, wishing to take advantage of lower tipping fees elsewhere, challenged an ordinance granting a waste disposal monopoly to the city's waste-to-energy plant. The court upheld the lower court's decision.
1984	*City of Elizabeth v. State Department of Environmental Protection* 486 A.2d 356 (N.J. Super. Ct. App. Div.) The owners of a landfill challenged a flow-control regulation.
1985	*Tri-State Rubbish, Inc. v. Waste Management, Inc.* 803 F.Supp. 451 (D. Me.) A waste hauler challenged flow control ordinances passed by twelve cities in Maine.
1985	*Harvey & Harvey, Inc. v. Delaware Solid Waste Authority* 500 F.Supp. 1369 (D. Del.) A waste hauler challenged flow control because the company did not want to lose the profits it made by taking garbage to cheaper, out-of-state disposal facilities.
1988	*J. Filiberto Sanitation, Inc. v. Department of Environmental Protection* 857 F.2d 913 (3d Cir.) A waste hauler challenged flow control because the company wanted to continue hauling to a cheaper, out-of-state landfill.
1990	*In re Fiorillo Bros. of New Jersey* 577 A.2d 1316 (N.J. Super. Ct. App. Div.) Waste haulers who violated a flow control order challenged the penalties levied by the New Jersey Board of Public Utilities.

Appendix D Continued

1990	*Waste Stream Management, Inc. v. St. Lawrence County* 555 N.Y.S.2d 213 (N.Y. App. Div.) The plaintiff, a commercial waste hauler, challenged a county ordinance requiring all waste to be taken to designated facilities.
1991	*Vinnie Montes Waste System, Inc. v. Town of Oyster Bay* 567 N.Y.S.2d 335 (N.Y. Sup. Ct.) Hauling companies challenged a flow control ordinance on the grounds that it deprived them of a proprietary interest in their garbage collection routes.
1991	*Browning-Ferris Industries of Tennessee, Inc. v. Metropolitan Government of Nashville and Davidson County* No. 01-A-019104CHOO156, WL 219383 (Tenn. Ct. App. Oct. 31, 1991) BFI challenged a flow-control ordinance because it wanted to take advantage of lower tipping fees elsewhere.
1992	*North Hempstead v. Westbury* 182 A.D.2d 272 (N.Y. App. Div.) The town and the solid waste management authority sued several villages that refused to comply with the town's flow control ordinance.

Source: Kim 1993

Appendix E

E Chapter 4 Court Decisions Overturning Flow Control

Court & Date	Case
District July 22, 1991	*De Vito Trucking, Inc. v. Rhode Island Solid Waste Management Corporation*: Court granted preliminary injunction enjoining enforcement of state's flow-control law.
Circuit November 18, 1991	*De Vito Trucking, Inc. v. Rhode Island Solid Waste Management Corporation*: Court affirmed lower court's decision.
District February 14, 1992	*Waste Systems Corporation v. Martin County, Minnesota*: Court invalidated county's flow control ordinance.
Circuit February 18, 1993	*Waste Systems Corporation v. Martin County*: Court affirmed lower court's decision.
Supreme Court Interstate Waste June 1, 1992	*Fort Gratiot Landfill v. Michigan DNR*: Court invalidated state-imposed waste import restrictions: statute forbade flow of solid waste over county lines.
District June 19, 1992	*Container Corp. of Carolina v. Mecklenburg County, North Carolina*: Court granted preliminary injunction stopping enforcement of county's flow-control ordinances.
District March 8, 1993	*Waste Recycling, Inc. v. Southeast Alabama Solid Waste Disposal Authority*: Court stuck down three ordinances, each took a different approach to flow control.
Supreme Court Flow Control May 16, 1994	*C&A Carbone, Inc. v. Town of Clarkstown, New York* On appeal from the state Supreme Court, which found in favor of the town when it sued the hauling company for refusing to comply with a flow control ordinance, the U.S. Supreme Court struck down Clarkstown's law and declared flow controls unconstitutional.

Sources: Kim 1993, Memishi 1994

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