Market Structure and Prices: Evidence from a Natural Experiment in the Solid Waste Industry*

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Abstract

This paper uses a natural experiment in the municipal solid waste industry to empirically measure the effect of market structure on prices. The 1993 Resource Conservation and Recovery Act Subtitle D amendments mandated that all active municipal solid waste landfills make costly technological improvements or exit. I assemble a data set of Illinois landfills and show that more than half of the active landfills chose to exit rather than make the necessary technological improvements. As compared to firms who made the technological improvements (survivors), exiting firms were smaller, older, more likely to be located in areas with high land prices, and less intensive in their operations as defined by a constructed measure of capacity usage. Using the change in concentration due to the regulation, I estimate the causal effect of spatial competition on prices among surviving landfills. I find that a one percent increase in the distance between landfills causes a 0.37 percent increase in price. In total, producer prices rose by 11 percent due to increased market power. This represents an increase in aggregate revenue of 51 million dollars for Illinois landfill owners, although the implied impact on per capita expenditure is small: consumers pay an additional $3.96 per year for garbage disposal due to the increase in spatial differentiation among landfills. Furthermore, for consumers the increase in the price of waste disposal due to increased market power is offset by an accompanying decrease in the price due to the exit of landfills with high marginal costs of production. The net change in the quantity-weighted average price is a decrease of $0.20 per cubic yard of waste.

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1. Introduction

Oligopoly theories of product differentiation predict that producer prices depend on the degree of differentiation. Locations farther apart in the product space reduce the competitive pressure to lower prices in order to gain market share, allowing producers to price above marginal cost. This implies that in a differentiated product industry, the relationship between market structure and prices depends not only on the number of producers but also on their locations in product space. Industries in which product differentiation is relatively easy to measure are those with spatial differentiation. Models of spatial competition predict that producer prices are increasing with respect to the physical distance between competitors due to lower residual demand elasticities. Surprisingly, there is little empirical work measuring the relationship between the degree of spatial differentiation and producer prices[1]. Asplund and Sandin (1999) use data on driving schools in Sweden and find evidence that producer prices are increasing with the geographical distance between markets. They also review the few empirical papers measuring the relationship between spatial differentiation and prices. Only Fik (1988) uses the distance between producers as a measure of spatial differentiation[2]. Like Asplund and Sandin, the other reviewed papers either use the geographic dispersion of firms in a pre-defined region or the distance between geographic markets[3].

The goal of this paper is to provide empirical evidence regarding producer prices and spatial product differentiation. To do this, I collect a new data set of municipal solid waste (MSW) landfills in the state of Illinois and take advantage of a natural experiment that occurred in the MSW landfill industry. This industry is a classic example of industries described by spatial models of competition: firms produce an arguably homogenous good differentiated only by the physical location of the producer, and consumers bear the cost of transporting the good. This lends itself to an objective and easily defined measure of product differentiation: the

[1] Of course there is a large body of literature looking at the relationship between the number of producers and prices, mostly in a homogenous goods context as pointed out by Mazzeo (2002). Earlier works by Breshnahan (1989), Schmalensee (1989), and Weiss (1989) review the empirical literature on market concentration and prices both across and within industries.

[2] Fik finds a positive correlation between producer prices and the distance to a producer's closest competitor, however he does not include any additional price controls in the regression.

[3] Recent work by Mazzeo (2002) and Cohen and Mazzeo (2007) look at the impact of market concentration and product differentiation on prices and profitability in the motel and retail banking industries, respectively. To my knowledge, there is an equally surprising lack of empirical papers looking at the degree of non-spatial product differentiation and the level of producer prices.

distance between producers. Using this measure of product differentiation, I find evidence that producer prices are increasing with respect to the distance between competitors.

The natural experiment that I use is the enactment of the 1993 Resource Conservation and Recovery Act Subtitle D amendments.[4] This regulation mandated that all active municipal solid waste landfills make costly technological improvements or exit. The main effect of the regulation was an increase in the fixed costs of operations for MSW landfills. From an empirical standpoint, the regulation is beneficial for two reasons. First, it created a large amount of variation in market structure that would likely not be exhibited otherwise. Over half of the active landfills chose to exit rather than make the necessary technological improvements. As I document in the paper, this led to exit rates and changes in the distance between competitors that differ greatly as compared to the periods before and after the regulation enactment.

The second beneficial aspect of the regulation is that it allows me to create an instrumental variable for the change in market structure experienced by the landfills whose owners chose to make the technological improvements (survivors) rather than exit. I show that surviving and exiting landfills differed on a set of observable characteristics. I use this result to estimate the predicted change in distance to the nearest competitor for all surviving landfills, based on the characteristics of all landfills (exiters and survivors) at the time of the regulation. I put forth the argument that a landfill's decision to exit or make the necessary technological improvements was independent of its competitors' decisions. Under this assumption, the predicted change in market structure can be used as an instrumental variable for the observed change in market structure among surviving landfills.

I estimate that a one percent increase in the distance between landfills increases prices by 0.37 percent, or alternatively in levels, an increase of one mile between landfills raises prices by $0.13 per cubic yard of waste. The average distance between landfills increased by 7.65 miles due to the exit induced by the regulation, implying that producer prices increased by $0.99 per cubic yard of waste due to increased spatial market power. As a share of per capita expenditures, this is a very small amount. The average Illinois consumer disposes of 4 cubic yards of waste

[4] Blair and Hite (2005) also use the 1993 Subtitle D amendments to look at the change in industry structure in the Ohio landfill industry. They are primarily interested in the location and capacity decisions of landfill owners. As part of their estimation strategy they estimate a price regression using reported average county level prices as proxies for individual producer prices. The authors regress the county level prices on individual landfill characteristics, county level demographics, a landfill's share of state-wide capacity, and the distance between counties with landfills.

per year, implying an additional cost of $3.96 per year due to increased distances between landfills. However, the increase in aggregate revenue for Illinois landfill owners is an additional 51 million dollars due to greater spatial product differentiation[5].

In order to motivate the relationship between prices and spatial product differentiation, and to explain why certain producers would choose to make the necessary technological improvements required by the regulation while others would elect to exit, I present a theoretical model of spatial competition with entry selection and heterogeneous producers. The model extends the work of Syverson (2004) to include two additional choice variables. Similar to other models of entry selection among firms with heterogeneous productivity levels, my model leads to a distribution of firms operating in equilibrium. A common result among these types of models is that an increase in the fixed cost of production leads to fewer but more efficient firms in equilibrium[6]. If firms differ in their marginal cost of production, then the firms best able to cover the higher fixed cost of production and increase their market share are those with lower marginal costs. As a result, the new equilibrium is characterized by fewer firms choosing to produce but a higher productivity level among the firms who do begin production.

I present empirical evidence supporting this comparative static. As I mentioned previously, significant differences existed among landfills that exited versus those that invested in the new technology. One significant predictor of exit from the regulation is a variable I create designed to capture the intensity of landfill operations. The primary activity of a landfill is to convert waste received (quantity) into volume occupied (capacity) through compaction. I create a measure of the volume of one compacted quantity unit of waste and based on industry operations, argue that over a time span of five years, this measure reflects the productivity of landfills. I estimate that a one standard deviation increase in the volume of compacted waste increased the probability of exit from the regulation by 28 percent. To the degree that differences in compaction volume represent underlying differences in productivity, this suggests that the landfills with high marginal costs chose to exit rather than make the technological improvements.

In addition, I document changes in the time-series of the quantity-weighted average price and effort (proxied by the volume of compacted waste) among active landfills that are consistent

[5] The 2006 United States Census Bureau's population estimate for the State of Illinois is 12.8 million.
[6] Examples in addition to Syverson (2004) include Hopenhayn (1992), Melitz (2003), and Asplund and Nocke (2006).

with the predictions of the model. Given that increases in the fixed cost of production induced the exit of landfills with high marginal costs, then both the average marginal cost and dispersion among equilibrium producers will decrease. Empirically this should manifest itself as a decrease in the average volume per compacted unit of waste and a reduction in observed dispersion among landfills. I show that there was a dramatic decrease in both the average level of volume per compacted unit and dispersion during the period of exit from the regulation.

For average prices there are two counteracting effects. Increased distances between producers enable landfill owners to raise prices without the risk of losing market share, resulting in a higher average price. At the same time, the exit of producers with high marginal costs of production lowers the average price, as individual producer prices are an increasing function of marginal costs. The net effect on the average price will depend on the relative magnitudes of these two changes. As mentioned, I estimate that producer prices rose by $0.99 per cubic yard of waste due to increased spatial market power. However, I observe a decrease in the quantity-weighted average price of $0.20 per cubic yard of waste. This implies that the cost savings to Illinois consumers from the exit of landfills with high marginal costs of production is $1.19 per cubic yard. Although surviving landfills enjoy greater spatial differentiation, allowing them to increase their prices, the net change in the average producer price has been a decrease of $0.20 due to concurrent exit of landfills with high marginal costs of production.

In addition to contributing to the empirical literature on market structure, product differentiation, and prices, my research relates to two other separate literatures. As I have outlined above, I find empirical evidence supporting the predictions of the class of models in which there is entry selection among heterogeneous producers. Another point of contact is with research regarding the effects of environmental regulation. A common theme in this literature is that policy evaluations need to take into account the fact that firms strategically alter their behavior in response to environmental regulation. The full cost of environmental regulation is not only the additional compliance costs but also any changes in welfare that may arise from an increase in market power[7]. While the purpose of my paper is not an evaluation of the 1993 Subtitle D amendments, my results do suggest that the regulation has caused an increase in concentration and market power among landfills. However, the composition of firms has

[7] For example, Ryan (2006) estimates the increased sunk costs of entry and welfare effects from the 1990 Clean Air Act. Other work such as Greenestone (1998), Becker and Henderson (2000), and List, et al (2003) examine the impacts of air quality regulations on industrial and economic activity.

changed as well, resulting in a net decrease in the quantity-weighted average price. From a policy standpoint, it is also important to consider the change in the composition of firms that environmental regulation may induce. The overall effect on prices faced by consumers, and hence welfare, will depend on the relative magnitudes of these two effects.

The remainder of this paper is as follows: Section 2 describes the MSW landfill industry and the regulation and Section 3 describes the data and relevant variables. In Section 4, I present a model of spatial competition with entry selection among heterogeneous producers and outline the empirical predictions. Section 5 presents the empirical results regarding exit, market structure, and prices, and Section 6 is my conclusion.

2. The MSW Industry and the 1993 Subtitle D Amendments

Municipal solid waste is defined as any waste that is non-hazardous and generated by residential or commercial sources. The MSW landfill industry is one of two disposal methods for MSW, the other being incineration. Both methods are considered upstream activities in the solid waste industry. Downstream activity is the collection of waste from households by waste haulers. Waste haulers contract directly with households or local municipalities, depending on the local ordinances, and transport the waste to the disposal site. Therefore, the waste haulers bear the cost of transporting the waste to the landfill for the service of disposal.

Industry trade literature suggests that competition among MSW landfills for demand from waste haulers is very local. The regulatory impact analysis for the state of Illinois quotes the average maximum distance traveled by waste collection companies from the center point of their collection area to a landfill was 15-20 miles[8]. I have confirmed through phone calls with waste hauling companies that travel distance is the key determinant in their choice of which landfill to service from.

The primary activity of a landfill is to reduce the volume of waste received through compaction. This can be interpreted as converting the quantity of waste received into volume occupied. The smaller the volume occupied by one unit of waste, the more waste that can be placed in a landfill. Landfill operations are very capital intensive. Industry trade journals are

[8] Camp, Dresser, and McKee (1990).

constantly comparing the latest equipment and their respective compaction volumes[9]. Fundamentally, the largest gains in compaction are made by utilizing heavier equipment. In addition to operations, the costs of construction and post-closure care are also capital-intensive[10]. Overall, capital costs represent 85 percent of the total costs of owning a landfill[11].

The largest environmental threat of a landfill is groundwater pollution. Precipitation that reaches decomposing waste percolates through the waste to form a liquid called leachate, which can be toxic. Decomposing waste also produces methane gas, which can lead to explosions if not properly dissipated. These threats were the motivation for the 1993 Subtitle D amendments.

2.1 The Subtitle D Amendments

The 1993 Subtitle D amendments of the Resource Conservation and Recovery Act were the first federal minimum standards for the design, operation, closure, and post-closure care of MSW landfills. Previous federal regulation had banned open dumps and set performance goals and objectives for municipal solid waste landfills, but left the development of regulation and the authority of regulating MSW landfills to the states[12]. At the time of the 1993 Subtitle D amendments, the existence and quality of state regulations varied widely. A national census in 1986 showed that just over half of the Nation's solid waste landfills were permitted and that the requirements and enforcement of permits varied widely by state[13]. For example, 35 states, representing only 38% of existing facilities, required groundwater monitoring at the time of the census.

The Subtitle D amendments were motivated by concerns that the state of technology for MSW landfills could not protect groundwater from potential leachate pollution. As a result, the

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[9] For example, every issue of the monthly publication *Waste Age* compares the latest compaction tractors and add-on features designed to increase compaction.

[10] It has been documented that approximately 15 percent of a landfill's total costs occur before operation (Duffy 2005). Activities that must be completed before receiving waste include site investigations, completing the permit process, land and equipment purchases, clearing and excavation, and construction of auxiliary structures and the initial sections of the landfill that will receive waste. As a landfill operates over time, it will continually develop new sections of its permitted disposal area. When the entire permitted disposal area has been developed and filled, the landfill owner must incur capital costs to close the landfill and then monitor it for a designated number of years (post-closure period).

[11] Duffy (2005).

[12] For example, the 1979 Resource Conservation and Recovery Act regulations for MSW landfills states that landfills "may not contaminate ground water beyond the solid waste boundary or ground water needed for human consumption," while the Subtitle D revisions state not only this goal but specific requirements for the type of groundwater monitoring devices, frequency of monitoring, steps for assessment, and an outline for corrective action if needed.

[13] USEPA (1991).

mandate introduced specific design and operation standards, such as the implementation of a liner covering the entire fill area of a landfill, installation of a leachate collection system, and the addition of groundwater monitoring wells and methane gas pipes. The technological improvements were primarily capital investments that increased the fixed costs of operating a landfill. Industry studies suggest that the regulation caused an average increase in capital costs for new landfills from 60 to 100 percent and 40 to 80 percent for existing landfills[14].

The first mention of creating new design and operation standards for MSW landfills occurred in the spring of 1988. In their announcement, The United States Environmental Protection Agency declared what areas of landfill operations they were most concerned with and outlined possible standards they would implement. Importantly, there was no mention of a compliance schedule that the final versions of the regulation would include. They also announced that the states could choose to implement their own version of the regulation as long as the state version was as least as strict as the final federal version of the regulation, to be released in 1991. Illinois published its version of the regulation on September 9, 1990.

In laying out the compliance dates for the regulation, Illinois listed three options for existing landfills. Landfills that currently did not meet the new standards and whose owners chose not to make the mandated technology investments would have to close by September 9, 1992. Any existing landfill already meeting a subset of the standards but whose owner(s) chose not to meet the remaining standards could continue operating until September 9, 1996. To operate after September 9, 1996, all of the new standards would have to be met[15]. All new landfills opening after September 9, 1992 would have to comply with the entire set of revised standards.

2.2 Impact of the Regulation on Market Structure

A unique feature of the Subtitle D regulation is that it dramatically changed the structure of the MSW landfill industry. While my data set, which I describe in the next section, covers only the state of Illinois, aggregate statistics by the USEPA suggest that in 1991, over half of the active landfills across the country chose to exit rather than make the necessary technological

[14] Camp, Dresser, and McKee (1990).
[15] The final compliance date of September 9, 1996 would eventually be pushed back to April 1998 for bureaucratic reasons. However, this was not determined until early in 1996, after the majority of landfills had already exited in order to meet the first compliance date.

improvements, decreasing the number of active landfills nationwide from 8000 prior to 1991 to 3,581 in 1995[16]. Likewise in Illinois, over 50 percent of active landfills chose to exit rather than meet the technology standards.

Figure 1 graphs the number of MSW landfills and exit rates for the State of Illinois from 1986-2003. The exit rates are the fraction of active landfills in a given year that receive zero waste in subsequent years. We can see there was a large increase in the fraction of landfills exiting in 1992, the year of the first compliance date. Of the landfills that reported in which month they closed, 70 percent listed September of 1992, the month of the first compliance date. There was also an increase in exit rates between 1996 and 1998, the second compliance date[17].

The closure of active landfills was not specific to one geographic area of Illinois. Figure 2 shows a map with the geographic location of landfills before and after the regulation. As evident in the figure, closures occurred throughout the state. In 1991, the average and median distances between a landfill and its closest competitor was 17.74 and 16.45 miles, respectively. By 1999 these distances had increased to 26.78 and 26.15 miles.

3. Data and Relevant Variables

In order to measure the effect of market structure on prices in the MSW landfill industry, I compiled a new data set using the Illinois annual "Nonhazardous Solid Waste Management and Landfill Capacity Reports" published by the Illinois Environmental Protection Agency. The reports are an annual publication that began in 1987 with the purpose of assessing the state's MSW disposal capacity[18]. Each report profiles every municipal solid waste landfill operating in the State of Illinois, including new facilities being planned as well as recently closed landfills. The result is a panel data set that includes the universe of MSW landfills in the State of Illinois spanning the years 1987-2003, with 1,344 landfill-year observations.

Each report includes information on the quantity of solid waste received, remaining capacity, price, landfill characteristics, and administrative data. Price is only reported for the years 1991-2003, resulting in only one observation per landfill before the regulation became binding. Landfill prices are the FOB price reported by landfill owners at the end of the calendar

[16] USEPA (2006) and (1996).
[17] There was also entry into the Illinois landfill industry beginning in 1995. 11 percent on the landfills active in 2003 entered post-1995.
[18] Each report lists the previous year's universe of landfills. The 1987 report only lists quantitative data for half of the year. Therefore, I only use the 1987 report for the purposes of entry and exit.

year and have been adjusted to constant 2000 dollars. Quantity, capacity, and price are reported in *gate cubic yards*, i.e. the volume of waste received by the landfill from the waste hauler before it is placed in the ground and compacted[19].

The 1993-1995 editions of the reports asked all landfills owners who exited during the period the following question, "Did you exit because of the Subtitle D amendments?" The reported answers to this question are the basis for my determination of which landfills exited because of the regulation. I classify a landfill as an exiter if that landfill is observed exiting between the years 1992-1994 and answered "Yes" to the above question. In total, there are 51 "exiters". The other group of landfills used in this paper is those classified as "survivors". These include the 38 landfills that were active as of 1990, and that either did not exit during the sample period or exited between the years 2000-2003.

I have supplemented the data in a number of ways. Using the Illinois EPA's online permit database I was able to fill in missing ownership data, allowing me to distinguish between privately and publicly owned landfills. I obtained additional data on landfill technology (methane gas and leachate collection systems) and permitted disposal acres for the years prior to 1995 from The Illinois Waste Management and Research Center, which publishes a GIS database of landfills including a number of attributes. The Annual Capacity Reports only began to collect this information in 1995. I use the Illinois Natural Resource Geospatial Data Clearinghouse GIS data on the distribution of bedrock aquifers to create a variable indicating if a landfill is located within five hundred vertical feet of an aquifer. As the motivation behind the Subtitle D amendments was the landfills' potential for causing groundwater pollution, their proximity to an aquifer might also have been a factor in the exit decision of landfill owners. The Clearinghouse also provides a GIS data set on highway infrastructure. I calculate the Euclidean distance from a landfill's location to the closest Illinois state road. This captures a landfill's accessibility and can be interpreted as a proxy for transportation costs faced by waste haulers.

To control for demand density I use the population density of the county in which each landfill is located. Annual population estimates were obtained from the United States Census Population Division and land areas from the Illinois Statistical Abstract. This is an imperfect measure of demand density, as the true consumers of landfills are waste haulers. The assumption

[19] The term "gate cubic yards" refers to the fact that the quantity of waste dropped off by waste haulers is determined at the front gate of a landfill.

here is that the waste hauling industry is perfectly competitive and the number of firms is determined by population density. I do not observe landfill factor costs, however I use a counties' average hourly construction wage constructed from the County Business Patterns data sets to proxy for locational differences in labor costs. To control for differences in land value, I include the county average farm value per acre using the United States Department of Agriculture's census.

Appendix A lists and describes all of the relevant variables used in the paper and Table 1 presents summary statistics. Of these variables, two are worth describing in detail here, as these variables are of significant importance to my analysis. The first variable, distance to the closest landfill, is the travel distance measured in miles between a landfill and its closest competitor, and represents the degree of product differentiation[20]. This was calculated by first mapping all of the landfills in ArcGIS, measuring the Euclidean distance between all landfills, identifying every landfill's closest competitor, and then calculating the travel distance between a landfill and its closest competitor using MapQuest.

The second variable that I have created is the volume of a compacted unit of waste. Using a stock and flow relationship of a landfill's annual reported remaining capacity and the cumulative quantity of waste received, I use the following formula to calculate the volume or space occupied by one quantity unit of waste after it has been compacted[21]:

$$\text{Volume of compacted qty unit} = \frac{\text{Total Volume of a Landfill}}{\text{Remaining Capacity in year t} + \sum_{k=\text{year open}}^{t} \text{Quantity received in year k}}$$

Given that remaining capacities and quantities are already measured in units of volume (cubic yards), my measurement of the volume of compacted waste can be interpreted as the reduction in one cubic yard of waste through compaction. This implies that the volume of compacted waste should be between (0,1][22]. If a landfill owner chooses not to exert any effort in compacting waste, then one cubic yard of waste dropped off by a waste hauler requires one cubic

[20] Distance to the closest landfill does not take into account ownership. After the regulation, a small fraction of neighboring landfills are owned by the same firm. The empirical results do not differ when I use distance to the closest firm rather than the closest landfill.

[21] Please see Appendix B for a more detailed description of the derivation of this formula and the empirical measurement.

[22] 12.8% of the landfill-year observations in the sample have a calculated volume per compacted quantity unit above 1.0.

yard of capacity for disposal. Otherwise the combination of effort exerted along with the technology used will enable one cubic yard of waste dropped off by a waste hauler to use less than one cubic yard of capacity.

The volume of a compacted quantity unit represents the intensive margin of space or volume usage in landfill operations. Given the fixed volume of a landfill, compaction determines the degree to which landfill operators utilize their capacity of space. The capital used in compaction is the primary determinant of the degree of compaction[23]. Investments in compaction machinery usually occur at a minimum of every five years. Therefore, over this time-horizon, the volume of compacted waste can be thought of as a fixed variable. Given that there were only two years between the regulation announcement and the first compliance date, I treat the volume of compacted waste as a fixed landfill characteristic when I explore the determinants of exit from the regulation.

4. Spatial Competition and Heterogeneous Producers

In order to gain insight into how producer prices depend on market structure and the degree of production differentiation, I present a model combining spatial competition and entry selection among heterogeneous marginal cost producers based on Syverson (2004). Allowing for differences in productivity among producers gives intuition as to which producers would be the most affected by a regulation that caused an increase in the fixed cost of production for all producers. It also provides a framework for comparing the pre- and post-regulation equilibriums. The model has been developed with the landfill industry in mind, following the setup of Blair and Hite (2005), although the results are common to models of entry selection among heterogeneous producers.

4.1 Demand

Identical consumers are located uniformly around a unit circle with a density of D consumers per unit length. Each consumer demands the service of disposing one unit of waste and will purchase the service of disposal if the price of disposal as faced by the consumer p' is below the consumer's reservation value. Reservation values are assumed to be high enough that in equilibrium, all consumers purchase the service of waste disposal. As each consumer

[23] In particular, the weight of the machine and type of wheels determine the degree of compaction.

demands the service of disposing only one unit of waste, total quantity of waste in the market is fixed at demand density *D*. The price faced by the consumer p' is comprised of the price set by the seller of disposal services, p, plus the transportation cost paid by the consumer, tx, where *t* is the unit transport cost and *x* represents the distance between the seller and consumer.

4.2 Producers

Producers are ex-ante identical and play a two-stage game. In the first stage, producers decide whether or not to pay a sunk setup cost *S* in order to receive an idiosyncratic marginal cost draw c_i from the ex-ante marginal cost distribution $g(c)$ with support $[0, c_u]$. All cost draws are private information. The cost draw c_i represents the marginal cost of effort exerted by the producer in compacting one unit of waste. Producers must use effort, e_i, to transform the quantity of waste dropped off by the consumer into capacity units for disposal. Let $\phi(e_i)$ represent the volume of a unit of waste with compaction effort level e_i, $e_i \in (0, \infty)$, where $\phi(e) > 0, \phi'(e) < 0, \phi''(e) > 0$. The function $\phi(\cdot)$ determines how much capacity is used by one quantity unit. Maximum capacity of the firm is given by its volume, which is assumed to be a linear function of the total number of disposal acres of land chosen by the firm. All firms face a common price of land per acre, P_A, and must ensure that the total volume of quantity units disposed of by the firm is less than or equal to its maximum capacity.

To review thus far, ex-ante identical producers learn of their marginal cost of effort c_i after paying the sunk cost *S*, and cost draws are private information. After receiving their cost draws, producers enter the second stage of the game and decide whether or not to begin production. Those who choose to produce are randomly placed at evenly spaced locations around the unit circle. They then simultaneously choose their price per quantity unit of waste, p_i, compaction effort per quantity unit of waste, e_i, and the total number of acres, A_i, given their expectations from the cost distribution *g(c)*, their unit cost of effort c_i, the price per acre P_A, a common fixed cost of production *f*, the function $\phi(\cdot)$, and a capacity constraint ensuring that the total expected volume of quantity units disposed of by the firm is less than or equal to its maximum capacity.

4.3 Market Equilibrium

In order to begin deriving insights from the model, consider the problem faced by producer *i* who has drawn unit cost c_i and has decided to begin production. The demand curve faced by this producer depends on his price, p_i, and the prices set by the producers immediately to his right and left along the unit circle. Between producer *i* and his right-hand neighbor *j*, there exists a location x_{ij} such that $p_i + tx_{ij} = p_j + t\left(\frac{1}{n} - x_{ij}\right)$, where *n* represents the number of producers beginning production. At this location, consumers are indifferent to purchasing from producer *i* or producer *j*, and the total demand captured by producer *i* between himself and producer *j* equals $x_{ij}D$. Likewise, there exists a location between producer *i* and his left-hand neighbor *k* such that total demand captured by producer *i* between himself and neighbor *k* equals $x_{ik}D$.

As producers simultaneously choose their price, effort, and the number of acres, and marginal cost draws are private information, they must make their choices based on expectations from the ex-ante cost distribution. Since all producers are identical ex-ante,

$$E(x_{ij}) = E(x_{ik}) = E(x_i) = \frac{E(p) - p_i}{2t} + \frac{1}{2}E\left(\frac{1}{n}\right) \qquad (1).$$

The maximization problem of a producer who has decided to begin production is therefore to maximize expected profits subject to the constraint that the volume of expected demand is less than or equal to the volume of the landfill.

$$\max_{p_i, e_i, A_i} \quad E(\Pi_i) = (p_i - c_i e_i)\left(\frac{E(p) - p_i}{t} + E\left(\frac{1}{n}\right)\right)D - P_A A_i - f \qquad (2)$$

$$s.t. \quad \alpha A_i \geq \phi(e_i)\left(\frac{E(p) - p_i}{t} + E\left(\frac{1}{n}\right)\right)D$$

The parameter α represents volume per acre and it is assumed $\alpha > 1$. In order to analytically work through the problem I assume the functional form $\phi(e_i) = 1/e_i$.

Solving for price, effort, and acres as functions of the marginal cost draw, exogenous parameters gives:

$$p_i = \frac{1}{2}\left(E(p) + tE\left(\frac{1}{n}\right)\right) + \sqrt{\frac{P_A c_i}{\alpha}} \qquad (3)$$

$$e_i = \sqrt{\frac{P_A}{\alpha\, c_i}} \qquad (4)$$

$$A_i = \frac{D}{t}\sqrt{\frac{c_i}{\alpha\, P_A}}\left(\frac{1}{2}\left(E(p) + tE\left(\frac{1}{n}\right)\right) - \sqrt{\frac{P_A c_i}{\alpha}}\right) \qquad (5).$$

Price is increasing with respect to the marginal cost of effort and the cost of land, as well as the expected distance between producers. Effort is decreasing with respect to the marginal cost of effort and increasing with respect to the price of land. This reflects the fact that effort and the size of a landfill are tradeoffs in production. Likewise, the total number of acres chosen by the producer is decreasing with respect to the price of land but increasing with respect to the marginal cost of effort. The number of acres is also increasing with respect to demand density *D* and the expected distance between producers.

As all producers have the same expectations, we can use equations 3-5 to solve for expected price, effort, and acres in terms of expected costs.

$$E(p) = tE\left(\frac{1}{n}\right) + 2\sqrt{\frac{P_A}{\alpha}}E\left(c^{1/2}\right) \qquad (6)$$

$$E(e) = \sqrt{\frac{P_A}{\alpha}}\frac{1}{E\left(c^{1/2}\right)} \qquad (7)$$

$$E(A) = \frac{D}{t}\sqrt{\frac{1}{\alpha\, P_A}}\left(tE\left(\frac{1}{n}\right)E\left(c^{1/2}\right) + \sqrt{\frac{P_A}{\alpha}}\left(\left(E\left(c^{1/2}\right)\right)^2 - E(c)\right)\right) \qquad (8)$$

A Bayesian-Nash equilibrium in expectations can be solved for by plugging equation 6 back into equation 3 and 5, and expected profits for producer *i* can be written in terms of the producer's own marginal cost draw, the exogenous parameters, the expectation of the square root of marginal cost, the expected distance between producers:

$$E(\Pi_i) = \frac{D}{t}\left(\sqrt{\frac{P_A}{\alpha}}\left(E\left(c^{1/2}\right) - c_i^{1/2}\right) + tE\left(\frac{1}{n}\right)\right)^2 - f \qquad (9).$$

Expected second-stage profits are decreasing with respect to the firm's marginal cost of effort. Provided the upper bound cost draw c_u is large enough, there exist cost draws for which the expected profits of producing are negative. Producers with a high marginal cost and who do

not expect to cover the fixed costs of production will not enter. This leads to a cutoff cost draw, $c*$, such that producers who draw a marginal cost higher than $c*$ choose not to begin production in the second stage[24]. The effect of $c*$ is to truncate the ex-ante cost distribution from above.

The cost cutoff $c*$ is determined in the first-stage of the game. At this stage a pool of ex-ante identical producers decide whether or not to pay the sunk cost *S* in order to receive a cost draw c_i. In order to pin down the expected number of producers, a free-entry condition is imposed: the expected number of producers adjusts to set the expected value of entry equal to zero, where the expected value of entry is equal to expected operating profits less the entry cost.

$$V^e = \int_0^{c*} E(\Pi_i \mid c \le c*) g(c) dc - S = 0 \qquad (10)$$

Using the zero-profit condition, equation 9 can be expressed as a function of $c*$. Rewriting 10 gives:

$$V^e = \int_0^{c*} \left[\frac{D}{t} \left(\sqrt{\frac{ft}{D}} + \sqrt{\frac{P_A}{\alpha}} \left(c*^{1/2} - c_i^{1/2} \right) \right)^2 - f \right] g(c) dc - S = 0 \qquad (11).$$

The equilibrium $c*$ will be a function of the parameters D, α, P_A, *t, f, S,* and the distribution $g(c)$.

4.4 Comparative Statics

As discussed, the main effect of the Subtitle D amendments was an increase in the fixed cost of production for all landfill owners. The key comparative static then, is how does $c*$, the marginal cost for which an entrant makes zero expected profits, change as fixed costs increase? To solve for this we can use the implicit function theorem:

$$\frac{dc*}{df} = \frac{-\partial V^e / \partial f}{\partial V^e / \partial c*}$$

Computing the derivatives yield

[24] This zero-profit condition implies that the marginal entrant earns zero expected profits. On average, expected profits among entrants are positive.

$$\frac{\partial V^e}{\partial f} = \int_0^{c*} \left[\sqrt{\frac{DP_A}{\alpha tf}} \left(c*^{1/2} - c_i^{1/2} \right) \right] g(c)dc \ > 0 \qquad (12)$$

and

$$\frac{\partial V^e}{\partial c*} = \int_0^{c*} \left[\frac{D}{t} \sqrt{\frac{P_A}{\alpha c*}} \left(\sqrt{\frac{ft}{D}} + \sqrt{\frac{P_A}{\alpha}} \left(c*^{1/2} - c_i^{1/2} \right) \right) \right] g(c)dc \ > 0 \qquad (13)$$

with the result that $\frac{dc*}{df} < 0$.

An increased fixed cost of production lowers the maximum marginal cost draw for which a producer would make non-negative expected profits. Higher fixed costs of production directly lower operating profits for any marginal cost draw. In order to preserve the condition that the expected value of entry equals zero, it must be that in equilibrium, firms produce larger quantities. Increasing market share will be easiest for producers with low marginal costs, making it more difficult for producers with high marginal costs to compete. The result is a decrease in the cost cutoff and further truncation of the equilibrium cost distribution.

Although the model is static, it does give insight into long-run effects of the Subtitle D regulation. Assuming the regulation increased fixed costs for landfill owners, the marginal cost for which expected operating profits equals zero fell from $c*$ to $c*_{new}$. We should expect that after the increase in the fixed cost of production, landfills with high marginal costs that were profitable before the regulation (c_i close to the original $c*$) now forecasted negative expected profits. It can be reasoned that these landfills ($c*_{new} < c_i \leq c*$) would exit and those whose marginal cost was equal or less than the new truncation point $c*_{new}$ would make the technological improvements.

Empirically, the marginal cost of effort is unobservable. However, the prediction of the model is that ceteris paribus, landfills with high marginal costs use their space less intensively. Controlling for the cost of land, we would expect producers with higher volumes of compacted waste to exit. This is one of the empirical predictions I will test in the next section.

We can also use the model to make long-run predictions regarding the surviving landfills. Individual producer prices are increasing with respect to the expected distance between producers (equation 3). After the exit of the landfills with high marginal costs, surviving landfills are more differentiated as the spatial distance between landfills has increased. This

leads to the primary empirical question: Do producer prices increase in response to greater spatial distances between landfills?

Lastly, average prices, effort, and acres (equations 6-8) are all functions of the expected cost among equilibrium producers, which is based on the truncated cost distribution:

$$E(c) = \int_0^{c^*} c \frac{g(c)}{G(c^*)} dc \qquad (14)$$

A decrease in c^* affects the truncated cost distribution by reducing the expected cost among equilibrium producers and by reducing the variance. Empirically, we should see these two effects when looking at the average price and effort among active landfills over time. From equation 7, a reduction in the expected cost of equilibrium producers will increase average effort levels and decrease effort dispersion. If the landfills with high marginal costs exited, then we should see average effort levels increasing over time while dispersion decreases. This should manifest itself as a decrease in the average volume of compacted waste as well as a reduction in the dispersion in the volume of compacted waste.

The equation for average prices, equation 6, tells us there will be two separate effects. First, average price should decrease due to a decrease in expected costs among producers. However, the separate effect of an increase in the average distance between landfills will cause an increase in the average price. The net effect will depend on the relative magnitudes of the two changes. This exemplifies the idea behind an equilibrium of heterogeneous producers that experiences an increase in the fixed cost of production; after the exit induced by the regulation, there are, on average, fewer but more productive producers. An increased distance between landfills allows the surviving producers to raise price, but now they compete against a tougher set of competitors in terms of marginal costs, reducing their ability to raise price. The effect on price dispersion is not obvious a priori as it will depend on the relative changes in dispersion of these two effects.[25].

In summary, the empirical predictions I will test are as follows:

- High marginal cost landfills exited rather than make the technological investments mandated by the regulation.

[25] The reduction in average costs and dispersion will also change the average size (acres) of equilibrium producers. Although, due to the interaction of expected distance and expected costs, the predictions for the net effect are less clear.

- Surviving landfill producer prices increased as the spatial distance among landfills decreased.
- The average volume per compacted quantity unit and dispersion decreased over time among active landfills.
- The average price among active landfills changed due to two separate effects: the increase in spatial distance between landfills and the decrease in average costs among active landfills.

5. Exit, Market Structure, and Prices

5.1 Exiting vs. Surviving Landfills

Do the observable characteristics in landfills that exited versus those whose owners made the technological investments differ? To test this, I run a series of probits using observable landfill characteristics measured before the first compliance date of 1992. Formally, I estimate the empirical model

$$\Pr(exit_i = 1 \mid X_{it}) = \Phi(\beta_0 + X_{it}\beta) \qquad (15)$$

where Φ is the standard normal cumulative distribution function and the vector X_{it} includes controls for individual landfill characteristics. The dependent variable equals one if a landfill is classified as an exiter, zero if it is a survivor[26].

I estimate equation 15 using separate cross-sections for the years 1987-1991, as well as the average values across this time period. Table 2 presents the probit results using the 1991 observables, as well as a test of equal means across the two groups[27]. Columns 1 and 2 report the marginal probabilities of exit and standard errors in parentheses. Column 3 shows the increase in the probability of exit for a one-standard-deviation increase in the significant variables[28]. Columns 4 and 5 show the means and standard deviations for each group, and Column 6 presents the difference in means and standard errors.

In column 2, we see that landfills more likely to exit rather than make the technological improvements were those that had higher compacted volumes per unit of waste, were older,

[26] Exiters are those landfills observed exiting between the years 1992-1994 and answered "Yes" to the question "Did you exit because of the Subtitle D amendments?" Survivors are landfills active as of 1990 and that either did not exit during the data period or exited between the years 2000-2003.
[27] Results using years 1987-1990 and the averages over 1987-1991 are similar to those presented in Table 2.
[28] The standard deviation from the 1991 observations is used.

smaller in terms of total acreage, and located in counties with higher per acre values of farm land. Each of these four variables has a non-trivial effect on the probability of exit. A one-standard-deviation increase in each variable (volume, age, and farm land value) increases the probability of exit by 28, 20, 37 percent respectively, and a one-standard-deviation increase in acres decreases the probability of exit by 19 percent.

Consistent with the predictions of the model, landfills with higher volumes per compacted quantity unit were more likely to exit, even after controlling for differences in land values. If differences in the intensity of operations reflect underlying differences in productivity, then ceteris paribus, the regulation caused the exit of less productive landfills. The fact that older landfills were more likely to exit may also reflect differences in technology. Older landfills also have fewer remaining years of operation to recoup the increased fixed costs.

Potential economies of scale in the increased fixed costs of the regulation could be a reason that larger landfills were more likely to make the technology improvements rather than exit. It is interesting to note that location in a county with high land prices increased the probability of exit, conditional on landfill characteristics, but that on average land prices did not differ between survivors and exiters (column 6). Conditional on landfill characteristics, increases in the fixed cost of operation will lower profits more for landfills with higher costs of land, giving us the result of a significant effect on the probability of exit. However, the t-test of equal means tells us that not all landfills located in areas with high land prices exited. This also lends support to the prediction that it was the underlying differences in individual costs (and profits) that influenced the decision to exit.

Two variables that exiters and survivors differed on, but do not predict exit were total quantity and ownership. Surviving landfills received larger annual quantities of waste than exiting landfills (column 6), but after controlling for compaction volumes and size, quantity received does not predict exit. Landfills with lower volumes of compacted waste would be able to receive more waste, as well as landfills with larger disposal acres. Exiting landfills were more likely to be publicly-owned. However, publicly-owned landfills also had significantly higher volumes of compacted waste. The average volume of compacted waste is three times higher among publicly owned landfills than among privately owned landfills, and ownership explains twenty percent of the sample variation in volume of compacted waste.

The remaining variables are not statistically significant predictors of exit. In particular, the existing market structure as measured by a landfill's distance to its closest competitor was not a predictive factor of exit. Therefore it is not the case that only the less differentiated landfills exited. Also, the locational variables representing a landfill's distance to the nearest state highway and whether or not a landfill was located in the Greater Chicago Metropolitan area are not statistically significant.

5.2 Market Structure and Prices among Surviving Landfills

As outlined in the theoretical section, prices are increasing with respect to the expected distance between producers. Increased distances between producers lower consumers' substitution possibilities, which lowers residual demand elasticities and increases producer mark-ups. It would be expected that surviving landfills which experienced increases in the distance to their nearest competitor after the regulation, ceteris paribus, would respond by increasing their price.

At first glance, the raw data suggests that both the average distance between competitors and price among surviving landfills increased between 1994 and 1996. Figure 3 graphs the annual percent change in the average distance and price for surviving landfills. The change in distance and price follow a similar pattern, although there is a two-year lag between them. Distance to the closest competitor increases by 16.3 percent in 1994 while prices do not increase until 1996, the year of the second compliance date. As Figure 1 indicates, by this point in time, the majority of exit from the regulation has already occurred. One possible explanation for this lag is that landfill owners were waiting out the transition period between the two compliance dates, 1992 and 1996, before responding to the change in market structure. If landfill owners were independently making their decisions to exit, then there would be uncertainty for surviving landfills regarding the potential change in their market structure. Only after the time window of possible exit has passed and the change in market structure has been revealed would the risk of losing market share due to higher prices be minimized.

To measure the relationship between landfill prices and distance between competitors as suggested in Figure X, I specify the empirical model

$$p_{it} = \beta_0 + \beta_1 dist_{it} + X_{it}\delta + \theta_t + l_i + \varepsilon_{it} \qquad (16)$$

where p_{it} is landfill *i*'s price per gate cubic yard in year *t*, $dist_{it}$ is the travel distance (in miles) between landfill *i* and its nearest competitor, X_{it} is a vector of price controls including observable landfill characteristics and local county demographics, θ_t is a time specific effect, l_i is an unobserved landfill specific effect, and ε_{it} is the unobserved random error component. I also estimate equation 16 in logarithmic form. The theoretical prediction is that β_1 is positive: price is increasing in distance between landfills.

Obstacles to identifying β_1 include possible correlation between $dist_{it}$ and l_i, as well as possible correlation between $dist_{it}$ and ε_{it}. To control for possible correlation between the landfill specific effect and distance, I estimate equation 16 using fixed-effects and a difference-in-differences (DD) approach. In the DD specifications, I collapse the data into two time observations per landfill, pre- and post-regulation, and estimate

$$\Delta p_i = \theta + \beta_1 \Delta dist_i + \Delta X_i \delta + \Delta \varepsilon_i \qquad (17).$$

Here, β_1 is identified by using cross-sectional differences in the change in distance to the nearest competitor, while under the fixed-effects estimation β_1 is identified by using the time-series variation experienced by each landfill. The DD approach also helps to address concerns regarding the lag between the change in distance and the change in price. I define the post-regulation period over four different periods: 1996 only, the 1996-1997 average, the 1996-2002 average, and the 1996-2003 average. The reasoning behind the first two post-regulation periods is that during the period 1996-1997 prices rose but entry had not occurred yet. The years 1998-2003 are included for comparison purposes. The pre-regulation period is defined as 1991.

To control for possible correlation between $dist_{it}$ and ε_{it}, I use an instrumental variable. If there were unobserved demand or factor cost shocks that also influenced a landfill's decision to exit in addition to the regulation, then distance to the closest competitor would be correlated with price unobservables and β_1 would not be identified. Shocks that were positively correlated with the number of producers, such as demand shocks, would downward bias β_1 as producer spacing would be denser. Changes in unobserved factor costs would upward bias β_1 as distance among producers would be positively related to factor costs. Sources of bias in β_1 are a

potential concern given that I do not observe factor costs and I am imperfectly measuring demand density.

The instrumental variable that I use is the predicted change in distance to the nearest competitor after the enactment of the regulation, wherein the prediction is based on the probit results of Section 5.1. I calculate the instrument as follows:

1) For each landfill *i* active in 1991, estimate

$$P\left(exit_j = 1 \mid X_{j1991}\right) = \Phi\left(\beta_0 + X_{j1991}\beta\right) \quad \forall j,\ j \neq i$$

and predict

$$\hat{P}\left(exit_i = 1 \mid X_{i,1991}\right)$$

2) For each landfill *i* order all competitors from closest to farthest. Calculate

$$\hat{D}_i = \left(1 - \hat{P}\left(exit_1 = 1 \mid X_{1,1991}\right)\right) * dist_{i1} + \left(\hat{P}\left(exit_1 = 1 \mid X_{1,1991}\right) * \left(1 - \hat{P}\left(exit_2 = 1 \mid X_{2,1991}\right)\right)\right) * dist_{i2} + \ldots$$

where $dist_{ik}$ is the distance between landfill *i* and its *k*th closest competitor and $\hat{P}\left(exit_k = 1 \mid X_{k,1991}\right)$ is the probability the *k*th closest competitor exits.

3) Instrument $\Delta dist_{i,1991-t} = dist_{i,t} - dist_{i,1991}$ with $\Delta \hat{dist}_i = \hat{D}_i - dist_{i,1991}$.

The first step in calculating the predicted change in distance to the nearest competitor is estimating each landfill's predicted probability of exit from the regulation. For a given active landfill in 1991, the full probit specification from Table 2 Column 2 was estimated on all of the *other* landfills in the sample. The coefficients from this estimation were used to calculate the predicted probability of exit from the regulation for the given landfill.

After this is estimated for all of the 108 active landfills in 1991, step two involves ordering each surviving landfill's competitors from closest to farthest. I then calculated the predicted distance to the nearest competitor for landfill *i* after the regulation as the probability weighted summation of each possible competitor becoming landfill *i*'s closest competitor. For example, $\left(1 - \hat{P}\left(exit_1 = 1 \mid X_{1,1991}\right)\right)$ is the probability that the closest competitor in 1991 remains the closest competitor after the regulation while $\left(\hat{P}\left(exit_1 = 1 \mid X_{1,1991}\right) * \left(1 - \hat{P}\left(exit_2 = 1 \mid X_{2,1991}\right)\right)\right)$ is the probability that the second closest competitor in 1991 becomes the closest competitor after

the regulation. Step three creates the instrument by using the difference in the predicted distance to the closest competitor after the regulation and the actual distance to the closest competitor in 1991.

As the instrumental variable only results in one observation per surviving landfill, I am not able to instrument under the fixed-effects specification. I can estimate the DD equations using the four different post-regulation time periods: 1996, 1996-1997, 1996-2002, and 1996-2003.

The assumption underlying the validity of the instrument is that each landfill independently decided whether to exit or make the technological improvements required by the regulation. If this were to be true, then in the specification using 1996 as the post regulation period,

$$Cov\left(\Delta \hat{dist}_{i,1991-1996}, \Delta\varepsilon_{i,1991-1996}\right) = 0 \qquad (18).$$

While equation 18 can never be tested, it can be shown that the surviving landfills that experienced large changes in distance to the nearest competitor did not differ in observables as compared to those that saw little change in distance to the nearest competitor, apart from being located in the Greater Chicago Metropolitan area. Table 3 presents means for the observables used in the probit specification by two groups: those for which $\Delta dist_{i,1991-1996}$ was above the median change in distance and for those whose change in distance was below the median.

From the probit results in Table 2, we know that the landfills most likely to exit rather than make the technological investments were those that were old, small in total acreage, located in areas with high land prices, and less intensive in their volume usage. Importantly, the surviving landfills across the two groups do not differ in these observables. This allows us to rule out stories such as this: landfills that saw the greatest increases in distance between competitors were old landfills that should have exited but chose not to because the owners determined that all of their nearest competitors were exiting.

The one observable that does differ across surviving landfill is whether they were located in the Greater Chicago Metropolitan area or not. Landfills that experienced increases in distance to the closest competitor below the median change were more likely to be located in the Chicago area. This is logical given that there were more active landfills in this area prior to the regulation and hence closer producer spacing. In Table 2, we see that landfills in the Chicago area were no

more likely to survive than landfills outside of the Chicago area. However, for those that did survive in the Chicago region, it would be expected that the increase in distance to the closest competitor would be less than the increase experienced by more rural surviving landfills, where the pre-regulation producer spacing was less dense.

The results of Table 3 lend support to the idea of the regulation acting as a natural experiment. Under the assumption that the active landfills in 1991 independently chose whether or not to exit, the regulation acted as a random treatment for the surviving landfills. Some surviving landfills witnessed a large change in market structure while others did not. It is this variation in the change in market structure for surviving landfills due to the exit induced by the regulation that I will use to identify the effect of spatial distance on producer prices.

5.2.1 The Instrument and First Stage Regressions

To illustrate the instrumental variable, Figure 4 plots the 1991-1996 change in actual distance to the closest competitor for surviving landfills against the predicted change in distance to the closest competitor. Table 4 presents the first stage regression results for the eight instrumental variable specifications estimated. Each column under Part A and B corresponds to a second stage regression in Tables 5-8. For example, the first column in Part A is the first stage regression of Column 7 in Table 5. The predicted change in distance to the closest landfill is a strong instrument for the actual change in distance. The coefficient on the predicted change in distance is statistically different than zero at the one percent level, and the partial R-squared is above 0.5 in all of the specifications.

5.2.2 Price Regressions

Tables 5-8 present the results of estimating equations 16 in levels and in logs. Table 5 presents the price regression in levels with no additional controls while Table 6 includes the total number of disposal acres, dummy variables for operating a methane gas and a leachate collection system, the county's average construction wage, the county's average value of farmland per acre, and the county's population density. Table 7 presents the log price regressions without controls and Table 8 with controls. In all of the tables, the standard errors are robust to heteroskedasticity and clustered at the county level.

Each table shows the results of ten separate specifications. The first two columns are the fixed effects ordinary least squares regressions. Column 1 includes the years 1991 through 1996 and Column 2 extends the time series to the year 2003. Both fixed effects regressions include year dummies. Columns 3 through 10 are the DD specifications in which I regress the change in price on the change in distance. All of the DD specifications use the change in a post-regulation observation and the 1991 pre-regulation observation. In Columns 3 and 7, the change is taken using the 1996 observation. In Columns 4 and 8 the post-regulation observation is the average of the 1996 and 1997 observations. Likewise, the post-regulation observation for Columns 5 and 9 is the 1996-2002 average and for Columns 6 and 10 it is the 1996-2003 average. Lastly, the Columns 7-10 are the instrumental variable regressions corresponding to the OLS regressions in Columns 3-6.

Starting with Table 5, I document patterns in the results that are common to all of the tables. First, all of the estimated coefficients are positive, and except for two specifications, they are statistically significant at the 5 to 10 percent level, depending on the specification. This is evidence that prices are increasing in the degree of differentiation between landfills, measured here as spatial distance. Second, the estimated coefficients under fixed effects are smaller than the estimated coefficients using the DD specifications. Third, the estimated coefficients under the ordinary least squares DD regressions in Columns 3-5 are similar in magnitude, although only the specifications using the post-regulation observations of 1996 and 1997 are statistically significant (Columns 3 and 4). Fourth, all of the IV coefficients are larger than the respective OLS coefficients, indicating a downward bias in the OLS estimated coefficients. The IV coefficients also exhibit stronger statistical significance. Fifth, similar to the pattern in the OLS coefficients, all of the IV coefficients are close in magnitude. Lastly, across all of the DD specifications, statistical significance is decreasing over time. The longer the time horizon in which the change is measured, the weaker the relationship between the change in distance to the closest landfill and the change in price.

One possible explanation for the downward bias in the OLS coefficients is that the waste hauling industry experienced a large consolidation during the second half of the sample period. Beginning in 1996, the top five national waste management companies began a series of mergers and acquisitions of waste hauling companies, including firms in the State of Illinois. To my knowledge, the number of establishments in Illinois did not decrease by a significant amount,

however the change in ownership could be equivalent to a negative demand shock. This change in the structure of the waste hauling industry could have also induced exit and increased distance between landfills, negatively biasing the OLS coefficients.

The same patterns in Table 5 also hold true when additional price controls are included. In Table 6 all of the estimated coefficients are positive and statistically different than zero, except for the specification using the 1996-2003 average as the post-regulation observation (Column 6). While the four IV coefficients in columns 7-10 are similar in magnitude, they are decreasing over time. This is present in the logarithm IV results in Tables 7 and 8 as well. In addition to decreasing statistical significance over time, including time-series observations further removed from the time period of the regulation weakens the magnitude of the estimated coefficient. This is not surprising as there is less price variation across landfills over longer periods of time.

In comparing Tables 5 and 6, we see that all of the estimated coefficients on distance to the closest landfill are larger when price controls are included as compared to their respective estimated coefficients without price controls. Overall the differences across the two tables are small, ranging from $0.002 per mile (Column 6 in Tables 5 and 6) to $0.021 per mile (Column 3 in Tables 5 and 6). Of the additional price controls included in Table 6, total disposal acres, county population density, and county average farmland value are statistically significant at the 5 to 10 percent level, although not across all specifications. Again, changes in these three variables are more likely to have statistical significance using the post-regulation periods of 1996 and 1997 rather than 2002 and 2003.

The results in Tables 7 and 8, in which a logarithmic functional form was estimated, also exhibit similar patterns. Again the estimated coefficients are smaller under fixed effects than in the DD specifications and the IV estimated coefficients are larger than the OLS coefficients. One pattern that is more pronounced in the logarithmic form is the decrease in the size and significance of the coefficients over time. When comparing the DD specifications using the post-regulation observations of 1996-2002 and 1996-2003 averages (Columns 5 and 6) to those using the 1996 and 1996-1997 average (Columns 3 and 4), neither of the estimated coefficients in the former specifications are statistically different than zero and are roughly one-half to one-third the size of the latter estimated coefficients. The same is true comparing Columns 9 and 10

to Columns 7 and 8 in the IV estimation. In Table 8, the log of total disposal acres is statistically significant at the five percent level in all of the DD specifications.

5.2.3 Interpretation

When estimating equation 16 in levels, the OLS estimated coefficients on distance to the closest landfill, $\hat{\beta}_1$, range from \$0.037 to \$0.086 per gate cubic yard of waste per mile, while the IV coefficients range from \$0.109-\$0.138 per gate cubic yard of waste per mile. Using the IV result of Table 6 Column 8, this implies that a one mile increase in a landfill's distance to its nearest competitor caused a \$0.13 increase in the price per gate cubic yard. The average increase in distance to the nearest competitor between the years 1991 to 1997 was 7.65 miles, changing from 17.74 to 25.39 miles. Therefore, the average total increase in price from increased distances was \$0.99 per gate cubic yard.

Percentage wise, the 1991 average landfill price was \$9.28 per gate cubic yard, meaning that average prices rose by 11 percent from the increased spatial market power, while the average distance increased by 30 percent. This implies that a one percent increase in distance to the closest competitor caused a 0.37 percent increase in price. This is similar to the percentage changes estimated by the logarithmic functional form. The estimated coefficients on log distance in Tables 7 and 8 range from 0.216 log points to 0.341 log points.

The Illinois Annual Capacity Reports state that the average Illinois consumer disposes of 4 gate cubic yards of waste per year[29]. Thus, the average impact on per capita expenditures is small: consumers pay an additional \$3.96 per year due to increased spatial market power[30]. However, in the aggregate, the 11 percent increase in price translates into an additional 51 million dollars captured by landfill owners.[31]

5.3 Dispersion, Average Compaction Volumes, and Average Prices

As outlined in Section 4.4, if the regulation induced the exit of the landfills with high marginal costs, then the marginal cost dispersion among equilibrium producers should decrease

[29] This may seem like a small volume per person, but gate cubic yards have already been compacted to some degree by the waste hauler. Waste collection trucks also compact waste as they go along their collection route.
[30] This is only a partial change in average prices. The total change in average producer prices also includes the savings due to a lower average cost among landfills after the regulation as compared to before the regulation. This is addressed in Section 5.3.
[31] The 2006 United States Census Population Estimates reported the Illinois population to be 12.8 million.

over time as these inefficient landfills exit. Empirically, this should manifest itself as a decrease in the dispersion of the volume per compacted quantity unit among producers. Figure 5 graphs the time-series of the dispersion in the volume of compacted waste among active landfills using three different measures: the ratio of the 90th to the 10th percentile, the 85th to the 15th percentile, and the 75th to the 25th percentile. All three dispersion measures exhibit a large decrease between the years 1990-1995. The 90th to 10th percentile falls by almost a fifth and the 85th to 15th percentile by a fourth. Furthermore, the differences across the three measures also significantly decrease in the period after 1995 as compared to before 1995. Figure 5 offers strong support to the hypothesis that it was the landfills with low marginal costs that survived while those with high marginal costs exited.

The model also gives predictions regarding the average volumes and price levels among active landfills. A reduction in the maximum marginal cost for which a producer will earn zero expected profits lowers the average cost among equilibrium producers. Ceteris paribus, lower average marginal costs will lower average effort, which will lower average observed volumes per compacted unit of waste (equation 7). Figure 6 graphs the time-series of the quantity-weighted average volumes per compacted unit of waste among active landfills. From the time-series we see that in 1993, the year of the first closures of landfills due to the regulation, the series began to decrease. The time-series of average volume per compacted unit continues to decline throughout the sample period although the declines are small after the year 2000. Overall, the average volume of compacted waste in 2000 is roughly one-half the 1990 level.

Lastly, Figure 7 graphs the time-series of the quantity-weighted average price among active landfills. From equation 6 we know that a reduction in average cost lowers average prices. However, average prices will also rise due to the increased spatial differentiation. In the time-series, average price begins to decline in 1992, spikes in 1996, and then begins to rise in 1998. The decline between 1993 and 1995 matches the massive exit occurring during this period, as market share is being transferred to lower cost landfills. The increase in the quantity-weighted average price in 1996 matches the increase in average producer prices among surviving landfills during this period (Figure 3). Further exit occurs between the years 1997-1999 as the second compliance date comes into effect, again shifting market share to lower cost producers, which by then had also raised their prices due to the increased distances between landfills. Overall, the quantity-weighted average prices in the years after 2000 are approximately $0.20

lower per cubic yard of waste as compared to the 1991 quantity-weighted average price. This decrease is composed of two parts: the decrease in price due to lower marginal costs among active landfills and the increase in price due to greater spatial market power among producers. In the previous section, I estimated that the increase in price due to the increased distance to the closest competitor was $0.99 per cubic yard. This would imply that the decrease in average price due to the exit of high marginal cost landfills was $1.19 per cubic yard.

The combination of greater spatial differentiation and lower marginal cost producers results in a decrease in landfill prices by $0.20 per cubic yard of waste. This does not necessarily imply that consumers experienced a decrease in their cost of waste disposal. The full cost to consumers must also take into account the additional transportation costs due to waste haulers having to now travel farther in order to reach the fewer and more distant landfills. Waste hauling companies do not quote their residential services on a per mile basis, rather consumers pay a monthly flat fee for waste collection. However, to get an idea of the size of the transportation cost I use the cost per mile charged by waste collection companies for commercial collection services. I conducted a very informal phone survey of waste collection companies in the city of Chicago in order to obtain price quotes.[32] The average price quote was a hauling charge of $3.14 per container per mile (converted to 2000 dollars) and the average container size is 30 cubic yards. Taking into account that average distances increased by 7.65 miles yields an additional transportation cost of $0.77 per cubic yard of waste. Therefore, combining the increase in average landfill prices from greater spatial market power ($0.99 per cubic yard), the decrease in average landfill prices from the exit of high marginal cost producers ($1.19 per cubic yard), and the additional transportation costs ($0.77 per cubic yard), leads to a net increase in the cost of waste disposal for Illinois consumers of $0.57 per cubic yard, or $2.28 per person per year.[33]

6. Conclusion

This paper empirically estimates the causal effect of spatial product differentiation on producer prices. I compiled a new data set of municipal solid waste (MSW) landfills in the State of Illinois and take advantage of a natural experiment that occurred in the MSW landfill industry. Using the increased spatial distances between landfills caused by the 1993 Subtitle D

[32] I called three nationally represented waste collection companies that provide collection services in the City of Chicago. This price quote should not be used for anything more than a "back-of-the-envelope" calculation.
[33] This assumes 4 gate cubic yards of waste per person per year.

amendments, I estimate that a one percent increase in the distance between producers causes prices to rise 0.37 percent, or in levels, an increase of $0.13 per cubic yard of waste per mile. In total, landfill prices increased by 11 percent due to greater spatial differentiation between producers.

I also present empirical evidence suggesting that the regulation caused the exit of producers with high marginal costs of production. A significant predictor of exit resulting from the regulation was a landfill's intensity of operations, defined as the volume of a compacted unit of waste. Ceteris paribus, a one-standard-deviation increase in this measure increased the probability of exit by 28 percent.

In addition, I document changes consistent with models of entry selection among heterogeneous producers in which the fixed cost of production increases. I show that the time-series of the quantity-weighted average price and effort, proxied by the volume of compacted waste among active landfills, reflect a shift to a new equilibrium in which there are fewer but more efficient producers. The net effect on landfill prices is a decrease of $0.20 per cubic yard of waste. Although producers enjoy greater spatial market power from increased differentiation, they now compete against a tougher set of competitors.

In addition, the cost of transporting waste to landfills has increased due to fewer and more distantly located landfills. Back of the envelope calculations suggest that transportation costs increased by $0.77 per cubic yard. The net effect of the change in average producer prices and the additional transportation cost is an increase in the cost of waste disposal for Illinois consumers of $0.57 per cubic yard. From a policy standpoint, these results suggest two important implications to consider when evaluating the impact of environmental regulation. First, when an industry is characterized by spatial product differentiation, changes in market structure not only change market power, but also change the transportation costs faced by consumers. Second, if firms differ in their productivity, then the type of firms producing in equilibrium may change as well. The impact on consumers will depend on the relative magnitudes of these three effects.

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Appendix A – Variable Description

Price is the reported annual price per cubic yard of waste received by a landfill. Prices have been deflated by the Midwest Consumer Price Index-All Urban Consumers (CPI-U) and are expressed in constant 2000 dollars. Price is reported starting in 1991. Source: Illinois Annual Capacity Reports.

Log Quantity is the reported annual gate cubic yards of waste disposed of by a landfill. Gate references the volume before compaction, that is, what is dropped off at the gate of the landfill. Source: Illinois Annual Capacity Reports.

Age is the number of years since a landfill first opened. Source: Illinois Annual Capacity Reports.

Total Disposal Acres is the total number of permitted acres for disposal. 1995-2003 Source: Illinois Annual Capacity Reports and 1987-1994 Source: The Illinois Waste Management and Research Center.

Leachate Collection System is a dummy variable equal to one if a landfill has implemented a system for collecting leachate. 1995-2003 Source: Illinois Annual Capacity Reports and 1987-1994 Source: The Illinois Waste Management and Research Center.

Methane Gas System is a dummy variable equal to one if a landfill has implemented a system for collecting methane gas. 1995-2003 Source: Illinois Annual Capacity Reports and 1987-1994 Source: The Illinois Waste Management and Research Center.

Private Ownership is a dummy variable equal to one if a landfill is privately owned. Source: Illinois Annual Capacity Reports.

Distance to Highway is the Euclidean distance, measured in miles, from a landfill's location to an Illinois state road. This was measured using ArcGIS. Source: Illinois State Geological Survey.

Within 500 vertical feet of an aquifer is a dummy variable equal to one if a landfill is located within five hundred vertical feet of a major bedrock aquifer. This variable was created by merging a landfill's location with an ArcGIS data set of polygon feature classes regarding the locations of aquifers. The average size of the polygon feature class is 203 square miles, roughly one third the size of the average Illinois county. Source: Illinois State Geological Survey.

County Population Density is the annual county population estimate per square mile. Source: United States Census, Population Division and Illinois Statistical Abstract.

County Log Average Construction Wage is the reported annual earnings per employee for the classification SIC 1700 (construction), divided by 2,040 hours (51 weeks x 40 hours a week). Wages are deflated by the Midwest Consumer Price Index-All Urban Consumers (CPI-U). Source: United States Census County Business Patterns.

County Log Farmland Value is the average county market value per acre of farmland. This variable is only available for the census years 1987, 1992, 1997, and 2002. The remaining years have been filled in as follows: if t is a census year, then for the years t-1 and t+1, the year t value is assigned, for the two middle years (t+2, t+3) the average of the census years t and t+5 is assigned. Source: United States Census of Agriculture.

Chicagoland is a dummy variable equal to one if a landfill is located in the following counties: Cook, DeKalb, DuPage, Grundy, Kankakee, Kane, Kendall, Lake, McHenry, and Will.

Appendix B - Calculation of Volume Per Compacted Unit of Waste

I construct each landfill's volume of a compacted unit of waste by using the following two relationships:

$$Landfill\ \ capacity\ \ in\ \ terms\ of\ \ quantity\ units = Volume\ of\ \ Landfill * \left(\frac{1}{Volume\ of\ \ one\ compacted\ \ quantity\ \ unit} \right)$$

$$Remaining\ Capacity\ in\ year\ t = \ Capacity\ \ in\ terms\ of\ \ quantity\ \ units - \sum_{k=1}^{t} Quantity\ \ received\ \ in\ year\ k$$

The first equation states that the capacity of an empty landfill, measured in units of waste, is equal to its volume divided by the volume of a unit of compacted waste. The second equation expresses the stock of remaining capacity at the end of year *t*, measured in units of waste, and equals original capacity less the sum of units used as of year *t*.

Using these two equations we can solve for the volume of one unit of compacted waste. Let ϕ_i represent the volume of one unit of compacted waste for landfill *i*, cap_{it} the remaining capacity for a landfill *i* at time *t* in terms of units of waste, qty_{ik} the units of waste received by landfill *i* in year *k*, and V_i the volume of landfill *i*. Rearranging for ϕ_i gives

$$\phi_i = \frac{V_i}{cap_{it} + \sum_{k=1}^{t} qty_{ik}}$$

I use the above formula to calculate the volume of one unit of compacted waste for all landfills in my sample in each year they are observed active, denoted $\hat{\phi}_{it}$. Of the variables in the formula, remaining capacity measured in units of waste and the quantity of waste received are observable for each year of the sample. In order to calculate the cumulative sum of total waste disposed as of year *t*, I multiple the age of the landfill in year *t* by the average quantity disposed over the observable sample years prior to and including year *t*. I do not observe the original volume of a landfill but I do observe a landfill's permitted disposal acres, height, and depth. Using these three pieces of information I calculate a landfill's volume based on a standard industry formula for the design volume of a landfill[34].

My measure of $\hat{\phi}_{it}$ can be expressed as

$$\hat{\phi}_{it} = \frac{f(Acres_{it}, height_i, depth_i)}{cap_{it} + Age_{it} * \overline{qty}_{it}}$$

Where $f(\cdot)$ is the function converting a landfill's acreage, height, and depth into volume, and $\overline{qty}_{it}$ is the average annual quantity received, from the year 1987 to year *t*.

[34] The design volume of a landfill is equivalent to the volume of two pyramids. The first is inverted and measures the volume of waste below the ground based on the permitted depth of the landfill, and the second measures the volume of waste buried under soil but above ground level, based on the permitted height of landfill. In reality, landfills do not reach a peak and the design formula takes into account the flat top and bottom.

Figure 1: Number of Landfills and Exit Rates

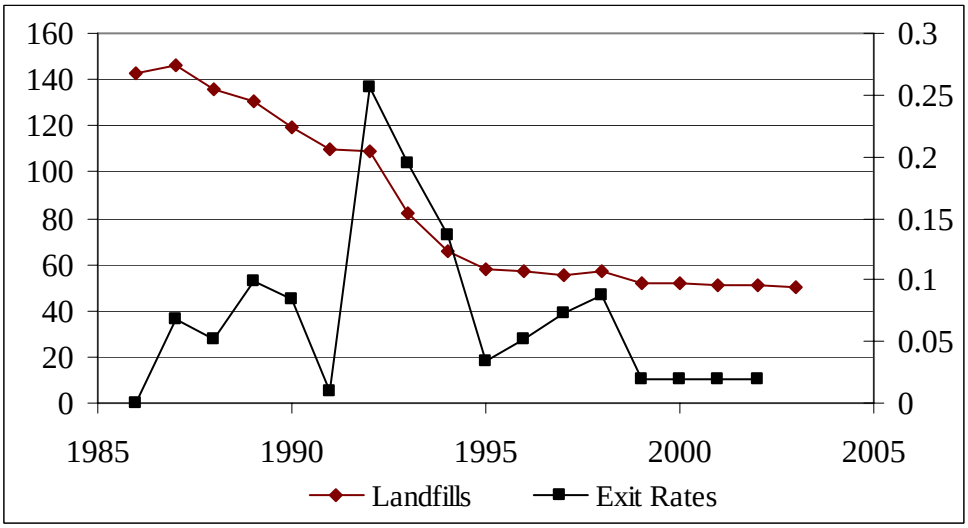
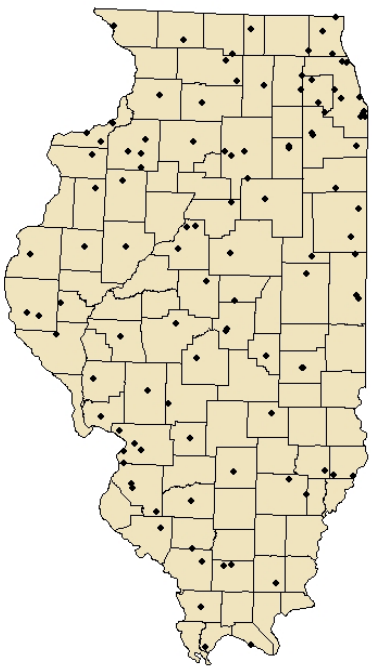
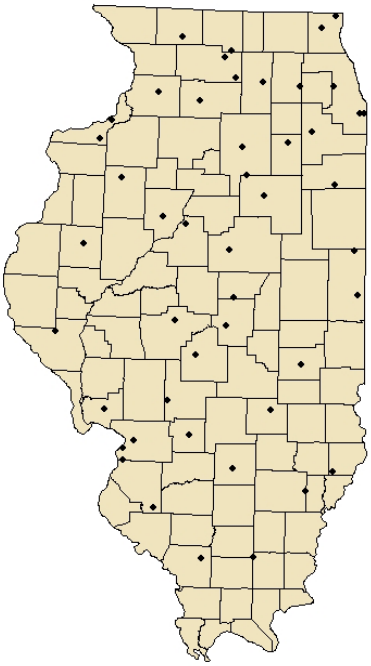


Figure 2



1991



1999

Figure 3: Annual Percent Change in Average Distance and Price among Surviving Landfills

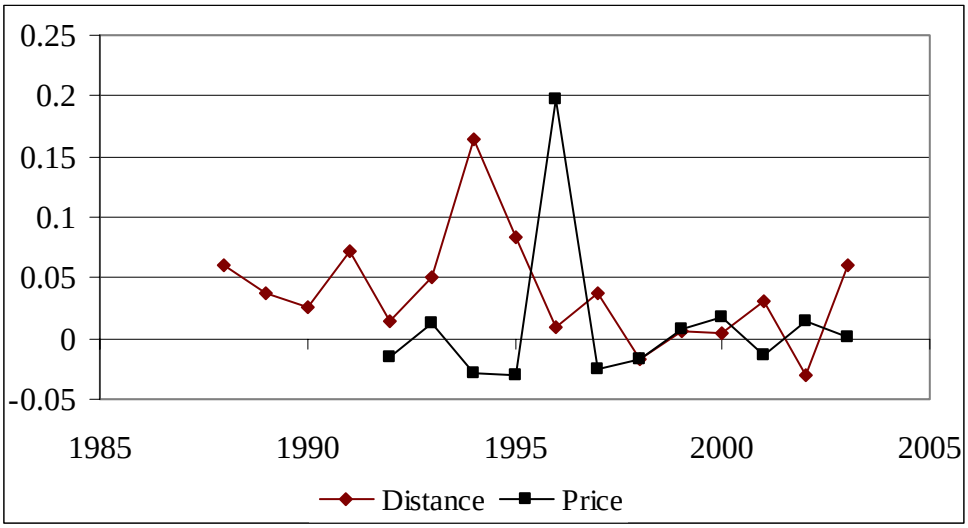


Figure 4: Instrumental Variables First Stage – Actual Change in Distance vs. Predicted Change in Distance for the Period 1991-1996

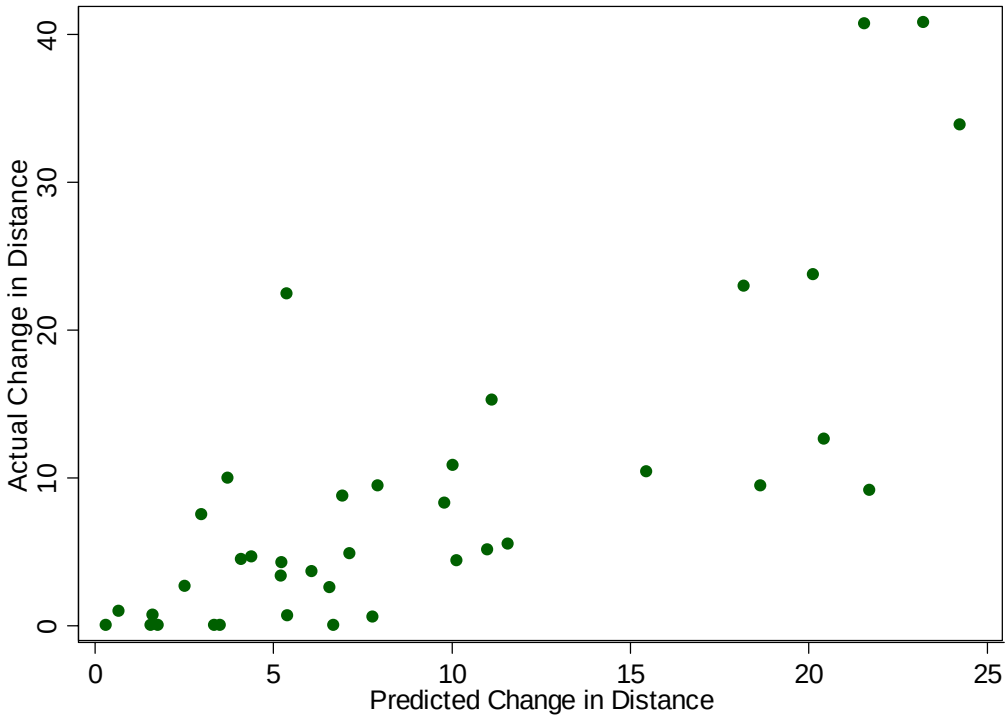


Figure 5: Dispersion in Volume per Unit

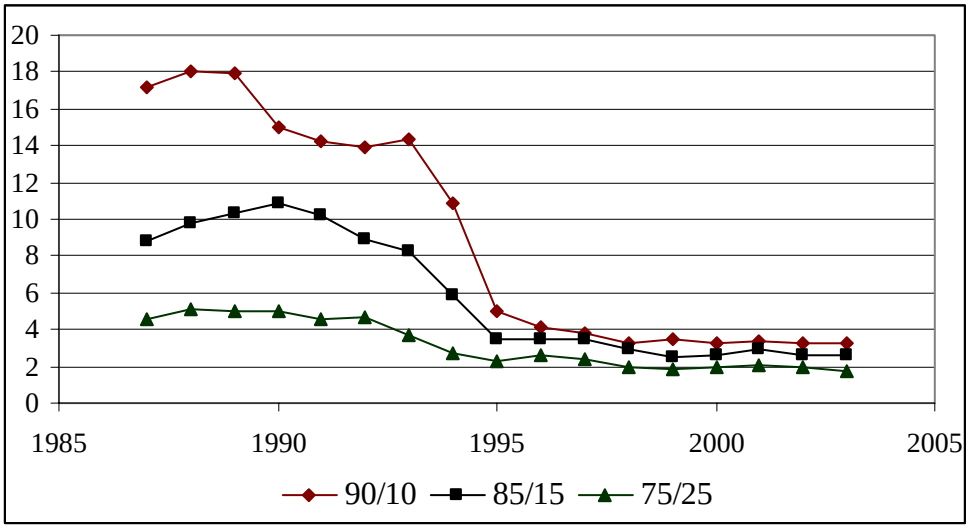


Figure 6: Quantity-Weighted Average Volume per Compacted Unit

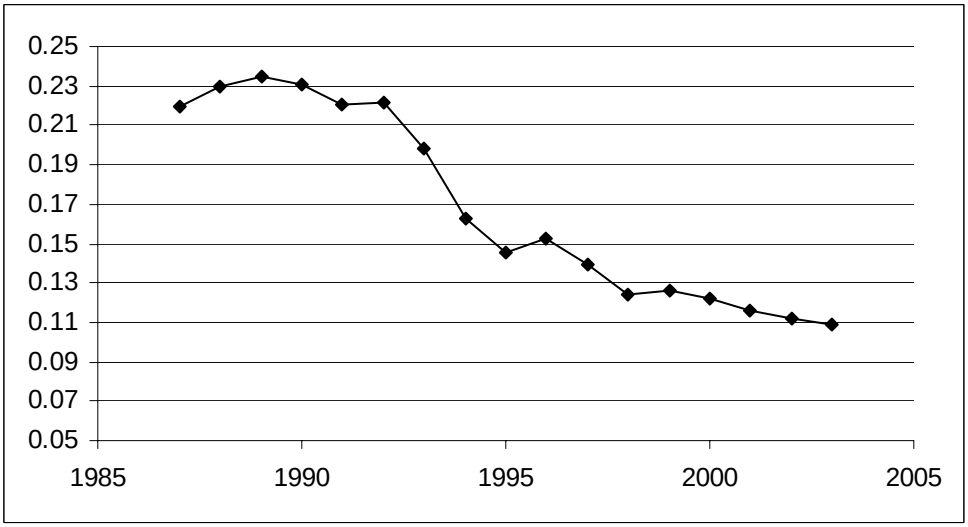


Figure 7: Quantity-Weighted Average Price

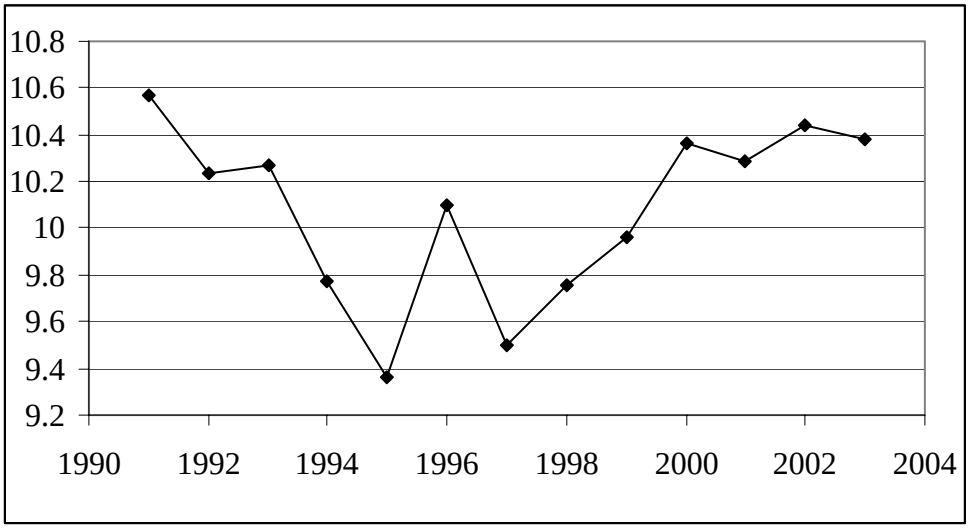


Table 1: Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
Price Per Cubic Yard (N=761)	9.577	3.291	3.606	25.850
Volume Per Compacted Unit	0.479	0.618	0.063	3.850
Distance to Closest Landfill	20.283	10.695	1.823	59.208
Log Quantity (Cubic Yards)	12.047	1.971	2.996	16.172
Age	15.990	6.661	1	37
Total Disposal Acres	68.620	56.708	3	372
Private Owner^	0.724	0.447	0	1
Distance to State Highway	6.983	8.514	0.008	48.962
Within 500 Vertical Feet of an Aquifer^	0.545	0.498	0	1
Leachate Collection System^	0.380	0.486	0	1
Methane Gas System^	0.157	0.364	0	1
County Population Density	653.700	1445.301	18.493	5685.589
County Log Average Construction Wage	2.785	0.279	1.689	3.340
County Log Farmland Value	7.779	0.478	6.770	8.928
Chicagoland^	0.256	0.437	0	1

This table shows descriptive statistics for the variables used in this paper. Statistics are across 1,344 landfill-year observations unless stated otherwise. ^ indicates a dummy variable.

Table 2: Predicting Exit Due to the Regulation

Dependent Variable=1 if Landfill Exited Due to the Regulation				Equality of Means		
1991 Observations			One Standard Deviation Effect	Survivors	Exiters	Difference
	(1)	(2)	(3)	(4)	(5)	(6)
Volume Per	0.351**	0.371**	0.28	0.394	0.894	-0.499**
Compacted Unit	(0.120)	(0.172)		(0.329)	(0.909)	(0.157)
Age		0.039**	0.20	13.11	16.46	-3.35**
		(0.015)		(5.90)	(3.89)	(1.038)
Total Disposal Acres		-0.004*	-0.19	75.00	44.46	30.54**
		(0.002)		(53.67)	(36.79)	(9.58)
County Log		0.725**	0.37	7.700	7.672	0.028
Farmland Value		(0.346)		(.463)	(0.540)	(0.110)
Distance to		-0.001		17.68	19.06	-1.38
Closest Landfill		(0.008)		(8.06)	(8.23)	(1.75)
Log Quantity		-0.075		12.43	11.09	1.34**
		(0.076)		(1.03)	(1.45)	(0.28)
Private Ownership^		-0.156		0.838	0.615	0.222**
		(0.153)		(0.373)	(0.491)	(0.096)
Distance to		0.008		5.77	8.43	-2.66
State Highway		(0.008)		(8.75)	(1.30)	(1.96)
Within 500 vertical		-0.014		0.514	0.596	-0.083
feet of an aquifer^		(0.162)		(0.507)	(0.495)	(0.108)
Leachate Collection		-0.195		0.135	0.077	0.058
System^		(0.251)		(0.347)	(0.269)	(0.066)
County Population		-5E-05		487.91	576.15	-88.24
Density		(7E-05)		(1215.89)	(1437.45)	(290.39)
County Log Average		-0.069		2.746	2.691	0.055
Construction Wage		(0.338)		(0.246)	(0.044)	(0.062)
Chicagoland^		-0.278		0.27	0.19	0.08
		(0.261)		(0.45)	(0.40)	(0.09)
N	89	89		38	51	89
Log Likelihood	-54.08	-36.79				
R-Squared	0.11	0.36				

Columns (1) and (2) present marginal probabilities and standard errors in parenthesis from a probit in which the dependent variable equals one if a landfill is classified as exiting from the regulation, zero if classified as a survivor (please see Section 3 for more details). ^ indicates a dummy variable. Columns (4)-(6) present means by the two groups and a test of equal means. Standard deviations (standard errors) are in parentheses. All results are based on the 1991 observations. ** indicates significance at the 5 percent level,* at the ten percent level.

Table 3: Test of Equal Means for
Surviving Landfills Below and Above the
Median Change in Distance

1991 Observations	Below	Above	Difference
Volume Per	0.345	0.356	-0.012
Compacted Unit	(0.296)	(0.324)	(0.101)
Log Quantity	12.62	12.496	0.126
	(1.262)	(0.992)	(0.368)
Age	12.42	13.68	-1.26
	(4.91)	(6.50)	(1.87)
Total Disposal Acres	75.47	67.05	8.42
	(53.96)	(51.64)	(17.13)
Private Ownership^	0.79	0.89	-0.11
	(0.42)	(0.32)	(0.12)
Distance to	16.55	18.82	-2.27
Closest Landfill	(10.65)	(14.24)	(4.08)
Distance to	4.43	7.76	-3.33
State Highway	(7.60)	(9.66)	(2.82)
Within 500 vertical	0.63	0.42	0.21
fee of an Aquifer^	(0.50)	(0.51)	(0.16)
County Population	773.71	463.11	310.60
Density	(1647.92)	(282.06)	(471.68)
County Log Average	2.800	2.668	0.132
Construction Wage	(0.217)	(0.290)	(0.084)
County Log	7.798	7.574	0.224
Farmland Value	(0.453)	(0.520)	(0.158)
Chicagoland^	0.42	0.16	0.26*
	(0.51)	(0.37)	(0.14)
N	19	19	38

* indicates significance at the 10 percent level.
Standard deviations (standard error) are in parentheses. ^ indicates a dummy variable. Results are based on the 1991 observations. "Below" ("Above") refers to landfills for which the change in distance to the closest competitor over the years 1991-1996 was below (above) the median change.

Table 4: First Stage Regressions of the Actual Change in Distance on Predicted Change in Distance

A. Levels

Dependent Variable: Actual Change in Distance to the Closest Landfill

	Table 5: Second Stage Regressions No Controls				Table 6: Second Stage Regressions With Controls			
	(7)	(8)	(9)	(10)	(7)	(8)	(9)	(10)
Predicted Change in Distance to the Closest Landfill	1.182*	1.233*	1.077*	1.059*	1.157*	1.219*	1.112*	1.092*
	(.227)	(0.200)	(0.186)	(0.206)	(0.244)	(0.224)	(0.216)	(0.234)
Time Period	1991 & 1996	1991 & 96-97	1991 & 96-02	1991 & 96-03	1991 & 1996	1991 & 96-97	1991 & 96-02	1991 & 96-03
(Partial) R-Squared	0.60	0.64	0.60	0.56	0.57	0.62	0.59	0.57
N	38	38	37	34	38	38	37	34

B. Logs

Dependent Variable: Actual Change in Log Distance to the Closest Landfill

	Table 7: Second Stage Regressions No Controls				Table 8: Second Stage Regressions With Controls			
	(7)	(8)	(9)	(10)	(7)	(8)	(9)	(10)
Predicted Change in Log Distance to the Closest Landfill	0.713*	0.772*	0.910*	0.917*	0.692*	0.742*	0.905*	0.914*
	(0.106)	(0.095)	(0.131)	(0.032)	(0.095)	(0.094)	(0.154)	(0.158)
Time Period	1991 & 1996	1991 & 96-97	1991 & 96-02	1991 & 96-03	1991 & 1996	1991 & 96-97	1991 & 96-02	1991 & 96-03
(Partial) R-Squared	0.55	0.60	0.70	0.69	0.60	0.63	0.67	0.67
N	38	38	37	34	38	38	37	34

This table presents the first stage regression results for the instrumental variables regressions of Tables 5-8. For example, the first column of part A corresponds to column (7) of Table 5. *indicates significance at the 1% level. Standard errors are robust to heteroskedasticity and clustered at the county level. Each specification regresses the actual change in (log) distance to the closest competitor on the predicted change in (log) distance to the closest competitor. The actual change in (log) distance is defined as the difference between a post-regulation observation and the 1991 pre-regulation observation. The post-regulation observation for column (7) is the 1996 observation and for columns (8)-(10) it is the average of the specified years. The predicted change in (log) distance is defined as the difference between the predicted post-regulation (log) distance to the closest competitor (see Section 5.2 for definition) and the actual (log) distance to the closest competitor in 1991. Please see Section 5.2 or Table 6 for the list of regression controls.

Table 5: Landfill Price Regression - Levels, No Controls

Dependent variable: Landfill Price	OLS						IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Distance to	0.037*	0.051*	0.063**	0.071*	0.077	0.076	0.120**	0.115**	0.120**	0.109*
Closest Landfill	(0.021)	(0.027)	(0.038)	(0.038)	(0.045)	(0.046)	(0.054)	(0.049)	(0.051)	(0.057)
Specification	FE	FE	DD	DD	DD	DD	DD	DD	DD	DD
Time Period	1991-1996	1991-2003	1991 & 1996	1991 & 96-97	1991 & 96-02	1991 & 96-03	1991 & 1996	1991 & 96-97	1991 & 96-02	1991 & 96-03
R-Squared	0.16	0.14	0.06	0.08	0.09	0.07	0.01	0.05	0.06	0.05
N	228	488	38	38	37	34	38	38	37	34

** indicates significance at the 5% level, * indicates significance at the 10% level. Standard errors are robust to heteroskedasticity and clustered at the county level. Landfill price is the price per cubic yard of waste and distance is the travel distance to the closest landfill measured in miles. Fixed effects specifications include year dummies. The DD specifications regress the change in price on the change in distance (and controls), where the change is defined as the difference between a post-regulation observation and the 1991 pre-regulation observation. The post-regulation observation for columns (3) and (7) is the 1996 observation and for columns (4)-(6), (8)-(10) it is the average of the specified years.

Table 6: Landfill Price Regression - Levels, With Controls

Dependent variable: Landfill Price	OLS						IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Distance to	0.037*	0.060**	0.084*	0.086**	0.085*	0.078	0.138**	0.129**	0.123*	0.112*
Closest Landfill	(0.021)	(0.027)	(0.043)	(0.041)	(0.047)	(0.050)	(0.064)	(0.058)	(0.060)	(0.063)
Specification	FE	FE	DD	DD	DD	DD	DD	DD	DD	DD
Time Period	1991-1996	1991-2003	1991 & 1996	1991 & 96-97	1991 & 96-02	1991 & 96-03	1991 & 1996	1991 & 96-97	1991 & 96-02	1991 & 96-03
R-Squared	0.2	0.2	0.19	0.2	0.18	0.15	0.15	0.18	0.17	0.14
N	228	488	38	38	37	34	38	38	37	34
Significant Controls										
Total Disposal Acres	-0.007*	-0.005	-0.018*	-0.019*	-0.014	-0.012	-0.022*	-0.022*	-0.015	-0.014
	(0.004)	(0.003)	(0.009)	(0.010)	(0.008)	(0.008)	(0.011)	(0.011)	(0.009)	(0.009)
County Population	-0.011*	-0.007**	-0.015	-0.011	-0.016*	-0.014*	-0.008	-0.007	-0.012	-0.012
Density	(0.006)	(0.003)	(0.010)	(0.009)	(0.008)	(0.008)	(0.012)	(0.010)	(0.010)	(0.010)
County Average	-0.0004**	-0.0004*	-0.0006**	-0.0005**	-0.0009	-0.0009	-0.0005*	-0.0004*	-0.0006	-0.007
Farmland Value	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0005)	(0.0005)	(0.0002)	(0.0002)	(0.0006)	(0.0006)

** indicates significance at the 5% level, * indicates significance at the 10% level. Standard errors are robust to heteroskedasticity and clustered at the county level. Landfill price is the price per cubic yard of waste and distance is the travel distance to the closest landfill measured in miles. Regression controls include the size of the landfill (acres), dummies for methane gas and leachate management systems, county average construction wage, county average value of farmland (per acre), and county population density. Fixed effects specifications include year dummies. The DD specifications regress the change in price on the change in distance (and controls), where the change is defined as the difference between a post-regulation observation and the 1991 pre-regulation observation. The post-regulation observation for columns (3) and (7) is the 1996 observation and for columns (4)-(6), (8)-(10) it is the average of the specified years.

Table 7: Landfill Price Regression-Logs, No Controls

Dependent Variable: Landfill Log Price	OLS						IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Log Distance to	0.136*	0.107	0.262*	0.268**	0.150	0.136	0.329**	0.303**	0.231*	0.216*
Closest Landfill	(0.073)	(0.071)	(0.136)	(0.128)	(0.108)	(0.111)	(0.152)	(0.135)	(0.122)	(0.122)
Specification	FE	FE	DD	DD	DD	DD	DD	DD	DD	DD
Time Period	1991-1996	1991-2003	1991 & 1996	1991 & 96-97	1991 & 96-02	1991 & 96-03	1991 & 1996	1991 & 96-97	1991 & 96-02	1991 & 96-03
R-Squared	0.17	0.18	0.10	0.11	0.05	0.04	0.10	0.11	0.03	0.03
N	228	488	38	38	37	34	38	38	37	34

** indicates significance at the 5% level, * indicates significance at the 10% level. Standard errors are robust to heteroskedasticity and clustered at the county level. Landfill price is the price per cubic yard of waste and distance is the travel distance to the closest landfill measured in miles. Fixed effects specifications include year dummies. The DD specifications regress the change in log price on the change in log distance, where the change is defined as the difference between a post-regulation observation and the 1991 pre-regulation observation. The post-regulation observation for columns (3) and (7) is the 1996 observation and for columns (4)-(6), (8)-(10) it is the average of the specified years.

Table 8: Landfill Price Regression-Logs, With Controls

Dependent Variable: Landfill Log Price	OLS						IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Log Distance to	0.127*	0.097	0.315**	0.290*	0.184	0.149	0.341**	0.311*	0.242*	0.219*
Closest Landfill	(0.070)	(0.073)	(0.143)	(0.149)	(0.118)	(0.116)	(0.159)	(0.152)	(0.131)	(0.127)
Specification	FE	FE	DD	DD	DD	DD	DD	DD	DD	DD
Time Period	1991-1996	1991-2003	1991 & 1996	1991 & 96-97	1991 & 96-02	1991 & 96-03	1991 & 1996	1991 & 96-97	1991 & 96-02	1991 & 96-03
R-Squared	0.20	0.23	0.26	0.26	0.15	0.12	0.26	0.25	0.14	0.12
N	228	488	38	38	37	34	38	38	37	34
Significant Controls										
Log Total	-0.063*	-0.051	-0.309**	-0.315**	-0.207**	-0.194**	-0.313**	-0.312**	-0.215**	-0.202**
Disposal Acres	(0.037)	(0.040)	(0.102)	(0.094)	(0.079)	(0.079)	(0.096)	(0.089)	(0.080)	(0.082)
Methane Gas	-0.074	0.027	0.180	0.220	0.179*	0.168*	0.187	0.213	0.193**	0.183*
System	(0.048)	(0.043)	(0.148)	(0.145)	(0.92)	(0.089)	(0.146)	(0.140)	(0.093)	(0.091)
Log Avg. County	0.037	0.032	0.239	0.270*	0.302	0.278	0.252	0.255	0.425	0.442
Farmland Value	(0.067)	(0.101)	(0.151)	(0.156)	(0.270)	(0.285)	(0.169)	(0.175)	(0.302)	(0.311)

** indicates significance at the 5% level, * indicates significance at the 10% level. Standard errors are robust to heteroskedasticity and clustered at the county level. Landfill price is the price per cubic yard of waste and distance is the travel distance to the closest landfill measured in miles. Regression controls include the log size of the landfill (acres), dummies for methane gas and leachate management systems, log county average construction wage, log county average value of farmland (per acre), and log county population density. Fixed effects specifications include year dummies. The DD specifications regress the change in log price on the change in log distance (and controls), where the change is defined as the difference between a post-regulation observation and the 1991 pre-regulation observation. The post-regulation observation for columns (3) and (7) is the 1996 observation and for columns (4)-(6), (8)-(10) it is the average of the specified years.