Regulation and Capitalization of Environmental Amenities: Evidence from the Toxic Release Inventory in Massachusetts

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Abstract

Environmental regulation in the United States has undergone a slow evolution from command and control strategies towards regulations that require polluting firms to publicly disclose information about their toxic emissions. One such innovation is the Toxics Release Inventory (TRI). The basic tenet of this regulation is that it corrects for informational asymmetries between polluters and households in the surrounding community and allows communities to pressure polluters to decrease their emissions. In the first eleven years, policy makers have judged TRI a tremendous success as national toxic releases have declined by 43 percent. Yet, the Coase Theorem casts doubt on the ability of regulation through disclosure to lead to an efficient outcome in the case of pollution.

We use an event study methodology with high-quality data on house prices and other local attributes to assess the extent to which the public values changes in toxic releases and thus the success of TRI. Our major findings include: 1) declines in toxic releases appear unrelated to any political economy variables that might lead to public activism; 2) initial information released under TRI had no significant effect on the distribution of house prices; and 3) house prices show no significant impact of declines in reported toxic releases over time. Standard errors are small enough that we can reject the hypothesis that large declines in toxic releases lead to more than a one-half percent increase in house prices. These results also hold when we control for differences in the availability of information on TRI and the possible impact of expectations. Our findings cast doubt on the ability of the public to process complex information on hazardous emissions and support the Coase Theorem in that “right to know” laws such as TRI may not be the most effective form of environmental regulation.

Environmental regulation in the United States has undergone a slow evolution from command and control strategies to more market-based approaches. In part, this transition is in response to the overwhelming growth in the direct cost of regulation and the price tag associated with meeting those regulations. In the United States, pollution abatement control expenditures are on the order of 1.5-2.5% of GDP per year. As the trend towards stricter, more pervasive environmental regulation continues, both the cost and the effectiveness of regulation have become hot topics on the public agenda.

One such "market-based" innovation adopted by the U.S. Environmental Protection Agency (EPA) is to require polluting firms to publicly disclose private information about their emissions. The basic tenet of this regulation is that it corrects for informational asymmetries that may exist.[1] One of the most pervasive examples of this is the Emergency Planning, Community Right to Know Act (EPCRA). The appeal of this type of regulation is evidenced by the proliferation of "Community Right to Know" laws at the state level. These laws take various forms -- from requiring state agencies to provide environmental data through the Internet, to increasing the reporting requirements for polluting plants.

Using disclosure of private information as an "informal" regulatory tool is attractive because it is relatively low-cost. Theoretically, both the cash-starved regulatory agency and the "regulated" plant could face lower pollution abatement control expenditures. Instead of directly regulating plants and ensuring compliance, the enforcement agency only would be responsible for collecting and maintaining a public database, increasing community awareness, and penalizing firms for inaccurate reporting. A polluting firm would be free to choose how much to change its emissions and to use whatever abatement technology it wanted. Community policing would pressure firms to reduce actual emissions.

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[1] The disclosure of private information has been used as a regulatory mechanism in several instances. One example is the required labeling of nutritional contents on food packages and another is the Occupational Safety and Health Act which requires employers to inform employees about workplace hazards. The effectiveness of such regulation, to our knowledge, has not been verified empirically.

In this paper, we focus on one particular example of this type of regulation, called the Toxics Release Inventory (TRI). Introduced by the EPA under the EPCRA in 1986, TRI requires manufacturing plants that emit more than a given threshold level of any listed toxic substance to provide emissions data to the EPA for use in a publicly available database. Prior to the TRI, no record of toxic emissions existed.

In the first eleven years of TRI regulation, the EPA claims that toxic releases have fallen significantly -- by approximately 43%. Support for Community Right to Know legislation and the TRI is very strong. In a Presidential memo dated August 8, 1995, the Administration wrote that the EPCRA of 1986 "...provides an innovative approach to protecting public health and the environment by ensuring that communities are informed about the toxic chemicals being released..." and that "...Right-to-Know protections provide a basic informational tool to encourage informed community-based environmental decision making and provide a strong incentive for businesses to find their own ways of preventing pollution." The apparent success of the TRI in reducing reported toxic emissions has made the TRI and Community Right to Know Laws an attractive form of regulation that may become even more widespread.[2]

From an economic perspective, one might question the effectiveness of disclosure-based regulation in the context of environmental emissions. Pollution is, after all, the classic example of an externality. Informing communities about toxic emissions in their neighborhood is quite different than giving employees data about hazards in the workplace or disclosing nutritional and fat content of pre-packaged foods. In the latter two cases, consumers or employees can choose to avoid a product or job if

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[2] A Presidential Memo dated October 26, 1993 provides evidence that the Administration believes in the efficacy of the TRI. It states: "Sharing vital TRI information with the public has provided a strong incentive for reduction in the generation, and, ultimately, release into the environment of toxic chemicals. Since the inception of the TRI program, reported releases to the environment under TRI have decreased significantly."

the price of the food, given its nutritional and fat content, is too high, or the wage is too low, given the workplace risks. Residents who live near a plant, however, face significant costs in leaving a neighborhood where a plant releases high levels of emissions; their homes may suffer from a decline in value. While employers or food manufacturers may care about a decline in sales, a manufacturer may not care about the decline in property values in the surrounding area and may, in fact, benefit from such a decline if land becomes cheaper for future expansion. Under the Coase Theorem, it is well understood that local community pressure will only discipline a plant's emissions level if: 1) most members of the community care about the pollution, 2) costs of collective action are low, and 3) communities can get around the "free rider" problem in gathering a coalition.

The TRI provides a unique opportunity to evaluate some important assumptions that underlie Community Right to Know types of legislation. In particular, how do communities and households react to information about environmental amenities? To what extent is this information "news" and how do localities value changes in those environmental amenities over time? Have declines occurred in places where political action is least costly or in communities that have a strong aversion to pollution? If communities do not value the information, or cannot use it efficiently, the effectiveness of Community Right to Know Laws as a stand-alone regulatory instrument is drawn into question.

In this paper we explore the reaction to TRI reporting in Massachusetts between 1987 and 1992. Reported toxic releases in Massachusetts are significantly larger on average than in the rest of the nation and percentage reductions in toxic releases have also been much larger than the national average. A state environmental regulation introduced in 1989 called the Toxics Use Reduction Act, further reinforced and supplemented TRI reporting requirements for Massachusetts manufacturing plants (as well as a number of non-manufacturing plants).

To understand the impact of TRI information, we use an event study methodology that estimates the capitalization of environmental amenities on house prices. We consider several "events" including the introduction of TRI reporting and subsequent changes in reported releases over time. This methodology allows us to observe how house prices react to the introduction of "new" information as well as how home owners value changes in toxic releases. This approach has a number of advantages relative to the cross-sectional hedonic models used in many earlier studies.[3] Our regressions use recently-available, quality-controlled house price indexes based on repeat sales. These indexes, available at the zip code level, are quite accurate and avoid the measurement error problems of more commonly used median sales prices. (See Case and Shiller [1987] and Case and Mayer [1996].) Also, the first differences specification implicitly deals with the omitted variable problem that can lead to biased coefficients in a cross-sectional regression. Environmental variables may be correlated with unobserved town fixed effects (such as proximity to manufacturing facilities or major polluters, the quality of housing, the amount of park space, or other amenities). One can never be sure that the coefficient on an environmental variable is driven by a distaste for pollution, versus the implicit value of some other amenity that is correlated with pollution. In the empirical work, below, we show that a cross-sectional hedonic regression would obtain a quite different conclusion than our event study (fixed effects) approach.

Another potential difficulty in using house prices to assess the impact of the TRI is that we do not observe community information and expectations regarding toxic releases. If communities know the level of releases in their neighborhood prior to the introduction of the TRI, house prices should not change with the introduction of the TRI -- that is, no new information has been provided. Similarly, if communities anticipate the future path of toxic reductions, those reductions would be capitalized *in advance* of the actual reported reductions. A failure to find any capitalization of TRI information on house prices in either case could be misinterpreted as showing that communities do not care about toxic

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[3] Some recent exceptions are Hamilton [1995] and Konar and Cohen [1997] which are event studies based on stock market valuations. These are discussed further in Section 2.

emissions. We take two approaches to dealing with this problem. First, we use data on newspaper readership to control for differential local access to information about toxic releases. Next, we attempt to model expectations directly, and explore whether house prices respond to deviations from (modeled) expectations. Finally, recognizing the difficulty in fully modeling expectations, we explore the extent to which changes in house prices lead announcements of changes in toxic releases.

Our primary finding is that information about toxic releases had little impact on local house prices. This result is inconsistent with the hypothesis that community reaction to the TRI has led to large declines in toxic releases. In particular, we find that (1) poorer, "blue collar" areas are more likely to have toxic emissions and (2) larger reductions in toxic emissions occur in higher value zip codes and zip codes with higher initial releases. However, (3) reductions in releases are unrelated to any political economy factors that might relate to the ability or willingness of a community to organize against major polluters. When measured by the initial *level* of toxic releases reported in 1987, (4) the introduction of TRI reporting had virtually *no* effect on housing prices and even more surprisingly (5) subsequent reductions in aggregate reported emissions between 1987 and 1990 have no significant effect on house prices, either in the aggregate or when disaggregated into the most hazardous types of chemicals or the most noxious air emissions. The standard errors are sufficiently small that we can reject that declines in toxic releases of one standard deviation above the mean are associated with more than a 0.5 percent increase in house prices with 95 percent confidence. Finally, informational differences about TRI or expectations do not appear to explain these results. We show that (6) the above findings hold even if we look at the unexpected information in TRI releases, (7) changes in house prices do not forecast changes in toxic emissions, as might be expected if communities anticipated increases or reductions in toxic releases, and (8) these results persist even in communities with high newspaper readership.

The paper is organized as follows. In Section 1 we describe the TRI and provide background on reported TRI releases over time. Section 2 provides an overview of the existing literature that examines the use of property values to capture the value of different community amenities and Section 3 describes the data. Sections 4 and 5 contain the empirical results and the final section provides an interpretation, together with concluding comments and discussion of further avenues for research.

1. Background

Before 1986, when the Superfund law was revised as the Superfund Amendments and Reauthorization Act (SARA), there was no systematic tracking of toxic releases in the United States. Under SARA, the Emergency Planning Community Right to Know Act (EPCRA) was introduced.[4] Included in the EPCRA is a provision known as the "Toxic Release Inventory." The TRI requires manufacturing firms to report their releases of listed toxic substances to the EPA for public disclosure.

The motivation behind EPCRA was two-fold. In part, EPCRA was a response to a number of environmental disasters involving toxic substances, the best known of which occurred in Love Canal, N.Y., and Bhopal, India. What became evident after those episodes was that, because residents were often unaware of what toxic substances were being used by local plants, communities were unprepared to deal with accidental releases. The EPCRA requires that communities prepare emergency procedures to deal with the accidental release of any toxic substance known to be present in the area. This requires firefighters, hospitals, and the police to know both the storage location of toxic substances in their community and how to handle different types of toxic substances in emergencies.

The second motivation of the EPCRA, through the TRI, was to reduce toxic releases without *formally* regulating polluters. Up until that point, toxic releases had not been touched directly by any existing environmental regulation.[5] Regulators hoped that by forcing private firms to disclose their toxic

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4 The EPCRA is also referred to as Title III of SARA.

5 There exist air pollution standards for hazardous air pollutants known as the National Emissions Standards for Hazardous Air Pollutants (NESHAP), but this particular regulation appears to have been completely unsuccessful.

releases and by providing the public with that information that firm polluting behavior would be affected.

Under EPCRA section 11023, a facility must report to the TRI if it is a manufacturing plant (SIC=2000-3999) with more than 10 full-time employees that either uses or manufactures more than a threshold level of any of the listed toxic substances.[6] Plants are required to file their reports with their state EPA. This information is then collected by the federal EPA and is made available to the public. Plants must file a separate form for *each* toxic substance for which they fall above the specified threshold reporting level. Threshold reporting levels differ for manufacturers of a toxic substance and also differ across substances. Thresholds can also change over time.

In the first eleven years of TRI regulation, the EPA claims that toxic releases have fallen by approximately 43%. In 1993, approximately 23,000 different facilities submitted reports to the TRI. Nationwide, more than 2.8 billion pounds of toxic releases were reported. These releases include extremely toxic substances as arsenic, mercury, and dioxin, as well as more "benign" substances (at least in small quantities) as ammonium sulfate, acetone, and sulfuric acid. It is important to note that *all* of these substances are considered to be hazardous to human health at relatively low levels of concentration and exposure.

The premise of TRI regulation is to provide information to the public. The official release of TRI data is made by the EPA. Hard copy versions of the yearly releases could be obtained directly from the EPA (at no cost) by individuals and later the data were made available on CD-Rom (or diskette) and on the Internet from the EPA or other environmental sources, for example, the Right-To-Know Network (RTK-Net). The RTK-Net started operations in 1989 and is operated by the OMB Watch and Unison Institute (Washington, D.C.). The TRI provides information on all reporting facilities *as reported*, including name and address of the facility, type of chemical released, and amount released (in pounds). The hard copy version of the data also included summary statistics. After 1993, data was provided on

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[6] At this time, there are over 300 listed toxic substances.

whether the substance was carcinogenic or had developmental or reproductive consequences.

The primary source of information to households, however, was probably not through the raw data release itself, but from the media. Media accounts of TRI releases have been numerous since TRI data has become available. A simple count of news reports in major newspapers between 1988 and 1995 on Lexis-Nexis was over 430. Some of these reports are very detailed in nature. The Los Angeles Times, for example, provided their readers with a list of the "Leaders in Toxic Releases"[7] which included a summary of what substances were being released, the health consequences of exposure to the substances as well as the names and addresses of the facilities responsible for the emissions. In addition, community newspapers, which do not show up in Lexis/Nexis, are a well-known source of local information on TRI.[8]

2. Previous Literature

The first work to incorporate environmental amenities into the study of residential property values is Ridker and Henning [1967]. Controlling for a number of property and region-specific characteristics, they regressed mean property values by Census tract on air pollution measures. Ridker and Henning find that air pollution, as measured by sulfate concentration, has a significant effect on property values -- more so than measures of school quality and time travel required to the center of the city. Furthermore, they estimated that if sulfation levels were reduced by at least 0.25 mg but not more than 0.49 mg, households in the St. Louis metropolitan statistical area would be willing to pay as much as $82,790,000 for that improvement in air quality.

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7 Hudson, Berkeley. Los Angeles Times, December 5, 1991. (Glendale Section: Part J; Page 1, Column 2).

8 An informal survey of local community newspapers in Massachusetts suggests that there were numerous stories on TRI during our sample period. However, these local newspapers do not store their past stories in an electronic medium such as Lexis/Nexis, making it nearly impossible to obtain a more precise measure of their coverage over our sample period.

Since 1967, there have been several other empirical studies that have found evidence that environmental amenities are capitalized in property values. Bednarz [1975] examines the relationship between individual selling prices of land and aggregated values (to the census tract level) of air pollution measures in Cook County (Chicago), Illinois. Bednarz finds that pollution decreases property values and that the correlation between particulate matter and the proportion of blacks in a community is 0.5, suggesting at least the possibility of "environmental injustice." Chay and Greenstone [1998] estimate that environmental regulations during the 1970s and 1980s were such that a one-unit reduction in suspended particulates resulted in a 0.7-1.5 percent increase in house prices. Greenberg and Hughes [1992] study the impact of hazardous waste Superfund sites on median housing prices in New Jersey. They focus their attention on 77 New Jersey communities that have Superfund sites and 490 communities without any Superfund sites between 1980 and 1988. The authors find some support for the hypothesis that Superfund hazardous waste sites depress housing prices (relative to the control community with no Superfund sites), particularly if located in rural communities and in communities that had the highest rate of price increases in the preceding five-year period. Surprisingly, however, the level of *risk* associated with the hazardous waste site was not found to be associated with changes in sales prices. This finding is consistent with the hypothesis that, although communities may be aware of the existence of a Superfund site in their locale, they do not have the ability to evaluate the relative dangers associated with higher- or lower- risk sites. A recent paper by Gayer et al [1998], however, finds that communities are able to respond to differences in cancer risk, as measured by changes in house prices, *when* that information is provided to them.

Both the methodology and interpretation used by Ridker and Henning (and, consequently, others) has been controversial, spawning a large number of studies that both support and refute their results. (See for example, Freeman [1971], Freeman [1974], Small [1975], Polinsky and Shavell [1975], and Harrison and Rubinfeld [1978]). Regardless of the controversy, hedonic studies on property values of the type that Ridker and Henning pioneered, are now commonly used to measure how changes in environmental amenities are valued. Smith and Huang [1995] conduct a meta-analysis of 37 studies to evaluate the robustness of this methodology and find that there is a consistent relationship between the marginal willingness to pay for a reduction in air pollution and the level of pollution in the local region. Zabel and Kiel [1998] provide more recent estimates for the marginal willingness to pay for air quality in four major cities in the U.S. The authors estimate that the benefits of achieving the National Ambient Air Quality Standards between 1974-1991 in those four cities are between $171 to $953 million.

The vast majority of these studies use a cross-sectional hedonic methodology in which they regress house prices on various observed attributes plus an environmental variable within a given city. As Gyourko, et. al. [1999] point out, "...spatial sorting on unobservables." may present a problem. After all, "If suppliers build nicer homes in terms of unobservables in the nicer parts of the city, then the econometrician will overestimate the value of the QOL (Quality of Life). Moreover, low environmental quality within a neighborhood may proxy for low quality of housing structure." (P. 1438)

A few studies look at changes over time in the capitalization of a news about a specific amenity such as highway noise in the Seattle suburbs (Palmquist [1982]), PCBs (Mendelsohn et. al. [1992]), a waste incinerator (Kiel and McCain [1995]) or a hazardous waste site (Kohlhase [1991]), avoiding the problem of unobservable quality. Palmquist [1982], in particular, has a nice discussion of the potential advantages of such an approach. All of these studies find that changes in news about the toxicity of the site are capitalized into house prices. One should use caution in applying the results of these studies more generally, however, as most these studies look at specific sites that usually received much media attention.

Two recent studies use an event study approach to evaluate the stock market response to TRI information. Hamilton [1995] finds that firms with higher *reported* releases have larger abnormal negative returns. Konar and Cohen [1997] model expectations and find that firms with *unexpectedly* high releases have lower stock market returns. Both studies conclude that (1) the TRI provided *new* information to the market and that (2) the stock market responded to that information.

Finally, a recent study by Oberholzer-Gee and Mitsunari [2002] looks at TRI-emitting plants in the Philadelphia area using detailed location data and find that, if anything, the prices of houses located nearest TRI-emitting plants may have risen a little bit on the initial announcement of TRI emissions and the initial announcement had no impact beyond a quarter of a mile. This study has the advantage of using detailed house locations, but has a much smaller geographic area and is limited to the first year of TRI announcemnts. The results of that paper are complimentary with what we find below.

3. The Data

We use data from several different sources, including: plant-level data on toxic emissions from the Toxics Release Inventory 1987-1992; repeat-sales house price data from 1982-1993; and various community characteristics from the 1980 and 1990 Censuses and the Commonwealth of Massachusetts. The separate data sets are linked either by zip code or community.

Plant level data on toxic emissions are taken from the TRI. Between 1987 and 1993, over 2000 different toxic emission records were filed annually in an average of 231 different zip codes in Massachusetts. Over the sample period, an average of 24,876,500 lbs/yr of toxic substances are released into the environment every year. We aggregate the emissions data up to the zip code level and focus on the sum of environmental releases by substance, under the assumption that communities have a similar valuation for toxic releases that occur through different environmental media.[9] However, we create separate categories for substances that are carcinogenic or have adverse developmental or reproductive

[9] The sum of environmental releases = sum of air + water + land releases. Unlike the criteria air pollutants, toxic releases have a localized effect on their surroundings so studying their effects at the zip code level is not unreasonable. In part, this is because they typically are not released into the environment through smoke stacks and other such means that facilitate the long-distance transportation of the pollutant.

effects on humans.[10] Summary statistics are provided in Tables 1 and 2. Zip codes that do not report any toxic releases are given a value of zero.[11]

A total of 144 different toxic substances were reported as TRI releases between 1987 and 1992 in Massachusetts. Of these, 18 (12.5%) were known to be carcinogenic, 21 (14.6%) were known to have adverse reproductive or developmental consequences, and 12 (8.3%) were known to have both carcinogenic and developmental or reproductive consequences.[12]

Between 1987 and 1992 (Table 2), reported toxic releases in Massachusetts fell by more than 77% from their initial levels. Similar reductions are found for carcinogenic releases (a 61% decrease) and a somewhat smaller reduction is observed with known adverse developmental or reproductive implications (19%). The number of records actually *filed* (separate releases) in the TRI went from 2129 to 1654, a decline of 22%. The average reported *single* toxic release in 1987 in Massachusetts was 32,636 lbs. The amounts released ranged from a low of 1 lb. to a high of 1,019,600 lbs.[13] Both the mean release and range fell dramatically in 1992 to 9674 lbs. with a range from 1 lb. to 502,157 lbs.

The house price indexes used in this paper are obtained from Case, Shiller and Weiss, Inc. and are estimated using a variation on the weighted repeat sales methodology first presented in Case and Shiller [1987].[14] Because the indexes involve repeat sales of the same property, they are not affected by the mix of properties sold in a given time period or differences in average housing quality across

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10 Only substances that are "known" by the EPA or California EPA to be carcinogenic or have developmental or reproductive hazards were tagged.

11 In these zip codes, either toxic releases fall below the threshold reporting level (and may be equal to zero), or plants fail to report releases.

12 A list of all toxic substances covered under the TRI that were reported as releases in Massachusetts between 1987 and 1993 may be obtained from the authors.

13 This excludes one Massachusetts outlier in 1987 of 11,451,447 lbs which is not included in our data set because we lack data on house prices in the surrounding zip code.

14 The method uses arithmetic weighting described by Shiller [1991] and is based on recorded sales prices of all properties that pass through the market more than once during the period. The Massachusetts file contains over 135,000 pairs of sales drawn between 1982 and 1994. First, an aggregate index was calculated based on all recorded sale pairs. Next, indexes were calculated for individual jurisdictions.

communities. In Massachusetts, indexes were estimated for 247 zip codes with a sufficient number of transactions to obtain reliable estimates after 1982. All price changes are measured from the second quarter of each year to correspond to the timing of the release of TRI data. Nominal houses prices in Massachusetts towns increased by an average of 176 percent from 1982-1989, and then declined by 10 percent in the next five years. However, the price increases and decreases were quite unevenly distributed across communities during this period, ranging from 132 to 330 percent in the earlier time period and between a 38 percent decline and a 4 percent increase in the later time period. Earlier work (Bradbury, Mayer, and Case [2001]) shows that shifts in economic variables such as employment, aggregate school enrollments, demographics, and changes in fiscal factors such as Proposition 2½ are significant factors in explaining the cross-sectional variation in changes in house prices.

We also use data on newspaper readership to explore the extent to which capitalization depends on information. We obtain average newspaper readership from 1995-98 from the Audit Bureau of Circulations.[15] While the dates of the data do not exactly correspond to the dates of our sample, we would expect that newspaper readership remains stable over a 10 year period, or at least the rank order of localities will not change much over this time period.

Demographic data are taken primarily from the 1980 or 1990 decennial censuses. In many cases, data are only available at the town level, and are attributed to zip codes on the basis of town. These data include median income and housing values, and age variables. School test scores and town unemployment rates, spending on health and welfare, and manufacturing employment were obtained from the Commonwealth of Massachusetts, land available for new construction from the University of Massachusetts, and data on new construction come from the U.S. Department of Commerce.

4. Where are the Toxic Emissions and Where do the Declines Occur?

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[15] Source: Circulation Data Bank. New York: Audit Bureau of Circulations, 1999.

We begin the analysis by documenting the characteristics of neighborhoods that surround plants that produce toxic emissions. (See Table 3.) Not surprisingly, plants that emit TRI-listed substances tend to be located in communities with relatively lower median incomes, house values and school assessment test scores compared to communities with no reported toxic emissions. Communities with toxic emissions are smaller and have a higher percentage of workers in manufacturing, but are quite similar in terms of age distributions and percentage of minority residents. Thus children are no more or less likely to live in neighborhoods with higher toxic emissions. In addition, communities with higher toxic releases have residents that are less likely to be college-educated, and more likely to be democratic, but do not differ in their newspaper readership. More of the plants are located not in the Boston metropolitan area, but further out from the city, suggesting locations in manufacturing sub-centers such as Lowell, Lawrence, and New Bedford, rather than in rural areas or downtown Boston. In terms of housing appreciation, the groups in the top and bottom panels appear to be quite similar, both before and after TRI reports began in 1987.

Next, we divide communities that reported positive TRI emissions in 1987 into two groups based on their subsequent change in emissions. The first 2 panels in Table 4 summarize the characteristics of communities whose change in emissions between 1987-92 was below average for all (Massachusetts) TRI-reporting communities. Notice that reported toxic emissions actually rose in the typical community within this group, indicating that declines in emissions were not uniform across locations. This finding casts doubt on the hypothesis that declines in TRI emissions are strictly due to firms intentionally over-reporting emissions in 1987 -- over one-third of the zip codes in this sample experienced an *increase* in reported emissions.

If community activism were an important factor in contributing to declines in emissions, we might expect greater declines in toxic emissions in communities with more college-educated or higher income residents, in communities with more children, or places with a higher percentage of registered voters or a higher newspaper readership. Yet, the two groups differ little in their average income, voting patterns, education, age distribution, or any other factors that might be related to political or community activism.

Communities that had the largest absolute reductions in releases tended to have slightly higher house prices, lower minority populations, were more likely to be located in the Boston area, and had a work force that was more heavily concentrated in manufacturing. The data also show very few differences between the communities in terms of their population growth or housing appreciation during any of the periods in question.

Because the correlations above are based on simple comparisons of means, we estimate regressions to identify the characteristics of communities where TRI-emitting plants are located, and where emissions fell furthest. These regressions should be interpreted in a strictly descriptive manner, not as suggesting any form of causality. The results, reported in Table 5, are mostly consistent with the findings above. Holding other factors constant, TRI-emitting plants are more likely to be located in poorer, democratic-voting communities, with more middle-aged residents, and further from Boston. In other words, these are solid blue-collar communities.

Yet few of the above factors are particularly characteristic of communities with the largest declines in emissions. (See column 2.) In fact, only median house price is correlated with changes in toxic releases--greater declines occurred in higher-priced communities. Political economy variables or factors that might relate to the ease or probability of political activism do not appear to matter. The third column confirms a strong trend towards reduced emissions in areas with the highest initially-reported releases. When controlling for initial releases, the coefficient on median house price is no longer statistically different from zero.

5. Estimation and Results

We now turn to house prices for direct evidence as to how home buyers value the change in emissions that occurred after the beginning of TRI reporting. To the extent that public pressure is related to the subsequent fall in emissions, house prices should have increased in communities whose local plants successfully cut toxic releases. Even absent public pressure, evidence of capitalization will help show how much the public values changes in reported emissions.

Capitalization of Toxic Releases in House Prices

In this context, the equilibrium price of housing in community *i* and base year *τ* can be represented as[16]:

$$(1)\quad P^{*}_{i\tau} = \alpha_0 + \alpha_1(\mathit{fixed\ amenities})_{i\tau} + \alpha_2(\mathit{environmental\ amenities})_{i\tau} + \alpha_3(\mathit{housing\ stock})_{i\tau} + \alpha_4(\mathit{economic\ factors})_{i\tau} + \varepsilon_{i\tau}.$$

In equation (1), α_1 is the value to the marginal home buyer of fixed amenities such as location and community characteristics. The coefficient α_2 represents the value of environmental amenities; in this case, toxic releases that are reported under TRI. The coefficient on the size of the housing stock (α_3) is expected to be negative as long as the supply of new units is not perfectly elastic. Zoning ordinances that set minimum lot sizes and limit redevelopment at higher densities and restrictions on setting up new

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16 Epple [1987] and Bartick{1987] provide critiques of the basic hedonic equation in Rosen [1974], specified above in equation (1), based on the likelihood households simultaneously choose quantities and prices of housing and land characteristics. Both papers suggest instruments from suppliers and household that are not available in most applications, including ours. Epple also suggests that identification of hedonic models can be reached under a set of strong, but not completely unreasonable assumptions. The subsequent literature has generally accepted repeat sales models as being a good approach to estimate capitalization in many contexts, including environmental amenities and school quality.

communities ensure an upward sloping supply curve within a metropolitan area, even in the long run.[17] Finally, local economic factors will also influence house prices, although they may also be simultaneously determined with house prices.

Our estimation procedure relies on an event study-type methodology, a variant of the process developed in Case and Mayer [1996]. In this context, we look for evidence as to how changes in toxic releases are capitalized into house prices. A simple first-differencing of equation (1) between base year τ and subsequent year t suggests that changes in house prices should be a function of changes in fixed amenities, changes in environmental amenities, changes in the supply of units, and changes in local economic factors, as below:

$$\begin{aligned} \Delta P_i = {} & \beta_0 + \beta_1(\Delta \mathit{fixed\ amenities})_i + \beta_2(\Delta \mathit{environmental\ amenities})_i \\ & + \beta_3(\Delta \mathit{housing\ stock})_i + \beta_4(\Delta \mathit{economic\ factors})_i + \mu_i, \end{aligned} \tag{2}$$

where Δ represents the change in the value between year t and the base year τ.

Modeling changes rather than levels has the advantage of removing a considerable degree of "fixed effect" differences among communities. By definition, changes in many "fixed amenities," such as location and community characteristics equal zero and thus drop out of equation (2). Using differences as above is particularly important in our context because these fixed effects might be correlated with environmental amenities in the cross-section. For example, communities with higher levels of toxic releases may have lower-quality houses, fewer parks, or worse schools. To the extent that these fixed factors are not fully observed, the estimated coefficient on environmental amenities in a

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[17] See Fischel [1990] for a summary of the literature on zoning. Hamilton [1975] shows that under a series of restrictive assumptions, including perfectly elastic supply and zoning ordinances that control the exact quantity of housing consumption, there is no capitalization of local amenities and thus α_1, α_2, and α_3 are equal to zero. As noted in Fischel, these assumptions are not satisfied empirically.

hedonic equation will be biased. However, this bias does not affect estimated coefficients in the differences equation (2).

While many of the other explanatory variables related to preferences, costs, and revenue capacity do not change noticeably over a three to five-year time span, these independent variables may still influence spending changes if their effects on spending levels (their coefficients in the levels equations) change during the period. Initial levels of town characteristics are included in the house price regression to account for possible changes over time in the capitalized value of fixed attributes. Aggregate shocks, such as an aging population, increasing school enrollments, and the relative decline of the manufacturing sector can cause such changes.

For example, the aging of the baby boom and the associated echo baby boom has led to an increase in public school enrollments in Massachusetts since 1990. The resulting growth in the number of households with children in public schools has increased the demand for houses in towns with good schools. Similarly, a town's initial age mix may be an indicator of amenities that are attractive to specific age groups. During this period, most baby boomers entered the 35-60 year-old age group, raising demand for amenities typically valued at those ages, such as town-sponsored day care and after-school programs, and better parks and playgrounds. Thus, communities with high initial concentrations of middle-aged households would be expected to experience a relative increase in housing demand and, hence, house prices. Finally, the initial percentage of manufacturing workers can proxy for the importance of manufacturing jobs to town residents at a time when this sector is losing jobs.[18]

Thus we estimate the equation below, which allows for the value of some fixed amenities to

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[18] The ability of jurisdictions to replicate desired amenities and housing types could counteract any impact of the aging of the baby-boom generation on cross-sectional house prices. Since the baby boom movement into middle age could be easily forecast, an efficient housing market would cause prices in towns that appeal to baby-boomers to have risen in previous periods in anticipation of baby-boomers entering the housing market. This is particularly true of towns with a large number of trade-up homes, which are very expensive to replicate given the limited supply of undeveloped land in many metropolitan areas.

change over time:

$$\Delta P_i = \gamma_0 + \gamma_1 (environmental\,emissions)_{i\tau} + \gamma_2 (new\,supply)_i + \gamma_3 (town\,characteristics) + \gamma_4 (\Delta economic\,factors)_i + \gamma_5 (location)_{i\tau} + \mu_i . \quad (3)$$

Changes in economic factors and new supply of housing permits are measured over the time period used in each regression, while town characteristics and location are assumed to be constant, so we use the value from the base year (τ), or in some cases an earlier year when these values were observed from the US Census. Environmental emissions are either measured in a single year to pick-up an initial announcement effect or between two years to capture the impact of changes in emissions over time. To begin, Table 6 presents estimates of the house price regressions without considering environmental amenities. These regressions use two-stage least squares to allow for endogenous new supply, with the amount of vacant land available in 1984 and lagged permits serving as additional instruments.

We also face potential endogeneity problems when considering changes in economic factors, including changes in town manufacturing employment, the unemployment rate, and spending on health and welfare. These variables help correct for a potential bias, because changes in toxic emissions might be negatively correlated with employment changes. That is, firms that reduce output will layoff workers and also reduce emissions, or vice versa. The beneficial impact of reduced emissions on house prices might be offset by reduced demand for housing from laid-off workers. Since the primary purpose of this paper is to explore the impact or TRI emissions on house prices, we are not interested in structural estimates of the coefficients of the economic variables. Yet the economic variables might be simultaneously determined with house prices, for example through employment changes in the construction sector.

Here we take three alternative approaches to deal with local economic changes. First, we include the employment variables directly in the equation, recognizing the coefficient estimates on these variables may be biased, but expecting that such simultaneity biases might not impact the environmental variables, especially since we have already included instruments for local supply. Second, we include a proxy for employment that is the number of workers in manufacturing sector in 1980, but drop the potentially endogenous changes in economic factors. This proxy would be appropriate if all communities had the same proportional drop in manufacturing employment. Our third approach is to instrument for the changes in economic factors with lagged changes in economic factors. While lagged values are not the ideal instruments, they are the only instruments that we can find at the local level. Since serial correlation might be a problem that biases instrumental variables estimation with lagged values of the endogenous variables as instruments, we also use longer lags. We report estimates using the first two approaches. All of the results below with regard to the TRI variables hold just as strongly when we use any of the other instrumental variables as in the third approach.

The basic regression coefficients in column (1) are of the expected signs, are almost all statistically significant, and are consistent with the coefficients in Case and Mayer. These results provide support for the hypothesis that aggregate trends change the capitalized value of school quality and location over time. In particular, houses in towns with good schools (as measured by 1988 test scores) actually increased in value from 1989-92, as aggregate school enrollments rose following national demographic factors. House prices also grew faster in communities with better access to downtown Boston and its suburbs, where job growth was relatively strong compared to other parts of the Commonwealth over this time period. Local construction is negatively related to changes in house prices, as anticipated. Finally, the coefficient on change in the unemployment is negative and significant, as expected, while the change in health and welfare spending has a positive relationship with house prices, as might be anticipated if state transfers raise local income, although only significant at the 90^{th} percentile. Controlling for the overall unemployment rate, the coefficient on change in manufacturing employment is highly insignificant.

In column (2) we substitute the initial percentage of residents who work in the manufacturing sector instead of the more direct but potentially endogenous measures of employment and economic changes in the community. The coefficient is negative and significant, suggesting that negative aggregate shocks to the manufacturing sector have a negative impact on house prices in communities whose residents relied heavily on that sector for jobs. The coefficients on other variables are nearly unchanged in size or statistical significance when we drop the potentially endogenous employment variables.

Cross-Sectional Relationship between TRI Releases and House Prices

Before beginning the analysis using our differences model described above, we explore the relationship between house prices and TRI releases using the cross-sectional data that is utilized by many earlier studies. In particular, we take median house prices from the 1990 Census and compare those prices to amount of toxic releases reported by TRI in 1990. As expected, in the raw data, aggregate TRI releases have a -0.12 correlation with median house prices (p-value 0.05). Communities with higher house prices have lower TRI releases. In a regression with log of median house prices in 1990 as the dependent variable, the coefficient on the log of TRI releases is negative and highly significant (p-value = 0.001), suggesting that a ten percent increase in TRI emissions leads to a 0.14 percent decrease in house values. While small in size, that coefficient remains statistically significant even when controlling for the percentage of manufacturing workers in a community (p-value= 0.005). Thus we can confirm previous findings that toxic releases are negatively correlated with house prices in a cross-sectional hedonic regression. As we will see below, however, this result will not hold-up in the differences estimation and is likely a function of unobservable variables.

Impact of Initial TRI Releases

We begin by supplementing the basic (differenced) house price regressions from Table 6 with a variable measuring the initial TRI releases in 1987. The interpretation for the coefficient on this variable is similar to that of other variables in an event study; it measures the impact of the announcement of TRI releases on house prices relative to expectations. As such, an insignificant coefficient might reflect either that the public does not place a large negative value on toxic releases or the announcement was in line with prior expectations.

Table 7 presents the regression coefficients on TRI variables using a number of different specifications. All equations also include the other variables listed in Table 6, which are not reported here for space considerations. Regression coefficients on these other variables change little from those reported in Table 6. The dependent variable measures house price changes over a one-year period, reflecting the possibility that house prices adjust slowly to new information. The results are quite similar if we use a two or three-year window, although these longer windows may incorporate information from subsequent TRI releases and thus do not provide as clean a test.

The coefficient estimates show that TRI releases had very little impact on house prices over this time period. TRI releases are made public with an 18 month lag. In this case, TRI information from 1987 was made public in the summer of 1989. Thus the dependent variable measures house price changes from the second quarter of 1989 through the second quarter of 1990, a full year. The top panel explores changes in house prices following the initial announcement and finds no statistically significant impact of the initial announcement on house prices. In fact, both the coefficient and standard errors suggest that the economic impact of TRI information is exceedingly low. The estimated coefficient indicates that a one standard deviation increase in announced aggregate TRI releases (408,521 pounds among communities reporting positive emissions) leads to a 0.095 percent decline in house prices over two years. Even looking at a two-standard deviation confidence interval around this estimate, we can reject that a 408,521 pound increase in emissions leads to more than a 0.33 percent decrease in house prices.

To confirm these results, we investigate other possible alternatives. While many of the toxics covered by TRI are relatively benign, a few of the substances have a particularly strong impact on public health. In the lower part of the top panel, we only include measures of chemicals that have a strong link to cancer or developmental and reproductive problems, representing some of the most hazardous chemicals covered by TRI. Again the coefficients are quite small and the standard errors show that one standard deviation changes in reported emissions of these severe toxics have a very small impact on local house prices. In both cases, we can reject (with 95 percent confidence) that a one standard deviation increase in announced toxic releases leads to more than a 0.16 percent decline in house prices over a year. The third set of regressions in the top panel considers emissions of noxious chemicals, that is, chemicals that emit distasteful odors and are thus most easily observable to the general public. While the coefficient is negative, the standard error is larger than the coefficient estimate and the relatively tight standard errors allow us to reject any meaningful effect of noxious emissions on house prices.

The next three columns of the top panel of Table 7 examine other specifications. The second column allows for the possibility that possibly endogenous economic changes might bias the coefficient on TRI emissions, and instead substitutes 1980 percent of residents in manufacturing for contemporaneous changes in economic variables. The coefficients on TRI variables in the second column are remarkably similar to those in the first column, suggesting that how we treat these economic variables has very little impact on the estimated impact of TRI on house prices.

We also allow for the possibility that TRI emissions have an impact beyond the immediate zip code where the plant is located. Column (3) reports results in which we add one-half of the emissions from immediately surrounding communities to the emissions in a given zip code. In these specifications, 218 of the 247 zip codes are now measured as having some positive exposure to emissions from plants in their zip code or in a surrounding zip code. This specification may be reasonable given that many of the TRI emissions might travel to surrounding locales thru the air or ground water. Yet in three of the four rows, the coefficients drop in size, in all cases the standard errors fall. None of these regression coefficients is close to conventional significance levels. The decreased standard errors suggest that TRI would have had an even small impact on house prices than in the first column. We have also tried other weights on emissions in surrounding communities, but have always found the same results, suggesting that the lack of impact of TRI announcements on house prices does not appear to be due to difficulties in defining the relevant impact area.

Another potential issue is that some communities may be better informed than others as to the extent of the toxic releases. After all, TRI covers all types of releases–ground, water and air– and many of the most hazardous chemicals are invisible and odorless. To control for this possibility, we look at communities whose newspaper readership is in the top one-half of the sample. These regressions are reported in the last column of Table 7. Even communities with high newspaper readership do not have statistically different capitalization behavior. In regressions not reported here, we examine alternative functional forms, including an interaction between newspaper readership and toxic releases. In none of these specifications was the coefficient on a toxic releases variable ever close to statistical significance.

While not reported here, we also ran regressions in which we removed the communities with the largest emissions, possibly because these communities already knew about the emissions in their area. Again, the results indicate that releases had no statistically significant impact on house prices.[19] An alternative hypothesis is that the public only cares about large releases. In other regressions, we found similar results when looking at capitalization of the largest 50% of releases.

Finally, we consider the possibility that the toxic releases in the reported TRI data were actually observed contemporaneously by local residents. For example, residents may be able to infer actual toxic releases from proxies such as aggregate production or employment at a plant. The bottom panel of Table 7 reports the results of the same regressions in the top panel, except looking at contemporaneous changes in house prices from 1987-1989. Once again, we find no evidence of any capitalization of TRI releases into house prices. None of the coefficients are statistically different from zero at the 95th percentile. In

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[19] This conclusion does not change if we remove the top 10th or 20th percentile of emissions.

these regressions, however, the standard errors rise from those found in the top panel, so a one standard deviation increase in aggregate TRI emissions can contemporaneously reduce house prices by up to 0.5 percent at the 95th percentile.

Changes in TRI Emissions, 1987-90

While the results in Table 7 show little impact of initial TRI reports, it is possible that house prices had already capitalized the level of toxic emissions. If true, house prices would be unlikely to react to the initial TRI data, but should respond to changes in toxics releases over time. However, we find no evidence of any such reaction.

To begin, we explore reported changes in the first year of TRI in Table 8, which repeats the basic specifications in Table 7, except that we look at changes in reported emissions between 1987 and 1988 and examine changes in house prices over a two-year period that corresponds to the dates of reporting of TRI releases. Aggregate releases were reported to decline almost 40 percent in the first year of the law. As shown above, these releases were not completely random; larger releases were reported for plants in high-housing value communities and in plants with higher initial reported releases. Yet these reported releases had little impact on local house prices. In fact, three of the four coefficients on the change in reported TRI releases in Column (1) are positive, although none are even close to being statistically different from zero at conventional levels. Two standard deviations around the estimate using total TRI releases in Row (1) and Column (1) suggests that we can reject with about 95 percent confidence that house prices will rise by less than 0.17 percent as a result of a rather large hypothetical decrease in emissions of 133,000 pounds (a one standard deviation decline in emissions). These basic conclusions do not change when looking at different specifications, types of toxics, or contemporaneous changes in house prices. We also obtain similar results with all of the alternative specifications.

Some observers of TRI have argued that early TRI reports were quite inaccurate as many firms did not have sufficient expertise to accurately estimate toxic releases. If accurate, some firms might have over-reported their initial releases to avoid the possible negative publicity of later having to admit that they under-reported toxic releases. Also, firms might have expected to receive positive publicity associated with reporting strong initial declines in emissions. To the extent that firms pursued such strategies, and the public knew this was happening, house prices might not have reacted to early announcements as much as subsequent reports.

Table 9 reports the same coefficients as Table 8, except that it explores changes in house prices in the second full year of TRI announcements. As suggested above, the results for changes in aggregate emissions suggest that the public had a stronger reaction to these second year results. Coefficients in the first row of Table 9 increase in size from their equivalent coefficients in the first row of Table 8, and are almost uniformly negative in all specifications except for noxious emissions. However, none of these coefficients exceeds its standard error and the magnitude of the effects are quite small. We estimate that a one standard deviation decrease in reported emissions (17,700 pounds) increases house prices by 0.015 percent and can reject at the 95^{th} percentile that it has more than a 0.08 percent effect on house prices. Our basic conclusions do not change if we examine any of the other coefficients in this table.

Finally, Table 10 presents evidence on the capitalization of changes in reported releases from the first three years of the program. While the coefficients on overall emissions and developmental and reproductive releases are actually positive and insignificant, the coefficient estimates on carcinogenic releases are uniformly negative and above conventional significance levels in Columns (2) and (3). In this case, a one standard deviation decline in carcinogenic emissions (approximately 18,000 pounds) results in a 0.20 percent increase in house prices over a four-year period. Relatively tight standard errors still allow us to reject with 95 percent confidence that this large decrease in carcinogenic releases leads to more than a 0.43 percent increase in house prices.

The results above are relatively consistent. No matter what the time period, the housing market just does not appear to react very strongly to any of the data released by TRI. While the coefficients on

TRI announcements of changes in toxic releases appear mostly negative, we can reject that a large one-standard deviation change in the announcement of any one of these variables has affected house prices by more than 0.5 percent over this time period. These results hold no matter what econometric specification we use, no matter how we treat emissions in surrounding communities, and even if we limit the sample to communities with greater access to information about toxic releases through high newspaper readership. We again note, however, that almost all other variables including new construction, change in economic conditions, and proxies for location and school quality do have a statistically significant and economically important impact on local house prices.

TRI Releases and Expectations

Although these results seem to suggest that home buyers do not place a large value on toxic releases by plants located in their zip code, other explanations are possible. Home buyers might have had expectations that were consistent with the exact path of reported TRI releases. According to this view, TRI releases were in line with expectations and thus the TRI announcements should not be expected to impact local house prices. Alternatively, TRI data might have been regarded as sufficiently low quality that it was ignored by home buyers. Research by Hamilton [1995] and Konar and Cohen [1997] is inconsistent with these possibilities. While home buyers and sellers did not seem to value changes in reported TRI releases, investors apparently did care. These event studies show that firms reporting higher TRI releases have significant negative stock market returns.

To address this hypothesis, we explicitly model the process that households use to determine their expectations of toxic releases, so that expected TRI releases are a function of employment at the town level, measured annually:

(4) $$E[TRI]_i = f(aggregate\ \ employment_i\ ,\ manufacturing\ \ employment_i).$$

In estimating (4), we use current and lagged employment variables. Next, we re-write equation (3) and express house prices as a function of *unexpected* TRI releases, as below:

$$\text{(5)} \quad \Delta P_i = \gamma_0 + \gamma_1 (TRI - E[TRI])_i + \gamma_2 (new\ supply)_i + \gamma_3 (town\ characteristics)_{i\tau} + \gamma_4 (\Delta economic\ factors)_i + \gamma_5 (location)_{i\tau} + \mu_i.$$

Results from equation (5) are presented in Table 11. The top panel reports coefficients exploring the impact of the initial announcement of TRI releases in 1987. Only one of the coefficients on any of the TRI variables has a t-statistic exceeding 1.2, which is the coefficient on noxious emissions when we include surrounding towns (t=1.78). However, this is the least likely place for TRI to have an announcement effect as the noxious emissions are already observed in the community. As in the equations above, the estimated economic impact of TRI is quite small. If we believe that household expectations about TRI releases are even somewhat accurate, the coefficients in Table 11 should be larger in magnitude than in earlier equations. Yet these coefficients are of the same order of magnitude as in the earlier tables.

The bottom panel estimates a differences version of equations (4) and (5). In this case, the first-stage expectations equation estimates changes in TRI releases as a function of change in the employment variables. Next, the difference between actual and forecast changes in TRI releases between 1987-88 are included in the second-stage house price equation. Once again, none of the unexpected changes in TRI releases has a statistically significant impact on house prices, and the magnitude of the coefficients is quite small. While not reported here, we get similar results if we use unexpected changes in emissions from 1988-89.

It is also possible that our forecasting equations may not do a good job of measuring "true" expected releases, possibly because we do not observe all information that is available to local households. To further explore the role of expectations, we take advantage of the forward-looking nature of house prices. If information arrives in an earlier period that helps forecast future emissions, house prices should immediately capitalize this information. For example, a local plant might announce that it will layoff one-half its workers in the next two years and scale back production. In an efficient market, house prices will fall immediately, even though employment and production fall two years later.

To allow for the possibility that house price anticipate announced TRI emissions, we regress TRI emissions on lagged house prices. If the public places a negative value on TRI releases, but is able to predict future changes, the coefficient on lagged changes in house prices should be negative. The empirical results in Table 12 seem to reject this hypothesis. Lagged house prices have little predictive power for future TRI announcements, no matter what the time period. The R-squared for all three equations (TRI announcements in 1987, change in TRI emissions between 1987-8 and change in TRI emissions between 1988-9) is exceeding low and F-tests cannot reject the hypotheses that the coefficients on all of the lagged house price terms are individually and jointly equal to zero.

6. Concluding Remarks

In this paper, we explore the impact of information released under the Toxics Release Inventory. Our results show little evidence to support the claim by many proponents of TRI that the act's introduction has caused communities to mobilize against polluters and induce large reductions in toxic emissions. We find that (1) poorer, "blue collar" areas are more likely to have toxic emissions and (2) larger reductions in toxic emissions occur in higher value regions and regions with higher initial releases. However, (3) reductions in releases are unrelated to any political economy factors that might relate to the ability or willingness of a community to organize against major polluters. When measured by the initial *level* of toxic releases reported in 1987, (4) introduction of the TRI reporting had virtually *no* effect on housing prices and even more surprisingly, (5) subsequent reductions in aggregate reported emissions between 1987 and 1990 have no significant effect on house prices, either in the aggregate or when disaggregated by type of toxic release. Finally, expectations do not appear to explain these results. We show that (6) the above findings hold even if we look at the unexpected information in TRI releases, (7) changes in house prices do not forecast changes in toxic emissions, as might be expected if communities anticipated increases or reductions in toxic releases, and (8) these results persist even in communities with high newspaper readership.

It is important to emphasize that our findings do not show that TRI has no impact on local house prices, but rather that the estimated effect of TRI is sufficiently small as to be undetectable using our relatively accurate house price series. In virtually all equations the coefficients on TRI information are not statistically different from zero. This finding is not due to large standard errors. We can reject with 95 percent confidence that a one standard deviation increase in announced TRI releases (or announced changes in TRI releases over time) lowers house prices by more than 0.5 percent. It is possible that we might find a larger impact if we looked at a much smaller neighborhood around plants that release toxics. However, these results seem to reject a broad-based community response to TRI.

Our findings that communities do not place a significant value on declines in toxic releases is in sharp contrast to the beliefs held by environmental policy makers and to the existing literature on the public valuation of another environmental amenity, air quality. How can we reconcile these results with the evidence in the existing literature, along with our basic intuition that household value clean air and water? One major difference between air quality and TRI releases is that the former is immediately identifiable to all households by both their visibility and odor -- being measures of the concentration of such pollutants as sulfur dioxide, particulate matter, and ozone -- while the chemical releases measured by TRI are difficult to observe. Some TRI substances are not associated with the smoke being emitted from a plant's smoke stack and tend to be both colorless and odorless. However, even when we disaggregate the TRI releases into those that are particularly noxious, we still find no statistical relationship between changes in toxic releases and changes in house prices. Our results may simply reflect an “out of sight, out of mind” problem. A community's inability to assess the risk associated with toxic releases would be consistent with the findings of Greenberg and Hughes [1992].

Another important difference between our results and other studies is methodological. Previous research relies on hedonic regressions that can produce negatively-biased coefficients if air quality is positively correlated with other community factors that negatively affect house prices. Even in our data it is true that there is a strong and significant correlation between median house prices and aggregate TRI releases in 1990. However, that correlation disappears when we look at differences over time, suggesting that the correlation is likely driven by negative unobservable factors that exist in houses and neighborhoods located near plants that emit TRI chemicals.

Finally, households may assume that existing EPA regulation is strong enough to protect them against harmful levels of chemical emissions. While firms were required to release information about toxic emissions under TRI, these firms were still subject to the usual battery of EPA regulations. Thus it would be inappropriate to extrapolate these results to a regime in which the only type of regulation is disclosure of public releases and firms were free to emit whatever they wanted.

Another puzzle is why investors appear to respond to information about TRI to a much greater degree than homeowners. A strong reaction by investors seems to rule out the possibility that TRI information was of sufficiently poor quality to be unreliable. The lack of a significant response in the housing market seems to suggest that communities either do not care about toxic releases or do not internalize the differential risk associated with being in a relatively "dirty" versus a slightly "cleaner" community. Investors may respond to the TRI information for a number of reasons; either because high reported toxic emissions are a signal of inefficiencies in the firm's production process (after all, pollution may mean that inputs are being released into the atmosphere instead of being utilized) or because large reported releases may be a sign that the firm will face future pressure from community groups or legal liability at some future date. To date, however, there is little evidence that TRI information has been successfully used for litigation purposes against polluting plants.[20] The vast majority of legal cases that have been resolved that are related to TRI are about communities suing individual plants for non-reporting. Taken together, our results suggest that broad-based community pressure is the least likely of these alternatives to explain the reported reduction in releases. This is consistent with the Coase Theorem, especially if one believes that the costs of organizing community residents are high and the public does not place a high premium on houses in communities with low or declining emissions.

So what was responsible for the decline in reported toxic releases? Factors that are unrelated to TRI regulation may play an important role in explaining the reduction. For example, between 1988 and 1992, Massachusetts lost almost one-third of its manufacturing jobs. This suggests that much of the reported TRI reductions may be due to decreases in manufacturing output. Further research can explore this proposition by looking at the specific declines in releases and compare them to the manufacturing industries that have left the state or reduced output. Dis-aggregate TRI data make this possible. In addition, firms may have improved their manufacturing efficiency over this time period, leading to a natural decline in emissions. Also, much of the reported declines in emissions occurred in early years, when firms may have been working on methodologies to accurately estimate their toxic releases. If firms initially over-reported emissions due to uncertainty about their actual emissions, this would lead to large initial declines. Our regression results are somewhat consistent with this hypothesis; zip codes with the highest initial releases had the greatest subsequent declines in releases. Yet almost one-third of plants reported increases in emissions, so all plants cannot have followed this strategy.

Another possibility is that polluting plants simply substituted away from the listed TRI substances to equally toxic, but unlisted substances. In this case, if communities are aware of this behavior, we would expect to see little, to no capitalization occurring with reported reductions in TRI emissions. This possibility would be worst of all outcomes in terms of the effectiveness of disclosure-based regulation, but is hard to reconcile with the stock market evidence.

Given that declines in TRI-listed substances in Massachusetts were much greater than for the U.S. as a whole, the results here cast considerable doubt on the premise of TRI; that public reaction can discipline industrial behavior. Before embarking on a major policy shift in favor of information-based regulation, regulators should assess the mechanism through which this regulation is expected to work and the areas where it will likely be most effective.

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[20] Based on summary of cases reported by Lexis-Nexis between 1987 and 1996.

Table 1:
TRI Releases - 1993

1993 Releases	Pounds
Total Releases:	2,808,618,413
Fugitive Air	490,040,607
Point Source Air	1,182,087,128
Surface Water	271,152,864
Underground Injection	576,285,233
On-site Land Releases	289,052,581

Source: TRI, 1993

Table 2:
Summary of TRI Releases[1]

Year	Aggregate Releases	Carcinogenic Releases	Adverse Developmental or Reproductive Releases	Noxious Releases
1987	50,029,900	5,491,783	738,390	2,614,877
1988	31,947,900	4,712,841	442,136	2,274,411
1989	26,275,600	4,121,111	472,059	1,313,492
1990	21,812,300	2,936,752	445,278	1,574,979
1991	17,585,600	2,411,321	466,084	565,767
1992	14,846,500	2,207,644	600,019	1,060,847
% Decrease: 1987-1992	70%	60%	19%	59%

1. All Releases are measured in pounds.

Table 3:
Summary of Data, By Reported Emissions

Toxic Emissions Reported in 1987 By Zip Code

	Non-Zero Emissions		Zero Emissions*	
	Mean	Std. Dev.	Mean	Std. Dev.
Average Reported Toxic Emissions (pounds)	218,213	407,521		
Percentage Change in House Prices, 1982-87	1.58	0.17	1.55	0.23
Percentage Change in House Prices, 1987-89	0.08	0.06	0.07	0.06
Percentage Change in House Prices, 1989-94	-0.11	0.07	-0.09	0.08
Median Household Income in 1980 (000's)	18.9	4.8	21.7	6.8
Median House Price in 1980 (000's)	47.9	13.5	56.5	22.7
Town Population in 1980	49,461	75,858	52,919	118,580
Percentage of Minority Residents in 1980	0.04	0.06	0.04	0.07
Percentage of Residents who work in the Manufacturing Sector in 1980	0.34	0.10	0.29	0.10
Percentage of Registered Voters who are Democrats	0.43	0.14	0.35	0.15
Percentage of Adults who are Registered to Vote	0.69	0.10	0.74	0.11
Average Daily Newspaper Circulation Per Capita from 1995-98	0.29	0.12	0.28	0.11
Percentage of Residents with a College Degree in 1980	0.16	0.09	0.23	0.13
Percentage of Residents aged 35-60 in 1980	0.27	0.03	0.28	0.04
Percentage of Residents under age 21 in 1980	0.35	0.03	0.35	0.04
Average Math and Reading Assessment Test Score	2588	179	2679	185
Dummy variable if in the Boston Metro Area	0.36	0.48	0.52	0.50
Distance from Boston if in the Boston Metro Area	20.3	16.5	22.8	17.4
New Housing Permits Issued as a Percent of the Total Number of Units from 1982-88	0.075	0.062	0.103	0.090
New Housing Permits Issued as a Percent of the Total Number of Units from 1989-93	0.037	0.035	0.050	0.048
Unemployment Rate in 1987	0.033	0.012	0.029	0.012
Health and Welfare Spending in 1987 (millions)	3.7	16.6	7.2	27.9
Number of Residents who work in the Manufacturing Sector in 1980	5,865	6,994	3,783	8,472
Number of Residents who Work in the Nonmanufacturing Sector in 1980	24,483	64,521	34,442	108,611
N	137		110	

Table 4:
Summary of Data, By Reported Change in Emissions between 1987-92

Change in Toxic Emissions Reported, 1987-92 By Zip Code

	Low Reductions or an Increase in Emissions		High Reductions	
	Mean	Std. Dev.	Mean	Std. Dev.
Average Reported Toxic Emissions in 1987 (pounds)	41,165	89,770	397,863	513,701
Average Change in Toxic Emissions in 1987-92 (pounds)	24,059	65,896	-287,408	404,328
Percentage Change in House Prices, 1982-87	1.58	0.19	1.58	0.15
Percentage Change in House Prices, 1987-89	0.08	0.07	0.08	0.06
Percentage Change in House Prices, 1989-94	-0.11	0.07	-0.10	0.07
Median Household Income in 1980 (000's)	18.5	4.7	19.2	4.9
Median House Price in 1980 (000's)	47.2	12.9	48.6	14.0
Town Population in 1980	52,013	77,631	46,871	74,503
Percentage of Minority Residents in 1980	0.05	0.07	0.03	0.05
Percentage of Residents who work in the Manufacturing Sector in 1980	0.33	0.10	0.36	0.11
Change in Percentage of Residents who work in the Manufacturing Sector between 1980 and 1990	-0.09	0.04	-0.10	0.05
Percentage of Registered Voters who are Democrats	0.43	0.14	0.43	.014
Percentage of Adults who are Registered to Vote	0.69	0.10	0.69	0.09
Avg. Daily Newspaper Circulation Per Capita, 1995-98	0.27	0.99	0.30	0.14
Percentage of Residents with a College Degree in 1980	0.16	0.09	0.16	0.10
Percentage of Residents aged 35-60 in 1980	0.27	0.03	0.28	0.03
Percentage of Residents under age 21 in 1980	0.35	0.03	0.35	0.03
Average Math and Reading Assessment Test Score	2575	189	2600	169
Dummy variable if in the Boston Metro Area	0.41	0.49	0.32	0.47
Distance from Boston if in the Boston Metro Area	17.6	15.7	23.0	17.1
New Housing Permits Issued as a Percent of the Total Number of Units from 1982-88	0.076	0.069	0.073	0.055
New Housing Permits Issued as a Percent of the Total Number of Units from 1989-93	0.035	0.035	0.039	0.035
Unemployment Rate in 1987	0.033	0.012	0.033	0.012
Change in Unemployment Rate from 1987-1992	0.063	0.020	0.063	0.019
Percentage Change in Manufacturing Employment between 1987 and 1992	-0.18	0.15	-0.14	0.17
Percentage Change in Nonmanufacturing Employment between 1987 and 1992	-0.052	0.139	-0.063	0.168
Health and Welfare Spending in 1987 (millions)	4.0	17.0	3.2	16.5
Percentage Change in Health and Welfare Spending between 1987 and 1992	0.31	0.78	0.26	0.51
N	69		68	

Table 5:
Determinants of TRI Emissions (000's)

Dependent Variable	TRI Emissions, 1987		Change in TRI Emissions, 1987-92		Change in TRI Emissions, 1987-92	
Equation Type	Tobit		OLS		OLS	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Median Household Income in 1980 (000's)	-49	25.8	30.9	26.5	-2.67	7.87
Median House Price in 1980 (000's)	3.9	6.1	-13.1	6.9	0.68	2.08
Town Population in 1980	-0.00043	0.00067	-0.00027	0.00064	-0.00015	0.00019
Percentage of Minority Residents in 1980	–394	983	286	874	-181	257
Percentage of 1980 Residents working in Manufacturing	763	465	425	426	-53.8	125
Percentage of Registered Voters who are Democrats	801	370	-247	331	35.2	97.9
Percentage of Adults who are Registered to Vote	-756	601	390	542	48.1	159.9
Average Daily Newspaper Circulation Per Capita from 1995-98 (000's)	356	308	-178	266	-227	786
Percentage of Residents with a College Degree in 1980	259	942	449	908	74.2	267.5
Percentage of Residents under age 21 in 1980	780	1,496	-1250	1483	499	439
Percentage of Residents aged 35-60 in 1980	4,618	2,036	-2,669	1,981	-574	586
Average Math and Reading Assessment Test Score	0.3	0.36	-0.39	0.34	-0.13	0.10
Dummy variable if in the Boston Metro Area	-117	87	126	84	-9.7	24.9
Distance from Boston if in the Boston Metro Area	22.8	8.5	-28	7.8	-1.57	2.29
(Distance from Boston if in the Boston Metro Area)^2	0.51	0.18	0.017	0.17	0.009	0.049
TRI Emissions in 1987 (000s)					-0.76	0.02
Constant ($x10^{-3}$)	-1,813	1,281	1,940	1,171	393	347
Log Likelihood	-2033.19					
R-Squared			0.13		0.93	
Number of Observations	247		137		137	

Table 6:
2SLS Regressions of Change in House Prices

Dependent Variable:	Change in House Prices, 1989-92		Change in House Prices, 1989-92	
	Coef.	Std. Error	Coef.	Std. Error
New Housing Permits Issued as a Percent of the Total Number of Units *	-0.66	0.20	-0.57	0.21
Percent Change in Manufacturing Employment in the Town	-0.0039	0.0061		
Change in Unemployment Rate in the Town	-0.39	0.20		
Percent Change in Health & Welfare Spending in the Town	0.0033	0.0019		
Percentage of Residents who work in the Manufacturing Sector in 1980			-0.060	0.024
Average Math and Reading Assessment Test Score (000's)	0.058	0.018	0.062	0.016
Percentage of Residents aged 35-60 in 1980	-0.023	0.076	-0.015	0.075
Dummy variable if in the Boston Metro Area	0.024	0.005	0.022	0.005
Distance from Boston if in the Boston Metro Area (00's)	0.12	0.05	0.10	0.04
$(\text{Distance from Boston if in the Boston Metro Area})^2$ (0,000's)	-0.30	0.10	-0.27	0.10
Constant	-0.27	0.04	-0.28	0.03

*Additional instruments include available land for development in 1984 and lagged permits in column 1 and also lagged employment change in column 2. Number of observations= 247.

Table 7:
2SLS Regressions of Change in House Prices on TRI Emissions in 1987*

Announcement Effect of Initial TRI Emissions
Dependent Variable: Change in House Prices Between 1989Q2-1990Q2

Specification	Base Equation		Alternative Equation without Employment Changes		Alternative Equation with Surrounding Towns		Base Equation: Communities with highest newspaper readership (N= 124)	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Aggregate TRI Emissions in 1987 (e^{-9})	-2.32	4.10	-1.86	4.15	0.20	2.99	-0.033	4.72
Carcinogenic Emission in 1987 (e^{-8})	-0.22	1.74	-0.54	1.75	0.41	1.37	-0.32	1.91
Adverse Developmental or Reproductive Emissions in 1987 (e^{-8})	1.21	5.45	3.05	5.46	0.70	4.46	-1.04	5.79
Noxious Emissions in 1987 (e^{-8})	-2.19	2.26	-1.84	2.28	3.57	1.95	0.071	2.93

Contemporaneous Effect of Initial TRI Emissions
Dependent Variable: Change in House Prices Between 1987Q1-1988Q1

Specification	Base Equation		Alternative Equation without Employment Changes		Alternative Equation with Surrounding Towns		Base Equation: Communities with highest newspaper readership (N= 124)	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Aggregate TRI Emissions in 1987 (e^{-9})	-3.23	6.64	-4.32	6.74	-3.64	5.11	-2.80	7.59
Carcinogenic Emission in 1987 (e^{-8})	-3.10	2.76	-3.53	2.81	-1.77	2.55	0.21	3.07
Adverse Developmental or Reproductive Emissions in 1987 (e^{-8})	-2.07	8.74	-3.50	8.78	-4.24	7.46	-2.68	9.52
Noxious Emissions in 1987 (e^{-8})	-1.11	3.63	-0.84	3.65	-1.09	2.93	2.99	4.75

* All equations also include the other independent variables listed in Table 6. The base specification is Column 1, Table 6. Each section reports coefficients from separate regressions. Number of observations=247, except where noted.

Table 8:
2SLS Regressions of Change in House Prices on Change in TRI Emissions between 1987-88*

Announcement Effect of Initial TRI Emissions
Dependent Variable: Change in House Prices Between 1989Q2-1991Q2

Specification	Base Equation		Alternative Equation without Employment Changes		Alternative Equation with Surrounding Towns		Base Equation: Communities with highest newspaper readership (N= 124)	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Aggregate TRI Emissions in 1987 (e^{-8})	1.30	1.30	1.16	1.27	-0.61	0.96	0.68	1.64
Carcinogenic Emission in 1987 (e^{-8})	-4.52	10.6	-5.58	10.4	-3.82	5.66	0.016	10.9
Adverse Developmental or Reproductive Emissions in 1987 (e^{-8})	3.81	8.47	2.66	8.27	-0.14	7.52	7.32	8.56
Noxious Emissions in 1987 (e^{-8})	4.12	2.80	3.59	2.75	2.65	2.51	-0.19	4.22

Contemporaneous Effect of Initial TRI Emissions
Dependent Variable: Change in House Prices Between 1987Q1-1989Q1

Specification	Base Equation		Alternative Equation without Employment Changes		Alternative Equation with Surrounding Towns		Base Equation: Communities with highest newspaper readership (N= 124)	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Aggregate TRI Emissions in 1987 (e^{-8})	-0.97	1.88	-0.82	1.90	0.64	1.32	-0.63	2.38
Carcinogenic Emission in 1987 (e^{-8})	3.67	15.3	2.34	15.5	3.24	10.5	-2.94	15.6
Adverse Developmental or Reproductive Emissions in 1987 (e^{-7})	0.34	1.26	0.96	1.24	0.040	1.21	0.87	1.33
Noxious Emissions in 1987 (e^{-8})	5.70	3.98	5.22	4.05	3.76	3.05	0.36	6.02

* All equations also include the other independent variables listed in Table 6. The base specification is Column 1, Table 6. Each section reports coefficients from separate regressions. Number of observations=247, except where noted.

Table 9:
2SLS Regressions of Change in House Prices on Change in TRI Emissions between 1988-89*

Announcement Effect of Initial TRI Emissions
Dependent Variable: Change in House Prices Between 1990Q2 – 1991Q2

Specification	Base Equation		Alternative Equation without Employment Changes		Alternative Equation with Surrounding Towns		Base Equation: Communities with highest newspaper readership (N= 124)	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Aggregate TRI Emissions in 1987 (e^{-9})	-8.30	22.5	-7.95	22.6	-8.71	12.0	-7.36	22.7
Carcinogenic Emission in 1987 (e^{-7})	-0.75	1.09	-0.91	1.11	-0.53	0.85	0.42	1.68
Adverse Developmental or Reproductive Emissions in 1987 (e^{-7})	-2.19	3.45	-1.06	3.50	-1.36	0.94	-1.21	4.43
Noxious Emissions in 1987 (e^{-8})	3.03	4.74	3.16	4.76	-0.73	2.58	23.6	20.8

* All equations also include the other independent variables listed in Table 6. The base specification is Column 1, Table 6. Each section reports coefficients from separate regressions. Number of observations=247.

Table 10:
2SLS Regressions of Change in House Prices on Change in TRI Emissions between 1987-90*

Announcement Effect of Change in TRI Emissions
Dependent Variable: Change in House Prices Between 1989Q2 – 1993Q2

Specification	Base Equation		Alternative Equation without Employment Changes		Alternative Equation with Surrounding Towns		Base Equation: Communities with highest newspaper readership (N= 124)	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Aggregate TRI Emissions in 1987 (e^{-9})	2.43	12.3	0.700	12.2	2.24	10.0	-5.88	13.4
Carcinogenic Emission in 1987 (e^{-8})	-11.0	6.0	-12.2	6.0	-9.19	4.37	-9.74	7.18
Adverse Developmental or Reproductive Emissions in 1987 (e^{-8})	1.74	12.3	1.37	12.2	1.44	10.2	2.00	11.2
Noxious Emissions in 1987 (e^{-8})	4.62	4.03	4.50	4.00	3.93	3.74	1.71	4.83

* All equations also include the other independent variables listed in Table 6. The base specification is Column 1, Table 6. Each section reports coefficients from separate regressions. Number of observations=247.

Table 11
2SLS Regressions of Change in House Prices on Unexpected TRI Emissions*

Announcement Effect of Unexpected TRI Emissions in 1987
Dependent Variable: Change in House Prices Between 1989Q2-1990Q2

Specification	Base Equation		Alternative Equation without Employment Changes		Alternative Equation with Surrounding Towns		Base Equation: Communities with highest newspaper readership (N= 124)	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Aggregate TRI Emissions in 1987 (e^{-9})	-1.37	4.29	-0.45	4.28	0.89	2.99	-0.057	5.26
Carcinogenic Emission in 1987 (e^{-8})	0.37	1.77	0.12	1.77	1.52	1.27	0.36	1.98
Adverse Developmental or Reproductive Emissions in 1987 (e^{-8})	2.65	5.80	5.42	5.73	-2.00	5.36	-1.04	6.58
Noxious Emissions in 1987 (e^{-8})	-2.28	2.27	-2.11	2.28	-3.90	2.19	-0.57	2.97

Announcement Effect of Unexpected Changes in TRI Emissions, 1987-88
Dependent Variable: Change in House Prices Between 1989Q2-1991Q2

Specification	Base Equation		Alternative Equation without Employment Changes		Alternative Equation with Surrounding Towns		Base Equation: Communities with highest newspaper readership (N= 124)	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Aggregate TRI Emissions in 1987 (e^{-8})	1.07	1.33	1.13	1.30	-0.48	1.11	0.73	1.73
Carcinogenic Emission in 1987 (e^{-8})	-4.65	10.8	-4.01	10.5	-8.04	6.52	-0.39	11.1
Adverse Developmental or Reproductive Emissions in 1987 (e^{-8})	7.64	9.56	6.14	9.27	0.12	9.00	14.9	10.1
Noxious Emissions in 1987 (e^{-8})	3.47	2.82	3.37	2.76	2.78	2.23	-1.58	4.26

* All equations also include the other independent variables listed in Table 6. The base specification is Column 1, Table 6. Each section reports coefficients from separate regressions. Number of observations=247.

Table 12:
Regressions of TRI Emissions on Lagged Changes in House Prices*

Dependent Variable	TRI Emissions in 1987		Change in TRI Emissions, 1987-1988		Change in TRI Emissions, 1988-1989	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Change in House Prices 1989-90					37,890	311,791
Change in House Prices 1988-89	-472,406	694,110	151,849	287,838	219,567	198,579
Change in House Prices 1987-88	486,676	623,196	-182,730	258,431	-108,757	198,682
Change in House Prices 1986-87	-568,035	485,661	128,556	201,397	132,668	147,382
Change in House Prices 1985-86	-73,319	468,220	-40,192	194,164		
Constant	275,896	218,415	-33,514	90,573	-56,987	46,836
R-Squared	0.007		0.003		0.009	

* TRI Emissions are announced 18 months after they occur. Thus TRI emissions from 1987 are announced in July, 1989. Number of observations=247.

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