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 market-based regulations. One such innovation is the Toxics Release Inventory (TRI), a regulation that requires polluting firms to publicly disclose information about their toxic emissions. The basic tenet of this regulation is that it corrects for informational asymmetries between polluters and households, allowing communities to pressure polluters to decrease their emissions. Policy-makers have judged the TRI a tremendous success, as national releases declined by 43% between 1988 and 1999. Yet many of the fundamental problems which are known to lead to the classic failure of the Coase theorem (such as high transaction costs and difficulties in organizing) cast doubt on the effectiveness of disclosure rules, alone, 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 0.5% increase in house prices. These results also hold when we control for differences in the availability of information on TRI and the possible effect 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.

I. Introduction

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 of 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.

In this paper, we focus on one 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.

Between 1988 and 1999, TRI reported emissions fell by approximately 40%. 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

Received for publication October 27, 2000. Revision accepted for publication December 4, 2002.

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The authors wish to thank seminar participants at the WEA meetings, the JFK School, Columbia University, Boston University, University of Toronto, and The Wharton School, along with Katherine Carmen, Lisa George, Wayne Gray, Joe Gyourko, Charlie Himmelberg, Bob Inman, Joel Waldfogel, Marty Weitzman, and two anonymous referees, for helpful comments. Any errors are our own.

[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.

The Review of Economics and Statistics, August 2003, 85(3): 693–708

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 prepackaged foods. In the latter two cases, consumers or employees can choose to avoid a product or job if 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. Whereas 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 standalone 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 larger on average than in the rest of the nation, and percentage reductions in toxic releases have been close to the national average. A state environmental regulation introduced in 1989, called the Toxics Use Reduction Act, reinforced and supplemented TRI reporting requirements for Massachusetts manufacturing plants (as well as a number of nonmanufacturing 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 over 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 & Shiller, 1987, and Case & 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, rather than 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—no new information is bring provided. Similarly, if communities anticipate the future path of toxic reductions, those reductions should 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 emissions. We approach this problem in three ways. 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, as would be the case if communities anticipated future changes in emissions.

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

[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."

[3] Some recent exceptions are Bui (2002), Konar and Cohen (1997), and Hamilton (1995), which use event studies based on stock market valuations. These are discussed further in section III.

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, with 95% confidence, the hypothesis that declines in toxic releases of one standard deviation above the mean are associated with more than a 0.5% increase in house prices. 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 II we describe the TRI and provide background on reported TRI releases over time. Section III provides an overview of the existing literature that examines the use of property values to capture the value of different community amenities, and section IV describes the data. Sections V and VI contain the empirical results, and the final section provides an interpretation, together with concluding comments and discussion of further avenues for research.

II. 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 twofold. In part, EPCRA was a response to a number of environmental disasters involving toxic substances, the best known of which occurred in Love Canal, New York, 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 releases and by providing the public with that information, firms' 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 emit more than 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.

Between 1988 and 1999 EPA reports that toxic releases fell by approximately 40%. In 1999, approximately 23,000 different facilities submitted reports to the TRI. Nationwide, more than 2.3 billion pounds of toxic releases were reported.[7] These releases include extremely toxic substances such as arsenic, mercury, and dioxin, as well as more benign substances (at least in small quantities) such 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 fairly low levels of concentration and exposure.

The TRI is meant to provide information to the public. The official release of TRI data is made by the EPA. Initially, hardcopy versions of the yearly releases could be obtained directly from the EPA (at no cost) by individuals. Now, the data are 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, DC). The TRI provides information on all reporting

[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 it is universally agreed upon that this particular regulation has been completely unsuccessful.

[6] During our period of study, there were a stable set of approximately 300 listed toxic substances. This number has increased significantly since 1995 to over 600 listed substances. Several substances have also been delisted over the years, although not during our sample period.

[7] This includes emissions only from the original industries that were required to report in 1987 and includes emissions from chemicals that were listed after 1995.

facilities *as reported,* including name and address of the facility, type of chemical released, and amount released (in pounds). The hardcopy version of the data also include summary statistics. After 1993, data were provided on 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 have become available. A simple count of news reports in major newspapers between 1988 and 1995 on LexisNexis 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,"[8] which included a summary of what substances were being released, the health consequences of exposure to the substances, and the names and addresses of the facilities responsible for the emissions. In addition, community newspapers, which do not show up in LexisNexis, are a well-known source of local information on TRI. An informal survey of local community newspapers in Massachusetts suggests that there were numerous stories on TRI during 1987–1992. However, these local newspapers do not store their past stories in an electronic medium such as LexisNexis, making it nearly impossible to obtain a more precise measure of their coverage during our sample period.

III. 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 regress 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 travel time 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.

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." 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, Hamilton, and Viscusi (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 the interpretation used by Ridker and Henning (and, consequently, others) have been controversial, spawning a large number of studies that support and that refute their results. [See, for example, Freeman (1971, 1974), Small (1975), Polinsky, Mitchell, 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) conducted 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. Kiel and Zabel (2000) provide more recent estimates for the marginal willingness to pay for air quality in four major cities in the United States. The authors estimate that the benefits of achieving the National Ambient Air Quality Standards between 1974 and 1991 in those four cities are between $171 million and $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, Kahn, and Tracy (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 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,

[8] Hudson, Berkeley, *Los Angeles Times,* December 5, 1991 (Glendale Section, part J; p. 1, column 2).

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.

Probably the most reliable estimates on the capitalization of environmental amenities in house prices, however, come from a recent study by Chay and Greenstone (2000), who show that a one-unit reduction in suspended particulates resulted in a 0.4%–0.5% increase in house prices. Unlike previous papers, Chay and Greenstone use regulatory changes during the 1970s as instruments to control for potentially endogenous changes in emissions.

Below, we examine the release of information about actual releases under TRI, which allows us to examine the effect of information about pollution on house values. Three 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. In contrast, however, Bui (2002) claims that there may be an error in the estimation of the standard errors used by Hamilton and by Konar and Cohen, which casts doubts on the robustness of their findings. Bui finds that for petroleum companies small negative abnormal returns exist only for the initial TRI announcement of 1987 emissions and that those returns are not significantly different from the returns for nonreporting petroleum companies in any period.

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 announcements. The results of that paper are complementary with what we find below.

IV. The Data

We use data from several different sources, including: plant-level data on toxic emissions reported under the TRI from 1987 to 1992; repeat-sales house price data from 1982 to 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 by community name.

Plant-level data on toxic emissions are taken from the TRI.[9] 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 lb. of toxic substances were 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.[10] However, we create separate categories for substances that are carcinogenic or have adverse developmental or reproductive effects on humans.[11] Summary statistics are provided in Table 1. ZIP codes that do not report any toxic releases are given a value of zero.[12]

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.[13]

Between 1987 and 1992, reported toxic releases in Massachusetts fell by 70%. Similar reductions are found for carcinogenic releases (a 60% decrease). Substances with known adverse developmental or reproductive implications decreased as well, but to a lesser extent (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 lb. The amounts released ranged from a low of 1 lb. to a high of 1,019,600 lb. Both the mean release and the range fell dramatically in 1992 to 9674 lb. with a range from 1 lb. to 502,157 lb.

The house price indexes used in this paper are obtained from Case, Shiller and Weiss, Inc. and are estimated using

[9] It should be noted here that the TRI provides data that is self-reported by the polluting firms and is not verified (or easily verifiable) by independent third parties. There may be reason to believe that the data may not, in fact, be very accurate. Systematic over- or underestimation of actual releases, however, does not appear to be a problem. For our purposes, whatever measurement errors may exist in the reported data are of little importance, because it is the reported TRI values that are provided to the public, and presumably that is the information on which households base their response.

[10] The sum of environmental releases equals the sum of air + water + land releases. In comparison with the so-called *criteria* air pollutants, toxic releases have a more localized effect on their surroundings, so studying their effects at the ZIP code level is not unreasonable.

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

[12] 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.

[13] 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.

TABLE 1.—SUMMARY OF TRI RELEASES[a]

	United States	Massachusetts			
Year	Aggregate Releases	Aggregate Releases	Carcinogenic Releases	Developmental or Reproductive Releases	Noxious Releases
1987	16,314,321,854	50,029,900	5,491,783	738,390	2,614,877
1988	5,676,700,269	31,791,507	4,712,841	442,136	2,274,411
1989	4,446,143,038	26,379,909	4,121,111	472,059	1,313,492
1990	3,751,675,394	22,210,877	2,936,752	445,278	1,574,979
1991	3,499,710,918	18,132,203	2,411,321	466,084	565,767
1992	3,319,222,779	15,445,165	2,207,644	600,019	1,060,847
Change 1987–1992	−80%	−70%	−60%	−19%	−59%

[a] All releases are measured in pounds.

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 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% from 1982 to 1989, and then declined by 10% 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% in the earlier time period and between a 38% decline and a 4% increase in the later time period. Earlier work (Bradbury, Mayer, & Case, 2001) shows that shifts in economic variables such as employment, aggregate school enrollments, demographics, and changes in fiscal factors such as Proposition $2\frac{1}{2}$ are economically important and statistically significant 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 to 1998 from the Audit Bureau of Circulations.[15] Although the dates of the data do not exactly correspond to the dates of our sample, we would expect that newspaper readership will remain stable over time, or at least the rank order of localities will not change much.

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 are obtained from the Commonwealth of Massachusetts, land available for new construction from the University of Massachusetts, and data on new construction from the U.S. Department of Commerce.

V. Where Are the Toxic Emissions, and Where do the Declines Occur?

We begin the analysis by documenting the characteristics of neighborhoods that surround plants that produce toxic emissions. (See Table 2, left panel.) Not surprisingly, plants that emit TRI-listed substances tend to be located in communities with lower median incomes, house values, and school assessment test scores than 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 age distribution 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 registered as Democrats, 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 subcenters such as Lowell, Lawrence, and New Bedford, rather than in rural areas or downtown Boston. In terms of housing appreciation, the groups in the left and right columns 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 right panel in Table 2 summarizes the characteristics of communities whose change in emissions between 1987 and 1992 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

[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.

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

TABLE 2.—MASSACHUSETTS TOXIC EMISSIONS BY ZIP CODE FOR SELECT VARIABLES

	Emissions in 1987 by ZIP Code				Changes in Emissions 1987–1992 by ZIP Code			
	Nonzero Emissions		Zero Emissions[a]		Small Reductions or Increased Emissions		Large Reductions in Emissions	
Statistic	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Average reported TRI (lb.)	218,213	407,521			41,165	89,770	397,863	513,701
Average change in TRI in 1987–1992 (lb.)					24,059	65,896	−287,408	404,328
Median household income in 1980 (000s)	18.9	4.8	21.7	6.8	18.5	4.7	19.2	4.9
Median house price in 1980 (000s)	47.9	13.5	56.5	22.7	47.2	12.9	48.6	14.0
Town population in 1980	49,461	75,858	52,919	118,580	52,013	77,631	46,871	74,503
Percentage of minority residents in 1980	0.04	0.06	0.04	0.07	0.05	0.07	0.03	0.05
Avg. daily newspaper circulation per capita, 1995–1998	0.29	0.12	0.28	0.11	0.27	0.99	0.30	0.14
Percentage of residents with a college degree in 1980	0.16	0.09	0.23	0.13	0.16	0.09	0.16	0.10
Percentage of registered voters who are Democrats	0.43	0.14	0.35	0.015	0.43	0.14	0.43	0.014
Percentage of residents aged 35–60 in 1980	0.27	0.03	0.28	0.04	0.27	0.03	0.28	0.03
Percentage of residents under age 21 in 1980	0.35	0.03	0.35	0.04	0.35	0.03	0.35	0.03
Average math and reading assessment test score	2588	179	2679	185	2575	189	2600	169
Dummy variable if in the Boston metro area	0.36	0.48	0.52	0.50	0.41	0.49	0.32	0.47
Distance from Boston if in the Boston metro area	20.3	16.5	22.8	17.4	17.6	15.7	23.0	17.1
Percentage change in house prices, 1982–1987	1.58	0.17	1.55	0.23	1.58	0.19	1.58	0.15
Percentage change in house prices, 1987–1989	0.08	0.06	0.07	0.06	0.08	0.07	0.08	0.06
Percentage change in house prices, 1989–1994	−0.11	0.07	−0.09	0.08	−0.11	0.07	−0.10	0.07
Percentage of residents in manufacturing sector, 1980	0.34	0.10	0.29	0.10	0.33	0.10	0.36	0.11
Percentage change in manufacturing employment between 1987 and 1992					−0.18	0.15	−0.14	0.17
Health and welfare spending in 1987 ($ millions)	3.7	16.6	7.2	27.9	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	137		110		69		68	

[a] ZIP codes that do not report any TRI releases but may have actual emissions greater than 0.

finding casts doubt on the hypothesis that declines in TRI emissions are strictly due to firms intentionally overreporting 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 in places with a higher percentage of registered voters or 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 and 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 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 3, 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 the 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 0.

VI. 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.

TABLE 3.—ASSOCIATIONS OF TRI EMISSIONS

	(1)		(2)		(3)	
	TRI Emissions, 1987		Change in TRI Emissions, 1987–1992		Change in TRI Emissions, 1987–1992	
	Tobit		OLS		OLS	
Dependent Variable	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Median household income in 1980 (000s)	−49	25.8	30.9	26.5	−2.67	7.87
Median house price in 1980 (000s)	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, 1995–1998 (000s)	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 ($\times 10^{-3}$)	−1,813	1,281	1,940	1,171	393	347
Log likelihood	−2033.19					
R-Square			0.13		0.93	
Number of observations	247		137		137	

A. *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]

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

In equation (1), α_1 represents the value of environmental amenities; in this case, toxic releases that are reported under TRI. The coefficient α_2 is the value to the marginal home buyer of fixed amenities such as location and community characteristics. 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, limit redevelopment at higher densities, and place restrictions on setting up new 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 determined simultaneously with house prices.

Our estimation procedure relies on an event study methodology, a variant of the process developed by 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 the base year τ and a 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:

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

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

[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 that households simultaneously choose quantities and prices of housing and land characteristics. Both papers suggest instruments from suppliers and households 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.

[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 by Fischel, these assumptions are not satisfied empirically.

Modeling changes rather than levels has the advantage of removing a considerable degree of fixed-effects differences among communities. By definition, changes in many fixed amenities, such as location and community characteristics, equal 0 and thus drop out of equation (2). This is important, as the maintained assumption is that the error term μ_t is uncorrelated with the included independent variables, including environmental amenities. 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 hedonic equation will be biased. However, this bias does not affect estimated coefficients in the difference equation (2) as long as the fixed amenities remain fixed over time.

If the coefficients in the levels equations (α_0–α_5) also remain unchanged over time, then $\alpha_i = \beta_i$. Although many (fixed) amenities do not change noticeably over a two- to four-year time span, which is the period for most of our analysis, these independent variables may still influence spending changes if their effects on spending levels (their coefficients in the level equations) change during the period. For example, Case and Mayer (1996) show that demand for certain local characteristics can change due to such aggregate shocks as an aging population or increasing school enrollments. Though their study covered a longer time period than our analysis, we nonetheless include initial levels of some town characteristics in the house price regression to allow for possible changes over time in the coefficients on these fixed attributes.

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.[18]

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

$$\begin{aligned}\Delta P_i = \gamma_0 &+ \gamma_1(\Delta\text{environmental amenities})_i \\ &+ \gamma_2(\text{fixed amenities})_i \\ &+ \gamma_3(\Delta\text{housing stock})_i \\ &+ \gamma_4(\Delta\text{economic factors})_i + \mu_i.\end{aligned} \tag{3}$$

Environmental emissions are measured either 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. Fixed amenities, including school test scores, the percentage of middle-aged households, and a location proxy, 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 taken from the U.S. Census.[19] We use the supply of new housing permits as a close proxy for Δhousing stock, but we instrument for new permits with the amount of vacant land available in 1984 and lagged permits to control for potential endogeneity problems.[20]

We also face potential endogeneity problems when considering changes in economic factors, such as (town-level) 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 lay off 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 of 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, and thus their inclusion can bias the coefficients on the environmental variables. Again, such a bias is unlikely given the lags in new construction and the short time period of our study, but we take it seriously nonetheless.

Below, we use three alternative approaches to deal with local economic changes. First, we include the employment variables directly in the equation, recognizing that the coefficient estimates on these variables may be biased, but expecting that such simultaneity biases might not affect the environmental variables, especially inasmuch as we have

[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's 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.

[19] Our measure of test scores cannot be compared across years, so we use an initial value rather than the last year to control for the (slim) possibility that changes in house prices might have affected the quality of students living in a community, although such an effect is quite unlikely over the short period of time used in our regressions. Also, the rank order of community test scores changes little over the sample period, which is consistent with the view that school quality is fixed over short periods of time. Due to the infrequent occurrence of the census, we also do not have multiple observations on the percentage of middle-aged households.

[20] Although we are not interested in the coefficients on change in housing stock and change in economic factors for this analysis, we correct for potential endogeneity so as to mitigate any correlations between the remaining error term and environmental amenities.

already included instruments for local supply. Second, we include a proxy for employment that is the number of workers in the 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. Although 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 approach, but 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.[21]

To begin, Table A1 in the appendix presents estimates of the house price regressions without considering environmental amenities. The basic regression coefficients are of the expected signs, are almost all statistically significant, and are consistent with the coefficients of 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 to 1992, 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 strong compared to other parts of the Commonwealth over this 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, and 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 90th percentile. Controlling for the overall unemployment rate, the coefficient on change in manufacturing employment is highly insignificant.

B. *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 have been 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 10% increase in TRI emissions leads to a 0.14% decrease in house values. Though 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 difference estimation and is likely a function of unobservable variables.

C. *Effect of Initial TRI Releases*

We begin by supplementing the basic (differenced) house price regressions from Table A1 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 effect of the announcement of TRI releases on house prices relative to expectations. Thus, an insignificant coefficient might reflect either that the public does not place a large negative value on toxic releases or that the announcement was in line with prior expectations.

Table 4 presents the regression coefficients on TRI variables using a number of different specifications. All equations also include the other variables listed in Table A1, which are not reported here for reasons of space. Regression coefficients on these other variables change little from those reported in Table A1. 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 approximately 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 lb. among communities reporting positive emissions) leads to a 0.095% decline in house prices over two years. Even looking at a two-standard-deviation confidence

[21] The previous version of our paper reported estimates from the second method. All estimates are available from the authors upon request.

TABLE 4.—2SLS REGRESSIONS OF CHANGE IN HOUSE PRICES ON TRI EMISSIONS IN 1987[a]

Specification	Base Equation		Alternative Equation with Surrounding Towns		Base Equation: Communities with Highest Newspaper Readership ($N = 124$)	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Announcement Effect of Initial TRI Emissions Dependent Variable: Change in House Prices between 1989Q2 and 1990Q2						
Aggregate TRI emissions in 1987 ($\times 10^{-8}$)	−2.32	4.10	0.20	2.99	−0.033	4.72
Carcinogenic emission in 1987 ($\times 10^{-8}$)	−0.22	1.74	0.41	1.37	−0.32	1.91
Adverse developmental or reproductive emissions in 1987 ($\times 10^{-8}$)	1.21	5.45	0.70	4.46	−1.04	5.79
Noxious emissions in 1987 ($\times 10^{-8}$)	−2.19	2.26	3.57	1.95	0.071	2.93
Contemporaneous Effect of Initial TRI Emissions Dependent Variable: Change in House Prices between 1987Q1 and 1988Q1						
Aggregate TRI emissions in 1987 ($\times 10^{-9}$)	−3.23	6.64	−3.64	5.11	−2.80	7.59
Carcinogenic emission in 1987 ($\times 10^{-8}$)	−3.10	2.76	−1.77	2.55	0.21	3.07
Adverse developmental or reproductive emissions in 1987 ($\times 10^{-8}$)	−2.07	8.74	−4.24	7.46	−2.68	9.52
Noxious emissions in 1987 ($\times 10^{-8}$)	−1.11	3.63	−1.09	2.93	2.99	4.75

[a] All equations also include the other independent variables listed in Table A1, which is the base specification. Each section reports coefficients from separate regressions. Number of observations is 247, except where noted.

interval around this estimate, we can reject that a 408,521 lb. decrease in emissions leads to more than a 0.33% rise in house prices.

To confirm these results, we investigate other possible alternatives. Many of the toxics covered by TRI are relatively benign, but a few have a particularly strong effect 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 effect on local house prices. In both cases, we can reject (with 95% confidence) that a one-standard-deviation decrease in announced toxic releases leads to more than a 0.16% increase 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. The coefficient is negative, but the standard error is larger than the coefficient estimate, and the tight standard errors allow us to reject any meaningful effect of noxious emissions on house prices.

Next, we examine the possibility that TRI emissions have an impact beyond the immediate ZIP code where the plant is located. The middle column 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 them or in a surrounding ZIP code. This specification may be reasonable if TRI emissions travel to surrounding locales thru the air or ground water. Yet in three of the four rows, the coefficients drop in size, and 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 smaller effect 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 affected area.

Another possibility 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 right-hand column of Table 4. 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.

We also ran regressions, not reported here, in which we removed the communities with the largest emissions, possibly supposing these communities already knew about the emissions in their area. Again, the results indicate that releases had no statistically significant impact on house

TABLE 5.—2SLS REGRESSIONS OF CHANGE IN HOUSE PRICES ON CHANGE IN TRI EMISSIONS BETWEEN 1987 AND 1988[a]

Specification	Base Equation		Alternative Equation with Surrounding Towns		Base Equation: Communities with Highest Newspaper Readership ($N = 124$)	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Announcement Effect of Initial TRI Emissions. Dependent Variable: Change in House Prices between 1989Q2 and 1991Q2						
Aggregate TRI emissions in 1987 ($\times 10^{-8}$)	1.30	1.30	−0.61	0.96	0.68	1.64
Carcinogenic emission in 1987 ($\times 10^{-8}$)	−4.52	10.6	−3.82	5.66	0.016	10.9
Adverse developmental or reproductive emissions in 1987 ($\times 10^{-8}$)	3.81	8.47	−0.14	7.52	7.32	8.56
Noxious emissions in 1987 ($\times 10^{-8}$)	4.12	2.80	2.65	2.51	−0.19	4.22
Contemporaneous Effect of Initial TRI Emissions. Dependent Variable: Change in House Prices between 1987Q1 and 1989Q1						
Aggregate TRI emissions in 1987 ($\times 10^{-8}$)	−0.97	1.88	0.64	1.32	−0.63	2.38
Carcinogenic emission in 1987 ($\times 10^{-8}$)	3.67	15.3	3.24	10.5	−2.94	15.6
Adverse developmental or reproductive emissions in 1987 ($\times 10^{-7}$)	0.34	1.26	0.040	1.21	0.87	1.33
Noxious emissions in 1987 ($\times 10^{-8}$)	5.70	3.98	3.76	3.05	0.36	6.02

[a] All equations also include the other independent variables listed in Table A1, which is the base specification. Each section reports coefficients from separate regressions. Number of observations is 247, except where noted.

prices.[22] 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 might be able to infer actual toxic releases from proxies such as aggregate production or employment at a plant. The bottom panel of Table 4 reports the results of the same regressions in the top panel, except looking at contemporaneous changes in house prices from 1987 to 1989. Once again, we find no evidence of any capitalization of TRI releases into house prices. None of the coefficients are statistically different from 0 at the 95th percentile. In these regressions, however, the standard errors rise from those found in the top panel, so a one-standard-deviation decrease in aggregate TRI emissions can contemporaneously raise house prices by up to 0.5% at the 95th percentile.

D. Changes in TRI Emissions, 1987–1990

Although the results in Table 4 show little effect of the 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 initial TRI data, but should react to changes in releases over time. We find no evidence of any such reaction.

To begin, we explore reported changes in the first year of TRI in Table 5, which repeats the basic specifications in Table 4, 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% 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 the first column are positive, although none are even close to being statistically different from 0 at conventional levels. Two standard deviations around the estimate using total TRI releases in the first row and column suggests that we can reject with about 95% confidence the hypothesis that house prices will rise by less than 0.17% as a result of a rather large hypothetical decrease in emissions of 133,000 lb. (a one-standard-deviation decline in emissions). These basic conclusions do not change on 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 because many firms did not have sufficient expertise to estimate releases accurately. Also, some firms might have overreported their initial releases, even if accurate, to avoid the possible negative publicity of later having to admit that they underreported 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

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

TABLE 6.—2SLS REGRESSIONS OF CHANGE IN HOUSE PRICES ON CHANGE IN TRI EMISSIONS BETWEEN 1988 AND 1989[a]

Specification	Base Equation		Alternative Equation with Surrounding Towns		Base Equation: Communities with Highest Newspaper Readership (N = 124)	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Announcement Effect of Initial TRI Emissions Dependent Variable: Change in House Prices between 1990Q2 and 1991Q2						
Aggregate TRI emissions in 1987 ($\times 10^{-9}$)	−8.30	22.5	−8.71	12.0	−7.36	22.7
Carcinogenic emission in 1987 ($\times 10^{-7}$)	−0.75	1.09	−0.53	0.85	0.42	1.68
Adverse developmental or reproductive emissions in 1987 ($\times 10^{-7}$)	−2.19	3.45	−1.36	0.94	−1.21	4.43
Noxious emissions in 1987 ($\times 10^{-8}$)	3.03	4.74	−0.73	2.58	23.6	20.8

[a] All equations also include the other independent variables listed in Table A1, which is the base specification. Each section reports coefficients from separate regressions. Number of observations is 247, except where noted.

the public knew this was happening, house prices might not have reacted to early announcements as much as to subsequent reports.

Table 6 reports the same coefficients as Table 5, 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 6 are increased in size from the corresponding coefficients in the first row of Table 5, 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 lb.) increases house prices by 0.015%, and we can reject at the 95th percentile the hypothesis that it has more than a 0.08% effect on house prices. Our basic conclusions do not change if we examine any of the other coefficients in this Table.

Finally, Table 7 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 negative and above conventional significance levels in the middle column. In this case, a one-standard-deviation decline in carcinogenic emissions (approximately 18,000 lb.) results in a 0.20% increase in house prices over a four-year period. Tight standard errors still allow us to reject with 95% confidence the hypothesis that this large decrease in carcinogenic releases leads to more than a 0.43% increase in house prices.

The results above are reasonably consistent. No matter what the time period, the housing market does not appear to react very strongly to any of the data released by TRI. Although the coefficients on TRI announcements of changes in toxic releases appear mostly negative, we can reject the hypothesis 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% 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

TABLE 7.—2SLS REGRESSIONS OF CHANGE IN HOUSE PRICES ON CHANGE IN TRI EMISSIONS BETWEEN 1987 AND 1990[a]

Specification	Base Equation		Alternative Equation with Surrounding Towns		Base Equation: Communities with Highest Newspaper Readership (N = 124)	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Announcement Effect of Change in TRI Emissions Dependent Variable: Change in House Prices between 1989Q2 and 1993Q2						
Aggregate TRI emissions in 1987 ($\times 10^{-9}$)	2.43	12.3	2.24	10.0	−5.88	13.4
Carcinogenic emission in 1987 ($\times 10^{-8}$)	−11.0	6.0	−9.19	4.37	−9.74	7.18
Adverse developmental or reproductive emissions in 1987 ($\times 10^{-8}$)	1.74	12.3	1.44	10.2	2.00	11.2
Noxious emissions in 1987 ($\times 10^{-8}$)	4.62	4.03	3.93	3.74	1.71	4.83

[a] All equations also include the other independent variables listed in Table A1, which is the base specification. Each section reports coefficients from separate regressions. Number of observations is 247, except where noted.

TABLE 8.—REGRESSIONS OF TRI EMISSIONS ON LAGGED CHANGES IN HOUSE PRICES[a]

Dependent Variable	TRI Emissions in 1987 Coef.	TRI Emissions in 1987 Std. Error	Change in TRI Emissions, 1987–1988 Coef.	Change in TRI Emissions, 1987–1988 Std. Error	Change in TRI Emissions, 1988–1989 Coef.	Change in TRI Emissions, 1988–1989 Std. Error
Change in house prices, 1989–1990					37,890	311,791
Change in house prices, 1988–1989	−472,406	694,110	151,849	287,838	219,567	198,579
Change in house prices, 1987–1988	486,676	623,196	−182,730	258,431	−108,757	198,682
Change in house prices, 1986–1987	−568,035	485,661	128,556	201,397	132,668	147,382
Change in house prices, 1985–1986	−73,319	468,220	−40,192	194,164		
Constant	275,896	218,415	−33,514	90,573	−56,987	46,836
R-square	0.007		0.003		0.009	

[a] TRI emissions are announced 18 months after they occur. Thus TRI emissions from 1987 are announced in July 1989. Number of observations is 247.

significant and economically important impact on local house prices.

E. *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 affect local house prices. One way to test this is to allow for the possibility that house prices *anticipate* announced TRI emissions. To do this 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 8 seem to reject this hypothesis. Lagged house prices have little predictive power for future TRI announcements, no matter what the time period. The R-square for all three equations (TRI announcements in 1987, change in TRI emissions between 1987 and 1988, and change in TRI emissions between 1988 and 1989) is exceedingly 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 0.

Alternatively, our results may simply reflect the fact that TRI data might have been regarded as sufficiently low in quality that they were ignored by home buyers. This would be consistent with the stock market results found by Bui (2002) for petroleum companies.

VII. 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) 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 (7) 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 rather 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% confidence the hypothesis 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%. It is possible that we might find a larger effect 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 households 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 their odor (these being measures of the concentration of such pollutants as sulfur dioxide, particulate matter, and ozone), whereas the chemical releases measured by TRI are difficult to observe (TRI emissions 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.

Investor response to TRI announcements seem in line with our findings. There is only weak empirical evidence that investors responded to the initial announcement of TRI releases, and subsequent announcements appear to have no significant effects on stock market returns. 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 have initially responded to the TRI information because large reported releases might 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 against polluting plants.[23] The vast majority of legal cases that have been resolved that are related to TRI are about communities suing individual plants for nonreporting. 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.

[23] Based on a summary of cases reported by LexisNexis between 1987 and 1996.

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 with the manufacturing industries that have left the state or reduced output. Disaggregated TRI data make this possible. In addition, firms may have improved their manufacturing efficiency over this period, leading to a voluntary decline in emissions. Also, much of the reported decline in emissions occurred in early years, when firms may have been working on methodologies to accurately estimate their toxic releases. If firms initially overreported emissions due to uncertainty about their actual values, 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 that case, if communities are aware of this behavior, we would expect to see little or 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.

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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APPENDIX

TABLE A1.—2SLS REGRESSIONS OF CHANGE IN HOUSE PRICES

	(1)[a]		(2)[a]	
	Change in House Price 1989–1992		Change in House Price 1989–1992	
Dependent Variable	Coef.	Std. Error	Coef.	Std. Error
New housing permits issued as a percentage of the total number of units	−0.66	0.20	−0.57	0.21
Percentage change in manufacturing employment in the town	−0.0039	0.0061		
Change in unemployment rate in the town	−0.39	0.20		
Percentage change in health and welfare spending in the town	0.0033	0.0019		
Percentage of residents who worked in the manufacturing sector in 1980			−0.060	0.024
Average math and reading assessment test score (000s)	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 (00s)	0.12	0.05	0.10	0.04
(Distance from Boston if in the Boston metro area)^2 (0,000s)	−0.30	0.10	−0.27	0.10
Constant	−0.27	0.04	−0.28	0.03

[a] 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 is 247.