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USING THE TOXIC RELEASE INVENTORY AS AN ENVIRONMENTAL PERFORMANCE INDICATOR: A SHIFT-SHARE INTERPRETATION

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ABSTRACT

This study addresses an important issue in environmental management: the issue of evaluation of environmental programs through environmental indicators such as the U.S. Toxic Release Inventory (TRI). The goal of this study is to use shift-share as an alternative analytical technique to measure environmental performance making use of the TRI program of the Environmental Protection Agency (EPA). The expected growth in TRI for the states from 1991 to 1994 using a shift-share model was compared to the actual TRI releases in 1994. On the basis of growth scenarios from 1988 to 1994, it is demonstrated that the relative environmental performance of states having comparatively large manufacturing bases was not necessarily worse than that of those states with comparatively small manufacturing bases, in contrast to the impression often conveyed when absolute performance indicator measures are used.

INTRODUCTION

Background

In the past two decades, public concern and support for environmental protection has risen significantly, and has spurred the development of a vast array of new policies that have substantially increased the government's domestic and international responsibilities for the environment and natural resources [1]. Given the magnitude and dispersed nature of such regulatory efforts, a crisis of oversight capacity was imminent. Public perception of environmental program failures, and frequent complaints by industries, give rise to a major paradigm shift in the 1980s. Clamor for alternative environmental regulatory approaches led to less "command and control" regulation and to greater reliance on incentive-based mechanisms (IBMs) and civic environmentalism.

One area in which regulatory capabilities has been problematic is that of toxic and hazardous wastes. Regulating these wastes, and the thousands of precursor substances that eventually lead to future wastes, has become a high priority of the government. Unfortunately, these efforts have proven to be enormously difficult, costly, and time consuming. By 1994, the EPA was enforcing thirteen major laws affecting hazardous substance use and disposal in the United States. The vast array of materials subject to regulation, inadequate data on the distribution and effects of these substances on man and the environment, the political and administrative impediments to implementation, and the widespread public criticisms and distrust are a major concern to implementing agencies [2].

In reaction to these concerns, EPA has initiated the development of environmental performance indicators. In 1995, EPA indicated that it intended to use toxic releases as part of its core measures of pollution prevention efforts in the United States. A central element of these efforts, initiated as part of a National Environmental Performance Partnership System, is a major emphasis on environmental indicators. EPA defined environmental indicators as "a quantitative measure over time of progress toward achieving environmental objectives, expressed as changes in ambient concentration of pollutants; in pollution uptake or body burden; or in health, ecological or other effects of pollutant levels" [3].

Although the Toxic Release Inventory (TRI) provides a basic indicator of compliance with an environmental policy, the EPA did not intend for the raw data to serve as benchmark for the media and the public of environmental performance. Absolute comparisons of industrial releases or transfers as commonly reported by the media can be very misleading. Absolute comparisons tend to penalize states with large chemical manufacturing bases, such as Louisiana and Texas. A more appropriate measure would reflect each state's industrial base.

Despite the TRI's shortcomings, it is likely to continue to be used as a measure of effectiveness of environmental regulations and of individual state performance. This study defines a measure that refines the use of TRI as a measure of performance. Our main objective is to demonstrate that the "shift-share" method of representing TRI data gives more reasonable evaluations of a state's environmental performance.

TRI Program

Three laws passed in the 1970s define the fundamental framework for regulating the disposal of toxic substances. These are the Toxic Substances

Control Act of 1976, the Resource Conservation and Recovery Act of 1976 (RCRA), and the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA or Superfund). The TRI is based on the Emergency Planning and Community Right-to-Know Act (EPCRA) in Title III of Superfund Amendments and Reauthorization Act (SARA), which authorized communities to get detailed information about chemicals made by, stored in, and emitted from local business. It was expanded under the Pollution Prevention Act of 1990 [4]. This Act required the formation of state and local planning committees to draw up a chemical emergency response plan for every community in the nation.

Under the TRI program, an industrial facility is required to file a report if 1) it conducts manufacturing operations within Standard Industrial Classification (SIC) codes 20 through 39; 2) has ten or more full-time employees; and 3) manufactures or processes more than 25,000 pounds or uses more than 10,000 pounds of any listed chemical during the calendar year. Other monitoring information also required includes quantity of toxics released, transferred, and recycled. Manufacturing facilities in the United States have reported on their TRI releases sine 1987.

EPCRA's primary purpose is to keep the communities and citizens informed of chemical hazards in their areas. The TRI helps citizens increase their knowledge and awareness of chemical usage in their area, and to use this information to affect community environmental policy. This is one reason TRI is commonly used by the media and the public as an indicator of environmental performance.

DATA

Data Organization and Limitations

The TRI database contains information on chemicals released into the local environment during the preceding year. This includes reporting on-site discharge of a toxic chemical to the environment via air, surface water, underground injections, and land releases in any given year. Information on the amount transferred includes shipment to a facility that is geographically or physically separate from the reporting facility for recycling, for energy recovery, for treatment, for disposal, and for other, unclassified waste management activity. Chemicals may be added or taken off reporting requirements at EPA's discretion. As of September 1997, 647 chemicals were subject to reporting requirements.

Initially, TRI reporting requirements were restricted to manufacturing industries, but in the spring of 1997 EPA added a number of non-manufacturing industry sectors to the TRI program. Among the proposed industry sectors included in the expansion are: metal mining, coal mining, electrical utilities, RCRA Subtitle hazardous waste treatment and disposal facilities; chemical and allied product wholesale distributors; petroleum bulk stations and terminals; and solvent recovery services. For easy access to the public and other interested users, TRI data is made widely available by the EPA through several sources and media.

For this study, TRI data was collected and organized by two-digit Standard Industrial Classification (SIC) for the manufacturing sectors of all the fifty states. Three "stable years" were selected between 1986, when TRI was initiated, and 1994, the most recent year for which full data was available. "Stable" years are defined as those years where there was no dramatic change in reporting rules or significant changes to the list of reportable chemicals. Since a common criticism of shift-share techniques is possible sensitivity to the base year selected, it is important to select base years carefully, to reduce the effect of base year selection-bias.

Total absolute releases and transfers of toxic chemicals in the designated manufacturing sectors in the TRI database between 1987 and 1994 are depicted in Figure 1. In 1987, total toxic chemicals released and transferred by these industries was more than 21,374 million pounds. By 1991, releases and transfers decreased to about 7.3 million pounds; and by 1994, the figure came to some 5.9 million pounds. Except for the year 1991, there has been a general decline in total industry releases and transfers of these chemicals. Although there was a very sharp decline in the year following initiation of the TRI program, the rate of decline in the subsequent years was steady. The steep decline from 1987 to 1998 is probably due to fine tuning and clearer understanding of reporting format. In addition, it may also be due to real voluntary compliance with the law as the public becomes more aware of the TRI program and state monitoring of compliance is put into effect.

As noted, we analyzed the years 1988, 1991, and 1994, when industries were generally familiar with changes in reporting requirements which affected all states similarly. Table 1 provides summary statistics for the sample period; total releases and transfers declined from approximately 8,000 million pounds in 1988 to about 6,000 million pounds in 1994. The mean releases and transfers of toxic chemicals in the manufacturing sectors also declined from 161.45 million pounds in 1988 to 119.66 in 1994. A similar pattern is evident in the variability in releases and production across states in the nation; the variability in 1994 was only about 35 percent of what it was in 1988. However, in absolute terms, there is a very high within-year variability in the data, irrespective of the year chosen, as evidenced by the yearly range of total releases and transfers. This high variability suggests that methods relying solely on absolute release comparisons will give misleading results.

For the chosen years, absolute percentage change for each state was estimated, as reported in Table 2. Generally, there was a decline in releases of these chemicals from 1988 to 1994 in most of the states. In 1991, the largest decline from 1988 was in Wyoming (301%); the smallest decline was recorded in South Dakota (0.05%). On the other hand, the largest increase in releases of toxic chemicals from 1988 to 1991 was by Tennessee (39%). The largest decline from

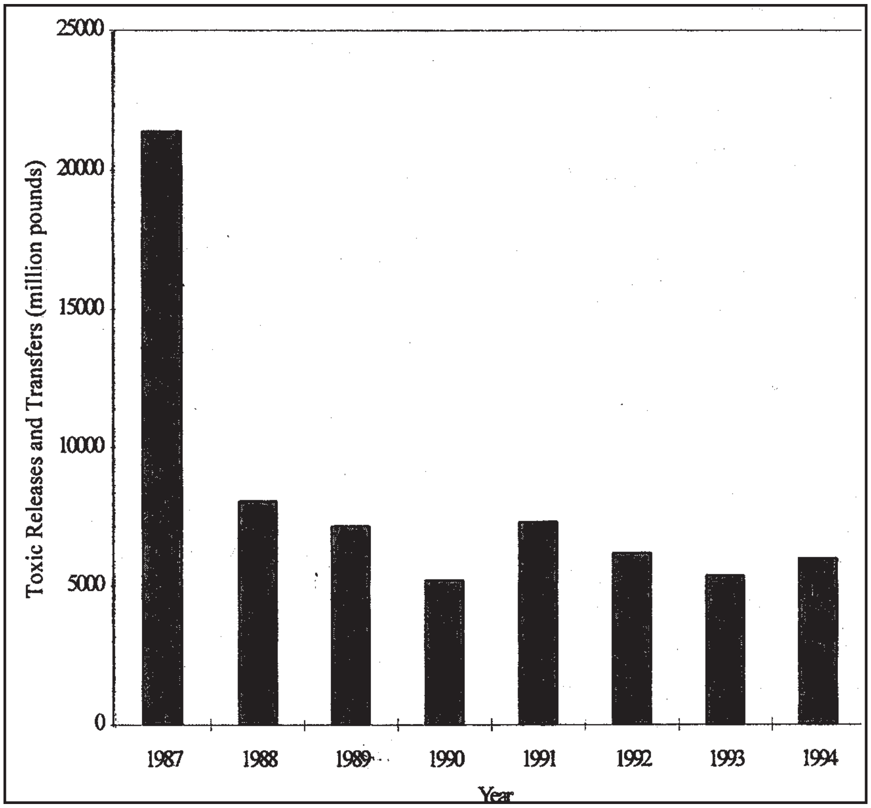

Figure 1. Total toxic releases and transfers, 1987-1994.

Table 1. Descriptive and Dispersion Statistics on Total Releases and Transfers (million pounds), 1988, 1991, and 1994

	1988	1991	1994
Mean	161.5	146.2	119.7
Variance	43520	28170	15051
Standard Deviation	208.6	167.8	122.7
Minimum	3.23	1	0.84
Maximum	1025	783	523.39
Total	8072	7309	5983

Table 2. Total Toxic Releases and Transfers by States (million pounds), 1988, 1991, 1994, and Percentage Change

State Code	% Change 1988-1991	% Change 1991-1994	% Change 1988-1994
AK	–52.64	–60.13	–73.88
AL	–37.15	–9.77	–34.21
AR	26.82	22.78	67.79
AZ	–17.65	–19.48	–31.56
CA	16.19	–45.57	35.05
CO	–165.24	13.66	–57.15
CT	–6.46	–16.54	–21.61
DE	7.45	34.41	45.23
FL	–26.21	–7.06	–26.36
GA	1.68	–17.51	–16.1
HI	–222.66	–15.54	–73.82
IA	12.79	25.34	43.72
ID	–62.43	–36.79	–61.08
IL	–3.51	0.56	–2.85
IN	1.69	–34.99	–33.87
KS	–26.6	–32.1	46.36
KY	–11.12	–25.55	–33
LA	–79.5	–57.32	–76.22
MA	–58.94	–7.1	–41.55
MD	10.28	13.92	26.97
ME	–9.82	–31.55	–37.67
MI	20.2	12.91	41.5
MN	–9.04	–28.99	–34.87
MO	–45.01	17.09	–19.26
MS	19.54	–3.32	20.16
MT	8.55	26.49	38.31
NC	23.14	–15.56	9.86
ND	–40.74	–19.48	–42.79
NE	35.49	–33.35	3.32
NH	–126.19	–18.07	–63.78
NJ	11.13	–28.01	–19
NM	22.46	–53.56	–40.11
NV	15.59	–1.45	16.75
NY	–25.8	–1.7	–21.86
OH	11.68	–25.57	–15.73
OK	–70.41	–20.04	–53.08
OR	–16.27	20.09	3.28
PA	–3.78	24.02	19.51
RI	–1.42	68.3	65.94
SC	25.81	–2.8	31.01
SD	–0.05	–9.55	–9.6

Table 2. (Cont'd.)

State Code	% Change 1988-1991	% Change 1991-1994	% Change 1988-1994
TN	38.55	–21.07	28.44
TX	–30.89	–33.15	–48.93
UT	–8.73	–36	–41.14
VA	–53.74	–20.27	–48.14
VT	17.57	–41.07	–28.5
WA	–6.49	–61.69	–64.03
WI	–21.39	21	–0.32
WV	–16.24	24.63	7.22
WY	–301.4	88.31	–53.09
Mean	–24.62	–9.56	–16.75
Total	–10.45	–18.14	–25.89

1991 to 1994 was recorded in Alaska (74%), the smallest decline in Wisconsin (0.32%); the largest increase in Arkansas (67.8%), and the smallest in Oregon (3.3%). For the entire United States, the mean was a 24.6 percent decline from 1988 to 1991, and a 17 percent decline from 1988 to 1994.

METHODS

Absolute Release-Based Models

Environmental performance rankings of states on the basis of the TRI have relied on three similar approaches. The first uses raw TRI data as reported by EPA, and ranks states according to the absolute volume of TRI releases and transfers. The second approach ranks according to percentage increase or decrease in TRI releases and transfers. This approach nonetheless ignores the prior industrial structure of the states; i.e., it penalizes for pre-TRI conditions in the states. The third approach relates TRI changes to expected changes in the GDP in the state and the nation. However, this approach gives little insight as to the sources of TRI declines or increases. In addition, EPA [4] has shown that GDP growth is independent of growth in TRI. The shift-share technique proposed here overcomes most of the limitations inherent in the three methods discussed.

Shift-Share Models

In theory, shift-share is a synthesis of two intuitions. One draws from traditional theory of economic development a presumption that the relationship between levels of development and sectoral shares in gross national product (GNP) is highly significant. Such a deterministic structure would imply clearly distinct growth rates among some economic activities. The second intuition is premised on the structural dissimilarities among the economies of different regions. Regional disparities are not only a function of different resource endowments, but also due to locational advantages as well as institutional factors such as rules, regulations, and policies [6].

Shift-share analysis is a mathematical tool for systematically describing differences in growth rates across industries and regions. Between two time periods, the absolute size change in a specific sector of a given area (measured either in terms of value added or employment, or any other economic variable) is divided into three components. The first component is called the national growth effect. It reflects the change in size that would have taken place had the regional sector grown at the same rate as the GNP. The second component, the composition or industrial mix effect, measures the change attributable to the relative importance of the individual sector in the overall economy. The difference between the total absolute change and the sum of national growth and composition effects defines the regional or competitive share effects. The share effects indicate, for each sector, how significantly the growth rates vary from one region to the other [6].

In the conventional shift-share formulation, the change in a regional economic indicator (say, output or employment) is partitioned into components representing national share, N^{r}_{i}, proportional shift, P^{r}_{i} (an industrial mix effect), and differential shift, D^{r}_{i} (local competitive effect):

$$C^{r}_{i,t} = N^{r}_{i,t} + P^{r}_{i,t} + D^{r}_{i,t} \tag{1}$$

where $C^{r}_{i,t}$ is the change in sector i in region r at period t. For output, for example, each component is defined as follows [7]:

$$\begin{aligned} &\text{National Share:} && N^{r}_{i,t} = Y^{r}_{i,t-1}\ G^{n}_{t} \\ &\text{Industrial Mix:} && P^{r}_{i,t} = Y^{r}_{i,t-1}\ (G^{n}_{i,t} - G^{n}_{t}) \\ &\text{Regional Shift:} && D^{r}_{i,t} = Y^{r}_{i,t-1}\ (G^{r}_{i,t} - G^{n}_{i,t}) \end{aligned} \tag{2}$$

where $Y^{r}_{i,t\backslash 1}$ is regional output in industry i in the base year, G^{n}_{t} is the growth rate for total output in the nation at period t, $G^{n}_{i,t}$ is the output growth rate in the nation in industry i at period t, and $G^{r}_{i,t}$ is the regional growth rate for industry i. Growth rates are defined as follows:

$$
\begin{aligned}
G_{t}^{n} &= (Y_{t}^{US} \big/ Y_{t\setminus 1}^{US} - 1) \\
G_{i,t}^{n} &= (Y_{i,t}^{US} \big/ Y_{t-1}^{US}) \\
G_{i,t}^{r} &= (Y_{i,t}^{r} \big/ Y_{i,t-1}^{r})
\end{aligned}
\tag{3}
$$

where Y_{t}^{US} is the total US output in, say, manufacturing, in period t; $Y_{i,t}^{US}$ is the US output in industry i (within manufacturing) in period t; and $Y_{i,t}^{r}$ represents the regional output in industry i (within manufacturing) in period t.

Although shift-share is really just a statistical framework for disaggregating regional growth effects, it can easily be converted into a forecasting technique. Hence, it is widely used at the local level because it provides relatively quick and easy forecasts [8]. The national growth and industry-mix component can be projected based on national forecasts of economic growth.

Shift-share as a method of regional analysis, despite its limitations, is still a popular tool among geographers and planners. It has been used to explain changes in competitive advantage for a local economy [9]. The traditional shift-share is flexible enough to be applied in several ways to industrial data, including analyzing regional productivity change [10], forecasting sectoral growth [8], analyzing economic and demographic shifts [11], measuring economic decline in metropolitan areas [12], measuring regional recessions and loss of competitiveness [13], and identifying changes in social and income structures. Shift-share methods have been extended to include economy-wide impact models [10, 14].

Typical approaches to forecasting the competitive component have included "constant share" and "constant shift" [15]. In the constant share case, it is assumed that the industries in the region will grow at the same rates as those of their counterparts in the nation, so the region will maintain its fraction (share) of national output of each industry. This approach means that the competitive component will be zero for all industries in the region. On the other hand, with the "constant shift" case, it is assumed that the output shift that occurred in the last period will continue to occur throughout the following period. This approach is justified on the basis that positive shift in the past in the region reflects regional comparative advantage which will continue to be maintained in the future. Despite several unresolved theoretical and empirical considerations, shift-share as an analytical tool of regional economic growth has become increasingly popular in the last twenty years as a predictive and descriptive model [16].

In most applications, the conventional simple static model in equation (1) is sufficient for forecasting and growth decomposition. For a regional description of the various effects, equation (1) does an adequate job. For a description of these effects at the industrial level (for example, manufacturing sectors in a state or even a county), the conventional model is neither capable of providing nor designed to provide meaningful results at the industrial level [17, 18].

Though the main focus is at the state (regional) level, the DEM (an acronym for Dunn [17, 19] and Estaban-Marquillas [20]) modification of the conventional model as described by Hoppes [18] is utilized. While not mainly focused on industrial level, the approach here is nonetheless structured to allow for such analysis. Hence, the utilization of DEM as the basis of the empirical shift-share TRI model.

In the DEM formulation, equation (1) is re-formulated for each region/state j to show that

$$C_{ij} = r(b_i/b) *(b_{it}/b_i - 1) + (r_i - (r*b_i/b))*(b_{it}/b_i - 1) + r_i(r_t/r_i - b_{it}/b_i) \qquad (4)$$

where, C_{ij} is growth in an economic indicator in industry i in the period under consideration in region j. Using output as the economic indicator, other terms are defined as follows: r_i indicates regional output in the initial year in industry i; b indicates national output in the whole industry in the initial year; b_t indicates national output in the whole industry in the terminal year; b_{it} indicates national output in industry i in the terminal year; b_i indicate national output in the industry in the initial year; r indicates regional output in the whole industry in the initial year; and r_t indicates regional output in the whole industry in terminal year. The economic indicator of interest here is the TRI. TRI can be considered as an undesirable output, i.e. a "bad" good, but it is nevertheless a complementary product of normal industrial output. Hence, references to "economic indicator" in equation (1) to equation (4) can be replaced with TRI.

Notice that equation (4) is similar to equation (1) in that each of the three terms in equation (4) is a reformulation of equivalent terms in equation (1). The main difference to be noted is that equation (4) is normalized with respect to relevant base-data so that inferential analysis that is commonly associated with state/regional conventional shift-share can be extended to industry-level and local-level analysis. In order to use the formulation in equation (4) as a forecasting device, it is necessary to make assumption as to the growth scenario of U.S. economy as previously discussed: constant growth, constant U.S. growth, and constant U.S. growth with stagnant regional growth.

Each of these scenarios of growth assumptions can be empirically estimated as follows (assuming a forecast of 1994 growth based on growth scenarios of 1988 to 1991):

$$C_{ij,1994} = (g_{ij} + K_{ij} + R_{ij}) * TRI_{ij,1991} \qquad (5)$$

$$C_{ij,1994} = ((g_{ij} = 0) + K_{ij} + R_{ij}) * TRI_{ij,\,1991} \qquad (6)$$

$$C_{ij,1994} = (g_{ij} + K_{ij} + (R_{ij} = 0)) * TRI_{ij,\,1991} \qquad (7)$$

where each of the three equations above is based on different assumptions of constant growth in TRI, stagnant growth in U.S. TRI releases and transfers, and under constant U.S. TRI growth and stagnant regional growth. g_{ij} is national share or effect, or national growth effect of change in the economic indicator within the period for the ith industry in region j; K_{ij} is industrial mix or proportional shift effect of change in the economic indicator for the ith industry within the period in region j; and R_{ij} is regional share, differential shift, or competitive effect of change for the i^{th} industry within the period in region.

Conceptually, any of the three scenarios depicted in equations (5-7) is possible, although the usual assumption is that of constant growth. The choice in this study is that of constant growth rate in TRI. This is because, in the absence of any prior knowledge of growth in the United States and in the region about TRI, the last two scenarios cannot be justifiably used. It is thus safer to assume that the past growth pattern will continue into the future (i.e., the first scenario).

To make the results in equation (4) useful as an environmental indicator, further extension is necessary. Having obtained estimates of growth rates for each industry in manufacturing in each of the states, a performance estimate for each industry is

$$PR = d/E\,(C_{ij}) * 100 \tag{8}$$

where, PR is performance rate, d is performance difference, expected TRI, $E(C_{ij})$ equals projected C_{ij}; actual TRI releases equals A_{ij}, and

$$d = E(C_{ij}) - A_{ij} \tag{9}$$

States can then be ranked on the basis of PR, which will show whether they perform below or above expectation. Equation (9) also allows for the relative comparison of one state to another. PR thus provides a better measure of performance than the other alternative measures discussed previously.

MODEL RESULTS AND DISCUSSIONS

Absolute Performance Ranking

The current use of TRI by the public and the media as an indicator of environmental performance is based on the reporting format underlying the rankings depicted in Table 3. Absolute figures of TRI in the chosen years were used to rank states. The state ranking of environmental performance based on the TRI in a given year is presented. In Table 3, in all the years, the state that performs best (lowest transfer and releases = rank 1) was Hawaii with Texas being the worst (highest transfers and releases = rank 50). In 1988, Hawaii, Nevada, Vermont, South Dakota, and North Dakota were the top five states, while Illinois, Indiana, Ohio, Louisiana, and Texas were the five worst performers. In 1991, there was little change in release performance. Except for Louisiana, there is a clear pattern of consistency in ranking in the top five and bottom five performers. Given the peculiarity of each state's industrial base, it is obvious that absolute measures are limited as indicators of environmental performance. Thus, absolute measure is inherently biased against states or regions with large chemical-based manufacturing industries.

Table 3. State Ranking Using Absolute Toxic Releases and Transfers by States (million pounds)

State Code	1988 Rank	1991 Rank	1994 Rank
AK	11	11	6
AL	45	40	41
AR	25	34	40
AZ	24	25	24
CA	42	43	36
CO	17	12	11
CT	19	19	17
DE	7	10	13
FL	35	30	32
GA	32	35	31
HI	1	1	1
IA	20	24	28
ID	8	7	7
IL	46	46	45
IN	47	47	47
KS	33	28	26
KY	34	33	29
LA	49	48	43
MA	23	20	20
MD	15	18	22
ME	9	13	9
MI	43	45	48
MN	21	23	19
MO	40	32	39
MS	29	37	37
MT	14	17	23
NC	39	41	42
ND	5	2	2
NE	10	14	15
NH	13	9	8
NJ	36	39	35
NM	12	15	10
NV	2	4	5
NY	37	36	34
OH	48	49	49
OK	26	21	18
OR	18	16	21
PA	44	42	46
RI	6	8	14
SC	28	38	38
SD	4	3	4
TN	38	44	44

Table 3. (Cont'd.)

State Code	1988 Rank	1991 Rank	1994 Rank
TX	50	50	50
UT	31	29	25
VA	41	31	30
VT	3	5	3
WA	27	26	16
WI	30	27	33
WV	22	22	27
WY	16	6	12

TRI Growth Decomposition

The result of applying equation (4) to TRI in all the fifty states in the United States is presented in Table 4. The result shows, for example, that Louisiana's TRI growth declined by about 430 million pounds from 1988 to 1991. Growth in this context is used in a generic sense to mean either "negative growth" (decline) or "positive growth" (increase). Of the total growth in TRI in Louisiana during this period, national decline was responsible for about ninety-two million pounds. Also, about 400 million pounds of the decline was due to the competitiveness of the manufacturing sectors in the state, whereas the nature of the mix of manufacturing sectors in Louisiana increased TRI growth by about sixty-two million pounds. These results are referred to as "summary-line" interpretation of the shift-share because they represent the addition of what is referred to as "industry-line summary." The industry-line summary reflects within industry growth performance compared to other similar regional industries given national growth rates. In the conventional shift-share, interpretation of the shift-share components is restricted to the summary line as indicated in previous discussions, whereas with the modification employed here the industry line can be afforded similar interpretation.

Thus, the summary line values are a combination of increases (undesirable) and decreases (desirable) in TRI over the period depending on the relative performance as explained earlier. In the case of Louisiana, it is observed that over the period considered some industries outperformed their national counterpart, some fared worse. The composition of the manufacturing industries in the state tends to work against it (positive figure); its competitive edge (negative competitive share) and relatively strong performance against national standard (negative national share) helps Louisiana overcome the disadvantage of its disproportional large chemical manufacturing sector.

Table 4. Shift-Share Components of TRI Growth, 1988-1991 (million pounds)

	Components of Growth					
State Code	National Growth	Industrial Mix	Competitive Share	Total Growth	Constant Growth Assumption	Expected 1994
AK	–2.61	–1.04	–5.85	–9.49	–3.24	14.79
AL	–28.68	–31.62	–21.78	–82.08	88.03	308.97
AR	–10.19	–2.01	51.64	39.45	10900	11095.3
AZ	–9.98	–7.86	2.02	–15.82	917.54	1007.19
CA	–22.4	26.44	41.69	45.73	3526.38	3808.77
CO	–4.67	–4.82	–21.27	–30.77	6.12	24.74
CT	–5.65	8.65	–6.62	–3.62	9.22	65.27
DE	–1.57	1.17	1.73	1.33	4711.69	4729.61
FL	–15.83	–0.86	–18.03	–34.72	2805.17	2937.65
GA	–13.78	–6.95	22.42	1.69	279.62	427.7
HI	–0.31	0.05	–1.97	–2.23	–0.38	0.62
IA	–6.08	0.09	15.4	9.41	244.04	317.62
ID	–2.04	0.09	–6.34	–8.28	0.46	13.73
IL	–32.06	–4.95	25.53	–11.47	9.53	336.69
IN	–48.08	–38.47	95.27	8.71	1867.66	2384.32
KS	–15.32	1.16	–19.85	–34.01	193.51	321.37
KY	–15.44	1.38	–2.26	–16.32	122.55	340.34
LA	–91.96	61.88	–400.15	–430.23	7332.28	7873.44
MA	–8.61	9.76	–34.89	–33.74	2109.09	2166.34
MD	–0.31	–0.06	0.97	0.6	7000.28	7004.12
ME	–2.26	0.16	–0.03	–2.13	23400	23379.51
MI	–24.7	8.09	82.67	66.05	283.19	610.16
MN	–7.54	32.07	–31.13	–6.6	7.94	80.97
MO	–19.96	–3.88	–41.6	–65.44	32.47	177.83
MS	–12.85	–0.62	46.44	32.97	1869.69	2038.41
MT	–3.9	–5.17	12.93	3.85	2517.65	2562.71
NC	–18.39	–4.17	81.04	58.48	334.4	587.17
ND	–0.38	0.85	–1.64	–1.18	98.69	101.58
NE	–2.44	1.4	15.24	14.2	57.31	97.32
NH	–3.69	3.73	–21.78	–21.74	6.97	24.2
NJ	–17.54	1.2	39.54	23.21	189.91	398.38
NM	–3	–4.02	16.18	9.17	32800	32857.85
NV	–4.15	–2.01	11.18	5.02	31700	31768.58
NY	–18.02	0.08	–21.1	–39.04	175.62	326.96
OH	–49.45	–15.5	134.02	69.07	414.09	1005.58
OK	–10.43	–3.48	–31.62	–45.53	–13.37	51.29
OR	–4.94	–2.36	0	–7.31	1.76	46.68
PA	–26.46	–16.44	32.72	–10.18	63.99	333.31
RI	–1.44	0.92	0.31	0.21	36.72	51.68
SC	–12.02	–5.03	61.22	44.17	173.34	344.5
SD	–0.34	0.2	0.14	0	33.5	37.07
TN	–18.11	–15.5	153.63	120.02	5674.49	5985.86
TX	–97.01	39.26	–184.08	–241.83	–98.59	684.35
UT	–13.56	–18.58	20.64	–11.49	370.43	502.15

Table 4. (Cont'd.)

	Components of Growth					
State Code	National Growth	Industrial Mix	Competitive Share	Total Growth	Constant Growth Assumption	Expected 1994
VA	–20.02	0.69	–54.6	–73.94	7.08	144.66
VT	–0.32	0.26	0.78	0.72	12.09	16.16
WA	–10.47	–7.31	11.04	–6.74	2955.82	3059.68
WI	–12.88	6.01	–17.1	–23.97	3.73	115.81
WV	–7.72	–3.83	0.16	–11.39	9306.88	9377.03
WY	–4.61	0.89	–32.86	–36.59	5209.89	5222.03
ALL U.S.	–764.17	–0.06	0	–764.25	159745.24	167168.05

In summary, ninety-two million pounds shows the change in TRI that would be experienced in Louisiana if all component industries were distributed in the same proportion regionally as nationally and each sector grew at the national sector growth rate [17]. Louisiana, by the industry mix results, thus tends to increase its share of TRI nationally by sixty-two million pounds because its industry structure places it in a position to share disproportionately in national growth. That is, if other components of growth were to have remained, as before, Louisiana would have actually increased its total TRI by at least sixty-two million pounds. It is the total performance of each of these industries in Louisiana compared to their national counterpart (competitive share) that was really responsible for the overall decline of 430 million pounds. Similar interpretations apply to entries for all other states. At the national level, total U.S. TRI net decline of 764.25 million pounds in TRI was composed of 764.17 million pounds due to general national decline, 0.06 million pounds due to industrial mix, and 0 due to competitiveness of the manufacturing sectors, as shown in Table 4.

Equation (4) was used under a constant growth assumption (Equation 8)—specifically that the growth rate experienced from 1988 to 1991 is maintained to 1994. The result is shown in the last two columns of Table 4. Under constant growth, Louisiana would produce 7,332.28 million pounds in TRI growth in 1994, giving an expected TRI for Louisiana for 1994 of 78,730.4 million pounds. Indeed, under constant growth all states would have increased their TRI releases substantially, and the nation would have released about 167,168.1 million pounds of toxic substances in 1994 compared to about 21,374 in 1987, a year after the TRI initiative began. This would have been an 800 percent increase.

Relative Performance of States

Reductions in TRI beyond or below the expected growth in each state may be interpreted as reflecting the effectiveness of the states in implementing the TRI initiative. In Table 5, the results of utilizing the components of the shift-share as well as the overall growth in TRI in ranking the states are shown. According to state ranking on the basis of national growth in TRI, the "top-five" performers are Texas, Louisiana, Indiana, Ohio, and Illinois, whereas the "bottom-five" performers are Hawaii, Maryland, South Dakota, Vermont, and North Dakota. This is almost a reverse of the situation of the ranking based on absolute releases to judge state performance. States that produce high volumes of TRI prior to program implementation will be at a disadvantage when absolute volumes are used since their industrial structure pre-dates the TRI. Absolute TRI measures of performance, as currently used by the media and the public, will be biased against such states as Louisiana, Texas, Ohio, and so forth. These states produce high amounts of toxic substances because of the very structure of their industrial base. A small reduction in these states' existing emissions may, in some cases, be more than the entire production in smaller states with relatively small manufacturing bases.

Rankings based on the industrial makeup of the states show Louisiana, Texas, California, Minnesota, and Massachusetts are in the bottom of the pack. On the other hand, Indiana, Alabama, Utah, Pennsylvania, and Ohio are the "top" performers. This ranking is less dependent on the absolute releases in the states and takes into account the composition of industries. In terms of competitiveness, Tennessee, Ohio, Indiana, Michigan, and North Carolina are the worst performers; Louisiana, Texas, Virginia, Missouri, and Massachusetts are the best. Overall, if total growth in national releases of toxic waste is examined, the states that have contributed the most to decline in the TRI are Louisiana, Texas, Alabama, Virginia, and Missouri. On the other hand, total TRI reductions in the United States have been less influenced by reductions in states like Tennessee, Ohio, Michigan, North Carolina, and California. In fact, these "worst" performers in terms of overall growth rates have actually increased their TRI in the period considered. Tennessee was responsible for the largest increase, approximately 120 million pounds (Table 4).

A more plausible ranking considers the relative position of each state and each industry prior to and during the implementation of TRI. The overall ranking shown in the last column of Table 5 is premised on such an indicator—the shift-share technique. The underlying estimate for overall ranking utilized Equation (8) and Equation (9). That is, the actual 1994 difference was calculated by taking the difference between actual TRI in 1994 and 1991. Expected difference from 1991 to 1994 was thus estimated by subtracting from the expected difference the total TRI in the industry for the state in 1991. The residual component is then the difference between the actual difference and the expected difference.

Finally, the overall performance was estimated by dividing the residual by expected 1994 TRI and multiplying by 100. The resulting figures were used in ranking the states (Table 5, column 5).

Based on the expected growth in TRI in the states, the top five states were Hawaii, Idaho, Alaska, Vermont, and New Hampshire. The worst performers were New Mexico, Nevada, West Virginia, Maine, and Arkansas. Again, these rankings reflect growth rates rather than strict absolute releases. Most of the worst performers in this case are states that produce relatively smaller amounts of TRI. Because the relative growth rates of the poor performers are larger than those of some high TRI producing states, the poor performers ranked lower. Therefore, a shift-share-based measure is less biased as a performance indicator. Although Louisiana is a high TRI producing state, and though it ranked first in terms of national growth rates, it ranked forty-third in terms of expected growth in TRI.

The ranking based on overall performance of the states is the main contribution of this study to developing an indicator of environmental performance evaluation. On the basis of this ranking, the best states in order of performance are Nevada, Maryland, New Mexico, Maine, and Wyoming. On the other hand, Pennsylvania, Oregon, Oklahoma, Wisconsin, and Hawaii are the worst performers. It is interesting also to note that Hawaii, the best state in terms of absolute ranking, is the worst performer in terms of expected versus actual achievement. It is also noted that, unlike absolute ranking, this relative ranking does not follow a particular pattern. That is, a large manufacturing-based economy is not necessarily worse-off; neither are absolute low TRI producing states necessarily the best performers. Using absolute measures, it is often the case that states with a relatively small manufacturing base will always rank better, even if these states maintain production at current levels. In this case, the relative performance measure will penalize such states since they will be worse-off relative to their initial position. This is in line with the goal of TRI.

Although the focus here is not on individual industry releases and transfers by industry, rankings also were examined to see how they correlate with overall state rankings. While space does not allow them to be reported here, the detailed results are available from the authors. The results show that when ranked in terms of absolute TRI amounts, the pattern across industries is as striking as the state rankings. First, there is a clear consistency in the rankings of these industries from year to year. With few exceptions, the top-ten performers in 1988 are always in the top-ten in other years, while the bottom-ten performers are almost invariably in that position in 1991 and 1994. Second, if most of the ten worst or ten best performing industries are concentrated in particular regions/states then that will likely bias rankings based on absolute TRI in favor or against those regions or states.

How correlated are these alternative measures with the shift-share measure of performance? A correlation analysis was performed on the two performance indicator rankings obtained from absolute TRI release measures and the

Table 5. State Ranking Using Shift-Share Growth Components

	Share Components of Growth						
State Code	National Growth Rank	Industrial Mix Rank	Competitive Rank	Total Growth Rank	Expected 1994 Rank	Actual (Absolute) 1994 Rank	Overall 1994 Performance Rank
AK	40	22	18	21	3	6	33
AL	6	2	9	3	18	41	39
AR	26	21	44	44	47	40	9
AZ	27	7	30	16	33	24	17
CA	9	47	42	46	40	36	14
CO	34	13	11	12	6	12	43
CT	32	45	16	26	11	18	40
DE	44	38	29	34	41	14	6
FL	16	23	14	9	38	32	16
GA	19	9	38	35	27	31	25
HI	50	26	20	27	1	1	50
IA	31	28	35	40	19	28	26
ID	43	29	17	22	2	7	37
IL	5	12	39	18	23	45	45
IN	4	1	48	38	36	47	20
KS	18	37	13	10	20	26	23
KY	17	40	19	15	24	29	27
LA	2	50	1	1	45	43	13
MA	28	46	5	11	35	21	12
MD	49	25	28	32	44	5	2
ME	42	30	22	28	48	9	4
MI	8	44	47	48	30	48	36
MN	30	48	8	25	12	20	38
MO	11	16	4	5	17	39	44
MS	22	24	43	43	34	37	18
MT	37	10	33	36	37	23	10
NC	12	14	46	47	29	42	28
ND	46	34	21	29	14	2	11
NE	41	41	34	41	13	16	24
NH	38	42	10	14	5	8	35
NJ	15	39	41	42	26	35	29
NM	39	15	36	39	50	11	3
NV	36	20	32	37	49	10	1
NY	14	27	12	7	21	34	31
OH	3	5	49	49	32	49	30
OK	25	18	7	6	9	19	47
OR	33	19	23	23	8	22	48
PA	7	4	40	20	22	46	46
RI	45	36	26	30	10	15	34
SC	23	11	45	45	25	38	32
SD	47	31	24	31	7	4	19
TN	13	6	50	50	43	44	15
TX	1	49	2	2	31	50	42

Table 5. (Cont'd.)

	Share Components of Growth						
State Code	National Growth Rank	Industrial Mix Rank	Competitive Rank	Total Growth Rank	Expected 1994 Rank	Actual (Absolute) 1994 Rank	Overall 1994 Performance Rank
UT	20	3	37	17	28	25	22
VA	10	33	3	4	16	30	41
VT	48	32	27	33	4	3	21
WA	24	8	31	24	39	17	8
WI	21	43	15	13	15	33	49
WV	29	17	25	19	46	27	7
WY	35	35	6	8	42	13	5

shift-share measure. The coefficient of correlation is 0.23, showing that there is very little correlation between these two rankings. Therefore, if one accepts the shift-share approach as a better measure of performance, the use of absolute measures may be very misleading in gauging states' environmental stewardship.

SUMMARY AND CONCLUSIONS

This study explored the possibility of using the shift-share model of regional analysis to refine the TRI as an environmental indicator. The current use of TRI that relies on absolute releases to rank states as a way to gauge states' environmental stewardship is flawed. The shift-share method showed that recognizing a state's initial conditions and its expected performance in the absence of the TRI program could minimize the bias inherent in using absolute TRI releases. The TRI shift-share also provides additional insight into the component of growth in toxic releases. This growth decomposition is valuable information to policy makers since it affords them a basis for some further action. That is, specific non-performing industry could be targeted for adequate enforcement or monitoring. In addition, the opportunities offered by the industry-line summary might be very important to policy makers who may want to target specific industries.

Although the preceding analysis enables the analyst to decompose and explain the growth in TRI in the states as well as sectors in the manufacturing industries, it does not offer any explanation for the differences observed in state performances. Thus, it is the "residual or competitive component" which has the attributable factors which cause each industry sector's TRI growth in a given state to deviate from their national averages over the period of analysis, possibly for diverse reasons [15]. Other than attributing the residual component to local factors, the shift-share does not provide any explanation for it. Finally, the static shift-share model is limited in its forecasting ability due to the arbitrariness of base year selection. Nonetheless, its usefulness in categorizing and organizing industry-based data such as the TRI outweighs its limitation. Besides, further extension and modification of the method can be explored to obtain more robust results.

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