Fetal Exposure to Toxic Releases and Infant Health

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Introduction and Background

Over 4 billion pounds of toxic chemicals are released by industry into the U.S. environment each year, including many recognized developmental toxicants.

But we have little evidence regarding the effects of these releases on human health.

We don’t know how proximity to releases translates into exposures, or (in many cases) how exposures are likely to affect health.

Many studies seek to examine effects of pollution on human health by examining proximity to sources of pollution.

E.g. Elliot et al. (BMJ 2001) find an increased risk of congenital anomalies and low birth weight among mothers living <2km from 9565 landfills (that operated between 82 and 97) in a study of 8.2 million births.

Downey and Van Willigen (2005) find that Chicago census tracts with higher proportions of Hispanics had more toxic releases in 1995 (not true of Census tracts with high proportions black) and residents of tracts with high releases were more likely to report personal powerlessness.

Woodruff et al. (1998) use a dispersion model to calculate a relationship between reported releases and concentrations of toxic chemicals in the U.S. and report that 90% of tracts had concentrations of benzene, formaldehyde, and 1,3-butadiene greater than cancer benchmarks.

But proximity to toxic emitters or residence in polluted census tracts is correlated with many other risk factors for poorer infant health outcomes (poverty, minority status) so it is difficult to make causal inferences.

In fact, there is a large literature on “environmental justice” which asks whether minorities are disproportionately more likely to be exposed to pollution.

If minorities are disproportionately more likely to be exposed there are many possible reasons:

- minorities are poor and polluted areas are cheaper to live in.
- minorities place less value on environmental amenities.
- new polluting facilities are more likely to be cited in minority areas (because land is cheap?)
- polluting facilities take less care in minority areas (because they face less risk from liability?)

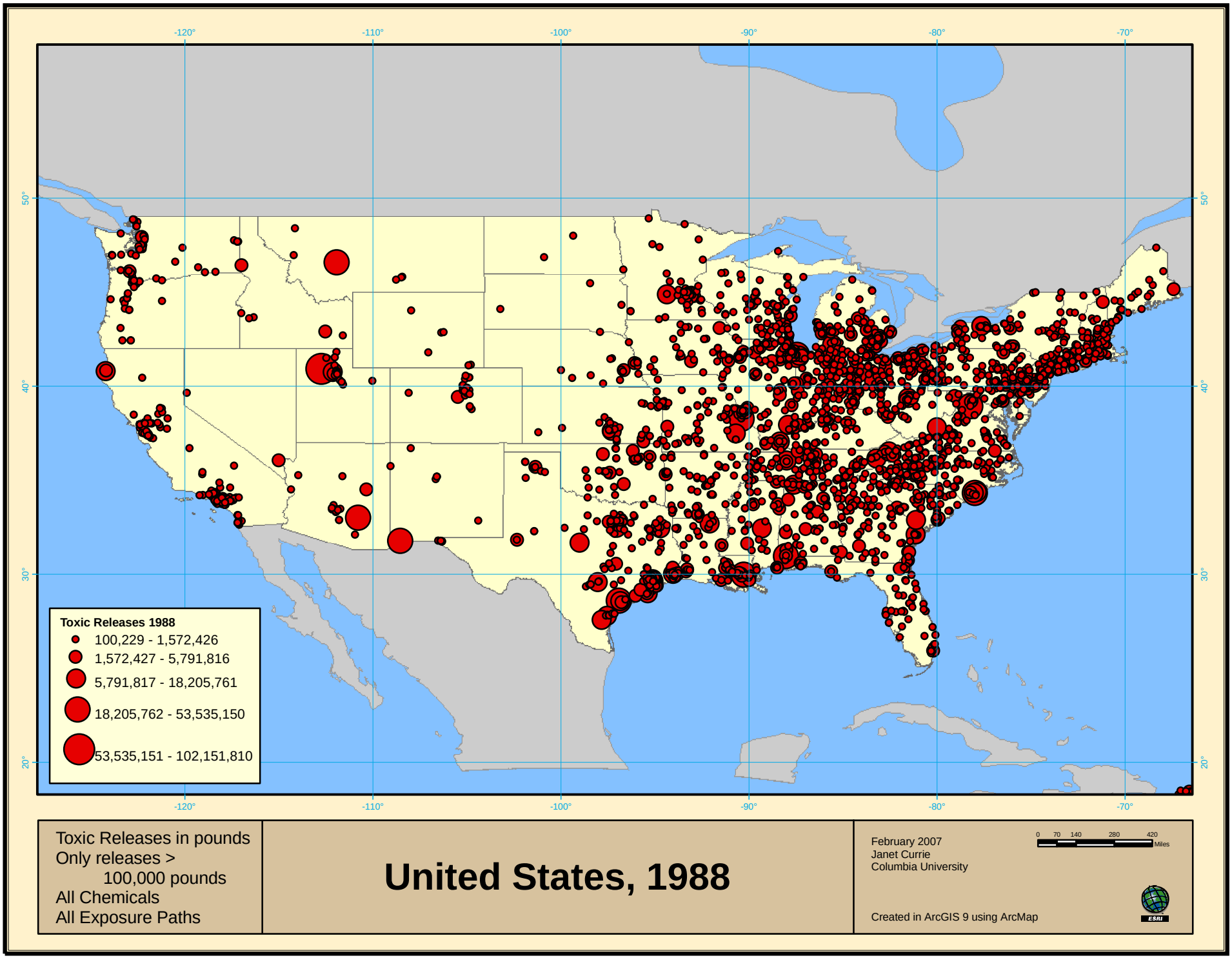
There is little research attempting to disentangle these reasons.

Data:

The U.S. Toxic Release Inventory database was established under the Emergency Planning and Community Right-To-Know Act of 1986.

Manufacturing plants with more than 10 full-time employees who use or produce more than threshold amounts of 6500 listed chemicals are required to report releases to air, water, and land annually.

Facilities can be penalized for failure to report ($27,500 per violation per day), even though in many cases, there is no penalty for emitting per se. In the first 5 years of the program, EPA conducted 3,200 inspections and fined 683 facilities.



Toxic Releases in pounds
Only releases >
100,000 pounds
All Chemicals
All Exposure Paths

United States, 1988

February 2007
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0 70 140 280 420
Miles

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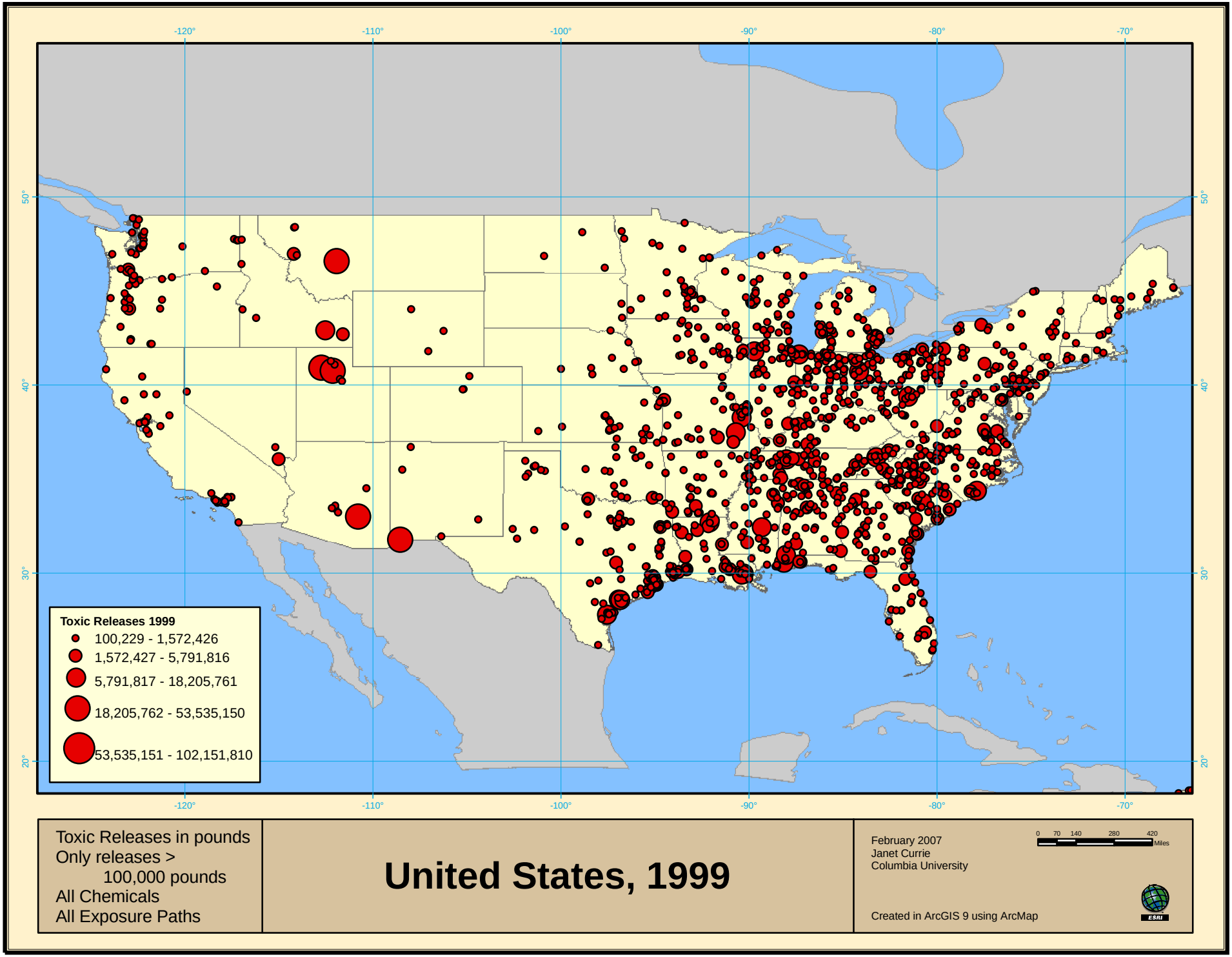
ESRI



Toxic Releases in pounds
Only releases >
100,000 pounds
All Chemicals
All Exposure Paths

United States, 1999

February 2007
Janet Currie
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0 70 140 280 420
Miles

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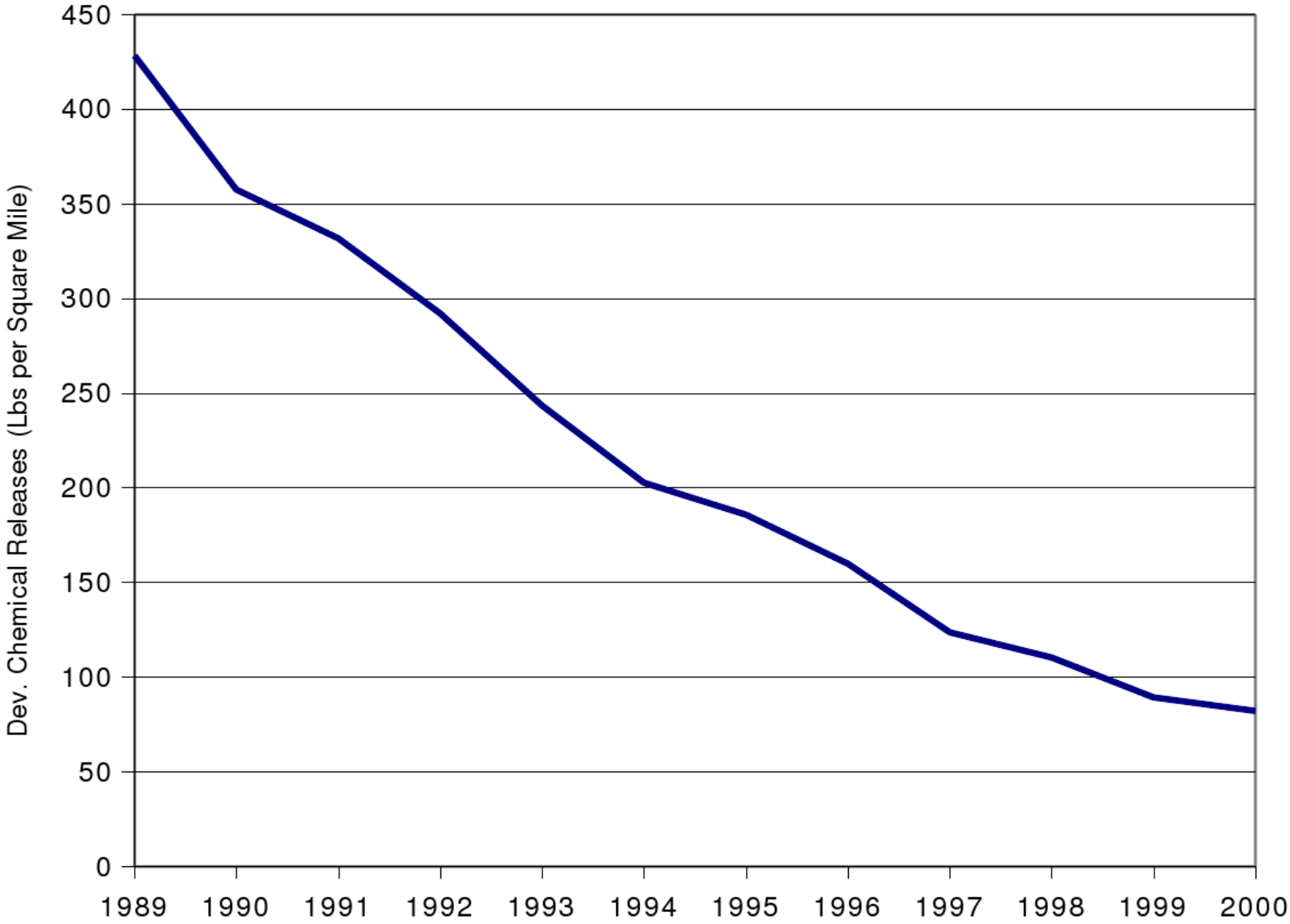
The Decline in Developmental Toxicants



By 1999, the introduction of the TRI has been associated with a 40 percent decline in reported emissions from 1988 levels.

But could this be associated with a decline in enforcement of reporting provisions, or with switching to unmonitored chemicals?

The TRI data are extraordinarily detailed and the best available for this project. But there are still many limitations.

1) There are non-compliers (i.e. plants that never reported at all). But audit studies suggest that these tend to be small polluters so that TRI figures are not much affected by their exclusion.

2) Many compliers have gaps in their reporting. Gaps are more likely at the end of the reporting period than at the beginning. Gaps could occur because a) plants went out of business, b) amounts purchased or used went below reporting thresholds, c) the plant stopped reporting. This makes it very difficult to interpret plant-level variation in reported emissions.

3) Reporting requirements have changed over time. We focus on pollutants that were consistently reported between 1988 and 1999.

4) Pollution levels are reported annually, by calendar year. In pregnancies that span years, we use a weighted average of pollution levels across years, where weights are given by the fraction of the pregnancy in each year.

5) Emissions are not the same as exposures.

We also use a list of known developmental toxicants from the California Office of Environmental Health Hazard Assessment. One would expect fetuses to be more affected by developmental chemicals than other chemicals (e.g. carcinogens).

However, it is possible that fetuses are affected by some third factor (e.g. soot) that is correlated with both releases of developmental and non-developmental chemicals.

Contribution

- First study to investigate the health effects of the releases tracked by the Toxic Release Inventory Program (TRI).
- Using Vital Statistics Natality and Mortality Data we find significant negative effects of a variety of toxicants on gestational length and birth weight.
- The effects are quite large at the lower end of the birth weight distribution: e.g. a two standard deviation increase in toluene is associated with an increase in the incidence of very low birth weight by 2.7 percent.
- There are large and significant increases in the infant death rate associated with releases of developmental chemicals.

Data on Infant Health

- Vital Statistics Data: Detailed individual information on nearly all births in the US on demographics, health at birth and infant mortality.
- County identifiers for counties with more than 100,000 population.
- Since exact time of releases is unknown: use only births occuring in January and merge to releases in the year before.
  For rare birth outcomes (low birth weight and infant mortality): use births January until March.
- Collapse birth, death and TRI data on county level (including demographics etc. as controls) and merge using county identifiers.
- Controls are age, education, race, smoking and drinking behavior of mother.

$$Outcome_{cnty,year} = Toxicant_{cnty,year}\beta + X_{cnty,year}\gamma + CountyFE + YearFE + \epsilon_{cnty,year}$$

- $Outcome_{cnty,year}$: Gestation (in weeks), birth weight (in grams), low birth weight rate (<2500g), very low birth weight rate (<1500g), and infant mortality rate (deaths per 1000 births).
- Identification of the effect comes from within county, year to year variation in pollution.
- Potential threat: omitted variables, such as economic conditions, may be correlated with trends in toxic releases.
- Health effects should be strongest for developmental toxicants and fugitive air releases. Non-developmental and stack air releases should be correlated with the same omitted variables.
- A crucial **identification check** is therefore to compare the effects of **fugitive air** vs. **stack air** releases and **developmental** vs. **non-developmental** toxicants.

Gestation and Birth Weight

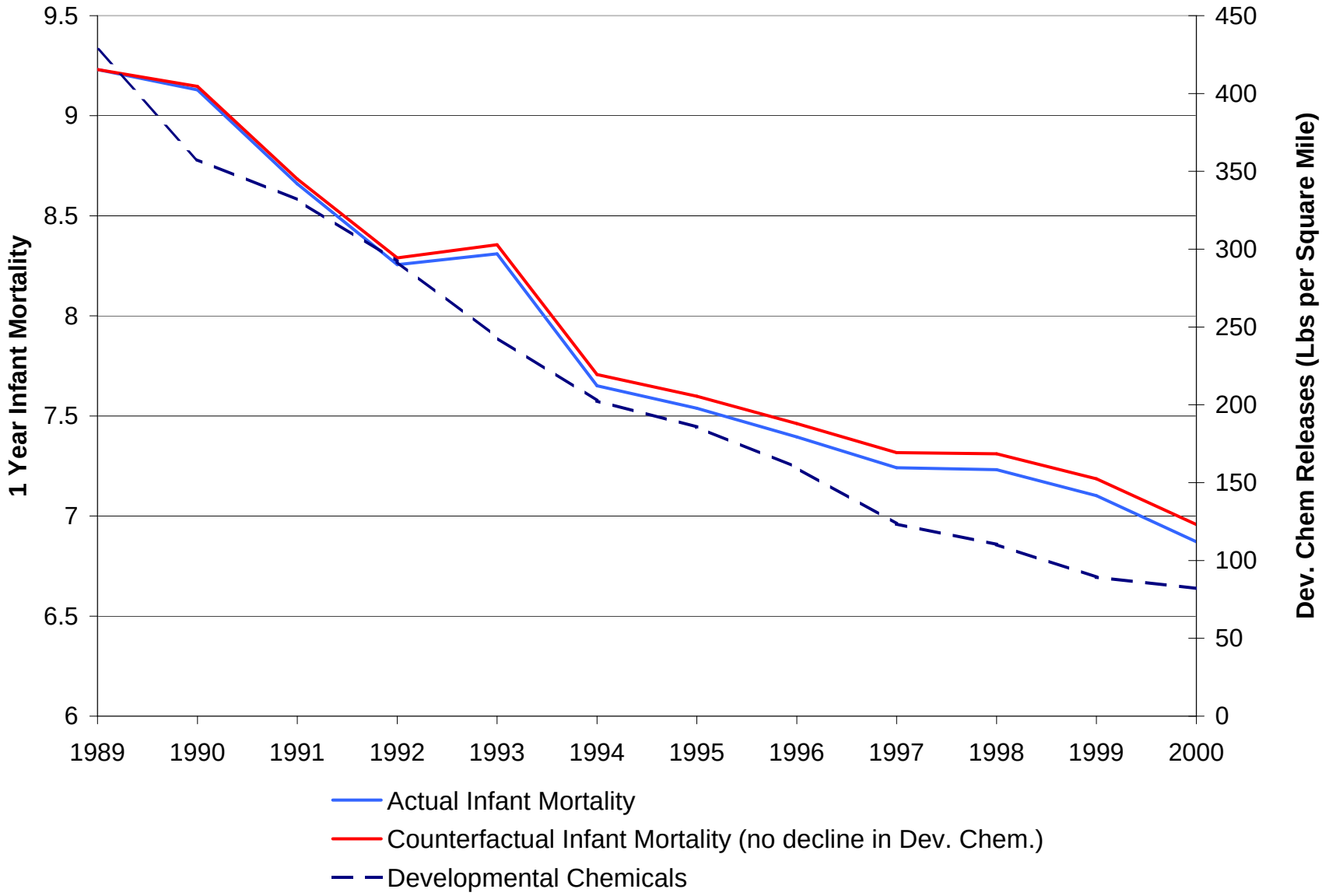
	Gestation	Birth Weight	Birth Weight < 2500 grams	Birth Weight < 1500 grams	Infant Deaths per 1000 births
Dev. Chem.	-0.0247 [0.00595]**	-2.862 [1.058]**	0.864 [0.201]**	0.232 [0.0833]**	0.249 [0.0536]**
Non-Dev. C.	-0.0147 [0.00367]**	-1.938 [0.473]**	0.503 [0.115]**	0.0921 [0.0563]	0.129 [0.0432]**
V.O.C.	-0.0246 [0.00617]**	-2.853 [1.094]**	0.876 [0.199]**	0.237 [0.0840]**	0.248 [0.0549]**
Toluene	-0.0244 [0.00695]**	-3.183 [1.084]**	0.976 [0.188]**	0.250 [0.0854]**	0.276 [0.0505]**
Epichlor	-1.212 [0.709]	-209.4 [73.40]**	18.42 [28.87]	25.04 [5.844]**	15.58 [6.647]*
Heavy Metals	-0.856 [0.473]	-176.8 [97.77]	55.83 [37.13]	10.06 [9.849]	8.579 [10.56]
Lead	-0.339 [0.270]	-75.73 [53.31]	15.56 [10.34]	3.264 [8.751]	-1.883 [7.404]
Cadmium	-2.653 [0.228]**	-527.8 [39.89]**	211.4 [15.59]**	40.77 [3.928]**	45.19 [3.206]**

Standard errors clustered on county level. * p<.05, ** p<.01.
Toxicants in 1000 lbs/mi^2
Coefficients for low and very low birth weight rates are multiplied by 1000.

Interpretation of Effects

- The effects are particularly strong at the lower tail of the distribution: E.g. a two standard deviation increase in
  - cadmium increases the low birth weight rate by 1.2 percent (very low: 1.4 percent).
  - toluene increases the low birth weight rate by 1.9 percent (very low: 2.7 percent).
  - epichlorohydrin increases the low birth weight rate by 0.2 percent (very low: 1.5 percent).
- The reductions in Toluene during the sample period translate to about 220 fewer deaths in 2000 than in 1989. Reductions in lead and cadmium imply 9 and 40 fewer deaths.

The Decline in Infant Mortality



Specification Check: Fugitive Air vs. Stack Air

	Birth Weight <2500 grams	Birth Weight <1500 grams	Infant Deaths
Dev. Chem. - fug. air	0.864	0.232	0.249
	[0.201]**	[0.0833]**	[0.0536]**
Dev. Chem. - fug. air	0.913	0.277	0.239
	[0.201]**	[0.0831]**	[0.0581]**
Dev. Chem. - stack air	-0.123	-0.111	0.0259
	[0.227]	[0.0518]*	[0.0677]
V.O.C. - fug. air	0.876	0.237	0.248
	[0.199]**	[0.0840]**	[0.0549]**
V.O.C. - fug. air	0.930	0.281	0.240
	[0.198]**	[0.0821]**	[0.0592]**
V.O.C. - stack air	-0.145	-0.118	0.0226
	[0.235]	[0.0510]*	[0.0702]
Heavy Metals - fug. air	55.83	10.06	8.579
	[37.13]	[9.849]	[10.56]
Heavy Metals - fug. air	55.59	9.764	8.302
	[36.87]	[9.654]	[10.36]
Heavy Metals - stack air	4.735	5.805	5.400
	[18.12]	[4.978]	[4.294]

Robustness and Probable Bias

- The results are robust to using a sample from different months.
- Coefficients are stable to including all chemicals in the same regression.
- Effects on fugitive air emissions are robust to controlling for ground and water releases.
- Results are similar (stronger for heavy metals) if releases are not scaled by county area.
- While the estimates are precise there are good reasons to think of these as **lower bounds** due to the many sources of measurement error.
  - Reporting requirements - not all plants have to report.
  - Exact timing of releases and when infants are most vulnerable is unclear.
  - Depending on weather, plant location, and type of release, actual exposure of infants may vary a lot.

Summary of Results

- We find clear and robust negative effects of toxic releases on infant health.
  - The effects are sizeable for extreme outcomes like low birth weight and infant death.
  - Overall we think these estimates are lower bounds of the true effects.
- First (research based) estimates of health costs of toxic releases. Important for regulation.
- TRI data collection has several shortcomings, e.g. reporting thresholds and requirements were lowered in 2007. High quality data very important for estimating health costs.