Intergenerational Spillover effects of Bhopal Gas Disaster

Prashant Bharadwaj Arushi Kaushik Gordon McCord

UC San Diego

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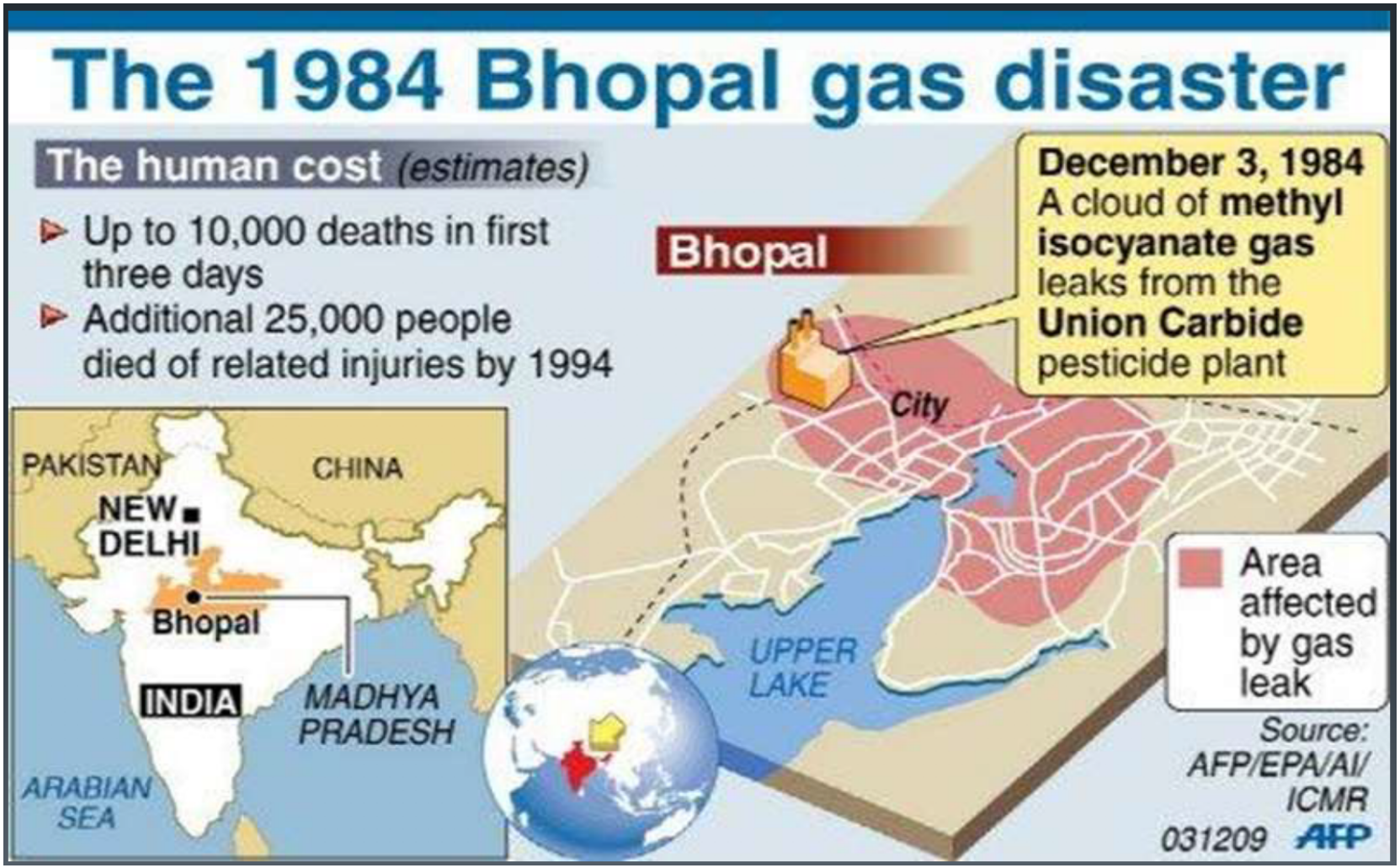
Introduction

- Many developing countries have weak regulatory environment, stemming from either weak regulations (environmental or labor standards) (Dean et al, 2009; Bocconi et al, 2008) or weak enforcement of existing regulations (Kanbur and Roconi, 2016)
  - Common argument : necessary for attracting industries, technological adoption or experimentation etc, and for promoting growth (Besley and Burgess, 2004; Dean et al 2009)
- However, little understanding of what the costs of such laxed regulatory environment entail:
  - On individual parties like workers and customers of the firm: the outcome less likely to be inefficient if faced with right damages liability (Coase Theorem)
  - More problematic for effects on society at large because:
    - ★ Diffused costs (Failure of Coase Theorem= high transaction costs, hence a case for govt negotiation on behalf of society)- e.g. data breach into organization's IT systems
    - ★ Externalities (Wrong pricing)- e.g., environmental disaster from BP oil spill, intergenerational spillover effects due to Fukushima nuclear disaster
- This project looks at Bhopal Gas disaster

Bhopal Gas Disaster

The worst industrial disaster in India.



Bhopal Gas Disaster

- In the intervening night of 2-3 December 1984, water leaked into a tank storing Methyl isocyanate (MIC) causing an exothermic reaction happened; due to pressure the gas leaked.
- As per Agency for Toxic Substances and Disease Registry (ATSDR), CDC:
  - Methyl isocyanate is irritating and corrosive to the eyes, respiratory tract, and skin. Could have Asthmatic reactions and long term respiratory and oculatory effects.
  - "..Methyl isocyanate may cross the placenta and enter a developing fetus.."
- Estimates of the death toll vary from 3,800 to 16,000, but government figures now refer to an estimate of 15,000 killed over the years.

Research Question and Motivation

- Study the (educational and health) effects of Bhopal Gas Disaster on those who were children or fetuses or not-yet-conceived at the time of the incident.

- Why Children?
  - Children= high risk population
  - MIC is twice as dense as air $\Rightarrow$ tendency to fall towards ground $\Rightarrow$ children would have inhaled higher concentrations
  - will have long term effects

- Under-compensated damage liability if we ignore the adverse effects on not-yet-born population (i.e., future generations)

Motivation (cont'd)

Lack of evidence from Public Health Perspective

As per Agency for Toxic Substances and Disease Registry (ATSDR), CDC

"**Reproductive and Developmental Effects**
Methyl isocyanate is not included in the list of Reproductive and Developmental Toxicants, a 1991 report published by the U.S. General Accounting Office that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. Increased rates of spontaneous abortions and neonatal deaths among victims of the Bhopal accident were observed for months following exposure. However, the precise role of methyl isocyanate in developmental toxicity is difficult to determine. Poor oxygenation resulting from compromised lung function may be involved...."

Preview of Results

- We do not observe any differential impact on children aged 10 years or below, or those who were not conceived at the time of disaster.
- However, those who were fetuses are 7% more likely to be suffering from cancer and 10.7% more likely to be suffering from employment disability.
- This cohort has finished 1.24 years less of schooling, mainly arising from lower class 8 and above completion rates.

Potential Mechanisms

- Exposure to MIC gas
- Disaster may affected the households of such children. E.g. Reduced earning ability of parents, say due to disability
- Living in disease-prone and polluted environment
- May have affected Chromosome structure (ATSDR, CDC)

Literature Review

- **Inhalation of MIC and mortality due to it**
  Sriramachari et al (1991)

- **Health effects of Bhopal Gas Disaster**
  Broughton (2005), Sriramachari (2004), Dhara and Dhara (2002), Cullinan et al (1996), Sathyamala (1996)
  - **Presence of symptoms or conditions that may lead to cancer in the exposed population**
    Dikshit and Kanhere (1999), Mishra et al (2009), Malla et al (2011), Pradyumna et al (2009)
  - **Health effects on the in-utero cohort**
    Bajaj et al (1993), Mishra et al (2009)

- **In-utero exposure to industrial/man-made disasters**
  Harville et al (2010), Lei et al (2014), Lederman et al (2004), Litcher et al (2000)

Data

- DHS (Demographic and Health Survey)- 2015-16
  - Men aged 15-54 who were surveyed in the subset of households
  - Cohorts covered are those born between 1965 and 1990
- GIS to obtain distance between current residence (clusters) from Bhopal
- For main analysis, sample restricted to men that report to be always living at their current residence in Madhya Pradesh
- For additional analysis and robustness checks, we also used:
  - IPUMS 1999
  - India Human Development Survey 2004-05
    - ★ Sample restriction similar to above

Identification Challenges

- Ideal data- to observe the universe of population living in Bhopal at the time of disaster, both before and after it.
  - Problem- Mortality
- Additionally, because such a time series data does not exist, we are using cross-sectional variation on the population observed to be currently (2016 in DHS and 1999 in IPUMS) living in and around Bhopal.
  - Problem- Migration
- This implies that we can not estimate the ATE of the Bhopal Gas disaster; instead we estimate how the disaster differentially affected younger cohorts vis-a-vis older cohorts.
  - The implicit identifying assumption is that the bodies and minds of older cohorts is more well developed and hence more resilient to the effects of the disaster compared to younger kids.

Identification Challenges

Because we are comparing younger cohorts with older ones, the identification problem becomes one of *differential* mortality and *differential* migration.

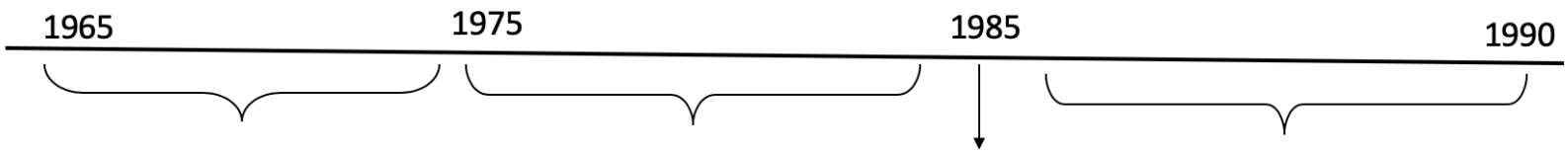
- Differential Mortality
  - Younger kids more susceptible to effects of disaster
  - Weaker kids more likely to die

  $\Rightarrow$ we are underestimating the true effects

- Differential Migration
  - Low migration rate (**add number here**)
  - Bhopal- fastest growing city in MP, so outmigration is not a problem but inmigration is
    - ★ All results restricted to those who have reported to be always living at the current residence

Identification Strategy

Older cohort is being used as control for younger cohorts



1965-1974	1975-1984	1985	1986-1990
Control	T1	T2	T3
>10 years old at the time of Bhopal tragedy	0-10 years old at the time of Bhopal tragedy	Fetuses at the time of Bhopal tragedy	Not yet conceived at the time of Bhopal tragedy

Empirical Strategy

Basic Specification:

$$Y_{itc} = \alpha_0 + \alpha_1 * Bhopal_c + \alpha_2 * T1_t + \alpha_3 * T2_t + \alpha_4 * T3_t + \beta_1 * T1_t * Bhopal_c + \beta_2 * T2_t * Bhopal_c + \beta_3 * T3_t * Bhopal_c + \epsilon_{itc}$$

where,
$Bhopal_c = 1$ if living in a cluster <= 100 Kms of Bhopal and 0 otherwise.

In alternate specifications, also included cohort and cluster FEs.

SEs clustered by Cohort*Region

Results: Incidence of Cancer

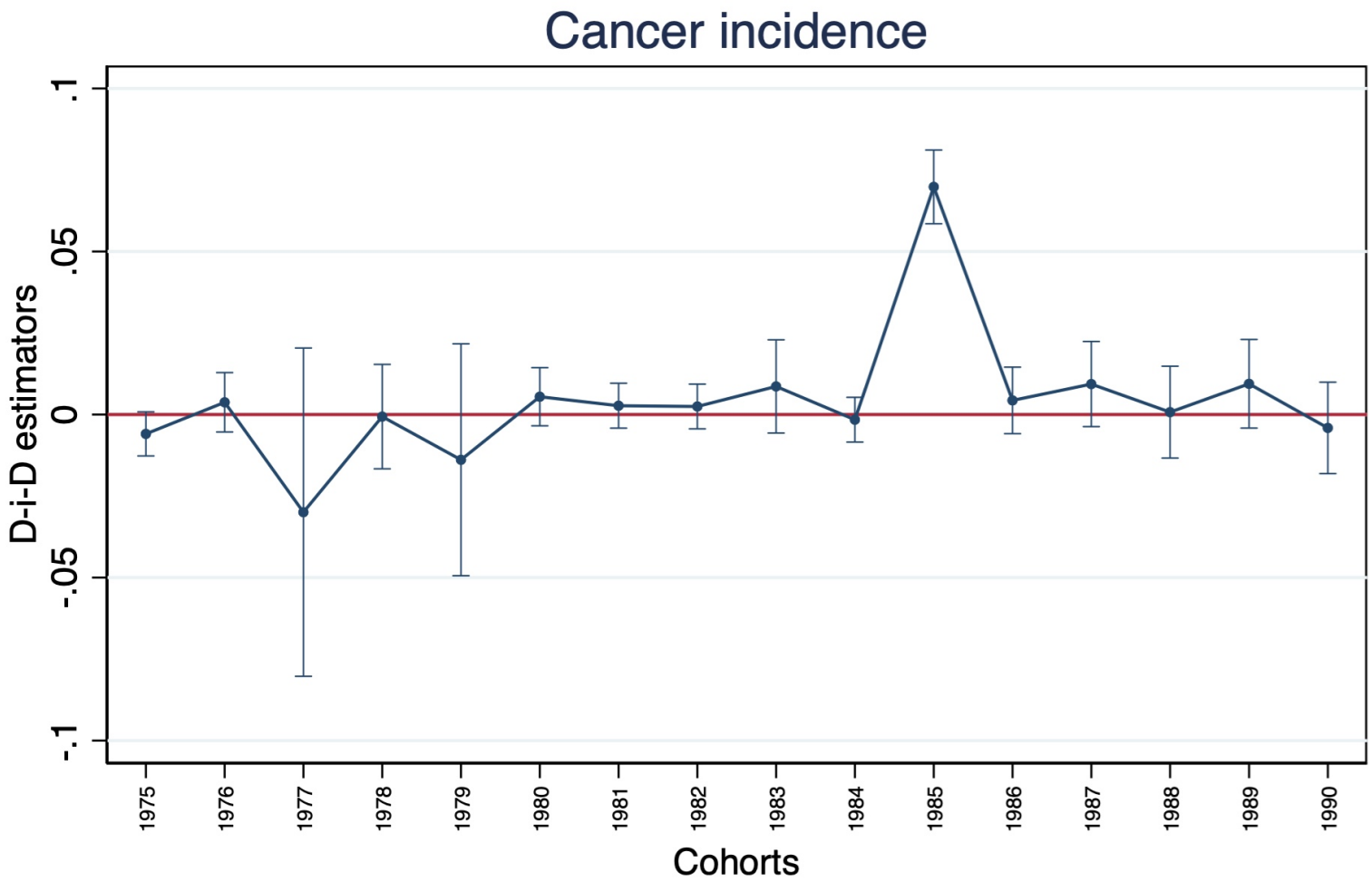
VARIABLES	Cancer Rate		
	(1)	(2)	(3)
1975-1984	-0.000677	-0.000978	-0.00403
	(0.00157)	(0.00145)	(0.00423)
1985	0.0676***	0.0675***	0.0694***
	(0.00111)	(0.000999)	(0.00506)
1986-1990	0.00205*	0.00190*	0.00359
	(0.00111)	(0.000999)	(0.00320)
Constant	0.00205*	0.000159	-0.00710***
	(0.00111)	(0.000221)	(0.00196)
Cohort FEs	No	Yes	Yes
Cluster FEs	No	No	Yes
Observations	4,380	4,380	4,380
R-squared	0.008	0.014	0.327

Robust standard errors in parentheses. SEs clustered by Cohort*Region.

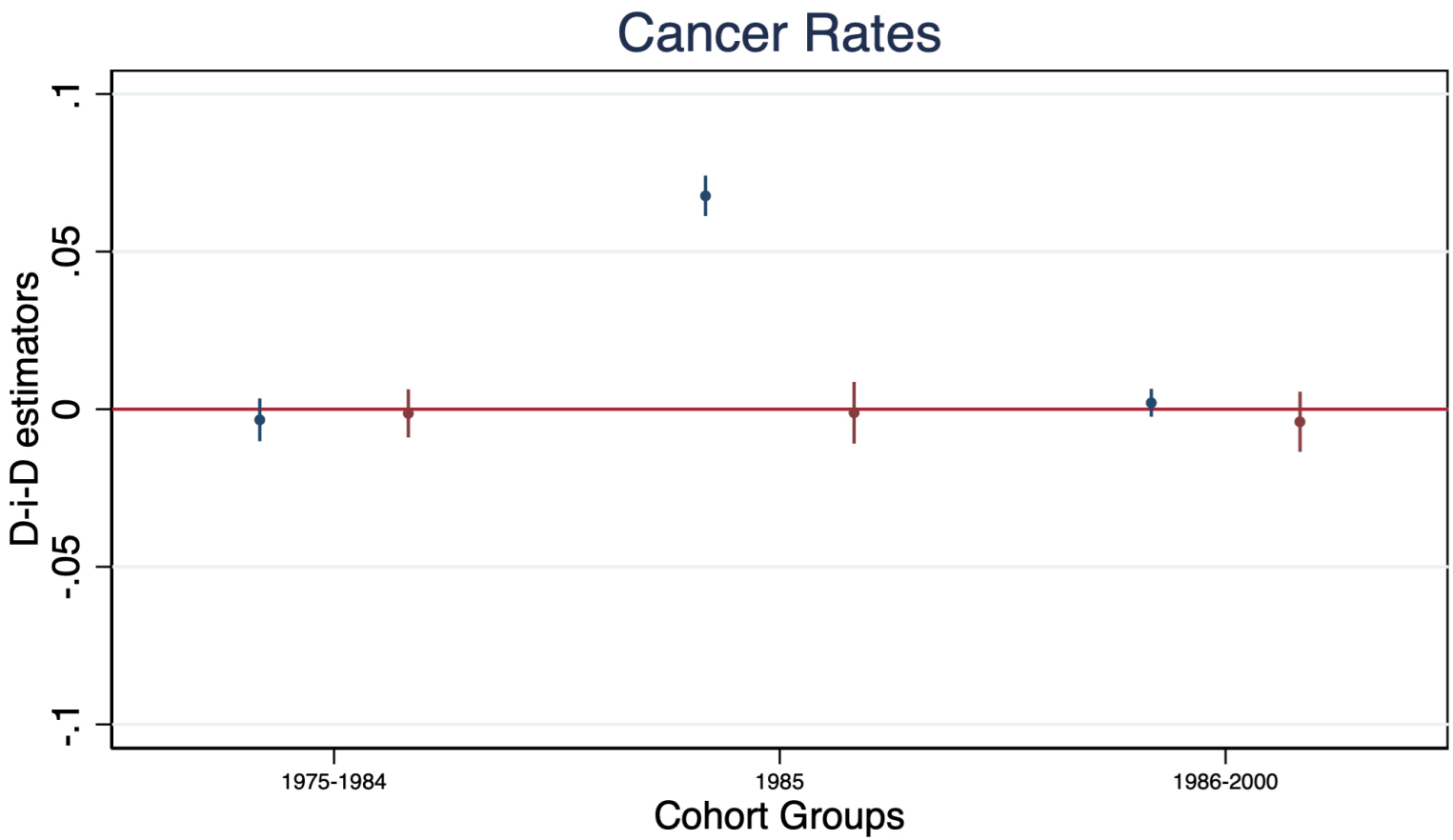
Sample consists of men who report to have always lived in the same location.

*** p<0.01, ** p<0.05, * p<0.1

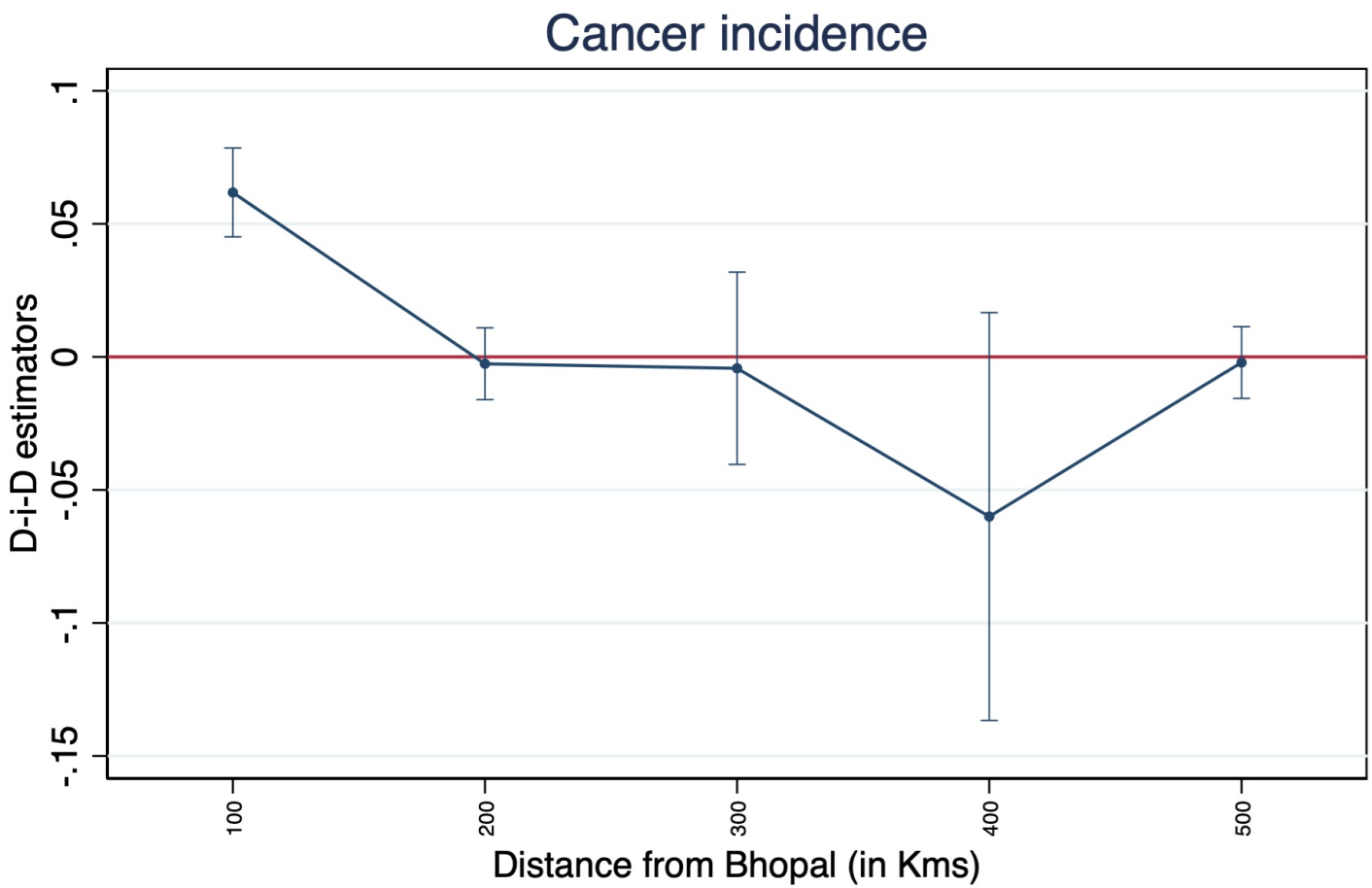
Incidence of Cancer



Incidence of Cancer: Movers V/s Non-Movers



Incidence of Cancer: Distance as Dose



Additional Results

Education Outcomes

VARIABLES	No. of years of education completed		
	(1)	(2)	(3)
1975-1984	-0.114	0.0326	0.0124
	(0.704)	(0.645)	(0.641)
1985	-1.577**	-1.444**	-1.245*
	(0.624)	(0.576)	(0.724)
1986-1990	0.306	0.411	0.589
	(0.665)	(0.633)	(0.644)
Constant	5.490***	3.675***	12.15***
	(0.196)	(0.248)	(0.134)
Cohort FEs	No	Yes	Yes
Cluster FEs	No	No	Yes
Observations	4,392	4,392	4,392
R-squared	0.042	0.056	0.384

Robust standard errors in parentheses. SEs clustered by Cohort*Region.

Sample consists of men who report to have always lived in the same location.

*** p<0.01, ** p<0.05, * p<0.1

Additional Results

Education Outcomes

VARIABLES	Primary School Completion Rate			Class 8 & above Completion Rate		
	(1)	(2)	(3)	(4)	(5)	(6)
1975-1984	-0.0447	-0.0357	-0.0106	0.0102	0.0238	0.0259
	(0.0643)	(0.0575)	(0.0632)	(0.0635)	(0.0616)	(0.0835)
1985	-0.128**	-0.118**	-0.148*	-0.177***	-0.166***	-0.231**
	(0.0539)	(0.0526)	(0.0873)	(0.0568)	(0.0577)	(0.0887)
1986-1990	-0.0544	-0.0451	-0.0562	0.0302	0.0402	-0.00820
	(0.0673)	(0.0665)	(0.0718)	(0.0752)	(0.0758)	(0.0834)
Constant	0.443***	0.281***	1.048***	0.371***	0.223***	1.029***
	(0.0205)	(0.0187)	(0.0171)	(0.0190)	(0.0346)	(0.0157)
Cohort FEs	No	Yes	Yes	No	Yes	Yes
Cluster FEs	No	No	Yes	No	No	Yes
Observations	4,392	4,392	4,392	4,392	4,392	4,392
R-squared	0.042	0.054	0.322	0.031	0.042	0.316

Robust standard errors in parentheses. SEs clustered by Cohort*Region.

Sample consists of men who report to have always lived in the same location.

*** p<0.01, ** p<0.05, * p<0.1

Additional Results

Employment Disability

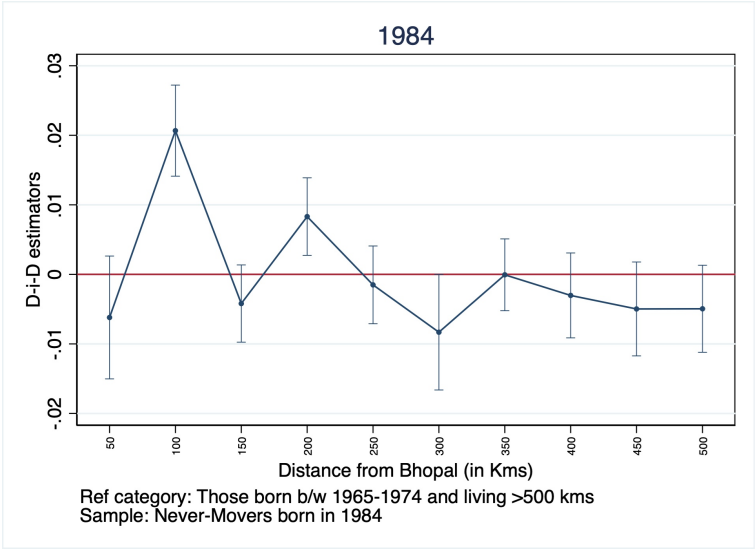
VARIABLES	Likelihood of Employment Disability		
	(1)	(2)	(3)
1975-1984	-0.00158	-0.00140	-0.00148
	(0.00499)	(0.00484)	(0.00505)
1985	0.00984**	0.00985**	0.0107***
	(0.00418)	(0.00404)	(0.00389)
1986-1990	-0.00289	-0.00275	-0.00257
	(0.00420)	(0.00405)	(0.00406)
Constant	0.00466***	-0.00335	-0.00615
	(0.00136)	(0.00574)	(0.00563)
Cohort FEs	No	Yes	Yes
Cluster FEs	No	No	Yes
Observations	10,422	10,422	10,422
R-squared	0.001	0.003	0.008

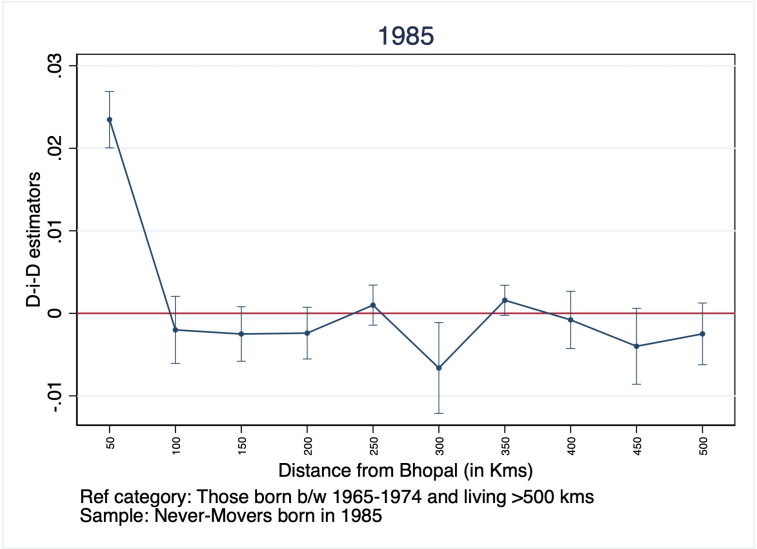
Robust standard errors in parentheses. SEs clustered by Cohort*Region.

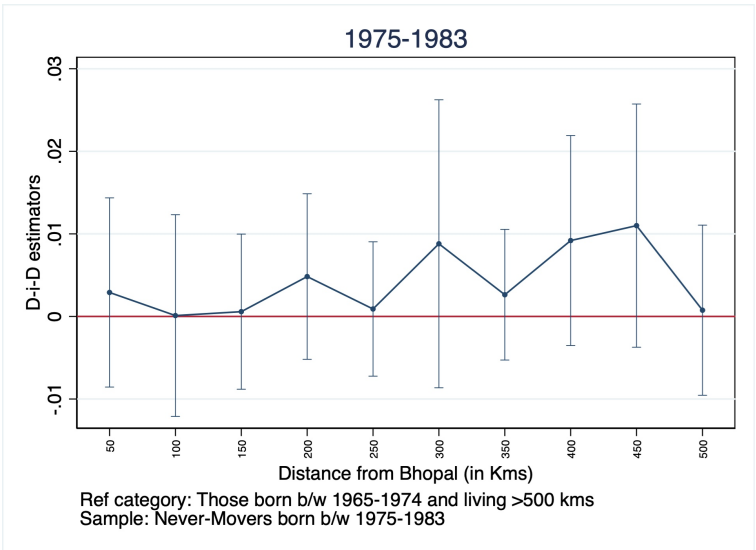
Sample consists of men who report to have always lived in the same location.

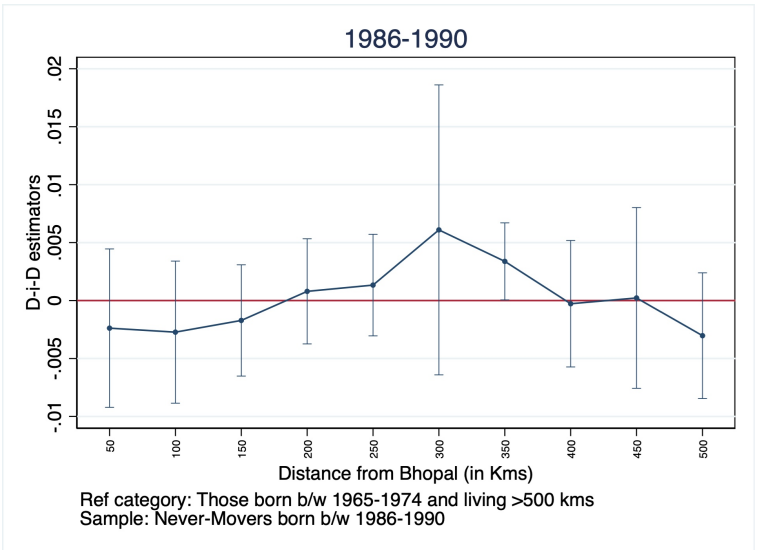
*** p<0.01, ** p<0.05, * p<0.1

Employment Disability across cohorts: Distance as Dose



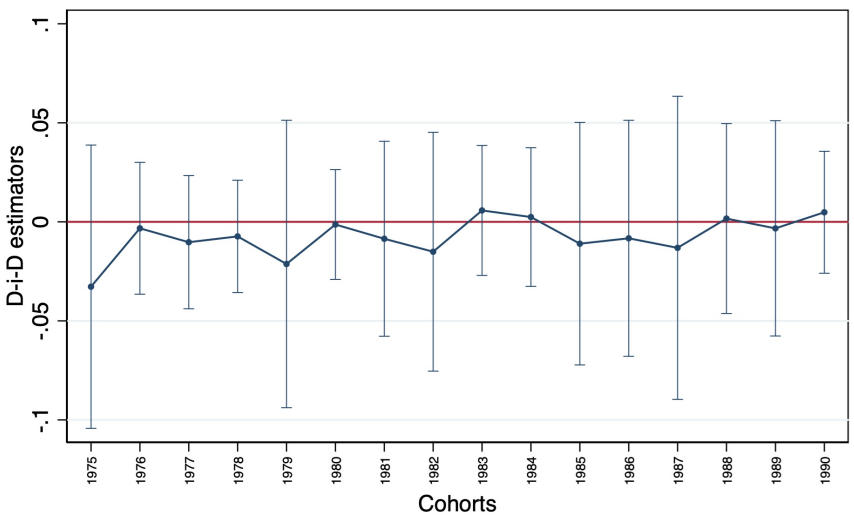




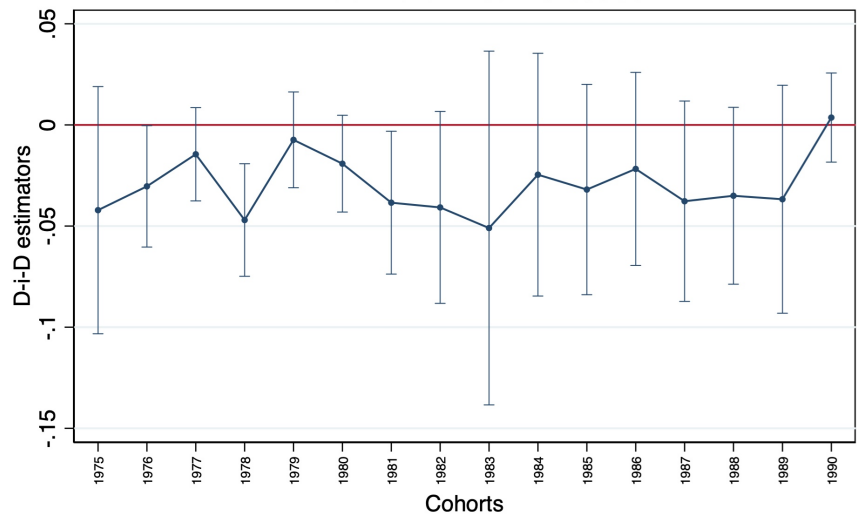


For combined cohort groups 1984 and 1985, the disability incidence goes down from 10.7% to 9% but remains statistically significant at 5% level.

Robustness Checks: Other Health Outcomes



Ref category: Those born b/w 1965-1974 and living >100 kms
Sample: Never-Movers



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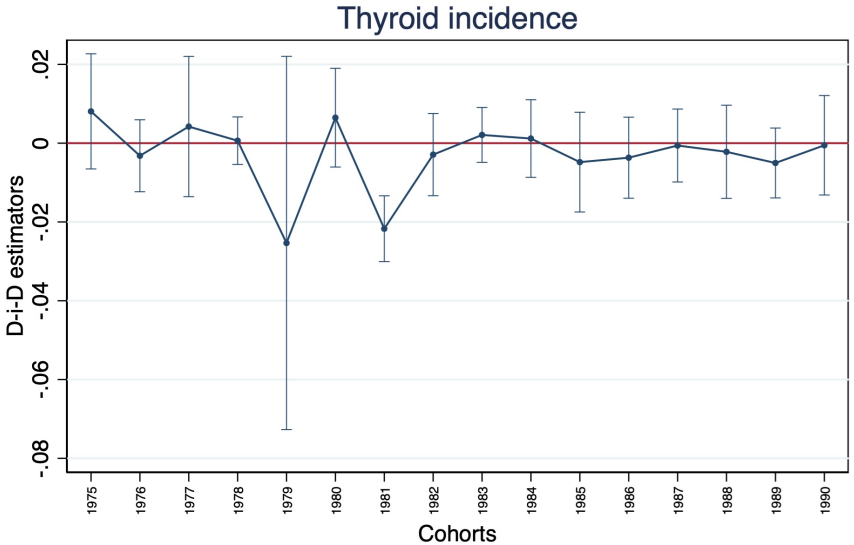

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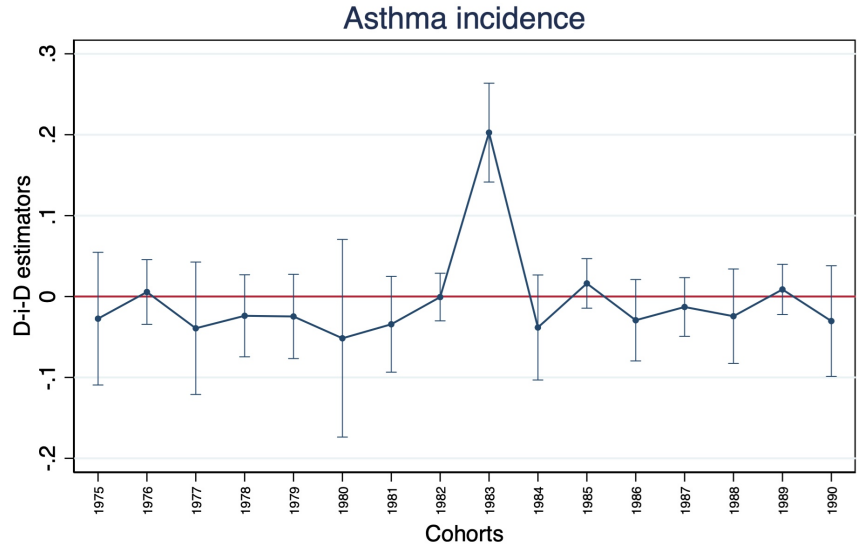
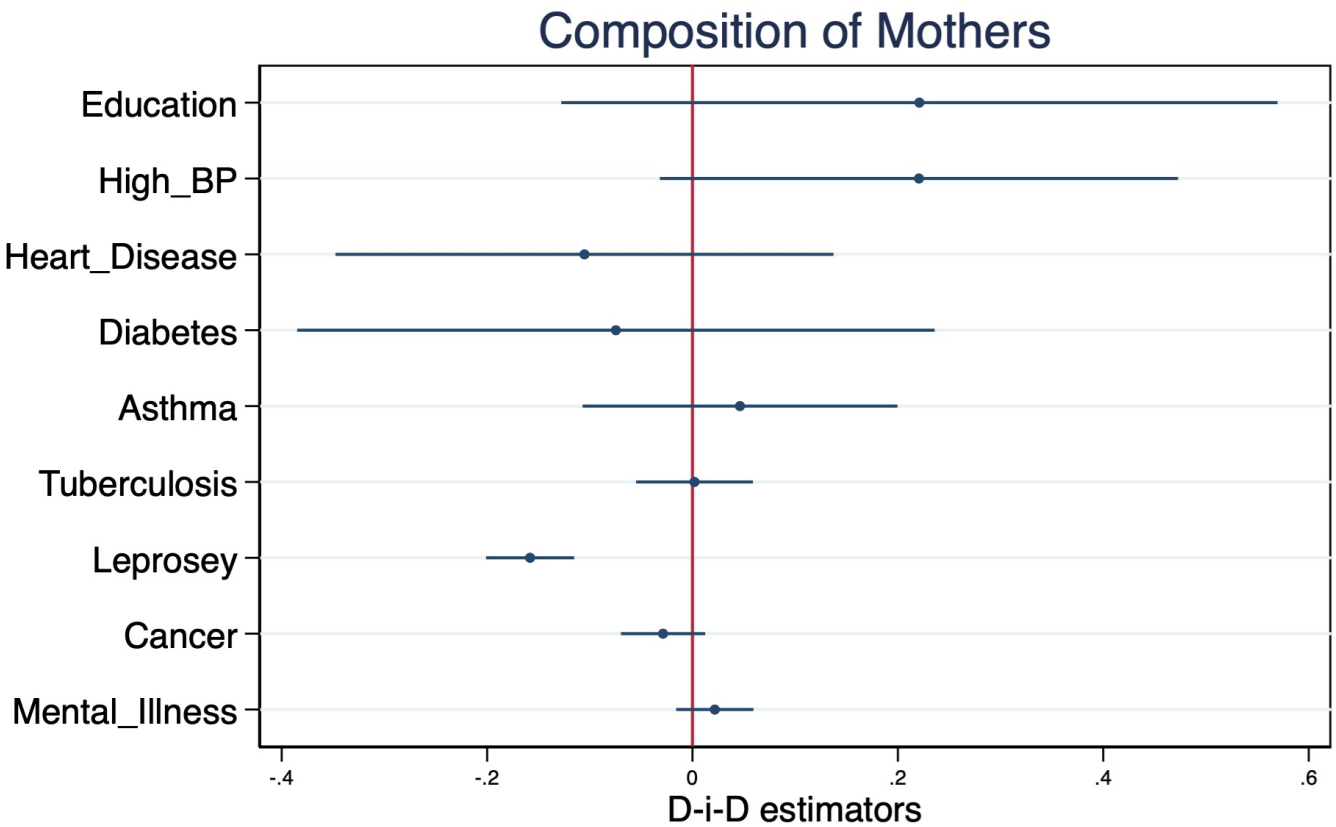
Sample: Never-Movers



Ref category: Those born b/w 1965-1974 and living >100 kms
Sample: Never-Movers

Robustness Checks: Composition of Mothers



Sample: Mothers of those born in 1985
Ref category: Those who were >= 10 year old at the time of disaster & living >100 kms

Conclusion

- Bhopal Gas incident seems to have differentially affected people who were fetuses at that time: they are about 7% more likely to be suffering from cancer compared to those who were 10 years or older at the time of disaster.
- This health effect has been consequential for this subpopulation:
  - Have completed 1.24 years less of schooling
  - 1.5% less likely to finish primary school
  - 2.31% less likely to have finished Class 8 and beyond
  - 10.7% more likely to report employment disability
- Due to mortality of the weakest kids in this cohort, these are likely to be underestimates of true effects.
- These effects exist only for non-movers.
- These effects are not due to change in composition of mothers.