The Social Costs of Keystone Species Collapse: Evidence From The Decline of Vultures in India

Intro to Empirical Economics

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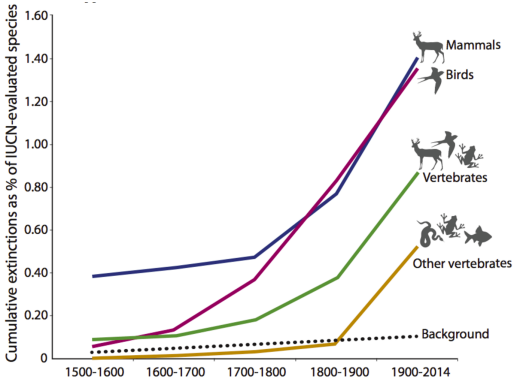
Economics & the Extinction of Species

Hard to quantify the effects of species declines

Attempts to reintroduce or stabilize species

Policy-makers face an allocation problem



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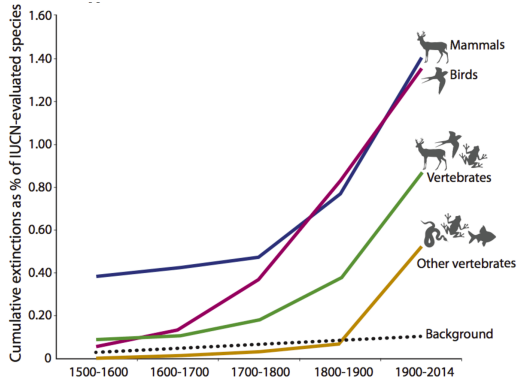

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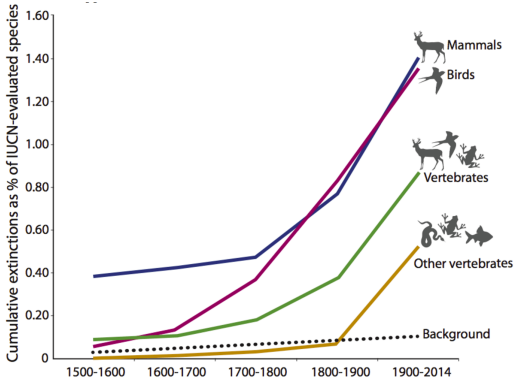

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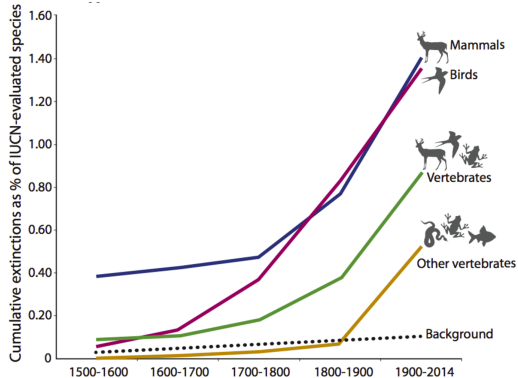

Collapse in Indian Vulture Populations

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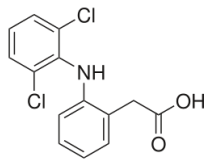

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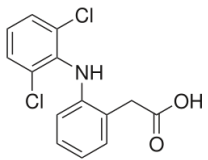
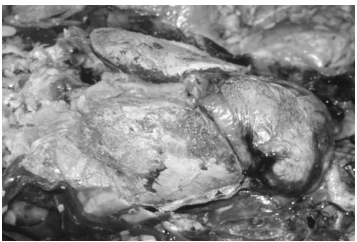
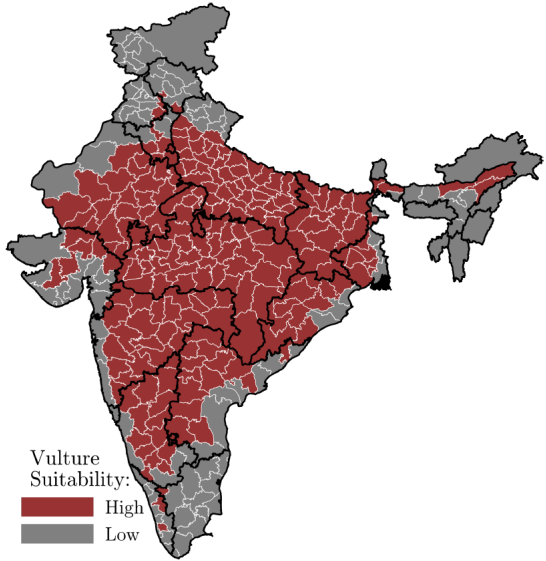




Empirical Strategy

Event-Study Design



What They Found

1. Average increase of 9.2% in all-cause death rates
2. Increase in dog populations and use of rabies vaccines
3. Water quality also deteriorated

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Contributions

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- Early works by Banerjee et al. (2010) and Alsan (2015)
- Use of insecticides for the loss of pest control species (Frank 2021)
- Impact of insecticide on health outcomes (Frank 2021; Taylor 2021)
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Long-Run Health Impacts of Income Shocks: Wine and Phylloxera in Nineteenth-Century France

Banerjee et al. (2010):

> Between 1863 and 1890, phylloxera destroyed 40% of French vineyards.
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> They find that those born in affected regions were about 1.8 millimeters shorter than others at age 20.
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> A large effect since average heights grew by only 2 centimeters in the entire nineteenth century.
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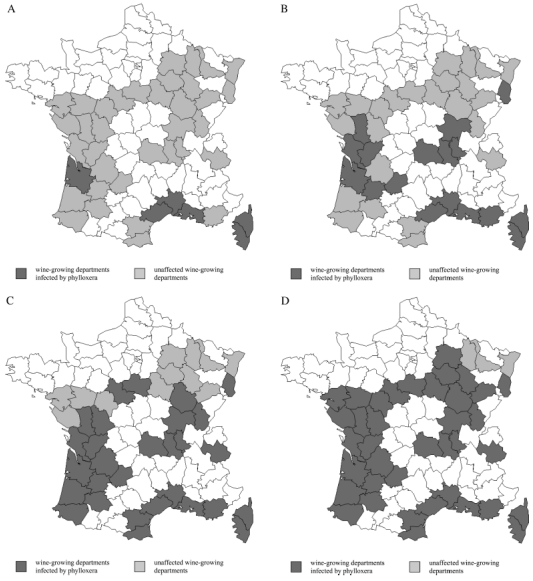
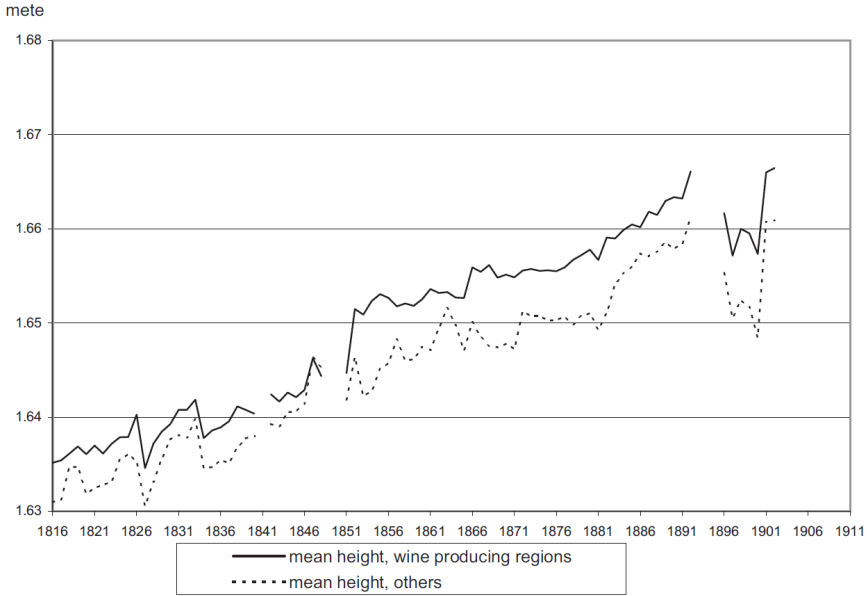


A: Phylloxera in 1870
B: Phylloxera in 1875
C: Phylloxera in 1880
D: Phylloxera in 1890


mete
1.68
1.67
1.66
1.65
1.64
1.63
1816
1821
1826
1831
1836
1841
1846
1851
1856
1861
1866
1871
1876
1881
1886
1891
1896
1901
1906
1911
mean height, wine producing regions
mean height, others

Wolves make roadways safer, generating large economic returns to predator conservation

Raynor et al. (2021):

> Quantify the effects of restoring wolf populations by evaluating their influence on deer–vehicle collisions (DVCs) in Wisconsin
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> Wolf entry reduced DVCs by 24%, yielding an economic benefit that is 63 times greater than the costs of verified wolf predation on livestock
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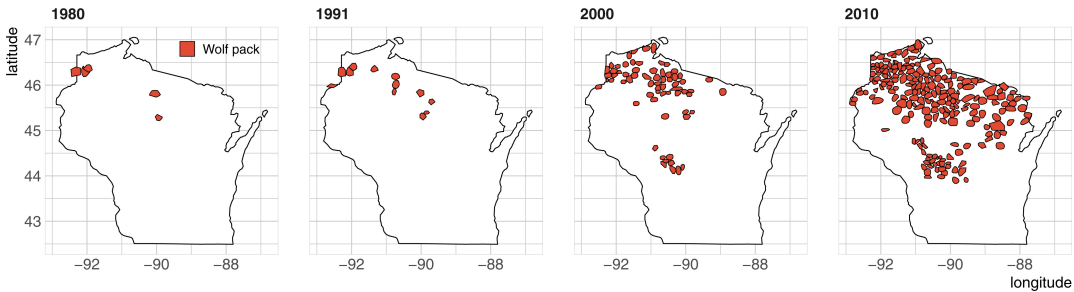
1980
1991
2000
2010
Wolf pack
latitude
47
46
45
44
43
−92
−90
−88
longitude

Cicadian Rhythm: Insecticides, Infant Health, and Long-term Outcomes

Taylor (2021):

Issue: nonrandom pesticide exposure

Solution: mass emergence of cicadas in 13 and 17-year cycles across the eastern half of the US

Exposed cohorts experience higher infant mortality and adverse health impacts, followed by lower test scores and higher dropout rates

+ 0.46 deaths per thousand. 95% CI: (0.11; 0.81)

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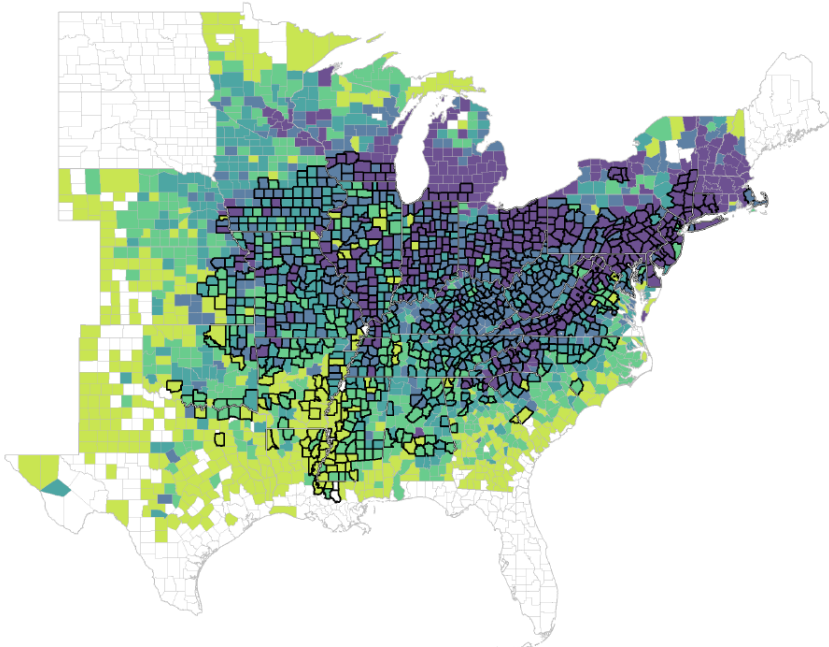
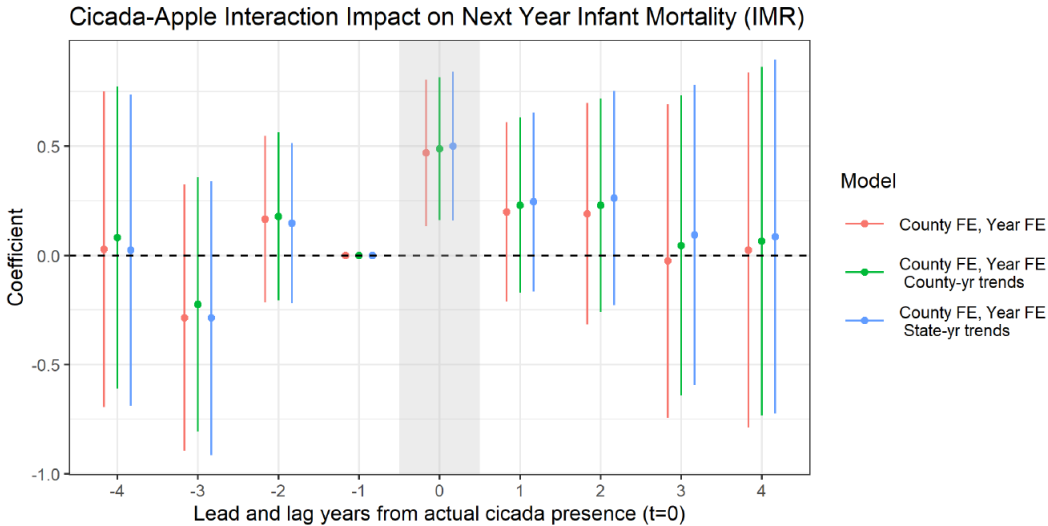


Timing	Spring and year(s) prior	Summer	Fall (and late summer)	Winter	Next spring (and throughout the following year)
Insecticide use	Some documented insecticide pre-spraying to kill nymphs before emergence	Primary spraying to prevent cicadas from mating and laying eggs in tree branches	Spraying to kill eggs and nymphs	Ground spraying/soil soaking to kill nymphs before establishment	Follow on treatments to kill nymphs
Cicada behavior	Nymphs increasing feeding, size, moving toward surface	Cicada emergence and mating	Eggs hatch and tiny nymphs fall to ground	Nymphs bury themselves into ground, feeding on tree roots	Nymph establishment and passive feeding for next 13/17 years
Health effects					

Maternal exposure to insecticides
(primary timing = solid line;
other potential timing = dashed line)

First birth impacts from 1st trimester exposure in previous summer


Cicada-Apple Interaction Impact on Next Year Infant Mortality (IMR)
Coefficient
0.5
0.0
-0.5
-1.0
-4
-3
-2
-1
0
1
2
3
4
Lead and lag years from actual cicada presence (t=0)
Model
County FE, Year FE
County FE, Year FE
County-yr trends
County FE, Year FE
State-yr trends

The Sudden Collapse of Vulture Populations in India

What Happened

Fastest decline of a bird species

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Patent expiration diclofenac in 1994

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Table 1 **Diclofenac residue testing results in kidney samples from wild OWBVs with and without renal failure**

Case no.	Date	Site	Age	Gout	Diagnosis	Diclofenac residues (μg g^{-1})
33	2001	KS	Juv	Yes	None	0.051
74	2002	KH	Ad	Yes	None	0.054
16	2001	KS	Ad	Yes	None	0.060
53	2002	KH	Ad	Yes	None	0.064
60	2002	ML	Ad	Yes	None	0.064 (0.076)
39	2001	KH	Ad	Yes	None	0.077
69	2002	ML	Ad	Yes	None	0.079
57	2002	KH	Ad	Yes	None	0.080
40	2002	ML	Ad	Yes	None	0.091
20	2001	KS	Ad	Yes	None	0.097
15	2001	KS	Ad	Yes	None	0.099
35	2001	KS	Ad	Yes	None	0.106 (0.077)
41	2002	KH	Ad	Yes	None	0.109
75	2002	KH	Ad	Yes	None	0.114
55	2002	ML	Ad	Yes	None	0.124
54	2002	ML	Ad	Yes	None	0.177
71	2002	KH	Ad	Yes	None	0.179
61	2002	ML	Ad	Yes	None	0.186
42	2002	KH	Ad	Yes	None	0.199
44	2002	KH	Ad	Yes	None	0.233
4	2000	KS	Ad	Yes	*M. avium* infection	0.450
38	2001	ML	Ad	Yes	None	0.451
59	2002	ML	Ad	Yes	None	0.504
45	2002	ML	Ad	Yes	None	0.642 (0.197)
56	2002	KH	Ad	Yes	None	0.643
2	2000	LH	Ad	No	Wire collision	BDL
3	2000	CW	Juv	No	Hit by car	BDL
12	2001	ML	Ad	No	None	BDL
14	2001	KS	Ad	No	Lead poisoning	BDL
28	2001	KS	Ad	No	Normal (trapped)	BDL (BDL)
31	2001	KH	Juv	No	Fell from nest	BDL
46	2002	KH	Juv	No	Fractured tibia	BDL
47	2002	KH	Juv	No	Intestinal foreign body	BDL
49	2002	KF	Ad	No	None	BDL
50	2002	ML	Juv	No	None	BDL
51	2002	KH	Juv	No	None	BDL
52	2002	ML	Juv	No	None	BDL
58	2002	ML	Ad	No	Organophosphate	BDL (BDL)

BDL indicates 'below detection limit' of diclofenac assay (0.005–0.01 μg g^{-1}). Results in parentheses are from the Toxicology Laboratory at the University of Pennsylvania New Bolton Center, which were performed as independent verification. This additional testing also did not detect acetaminophen (0.05), flunixin (0.05), ibuprofen (0.50), phenylbutazone (0.10), oxyphenylbutazone (0.05), indomethacin (0.05), ketoprofen (0.25), mefenamic acid (0.50), salicylic acid (1.0), tolmetin (0.05), or naproxen (1.0) (detection limits, in parentheses, are in μg g^{-1}). Ad, adult; CW, Chichawatni; Juv, juvenile; KF, Katora Forest; KH, Khanewal district study site; KS, Kasur district study site; LH, City of Lahore; ML, Muzaffargarh–Layyah district study site.

Vulture Presence, Health, & Livestock Census Data

Vulture Habitat Ranges

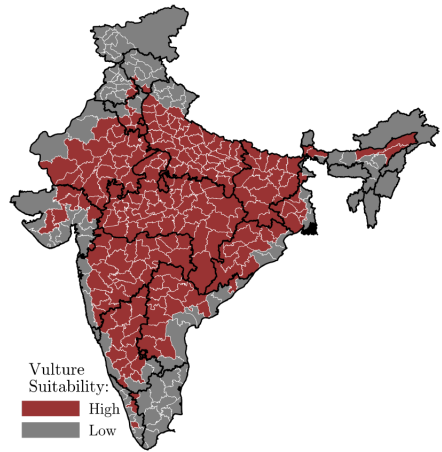
Maps from BirdLife International

Intersection with 1982 districts

Compute overlap between the range map and the districts

Issue of measurement error

Would be cool to test their approach with observed counts of birds



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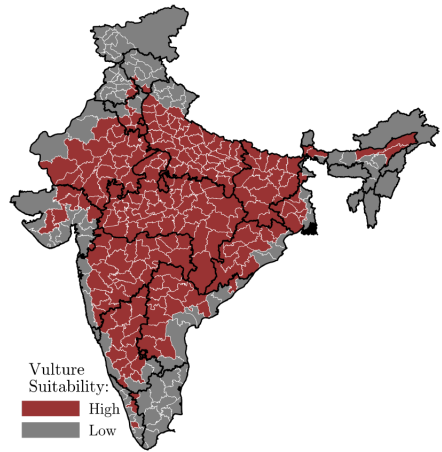

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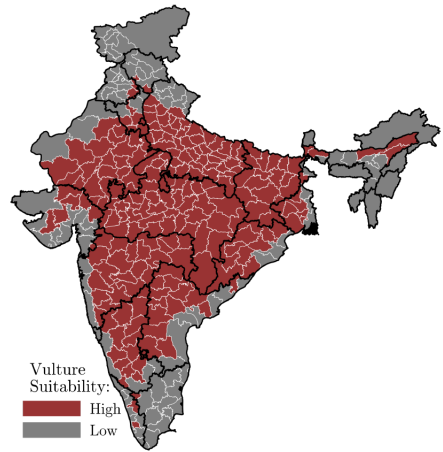

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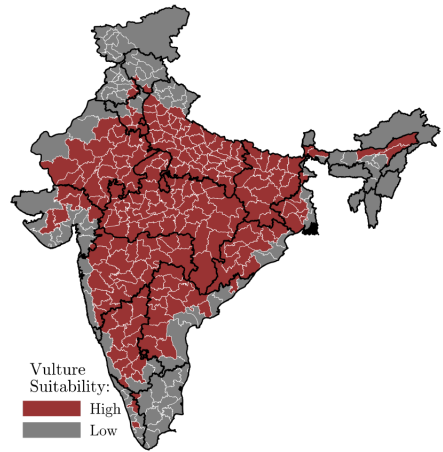

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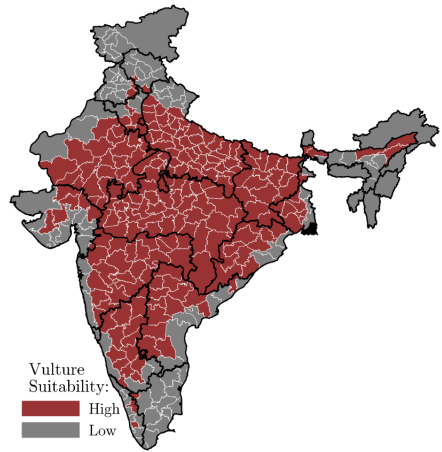

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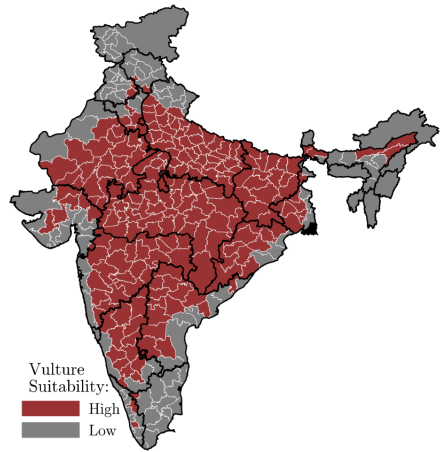
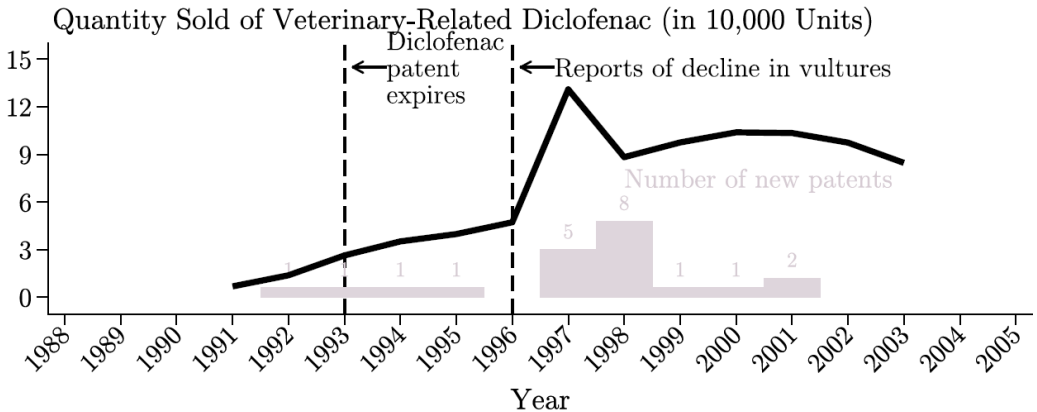
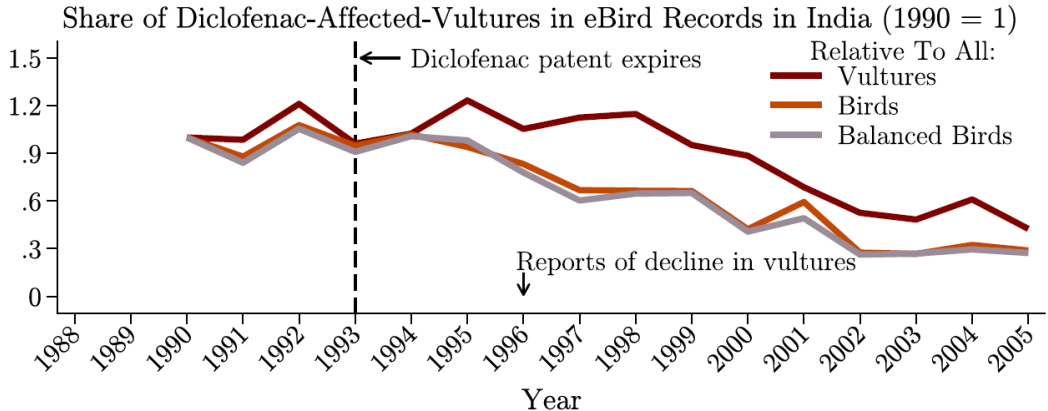


Sales & Product Entry of Pharmaceuticals



Observation Records of Bird Species



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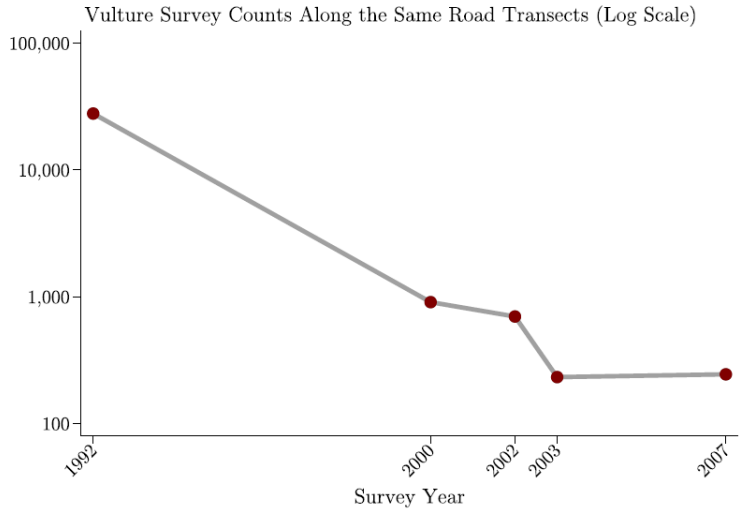
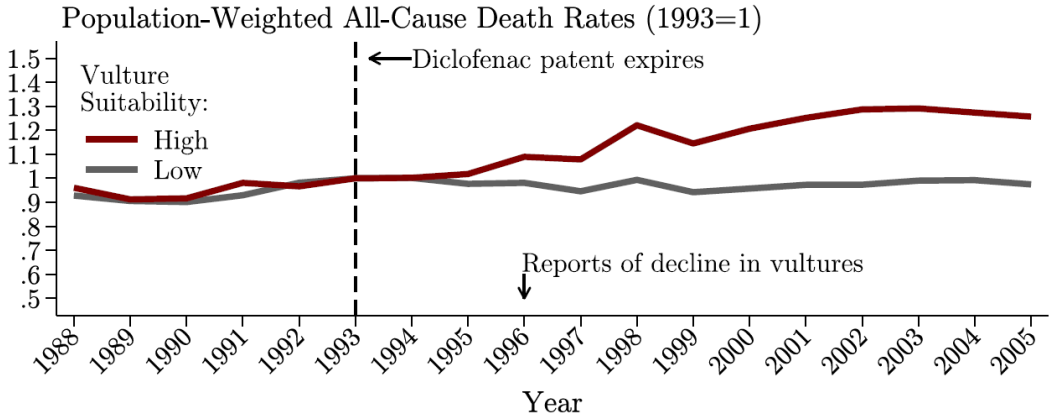


Health Outcomes



Livestock Census

Number of dogs recorded at the district level in 2012

Test for an increase in feral dog population

Proxy for an increase in mammalian scavengers such as dogs and rats

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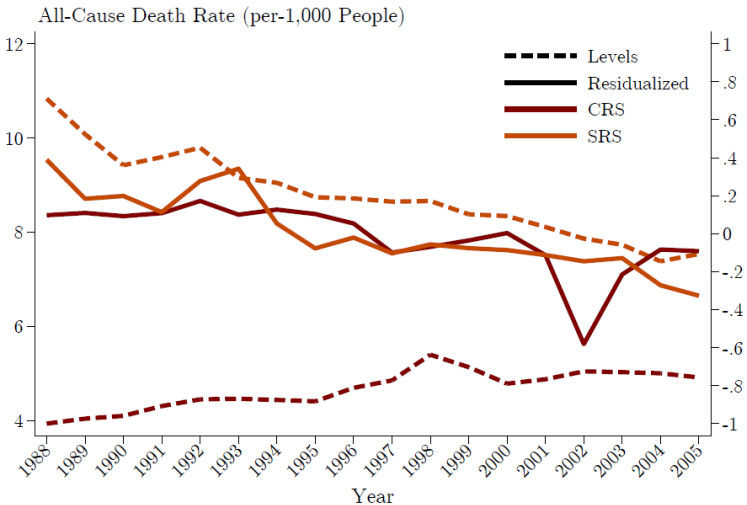
Quantifying Under-Reporting in the CRS Data



Sample Size

2,754 observations

135 clusters

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The Collapse of Vultures in India as a Natural Experiment

Assumptions

1. Vulture populations were in equilibrium prior to the onset of diclofenac use
2. Diclofenac use was not restricted only to the areas with high suitability for diclofenac-affected vultures
3. Districts would have seen their health outcomes develop along parallel trends in the absence of the collapse in vulture population

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Assumptions

1. Vulture populations were in equilibrium prior to the onset of diclofenac use
2. Diclofenac use was not restricted only to the areas with high suitability for diclofenac-affected vultures
3. Districts would have seen their health outcomes develop along parallel trends in the absence of the collapse in vulture population

Differences in Observables Prior to Treament

	(1) Group Means	(2)	(3) Difference	(4) N
	Low Vulture Suitability	High Vulture Suitability		
Death Rate, per-1,000 people (1988-1993)	5.3	4.2	-1.2	153
	(1.8)	(1.8)	(.32)	
Degree Days Above 30°C (1988-1993)	54	66	12	153
	(43)	(35)	(6.8)	
Precipitation in mm-km^{-2} (1988-1993)	.25	.12	-.12	153
	(.42)	(.18)	(.044)	
Number of Livestock (1987, 1992)	1,632	1,615	-17	138
	(874)	(731)	(158)	
Log(Dissolved Oxygen) (1988-1993)	1.9	1.9	.0045	95
	(.18)	(.27)	(.047)	
Log(Fecal Coliform) (1988-1993)	7.2	7.4	.25	76
	(2.2)	(1.7)	(.48)	
Pop. Share [1, 24] (1991)	.43	.51	.086	142
	(.14)	(.08)	(.023)	
Pop. Share [25. 54] (1991)	.3	.33	.028	142
	(.095)	(.058)	(.016)	
Pop. share [55, 100] (1991)	.085	.088	.0034	142
	(.029)	(.018)	(.0048)	
Share Literate (1991)	.55	.41	-.14	140
	(.13)	(.12)	(.022)	
Water Taps per-100,000 People (1991)	12	13	.84	141
	(28)	(21)	(2.8)	
Water Wells per-100,000 People (1991)	24	57	33	141
	(25)	(42)	(6.1)	
Hospitals & Health Centers per-100,000 People (1991)	1.7	2.4	.66	141
	(1.7)	(2.5)	(.35)	
Doctors & Health Workers per-100,000 People (1991)	8.6	9.8	1.2	141
	(7.6)	(8.6)	(1.6)	

Differences-In-Differences Design

$$y_{daszt} = \sum_{\substack{\tau \in \{\underline{T}, \ldots, \bar{T}\} \\ \tau \neq 1993}} \beta_\tau (\text{High Vulture Suitability})_d \times \mathbb{1}\{t = \tau\} + \lambda_{da} + \delta_{dz} + \mathbf{X}_{daszt}\theta + \epsilon_{daszt}$$

Differences-In-Differences Design

$$y_{daszt} = \beta_\tau(\text{High Vulture Suitability})_d \times (\text{Post-Diclofenac Use})_t + \lambda_{da} + \delta_{dz} + \mathbf{X}_{daszt}\theta + \epsilon_{daszt}$$

Utilizing Sub-Groups in a Triple-Differences Design

$$y_{daszt} = \beta_\tau(\text{High Vulture Suitability})_d \times (\text{Post-Diclofenac Use})_t + (\text{Sub Group})_d + \lambda_{da} + \delta_{dz} + \mathbf{X}_{daszt}\theta + \epsilon_{daszt}$$

The Consequences of Vulture Die-offs on Human Health

Results for All-Cause Death Rate

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An average increase in 0.85 deaths per-1,000 people

Equivalent to an average 9.2% relative increase in mortality

95% CI: (5.8, 12.6)

By 2005, the difference is 15%!

What are your thoughts on the magnitude of estimates?

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If true effect size is equal a 5% increase, power is 90%

If true effect size is equal a 3% increase, power is 44% and Type-M error is 1.5

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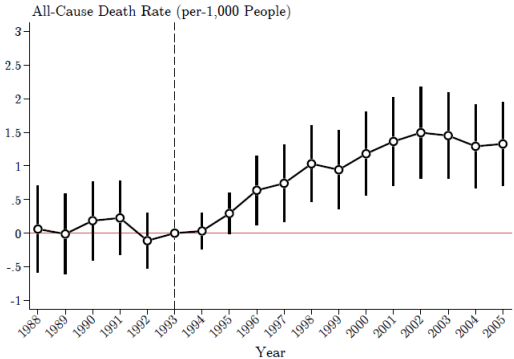

Urban areas experienced an earlier increase in death rates relative to rural areas

Making Sense of Estimates Sizes

An additional hot day, above 34°C, relative to the reference category of 22°C to 24°C, results in close to **0.2** additional deaths per-1,000 deaths

Equivalent to a relative increase of **2.2%**

Decline in vultures is comparable to a week-long heatwave in India

Perhaps better to compare to water-related policies with long-term impacts

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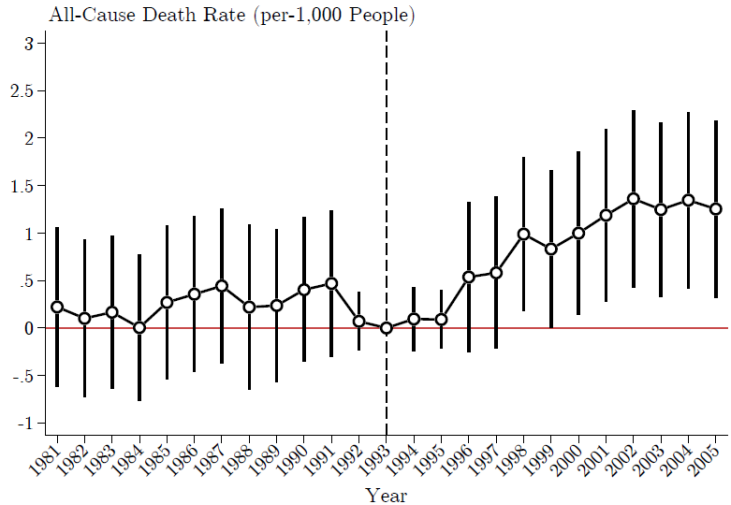
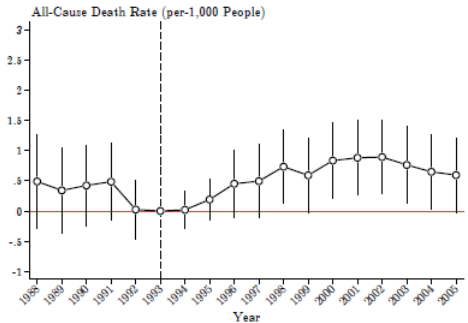
Sensitivity Analysis & Robustness Checks

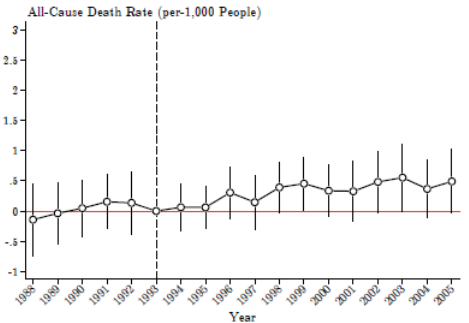


Sensitivity Analysis & Robustness Checks

(a) State-Linear Time Trends



(b) State-by-Year Fixed Effects



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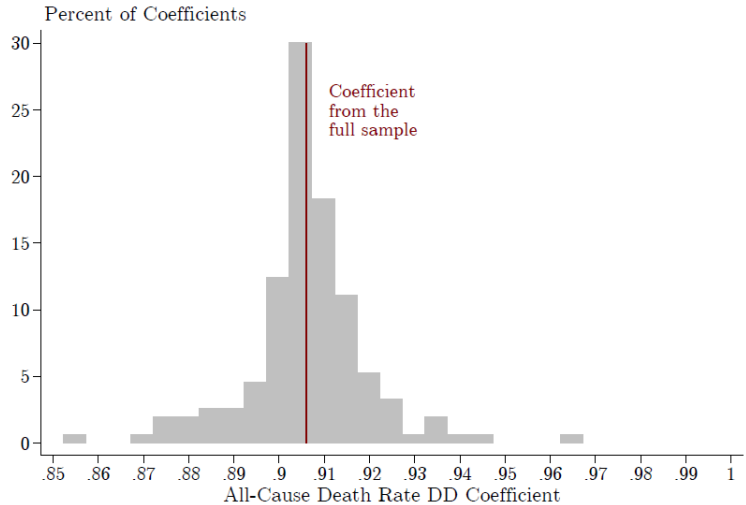

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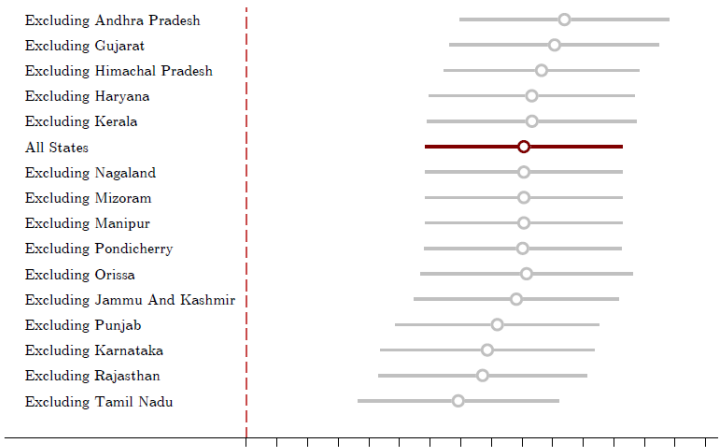
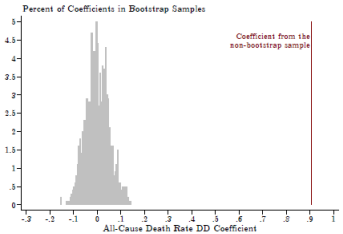
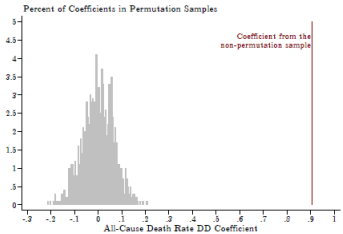


Sensitivity Analysis & Robustness Checks

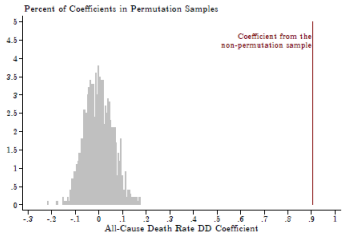
(a) Full



(b) Block



(c) Within



Differential Impacts in Urban Areas & High Livestock Districts

Find a larger increase of 0.91 deaths relative to 0.79 deaths in urban relative to rural areas

Find that following the collapse in vulture populations, high-vulture-suitability districts that had a high level of livestock at baseline saw an increase of 0.73 deaths per-1,000 people

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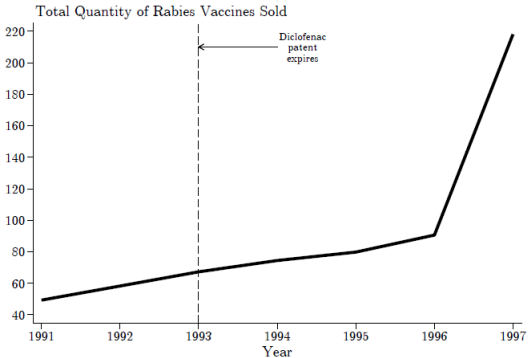
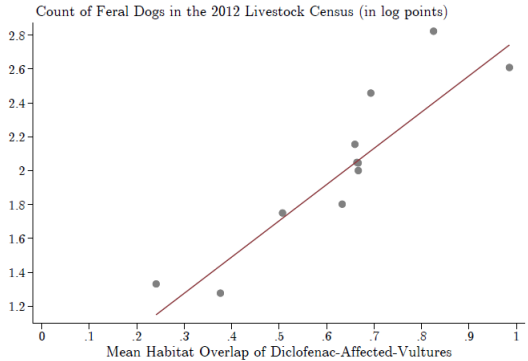
Suggestive Evidence For Increasing Dogs, Rabies & Degraded Water Quality





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Water quality deteriorates, but only in the urban subsample

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Fecal coliforms more than double in water samples in either the DDD or DD comparison

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Impressive detective work *à la* John Snow (1855)

Refrain from using the NHST language

Relatively neat graphs for econ

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