Hog production and Surface Water Quality: Evidence from the Foot-and-Mouth Disease Outbreak in Taiwan

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Introduction

- Increasingly concentrated livestock production has raised environmental and public health concerns
- Limited literature establishing the causal link between concentrated livestock facilities and negative environmental quality
  - Sneeringer (2009; 2010); Raff and Meyer (2021)
  - Most rely on variation in the number of livestock facilities
- Little evidence on effectiveness of regulating livestock facilities
  - Federal/state water pollution regulations: Chen et al. (2022); Skidmore et al. (2022)
  - California Proposition 12 seeks to ban concentrating feeding
- 1997 Foot-and-Mouth Disease (FMD) outbreak in Taiwan provides a quasi-experiment to examine how concentrating feeding affects surface water quality
  - Plausibly exogenous shock in hog production

Research Question

- **Does less concentrated livestock production as a result of the 1997 FMD outbreak benefit nearby water quality?**

Background

- Taiwan was a major hog country prior to the 1997 FMD outbreak
  - More than 10 million heads prior to FMD
  - Highly concentrated in the southwestern part of the country
- FMD affects primarily livestock animals (not zoonotic)
- FMD outbreak between March and July 1997 wiped out more than 3 million pigs

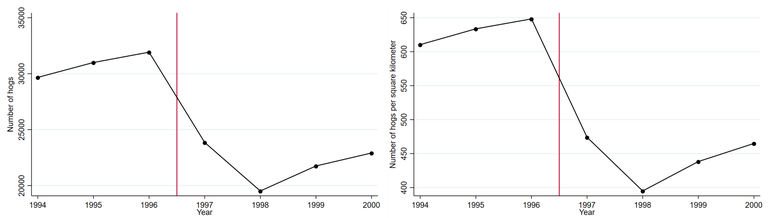

Figure 1. Township average number of pigs (left) and number of pigs/km^2 (right)

Data

- Hog production (NAIF and the Council of Agriculture of Taiwan)
  - Biannual survey on farm-level hog inventory; township level
- Surface water quality (Taiwan EPA)
  - Water quality test conducted once a month; lat/long
- Weather controls (Central Weather Bureau)
  - Monthly IDW average precipitation and temperature; township level

Table 1. Summary statistics

	Pre-outbreak			Post-outbreak			Mean difference
	N	Mean	SD	N	Mean	SD	(Post - Pre)
Water quality measures							
Ammonia	6,738	4.06	13.23	7,795	3.01	7.25	-1.05
Biochemical oxygen demand (BOD)	6,745	8.08	18.23	7,795	5.94	10.81	-2.14
Chemical oxygen demand (COD)	4,578	36.37	58.75	5,404	27.76	43.44	-8.61
Control variables							
Monthly mean precipitation (°C)	6,782	4.76	5.24	7,853	5.89	6.45	1.13
Monthly mean temperature (cm)	6,782	21.86	4.92	7,853	23.32	4.26	1.46

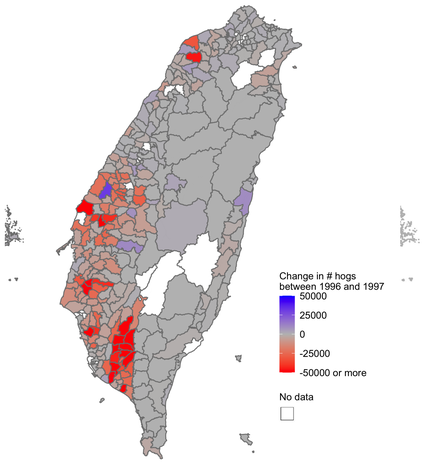

Figure 2. Change in hog production by town, 1994 to 2000

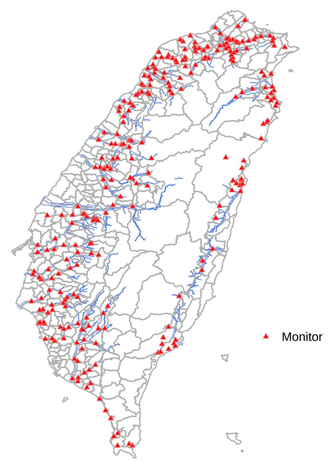

Figure 3. Water quality monitors

Research Design

Difference-in-Differences with continuous treatment

For monitor i in town j on year y, month-of-year m, and day-of-month d:

$$\ln(Y_{ijymd}) = \beta P_j \times FMD_t + \boldsymbol{X'_{jym}\delta} + \eta_i + \eta_y + \eta_m + \varepsilon_{ijymd}$$

Y = Monitor-level water quality reading (Ammonia; BOD; COD)

P = Treatment variable at township level

1. Reduction in the number of hogs (10,000) between 1996 and 1998
2. Reduction in hog density (100 hogs/km^2) between 1996 and 1998

FMD = Post-FMD indicator

$\boldsymbol{X}$ = Weighted average precipitation and temperature at township level

$\eta_{i,y,m}$ = Spatial (monitor) and temporal (year, month) FEs

Preliminary Results

Table 2. Effects of hog production on water quality

	ln(Ammonia)	ln(BOD)	ln(COD)
Panel A: Treatment = Δ number of hogs (10,000)			
FMD	-0.073***	-0.034***	-0.024**
	(0.024)	(0.009)	(0.010)
Adjusted R-squared	0.736	0.674	0.634
Observations	13,205	13,246	8,894
Panel B: Treatment = Δ hog density (100 hogs/km^2)			
FMD	-0.060***	-0.026***	-0.016**
	(0.014)	(0.007)	(0.007)
Adjusted R-squared	0.737	0.674	0.634
Observations	13,205	13,246	8,894
Town FEs	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes
Month-of-year FEs	Yes	Yes	Yes
Control variables	Yes	Yes	Yes

Note: Standard errors in parentheses are clustered at the town level. * p < 0.10, ** p < 0.05, ***p < 0.01.

Discussion/Future Work

- 1997 FMD outbreak that decreased concentrated production led to improved water pollution from hog operations
- Will test whether ambient air quality also improved after FMD
- Will test causal link between heath outcomes and FMD
  - Explore air and water quality improvement as the mechanism
- Results will add insights to the design of environmental regulations