The Long-Run Environmental Consequences of Land Development

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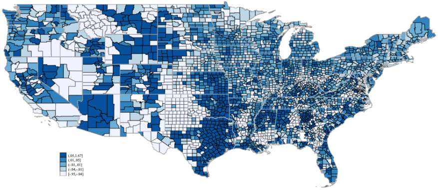
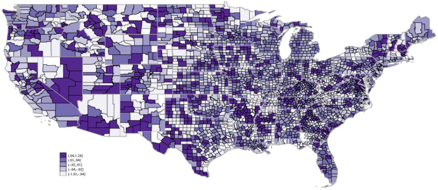
Introduction

- **Land underpins various facets of economic growth**
  - Grether and Mieszkowski (1980), Holmes (1998), Galor and Weil (2000), Deininger and Feder (2001), Plantinga et al. (2002), Kline and Moretti (2014), Kurvinen and Vihola (2016)
- **However, land development is costly**
  - Short run: Land acquisition cost, construction cost
    Ding (2007), Burchell and Listokin (2012), Chakravorty (2013), Danso and Manu (2013), Qian (2015), Tarmizi et al. (2017)
  - Long run: environmental cost, e.g. redrawing flood zones in response to land development (Pralle, 2019)
- **Our paper**
  - Provides a first measure of the environmental cost associated with land development
  - Documents and rationalizes uneven distribution of land development and its environmental cost across social demographics

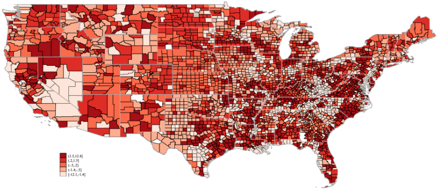
Motivating Evidence



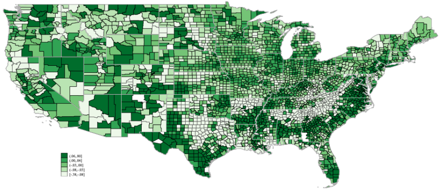
(a) Change in Developed Land



(b) Change in Job Access



(c) Change in Flood Claims



(d) Minority Share

Preview of Findings

- Estimate the long-run environmental cost of land development
  - A significant positive effect that is progressive over longer horizons
  - Primarily driven by developed land sourced from treeland and cropland, and in areas with high initial development conditions
  - Estimated lifetime cost is $2.59B in total
- Document the uneven distribution of land development and its environmental cost across races
  - Estimated cost is $5,837 per hectare in areas in the top quartile by minority proportion, roughly 69 times higher than areas in the lowest quartile.
- Rationalize the disproportionately higher cost of land development born by minorities
  - Land development generates job benefits and brings climate costs
  - Benefits are enjoyed by residents who live in local and also nearby neighborhoods
  - Climate costs suffered by local residents, with no evidence of spillover effects

Data

- NFIP Flood Damage
  - \$1.28T insurance in force (5 million policies)
  - \$20.5B outstanding debt with Treasury
  - Over 2,000,000 claims, providing location and claim amount information
  - Total NFIP claims increased from \$1.03B to \$5.03B from 2001 to 2016
- USGS's LCMAP Data
  - Provides annually land cover information at the 30m $\times$ 30m pixel level
  - Developed, cropland, grass/shrub (grassland), treeland, water, wetland, ice/snow, and barren
- The adoption of RTW laws at the state level during the sample period
- Demographic characteristics at the zip code level from Census

Data

- FHFA House Price Index Data
  - A repeat-sales index of single-family house prices
  - At 5-digit zip code-by-year level, available for around 17k zip codes
- Precipitation Data
  - PRISM Climate Group from Oregon State University
  - Provide monthly precipitation observations with longitude and latitude information
- Employment Data
  - Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics (LODES) from Census
  - Residence Area Characteristics (RAC): the number of jobs as defined in residence areas

2SLS Regression

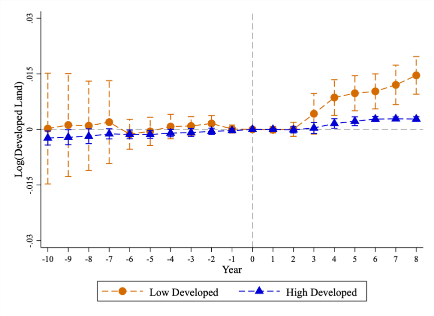
- Use 2SLS approach and leverage state differences in the adoption of RTW law and local initial conditions as IVs

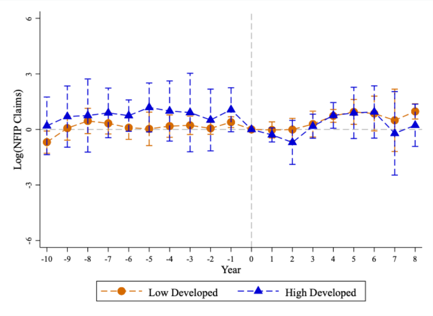
$$\text{Log}(\text{FD}_{i,t}) = \beta \cdot \widehat{Log(Dev_{i,t})} + \theta \cdot Log(X_{i,t}) + \mu_{s,t} + \varepsilon_{i,t}$$

  - $Log(FD_{i,t})$ and $Log(Dev_{i,t})$: log of flood damage and developed land in zip code i in year t. $Log(Dev_{i,t})$ is instrumented with the interaction of $I(\text{Post RTW}_{i,t})$ that varies by state and year, and initial development condition at the zip code level.
  - RTW is one of the signature pro-business laws. It often comes with other pro-business policies aimed at attracting businesses.
  - While RTW law adoption affects the state-wide economic incentives of land development, its effect is also determined by the development conditions and land availability prior to the law.
  - $Log(X_{i,t})$: log of housing units, housing value, income, population, and CRS

2SLS Regression

Statewide adoption of RTW law × Local initial development conditions





- Z is highly predictive of X, but does not affect Y directly.

2SLS Regression

Dep Var	Log(FD)		
Sample	Full	RTW Subsample	
Specification	OLS	OLS	IV
	(1)	(2)	(3)
Log(Dev)	0.545***	0.506***	1.640*
	(0.047)	(0.079)	(0.841)
Zip Code Covariates	Yes	Yes	Yes
State $\times$ Year FE	Yes		
State FE		Yes	Yes
State Pair $\times$ Relative Year FE		Yes	Yes
N	501,657	275,443	275,443
adj. R-sq	0.333	0.204	0.152

- This result suggests that an increase in land development has a causally positive effect on the change in flood risk.

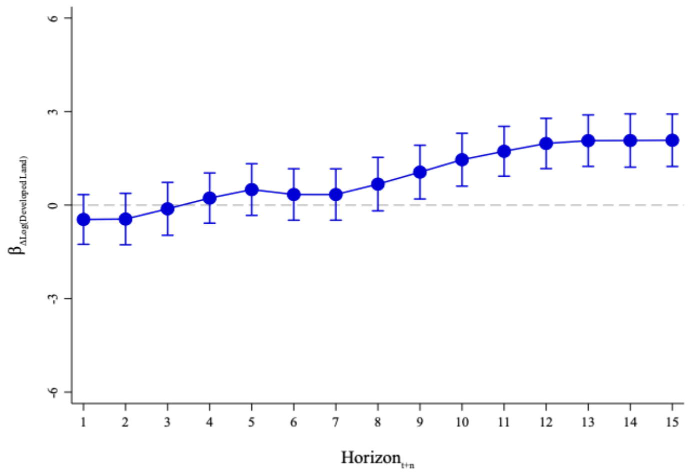
Dynamic Patterns

- Estimate the temporal variation in the effect of land development over different horizons
- Use stacked long differences (LD) and control for state-by-cohort year fixed effects and various zip code-level covariates

$$\Delta Log(FD_{i,t_0+n}) = \beta \cdot \Delta Log(Dev_{i,t_0+n}) + \theta \cdot \Delta Log(X_{i,t_0+n}) + \mu_{s,t_0} + \varepsilon_{i,t_0+n}$$

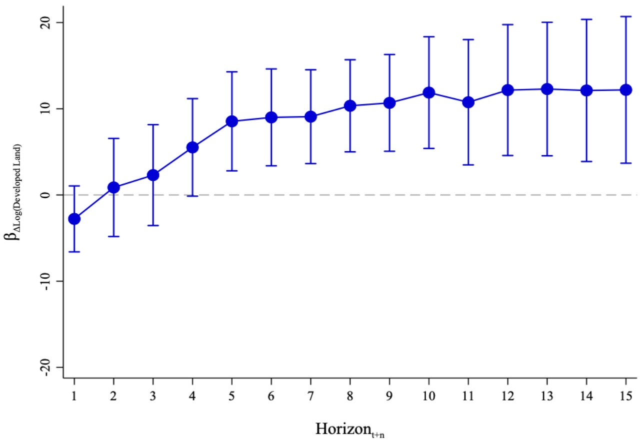
  - $\Delta Log(FD_{i,t_0+n})$ and $\Delta Log(Dev_{i,t_0+n})$: log change of flood damage and developed land over an n-year ($n = 1, 2, \ldots, 15$) horizon
  - $\Delta Log(X_{i,t_0+n})$: log change of housing units, housing value, income, population, and CRS
  - μ_{s,t_0}: state $\times$ cohort year fixed effects
  - Standard errors are clustered at the county level

LD Results Based on Full Sample



- Land development is associated with a significant increase in flood damage in the long term. The relationship is steadily increasing.

Alternative Measure: SHELDUS Hazard Losses



- SHELDUS is a county-level hazard data set and is not biased by insurance coverage rate.

Alternative Measure: NC Inundation Map

- Distinguish damage effect and climate change effect
- NC OneMap data
  - Provide an estimate of flood extent following Hurricane Matthew (2016) and Florence (2018) across the Piedmont and Coastal Plain of North Carolina
  - Each pixel will be denoted as "non-flooded" or "flooded"
- Calculate the percentage change in flooded areas in each zip code between 2016 and 2018 and run the 2-year LD regression

Dep Var	ΔLog(Flooded area)
ΔLog(Dev)	2.919*
	(1.492)
Zip Code Covariates	Yes

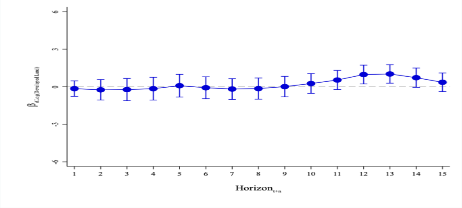
Land Development Sources

	ΔLog(FD)							$X\beta \times 100$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔLog(Dev)	2.080***	2.014***	1.993***	2.094***				
	(0.512)	(0.490)	(0.490)	(0.505)				
ΔLog(Dev from Wetland)					3.361	4.454	4.827	0.411
					(4.200)	(4.198)	(4.233)	
ΔLog(Dev from Cropland)					4.133***	4.024***	4.309***	5.602
					(1.038)	(1.022)	(1.030)	
ΔLog(Dev from Treeland)					3.076**	3.013**	3.578***	5.921
					(1.373)	(1.369)	(1.374)	
ΔLog(Dev from Grassland)					-0.186	-0.176	-0.262	0.009
					(0.757)	(0.761)	(0.759)	
ΔLog(Dev from Water)					-1.010	-1.946	-1.012	-0.001
					(4.324)	(4.292)	(4.204)	
ΔLog(Dev from Barren)					2.755	2.254	1.141	0.278
					(3.088)	(3.171)	(2.944)	
ΔLog(Non-Dev)		Yes						
ΔLog(Wetland)			Yes	Yes		Yes	Yes	
ΔLog(Other Land uses)				Yes			Yes	
	Full Sample; Other Controls							

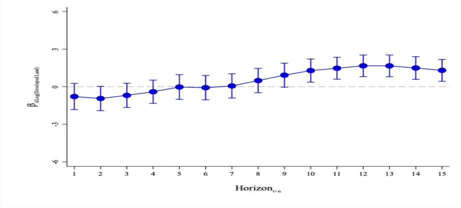
- Land developed from treeland and cropland is associated with an increase in flood risk.

Initial Development Conditions

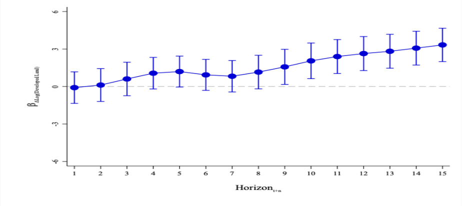
Low



Medium



High



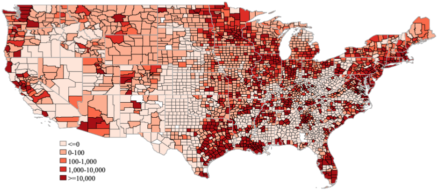
- Land development in areas with high initial developed land conditions is associated with the highest flood cost.

Estimate Environmental Cost of Land Development

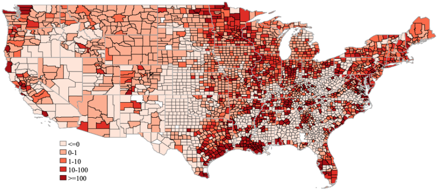
Dep Var	ΔLog(FD)$_{i,t_0+15}$		
	Initial Conditions		
	Low	Medium	High
ΔLog(Dev: Cropland)$_{i,t_0+15}$	1.512	2.595**	5.892***
	(1.011)	(1.097)	(1.434)
ΔLog(Dev: Treeland)$_{i,t_0+15}$	0.031	0.385	6.170***
	(1.754)	(1.912)	(1.674)
ΔLog(Dev: Other)$_{i,t_0+15}$	-0.414	0.696	-0.961
	(0.503)	(0.724)	(1.420)
Zip Code Covariates	Yes		
State $\times$ Year FE	Yes		

- Estimated cost of land development:
  - Lifetime: $2.59B in total, accounting for 15% of the total actual $\Delta(FD)$
  - $2,164 per hectare, accounting for 22% of the market value of land

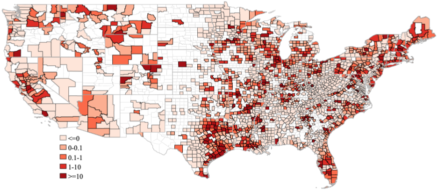
Spatial Distribution



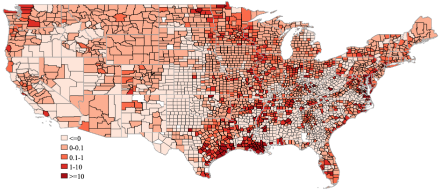
(a) Total Estimated Cost ($)



(b) Estimated Cost Per Hectare ($)



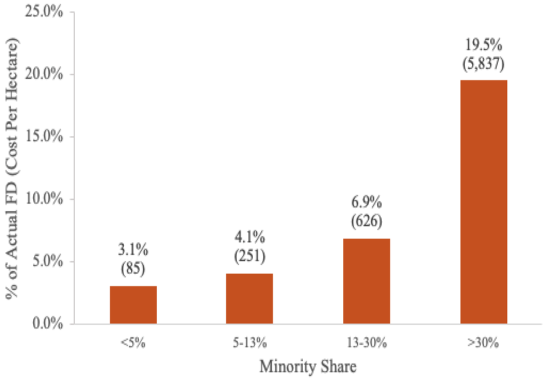
(c) Estimated Cost as % of Actual ΔFD



(d) Estimated Cost as % of Land Value

- Most of the flood cost is spatially concentrated in a few hotspots.

Demographic Distribution



- The lifetime flood cost is disproportionately higher in areas with a higher minority share.

Hedonic Analysis

- Rationalize the uneven distribution of land development and flood costs
- As land development is associated with expected changes in benefits and costs, it will affect the price of properties by changing the hedonic value in the location.
- Hedonic analysis: quantify the tradeoff local residents face between the (job) benefits of land development and (climate) cost of land development
  - 5-year LD, using the changes during 2001-2006 and 2014-2019 (excluding the GFC period)
  - "Bartik" (1991) type shocks: leverage variation in local housing demand shocks that are uncorrelated with supply factors

Bartik Instrument

- The Bartik-type shocks are constructed by interacting cross-sectional differences in industrial employment composition with national changes in industry employment levels, which can be written as follows

$$Bartik_{i,k,t_0+n} = \frac{L_{i,k,t_0}}{\sum_k L_{i,k,t_0}} [ln(E_{-i,k,t_0+n}) - ln(E_{-i,k,t_0})]$$

  - $L_{i,k,t}$: the number of jobs in zip code i in industry k in year t
  - $E_{-i,k,t}$: the national total number of jobs in industry k in year t excluding zip code i and zip codes within 50 miles

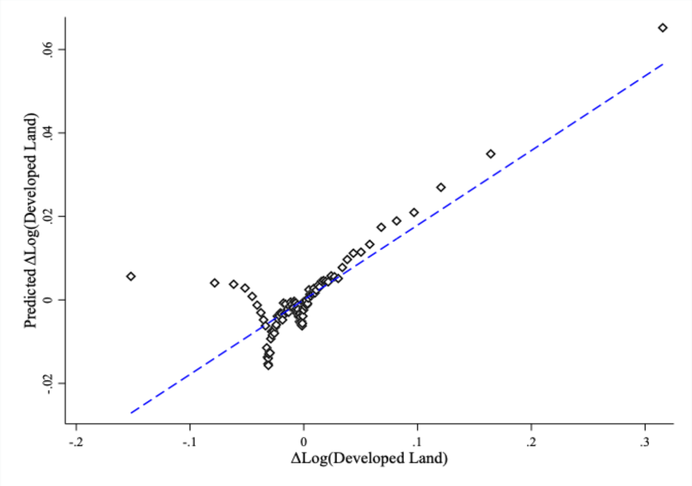
First Stage Estimation

- We get $\Delta \widehat{Log(Dev_{i,t_0+n}})$ by estimating

$$\Delta Log(Dev_{i,t_0+n}) = \sum_k \beta_k Bartik_{i,k,t_0+n} + \theta \cdot \Delta Log(X_{i,t_0+n}) + \mu_i + \lambda_{t_0} + \varepsilon_{it_0}$$

  - $\Delta Log(X_{i,t_0+n})$: log change of income and population
  - μ_i, λ_{t_0}: zip code and year fixed effects
  - We allow each industry to have a separate coefficient for developed land change considering different land intensities across industries.

First Stage Estimation



- Bartick shocks predict land development changes well.

Hedonic Analysis

$$
\begin{aligned}
\Delta Log(HPI_{i,t_0+n}) = & \sum_q \beta_{1,q} \cdot \Delta Log\widehat{(Dev_{i,t_0+n,q})} \\
& + \sum_q \beta_{2,q} \cdot \Delta Log\widehat{(Dev_{i,t_0+n,q})} \cdot \Delta Log(HPP_{i,t_0+n,q}) \\
& + \theta \cdot \Delta Log(X_{i,t_0+n}) + \mu_{c,t_0} + \varepsilon_{i,t_0+n}
\end{aligned}
$$

- $\Delta Log(HPI_{i,t_0+n,q})$, $\Delta Log\widehat{(Dev_{i,t_0+n,q})}$ and $\Delta Log(HPP_{i,t_0+n,q})$: log change of HPI, predicted developed land and high precipitation over an n-year horizon in zip code i in neighborhood $q \in \{local, close, far\}$
- $\Delta Log(X_{i,t_0+n})$: log change of income, population, average precipitation and high precipitation
- μ_{c,t_0}: county $\times$ cohort year fixed effects
- Standard errors are clustered at the county level

Hedonic Analysis

	ΔLog(HPI)			
	(1)	(2)	(3)	(4)
$\Delta Log(Dev)$	-0.056***			
	(0.016)			
$\Delta\widehat{Log(Dev)}$ (Local)		1.739***	1.587***	1.711***
		(0.231)	(0.185)	(0.192)
$\Delta\widehat{Log(Dev)}$ (Close)				2.050***
				(0.522)
$\Delta\widehat{Log(Dev)}$ (Far)				0.393
				(0.453)
$\Delta\widehat{Log(Dev)} \times \Delta Log(HPP)$ (Local)			-0.313**	-0.319**
			(0.157)	(0.151)
$\Delta\widehat{Log(Dev)} \times \Delta Log(HPP)$ (Close)				3.701
				(3.719)
$\Delta\widehat{Log(Dev)} \times \Delta Log(HPP)$ (Far)				0.019
				(1.276)
Observations	31,858	31,858	31,858	31,858
Adjusted R-squared	0.865	0.870	0.870	0.871

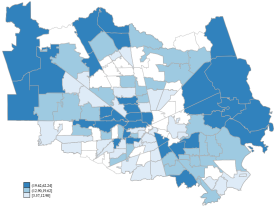
- Land development generates positive effects on housing prices by job access and negative effects on housing prices by flood cost.
- Benefit has a spillover effect while cost is more localized.

Hedonic Analysis

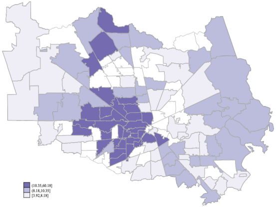
- The difference in spillover effects makes it feasible to strategically locate land development in nearby neighborhoods to enjoy the job benefits brought by land development (by commuting) without directly suffering from the environmental consequences.
- Interpretation and magnitude: Back-of-envelop estimation of the change in HPI using Harris, TX as an example (Greater Houston Area)

Back-of-Envelop Estimation (Houston, TX)

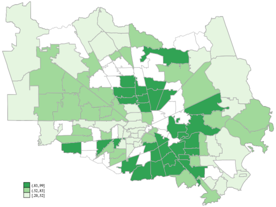
Benefit (Local)



Benefit (Close)



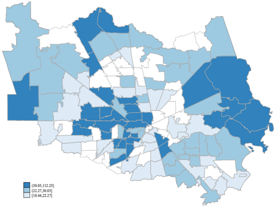
% of Minority



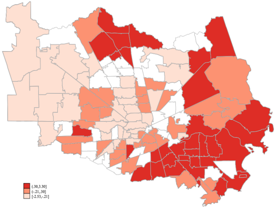
- Areas with higher minority shares do not have the advantage of enjoying the benefits, especially the spillover benefits from their nearby zip codes.

Back-of-Envelop Estimation (Houston, TX)

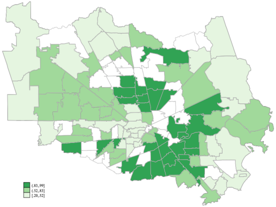
Benefit (Total)



Cost



% of Minority

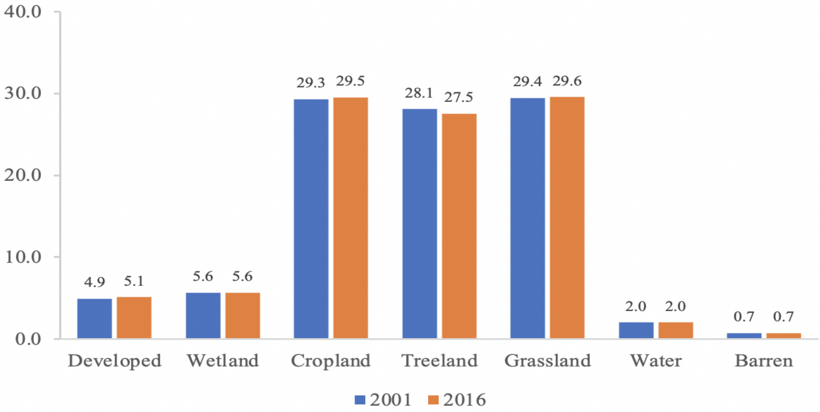


- Areas with higher minority shares do not have the advantage of enjoying the total benefits but tend to suffer more from the cost.

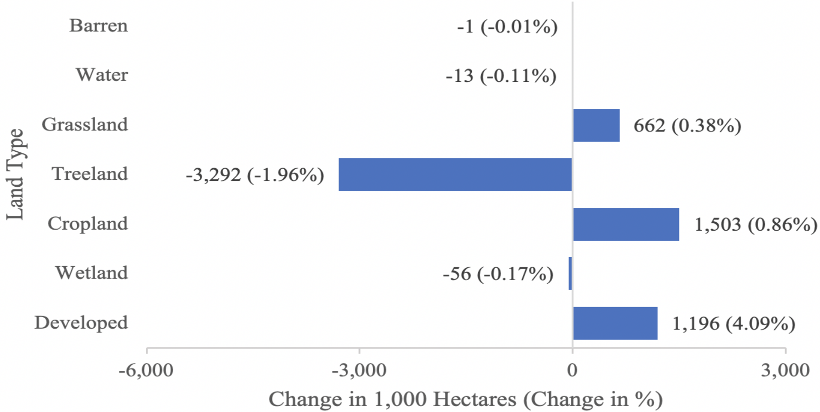
Conclusion

- Land development leads to a substantial increase in flood damage.
- There is substantial heterogeneity in this relationship across different sources of land development and initial development conditions.
- We quantify the lifetime flood cost of land development, which has been found to be unevenly borne across demographic groups.
- Hedonic analysis reveals that land development brings job benefits and climate costs. The benefit side shows spillover effects while the cost side is localized.

Appendix: Change in Land Covers



Appendix: Land Covers (%)



Appendix: Land Development Sources

% of Change in Developed Land (%)

Source of Developed Land	1-Year	5-Year	10-Year	15-Year
Dev: Wetland	2.43	2.64	2.78	2.62
Dev: Cropland	41.54	39.73	39.50	39.98
Dev: Treeland	47.07	52.80	61.26	50.89
Dev: Grassland	2.15	-3.15	-13.42	-1.02
Dev: Water	0.32	-0.01	-0.22	0.04
Dev: Barren Land	6.49	7.99	10.10	7.50
Total	100.00	100.00	100.00	100.00

- Treeland and cropland stand as the two predominant sources of developed land.

Appendix: Land Development by Initial Conditions

	Low	Medium	High
Initial Land Attributes			
Initial Developed Share (%)	3.45	17.30	42.90
Initial Density Index	826	1998	3813
NFIP			
FD_0 (\$)	19,504	68,687	273,419
FD Change (\$)	-5,309	-26,872	-78,222
FD Change (%)	-27.22	-39.12	-28.61
Change in Developed Land (ha)	2.56	16.81	81.80
% of Change in Developed Land (%)			
Dev: Wetland	12.88	5.64	1.73
Dev: Cropland	11.25	39.43	40.77
Dev: Treeland	214.64	80.61	40.69
Dev: Grassland	-171.22	-39.09	11.12
Dev: Water	-0.68	0.07	0.05
Dev: Barren Land	33.12	13.36	5.65
Total	100.00	100.00	100.00

- 80% of the land developed in the past decades is in zip codes with high initial conditions.

Appendix: Demographics

Independent Var	ΔLog (Dev)	Initial % of Cropland	Initial % of Treeland	Initial % of Other Non-Dev	Initial Conditions Medium	Initial Conditions High
	(1)	(2)	(3)	(4)	(5)	(6)
Demographics in 2000:						
% Minority of	-0.397***	-0.247***	-0.348***	-0.229***	0.041***	0.110***
	(0.041)	(0.019)	(0.017)	(0.021)	(0.005)	(0.009)
Demographics change between 2001-2016:						
Δ % of Minority	0.126***	-0.060***	-0.076***	-0.053***	0.017***	0.054***
	(0.014)	(0.005)	(0.005)	(0.009)	(0.001)	(0.002)

- Slower developed land growth rate in minority areas, but more minorities live in areas with high initial development conditions.
- Land development is associated with an increase in minorities, and areas with high initial conditions see more increase in minorities.