# Virtual Seminar on Climate Economics

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# Expecting Floods: Firm Entry, Employment, and Aggregate Implications


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# Introduction

- Floods: more frequent and severe with climate change
  - 13 million Americans lived within FEMA 100-year flood zone in 2018 (Federal Emergency Management Agency, FEMA)
  - floodplains are expected to grow by 45% by 2100
- Existing papers: individual and housing market responses to floods
- Less is known about impact of floods on firms and aggregate implication
  - less attention is paid to changes in flood risk
- We ask:
  - What is the impact of floods and flood risk on firms and workers?
  - How large is aggregate productivity impact of floods and flood risk?

# Empirically, increases in flood risk lower firm entry in the long run

- Data: FEMA flood zone maps in 1998 and 2018, Business Dynamic Statistics, and actual flood data from DFO
- **Long run:** Between 1998–2018, one std increase in a county's flood risk
  - reduces firm entry by 1.2% and reduces real GDP by 2.4%
  - leads to decrease in employment (1.2%) and population (0.8%)
- **Short run:** In contrast, annual occurrence of actual floods has very little impact on firm entry/exits and employment

# Why is impact of long-run change in flood risk larger?

- We develop a spatial model with firms and workers' long-run adjustments
- In response to changes in regions' flood risk:
  - firms decide entry; workers decide location & labor supply
- Occurrence of actual floods has direct damage on output, but does not affect firm entry and workers' choices — too short time to adjust
- Impact of increases in flood risk on output:
  - direct productivity impact due to more flood events
  - expectation channel through long-run adjustments: lower employment and firm entry ("love of variety")

# Quantitatively, we find that

1. Flood risk in 2018 cause a 0.52% decline in annual output
   - direct damage channel: 0.11%
   - employment channel: 0.33%; the variety channel: 0.08%
2. Larger regional heterogeneity: 7–14% loss in top 5% counties (such as Cape May and New Jersey)
3. Expected increase in flood risk btw 2020–50 cause 0.12% output loss
   - heterogeneity: 0.8–4.4% loss in top 5% counties

## Related literature

1. Aggregate impact of SLR: e.g. Balboni (2019), Desmet et al. (2021)

   Our contribution: 1) incorporate all types of flood risk rather than coastal floods; 2) we reconcile the quantitative analysis with reduced form evidence and examine endogenous labor supply

2. Empirical literature on the impact of natural disasters: e.g. Gallagher (2014), Hsiang and Jina (2014), Deryugina (2017), Hsiang et al. 2017, Kocornik-Mina et al. (2020)

   Our contribution: 1) we use national digitized historic flood zone maps; 2) show changes in flood risk can induce larger long-run consequences

3. Flood risk and housing/households: Hino and Burke (2021), Mulder (2021)

   Our contribution: we incorporate firm and employment margins both empirically and quantitatively

# Data

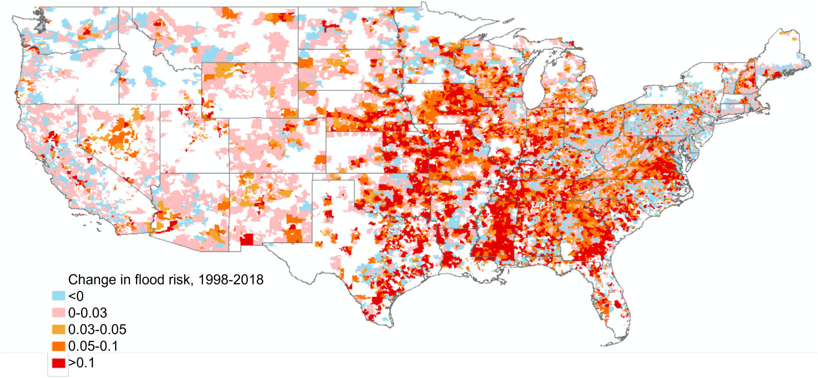
- Historic flood zone designation: Q3 (newly digitized)
  - corresponds to FEMA Flood Insurance Rate Map in 1998
  - available for 1368 counties in the U.S.
  - "Special Flood Hazard Areas" (SFHA) represent areas that will be inundated by flood event having 1-percent chance in any given year

- Current flood zone designation: National Flood Hazard Layer in 2018

- Additional data: flood risk projection (First Street Foundation), actual flood occurrence (DFO), spatial and climate variables (ERA5), county-level and zipcode-level data on firm dynamics, employment, demographics, etc.

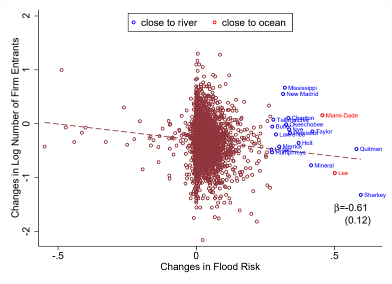
# Change in US flood risk: 1998 to 2018

Figure 1: Change in share of areas in 100-year FEMA flood zone

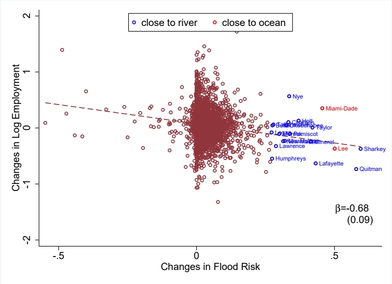



Regions are based on US ZIP Code

# Motivational evidence: Glance at the raw data




(a) Firm Entry




(b) Employment

## Empirical specification

$$lnY_{i,t} = \alpha + \beta_1 FloodRisk_{i,t} + \sigma_i + \gamma_{s,t} + X_{i,t} + \beta_2 ActualFlood_{i,t} + \varepsilon_{i,t}$$

- $Y_{i,t}$ is number of establishment entry (other outcomes)
- $Floodrisk_{i,t}$ is percentage of land area within 100-year floodplain in county $i$, year $t$
- $\sigma_i$: county fixed effects; $\gamma_{s,t}$: state-level business cycles.
- $X_i$: a rich set of economic, demographic, and geographic controls (e.g., manufacturing employment share, China import penetration)
- We also control for actual flood area $ActualFlood_{i,t}$
- Standard errors are clustered at the county level

# Long-run effects

Table 1: The Impact of Long Run Change in Flood Risk

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | log(Entry) | | log(Exit) | | log(Employment) | | log(Population) | | log(Output)[a] | |
| Flood risk | -0.172** | -0.173** | -0.119* | -0.119* | -0.171*** | -0.171*** | -0.114*** | -0.115*** | -0.337*** | -0.337*** |
| | (0.079) | (0.079) | (0.072) | (0.072) | (0.059) | (0.059) | (0.041) | (0.041) | (0.072) | (0.072) |
| Observations | 5188 | 5188 | 5174 | 5174 | 5280 | 5280 | 5282 | 5282 | 5222 | 5222 |
| County FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| State×Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| OtherControls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| ActualFlood | | Yes | | Yes | | Yes | | Yes | | Yes |
| ymean | 4.080 | 4.080 | 4.022 | 4.022 | 9.03 | 9.03 | 9.914 | 9.914 | 13.73 | 13.73 |

One std increase in a county's flood risk reduces firm entry by 1.2%, real GDP by 2.4%, employment by 1.2%, and population by 0.8%.

ZIP code level Q3 IV Placebo

# Long-run Effects: IV

Table 2: Change-on-Change Estimates

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Δlog(Entry) | | Δlog(Exit) | | Δlog(Employment) | | Δlog(Population) | | Δlog(Output) | |
| ΔFlood risk | -0.188** | -0.167** | -0.134* | -0.097 | -0.183*** | -0.193*** | -0.123*** | -0.136*** | -0.328*** | -0.308*** |
| | (0.080) | (0.085) | (0.073) | (0.079) | (0.060) | (0.065) | (0.042) | (0.053) | (0.070) | (0.074) |
| Observations | 2594 | 2593 | 2587 | 2586 | 2640 | 2639 | 2641 | 2640 | 2611 | 2610 |
| KP F stat | | 63 | | 66 | | 66 | | 65 | | 65 |
| State FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Other Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Cum. Floods | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Specification | OLS | IV | OLS | IV | OLS | IV | OLS | IV | OLS | IV |

- Bartik-style instruments: average change in flood risk in the rest of the state * own geo-climatic features
- Intuitively, this general change likely matters more for counties with certain geo-climatic conditions such as heavy rainfalls

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# Long-run Effects: Placebo for IV

Table 3: Change-on-Change Estimates, Placebo

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Δlog(Entry) | | Δlog(Exit) | | Δlog(Employment) | | Δlog(Population) | |
| ΔFlood risk | 0.001 | 0.088 | 0.063 | 0.072 | -0.049 | -0.026 | 0.079* | 0.031 |
| | (0.060) | (0.120) | (0.063) | (0.147) | (0.039) | (0.111) | (0.043) | (0.151) |
| Observations | 2607 | 1154 | 2613 | 1155 | 2643 | 1163 | 2644 | 1163 |
| State FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Other Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Flood Cumulative | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Sample | | Q3 | | Q3 | | Q3 | | Q3 |

- pre-trend test: flood risk changes from 1998-2018 on pre-period outcomes between 1990-1998 (Goldsmith-Pinkham et al. 2020)

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# Short-run effects

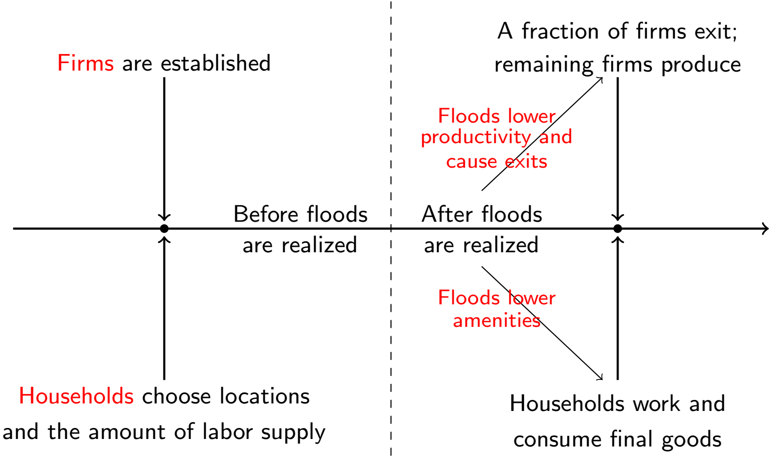
## Table 4: The Impact of Short Run Actual Floods

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | log(Entry) | | log(Exit) | | log(Employment) | | log(Population) | | log(Output) | |
| Flood share | 0.002 | 0.001 | 0.002 | 0.003 | -0.000 | -0.001 | 0.001*** | 0.001*** | -0.005*** | -0.005*** |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.001) | (0.001) | (0.000) | (0.000) | (0.002) | (0.002) |
| Observations | 51595 | 50782 | 51584 | 50931 | 53195 | 52666 | 53244 | 52683 | 52320 | 51816 |
| County FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| State×Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Initial Controls | | Yes | | Yes | | Yes | | Yes | | Yes |
| ymean | 4.018 | 4.036 | 3.979 | 3.991 | 8.864 | 8.870 | 9.816 | 9.825 | 13.66 | 13.67 |

Lagged Shocks

real gdp loss of -0.5% comparable to Kocornik-Mina et al. (2020)

# Overview of model setup




We model realization of floods with a set of possible states of nature $S = \{s_1, s_2, ...\}$—each associated with prob $\Pr(s)$ and specific flooding events.

# Production

- Each region $m$ produces a composite final good composed of varieties:

$$Y_m(s) = \left( \int_{\omega \in \Omega_m(s)} y(\omega, s)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}$$

  - $\Omega_m(s)$: the set of varieties produced in region $m$ and state $s$
  - we abstract from trade in baseline model

- Establishing a firm in region $m$ requires $f_m$ units of labor
  - each firm obtains a blueprint for a differentiated variety

## Firms' production

- Firms' production uses labor:

$$y_m(s) = A_m(s) l$$

  - $A_m(s) = \bar{A}_m \exp(-\delta \xi_m(s))$ ($\xi_m(s) = 1$ if floods occur)
  - portion $\kappa(s) = \bar{\kappa} \exp(\delta_\kappa \xi_m(s))$ of firms exit before production

- Firms are engaged in monopolistic competition

- Free entry requires that expected profits equal entry costs:

# Households

- Workers' utility function:

$$U_m(s) = v_m B_m(s) \left( c_m(s) l_m - \psi_m \frac{l_m^{1+1/\phi_L}}{1+1/\phi_L} \right),$$
$$s.t.\ P_m(s) c_m(s) \leq W_m(s).$$

  - location preferences $\{v_m\} \sim \text{i.i.d.}\, G(v) = \exp(-v^{-\phi_M})$
  - amenities $B_m(s) = \bar{B}_m^{1/\phi_M} \exp(-\eta \xi_m(s))$ with flood damage $\eta > 0$
  - $c_m(s)$ denotes expenditures per labor on final goods in state $s$

- Household chooses location and labor supply to maximize expected utility:

$$\max_{m, l_m} \sum_s \Pr(s) U_m(s)$$

## Regional responses to changes in flood risk

**Proposition.** Let $r_m = \sum_s \Pr(s)\xi_m(s)$ be the probability of floods occurring in region $m$. For a small region $m$, in response to a change in flood risk $dr_m$,

1. Changes in labor supply
$$d\hat{l}_m = -\phi_L \frac{\delta + \frac{1}{\sigma-1}\bar{\kappa}\delta_\kappa + \frac{1}{\sigma-1}\phi_M \eta}{1 - \frac{1}{\sigma-1}(\phi_L + (\phi_L+1)\phi_M)} dr_m.$$
2. Changes in population share
$$d\hat{\Lambda}_m = \phi_M \left[(1+1/\phi_L)d\hat{l}_m - \eta\, dr_m\right].$$
3. Changes in aggregate labor supply
$$d\hat{L}_m = d\hat{l}_m + d\hat{\Lambda}_m.$$
4. Changes in number of entry firms
$$d\widehat{\mathbb{E}N}_m = d\hat{L}_m - \bar{\kappa}\delta_k dr_m.$$
5. Changes in aggregate output
$$d\widehat{\mathbb{E}Y}_m = -\underbrace{\delta\, dr_m}_{\text{direct damage}} + \underbrace{d\hat{L}_m}_{\text{employment response}} + \underbrace{\frac{1}{\sigma-1} d\widehat{\mathbb{E}N}_m}_{\text{variety effects}}.$$

# Quantification

## Calibration procedure

- Several parameters directly from literature and data
- Internally calibrated parameters
  - method of moments: calibrate region-specific parameters
    $$\{\underbrace{\bar{A}_m}_{\text{productivity}}, \underbrace{\bar{B}_m}_{\text{amenity}}, \underbrace{\psi_m}_{\text{labor disutility}}, \underbrace{f_m}_{\text{entry costs}}\}$$
    to match regional GDP, population, employment, and firm count
  - indirect inference: discipline labor elasticities $\{\phi_L, \phi_M\}$ by reduced-form evidence on emp and pop responses to flood risk

# Exogenously calibrated parameters

| Parameter | Value | Sources |
|---|---|---|
| $M$—Number of counties | 2,772 | data |
| $\sigma$—Elast. of substitution across varieties | 5 | Head and Mayer (2014) |
| $\bar{\kappa}$—Constant in firm exit rates | 0.08 | data |
| $r_m$—Region-specific probability of floods | 0.18 (0.10) | data |
| $\delta$—GDP loss due to flooding events | 0.005 | see regression table |
| $\delta_k$—Firm exits due to flooding events | 0.003 | see regression table |
| $\eta$—Utility loss due to flooding events | 0.002 | Barrage (2020) |

Notes: Parameter values for $\{r_m\}$ are averages across all $M$ counties. The standard deviations are in parentheses.

## Internally calibrated parameters

| Parameter | Value | Targeted Moments |
|---|---|---|
| $\bar{A}_m$—Region-specific productivity | 2.40 (2.53) | regional real GDP |
| $\bar{B}_m$—Region-specific amenity | 0.41 (0.66) | regional population |
| $\psi_m$—Region-specific labor supply disutility | 0.35 (0.34) | regional emp-to-pop ratio |
| $f_m$—Region-specific firm entry costs | 0.09 (0.03) | regional firm count |
| $\phi_L$—Convexity of labor disutility | 1.55 | Emp and pop responses to flood risk |
| $\phi_M$—Shape param of loc preferences | 0.83 | |

Notes: Parameter values for $\{\bar{A}_m, \bar{B}_m, \psi_m, f_m\}$ are averages across all $M$ counties. The standard deviations are in parentheses.

- elasticity of regional population to real wages is $\phi_M(1+\phi_L) \approx 2.1$, within the range of 1.1–2.5 (mean 1.8) surveyed by Fajgelbaum et al. (2018)

# Comparison of actual and model-generated regression results

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | Targeted | | Non-targeted | | |
| | log(Emp) | log(Pop) | log(Output) | log(Entry) | log(Exit) |
| **Actual Data:** | | | | | |
| flood risk | -0.171*** | -0.114*** | -0.337*** | -0.173** | -0.119* |
| | (0.059) | (0.041) | (0.072) | (0.079) | (0.072) |
| **Model-generated Data:** | | | | | |
| flood risk | -0.176*** | -0.103*** | -0.182*** | -0.176*** | -0.174*** |
| | (0.003) | (0.002) | (0.003) | (0.003) | (0.003) |

Note: We perform the panel regression using the observed and model-generated data in 1998 and 2018.

# Counterfactual Exercises

# Aggregate effects of flood risk in 2018

*Panel A: Aggregate Effects*

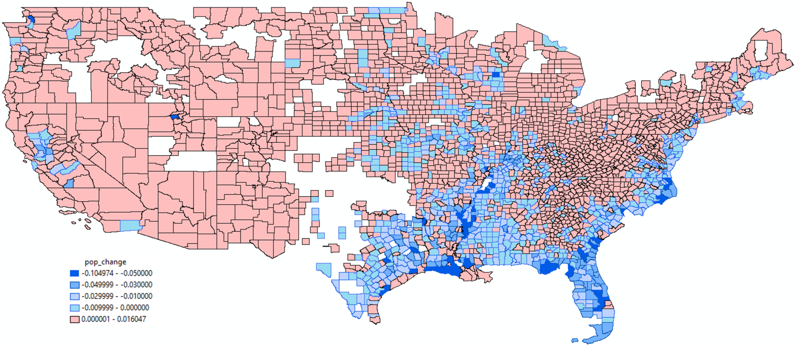
| | Output | Employment | Firm Entry | Firm Exits |
|---|---|---|---|---|
| Overall risks in 2018 | -0.52% | -0.31% | -0.30% | -0.24% |

*Panel B: Decomposition of Output Losses*

| | Decomposition of Output Losses | | | |
|---|---|---|---|---|
| | Direct Damage | Labor Relocation | Labor Supply | Variety Effects |
| Overall risks in 2018 | -0.11% | 0% | -0.33% | -0.08% |

- FEMA estimates cost of flood damage as approximately $17 billion annually between 2010–18 (Grimm 2020), representing roughly 0.1% of annual GDP.

# Distribution of population responses to floods across regions




As a result, there is large regional heterogeneity in output losses: 7% and 14% losses in top 5% and 1% counties

# Alternative model setup and quantitative results

| | Output | Employment | Firm Entry | Firm Exits |
|---|---|---|---|---|
| (1) Baseline model | -0.52% | -0.31% | -0.30% | -0.24% |
| (2) Entry costs in goods | -0.57% | -0.31% | -0.56% | -0.51% |
| (3) With interregional trade | -0.62% | -0.47% | -0.41% | -0.35% |
| (4) With capital & intermediate inputs | -0.67% | -0.38% | -0.36% | -0.31% |

# Impact of future changes in flood risk

- Use First Street Foundation's predicted flood risk in 2050
- On average, flood risk increase by 4.2% between 2020 and 2050 (increase by more than 14% in top 5% counties)

| *Panel A: Aggregate Effects* | | | | |
|---|---|---|---|---|
| | Output | Employment | Firm Entry | Firm Exits |
| Δ risks, 2020–2050 | -0.12% | -0.05% | -0.05% | -0.04% |
| *Panel B: Decomposition of Output Losses* | | | | |
| | Decomposition of Output Losses | | | |
| | Direct Damage | Labor Relocation | Labor Supply | Variety Effects |
| Δ risks, 2020–2050 | -0.014% | 0% | -0.086% | -0.024% |

Regional heterogeneity: 0.8% and 4.4% loss in top 5% and 1% counties

# Conclusion

- Increased flood risk has larger long-run impact whereas actual floods reduce output in the short run
  - only accounting for direct damages largely underestimates actual losses of natural disasters
  - firms and workers rationally change economic activities in long run
- Policy aiming to alleviate climate damages needs to take into account firms' and workers' long-run adjustments

Suggestions and feedback: wxie@scu.edu

## ZIP-Code-Level Results

### Table 5: The Impact of Long Run Change in Flood Risk

**Panel B: ZIP Code Level**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | log(Establishment) | | log(Employment) | | log(Payroll) | |
| Flood risk | -0.233*** | -0.234*** | -0.240*** | -0.242*** | -0.221*** | -0.223*** |
| | (0.040) | (0.040) | (0.066) | (0.066) | (0.072) | (0.072) |
| Observations | 43330 | 43330 | 41032 | 41032 | 41034 | 41034 |
| ZCTA FE | Yes | Yes | Yes | Yes | Yes | Yes |
| State×YearFE | Yes | Yes | Yes | Yes | Yes | Yes |
| OtherControls | Yes | Yes | Yes | Yes | Yes | Yes |
| ActualFlood | | Yes | | Yes | | Yes |
| ymean | 4.330 | 4.330 | 6.611 | 6.611 | 9.964 | 9.964 |

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# Long-run Effects: Q3 Only

Table 6: Fixed Effects Estimates, Q3

| | (1) log(Entry) | (2) log(Exit) | (3) log(Employment) | (4) log(Population) | (5) log(Output) |
|---|---|---|---|---|---|
| Flood risk | -0.357** | -0.217 | -0.333*** | -0.240** | -0.226* |
| | (0.150) | (0.159) | (0.115) | (0.104) | (0.130) |
| Observations | 2304 | 2298 | 2326 | 2326 | 2300 |
| County FE | Yes | Yes | Yes | Yes | Yes |
| State×Year | Yes | Yes | Yes | Yes | Yes |
| Other Controls | Yes | Yes | Yes | Yes | Yes |
| Flood Cumulative | Yes | Yes | Yes | Yes | Yes |

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## Short-run Effects: Controlling for Lagged Shocks

Table 7: The Impact of Short Run Actual Floods, 2001-2018

| | (1) log(Entry) | (2) log(Exit) | (3) log(Employment) | (4) log(Population) | (5) log(Output) |
|---|---|---|---|---|---|
| Flood share | 0.000 | 0.003 | -0.001 | 0.001*** | -0.005*** |
| | (0.004) | (0.004) | (0.001) | (0.000) | (0.002) |
| L.Flood share | -0.004 | 0.004 | -0.000 | 0.000 | -0.000 |
| | (0.004) | (0.004) | (0.001) | (0.000) | (0.002) |
| Observations | 50782 | 50931 | 52666 | 52683 | 51816 |
| County FE | Yes | Yes | Yes | Yes | Yes |
| State×Year FE | Yes | Yes | Yes | Yes | Yes |
| Initial Controls Trends | Yes | Yes | Yes | Yes | Yes |
| ymean | 4.036 | 3.991 | 8.870 | 9.825 | 13.67 |

main

# Distribution of direct damages of floods across regions