Avoidance Behavior During Tropical Cyclones

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Background and Motivation

- Tropical cyclones, known as hurricanes and typhoons, cause fatalities and significant economic losses every year.
- **Alarm information** plays a crucial role in enabling people to make **avoidance decisions** to mitigate the impacts of these natural disasters, such as staying at home or evacuating to a safe place.
- We investigated whether **mandatory orders from the government,** such as typhoon day-off order in Taiwan, are more effective than **alarms/warnings** in helping people avoid such disasters.

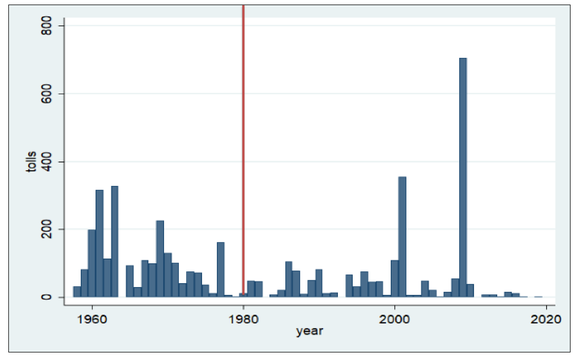
Data

- Transportation data: **daily time-series data** from Taipei Rapid Transit Corporation and the Kaohsiung Rapid Transit Corporation (2009-2019), Department of Transportation and Public Works (2015 Oct-2019).
- Hurricane and tropical cyclone data: Central Weather Bureau in Taiwan, National Hurricane Center and Central Pacific Hurricane Center
- Weather data: National Oceanic and Atmospheric Administration
- Day-off data: Taiwan Directorate-General of Personnel Administration

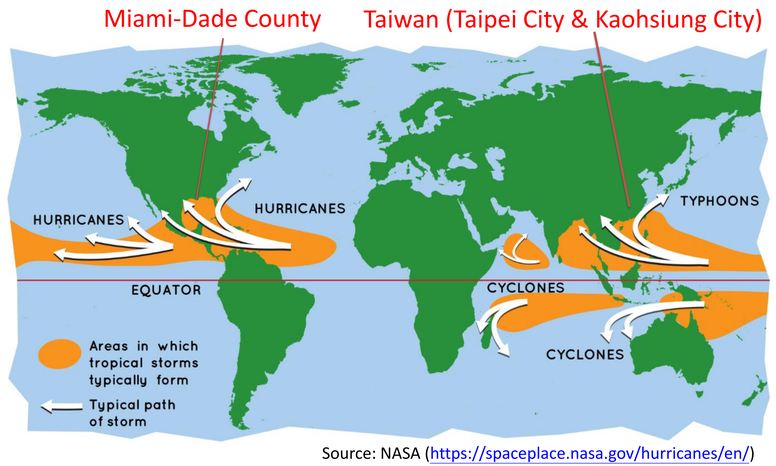
Taiwan		Miami-Dade County	
Scale	Wind speed(km/hour)	Scale	Wind speed (km/hour)
Mild typhoon	62-117	Tropical Storm	62-118
Moderate typhoon	118-183	Hurricane-Category 1	119-153
Severe typhoon	> 183	Hurricane-Category 2	154-177
		Hurricane-Category 3	178-209
		Hurricane-Category 4	210-249
		Hurricane-Category 5	> 249
Day-off: 23 (T) and 27(K), Total typhoon: 53		13 Hurricanes or Tropical storms	

Conclusions

- The number of passenger rides significantly drops after receiving information, indicating that people **respond both to alarms and government-mandated orders in similar ways**.
- Kaohsiung and Miami-Dade counties, which have similar weather conditions, populations, and rates of public transportation usage, exhibit **similar patterns and magnitudes** of avoidance behavior.
- Policy discussion: Government-mandated orders sometimes incur social costs, such as traffic jams and fatalities during evacuation, or economic losses when announcing a day-off in advance but tropical cyclones do not make landfall. Therefore, if there is no significant social benefit to issuing mandatory orders, **providing reliable alarms for people to make individual decisions might suffice**.



Tolls during tropical cyclones in Taiwan (1958-2019)



Source: NASA (https://spaceplace.nasa.gov/hurricanes/en/)

Methods

- **Aggregate data** are used to investigate avoidance behaviors, such as reducing cycling for avoiding heatwave. To our knowledge, there are no studies that use aggregate data to investigate avoidance behavior in the context of tropical cyclones and how people respond to alarms.
- Avoidance behavior is one variable in the safety production function:

Safety=f(tropical cyclone*avoid, V)

- Dependent variables, $\log(PR_t)$, are log of passenger rides of public transportation system; precipitation and wind speed are weather factors; we controlled t-1 period of weather factors which are the information government used for making day-off order decisions; we also control time fixed effect such as day of week and month of year in the model. Specifications:

$$\text{(I) } \log(PR_t) = \rho_1 \log(PR_{t-1}) + \rho_2 \log(PR_{t-2}) + [\beta_1 Day\_off_t + \gamma_1 wind_{t-1} \cdot route_{t-1} + \gamma_2 rain_{t-1}] + [\rho_1 rain_t + \rho_2 wind_t] + \alpha_1 nholidy_t + \alpha_2 DOW + \alpha_3 MOY + \varepsilon_t$$

$$\text{(II) } \log(PR_t) = \rho_1 \log(PR_{t-1}) + \rho_2 \log(PR_{t-2}) + \beta_1 Hurricane\_watch_{t-2} + \gamma_1 wind_t + \gamma_2 rain_t + \alpha_1 DOW + \alpha_2 MOY + \varepsilon_t$$

Results

	With Mandatory Order				Without	
Passenger Rides	Taipei City		Kaohsiung City		Miami-Dade County	
Alarms	-0.948***	-0.839***	-0.712***	-0.581***	-0.815***	-0.787***
Rain		-0.001***		-0.001***		-0.071***
Weather	No	Yes	No	Yes	No	Yes
Time-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Serial Correlation controlled	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.790	0.803	0.741	0.752	0.781	0.788
Observations	4,017		4,017		1,825	

Level of significance: *** 1%,** 5%, *10%. (c) Business types are pure farm, diversified company (e.g. LED company), and charitable organization.