The Effect of Tropical Cyclones in Economic Activities: Micro Level Evidence from Mexico for Secondary and Tertiary Activities

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Abtract

In this paper, we study the effects of climate and Tropical Cyclones on the economic activity at the firm level of the manufacturing and services sectors across Mexico.

One contribution of this paper is based on the more disaggregated temporal and spatial character of the results, which characterize how heterogeneity plays a role on the magnitude of the effect, which is especially useful for policy design.

Introduction

- The interest in studying the TC comes from their potential devastation:
  1. *Record-breaking 2005 Atlantic hurricane season that included three of the ten most intense hurricanes: Katrina, Wilma and Rita.*
  2. *In Mexico in 2010, Alex Hurricane and Odile hurricane in 2014.*
  3. *The 2017 Atlantic hurricane season was a hyperactive and catastrophic featuring 17 storms, 10 hurricanes and 6 major hurricanes.*
- Since 1975 there has been a substantial and observable regional and global 25–30% increase in the proportion of Category 4 to 5 hurricanes per 1°C of global warming (Holland and Bruyere 2014).
- Mexico is located at a middle latitude in the Tropic of Cancer, according to Hsiang and Jina (2014), Mexico is the number nine country in terms of its average exposure to TC.

Literature Review

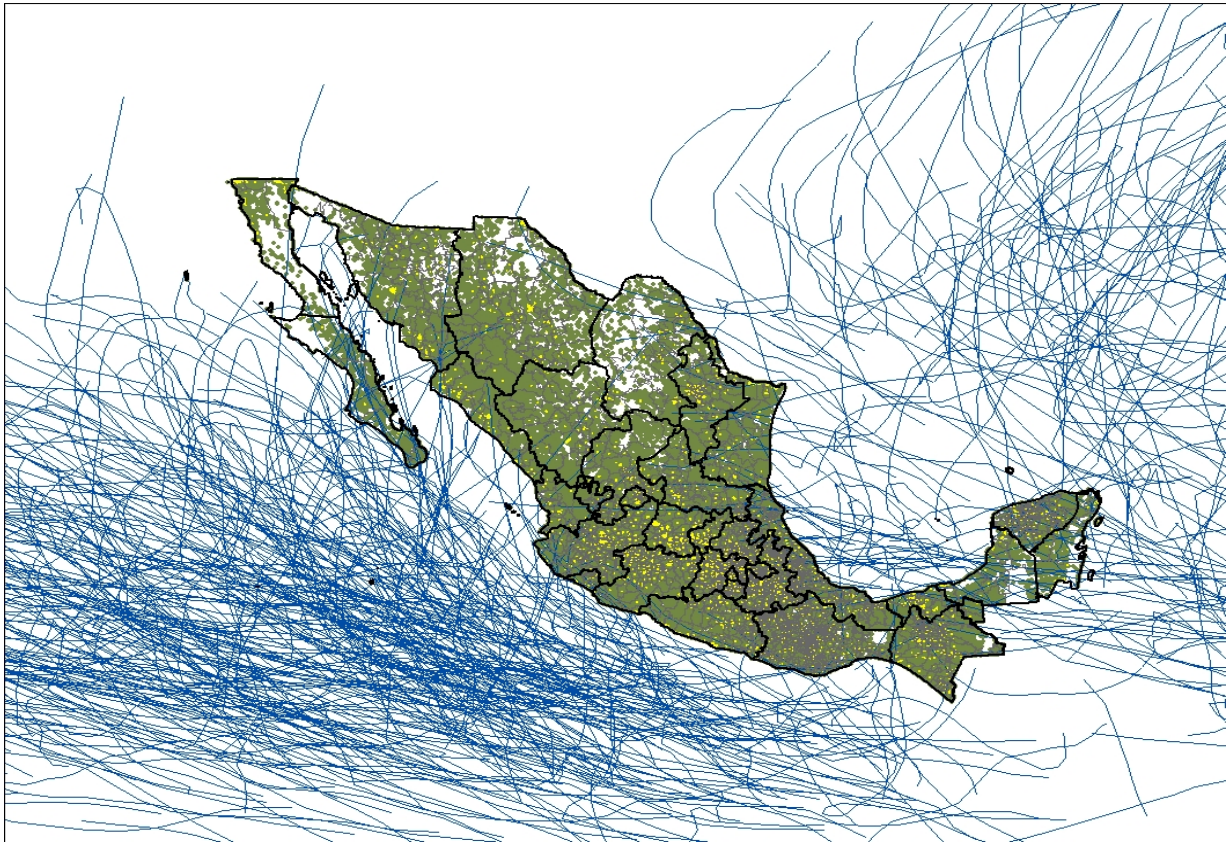
- Nordhaus (2010) examined the economic impacts of US hurricanes from 1900 to 2008, using a damage function of the winds records of hurricanes, he found that US hurricanes damages would increased by 0.08% of GDP if CO2-equivalent is doubling.
- Hsiang (2010) documented the response of economic activities in 28 countries of the Caribbean basin and he found that temperature and TC are correlated. So, explicitly controlling by TC the output losses in nonagricultural production exceeds losses in agricultural sector.
- Hsiang and Jina (2014) studied the long-term effects on growth of TC and they found that lower growth rates in the following fifteen years after the disaster generate a significant effect in the path of growth.

Stylized Facts

The map show the trajectory of 708 TC

- Most of the landfalls of hurricanes have occurred in states like Baja California Sur, Sonora, Tamaulipas, Jalisco, Yucatan and Quintana Roo.

Tropical Cyclones Paths and its Maximum Sustained Winds, 1994 – 2017

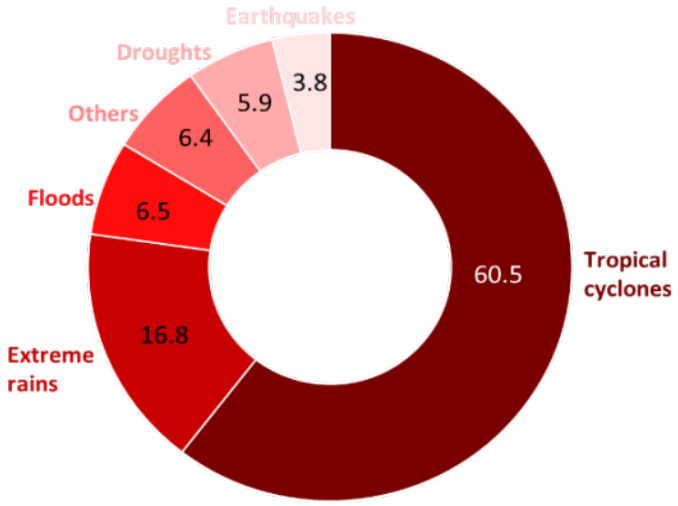


Source: Own elaboration using the IBTracs from NOAA.

Stylized Facts

In 2000, Mexico stablished the Mexican Fund for Natural Disasters (FONDEN) as a mechanism for funding the recovering of federal and state infrastructure affected by natural disasters.

Resources Exercised as a Result of Natural Disasters in Mexico, 2000 - 2015
Percentages



Source: Own elaboration using data from National Center for Disaster Prevention (CENAPRED).

Hurricanes that have Caused the Biggest Damages and Losses in Mexico, 2000 - 2015

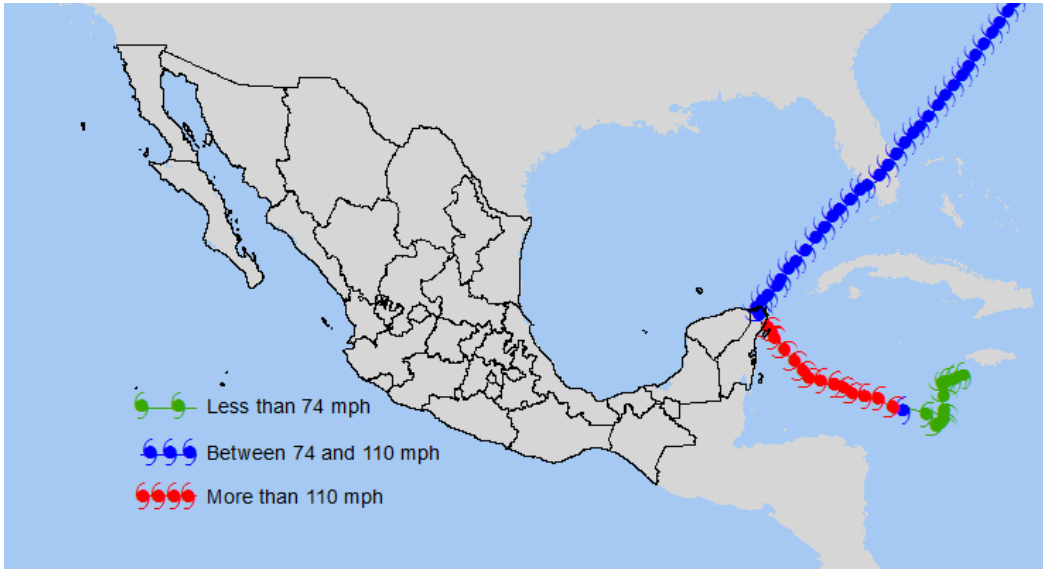
	Month/Year	Name	State	Total of resources exercised Percentajes
1	September 2010	Karl and Matthew	Veracruz	11.1
2	September 2014	Odile	Baja California Sur	10.2
3	Septiember 2013	Ingrid and Manuel	Guerrero	10.3
4	June 2010	Alex	Nuevo Leon	9.7
5	October 2005	Wilma	Quintana Roo	9.5
6	October 2005	Stan	Chiapas	7.8
7	September 2002	Isidore	Yucatan	3.8
				62.4

Source: Own elaboration using data from National Center for Disaster Prevention (CENAPRED).

Stylized Facts

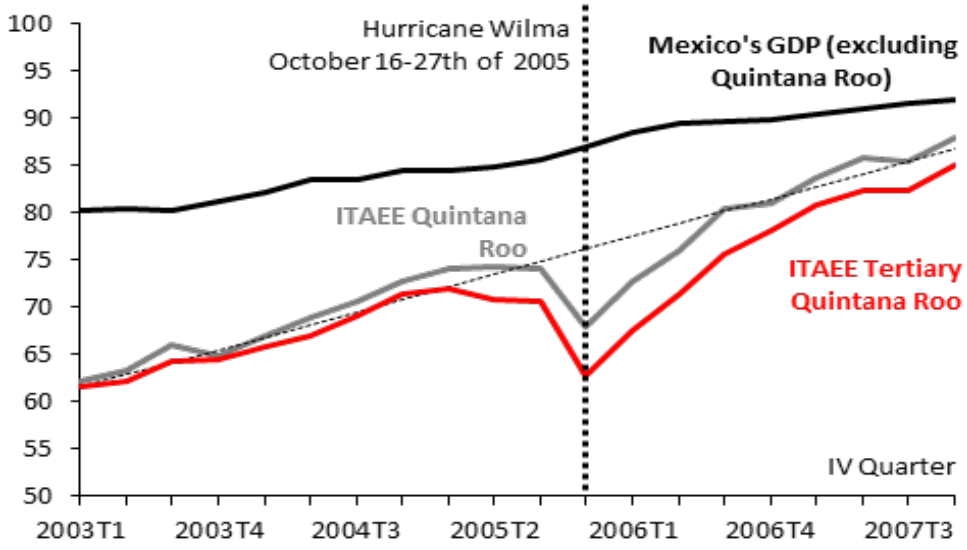
- For Mexico, an emblematic case of the effect of TCs on economic activity is Hurricane Wilma, one of the most intense registered in the Atlantic basin, which impacted the state of Quintana Roo in October 2005.

Trajectory of Hurricane Wilma



Source: Own elaboration using the IBTracs from NOAA.

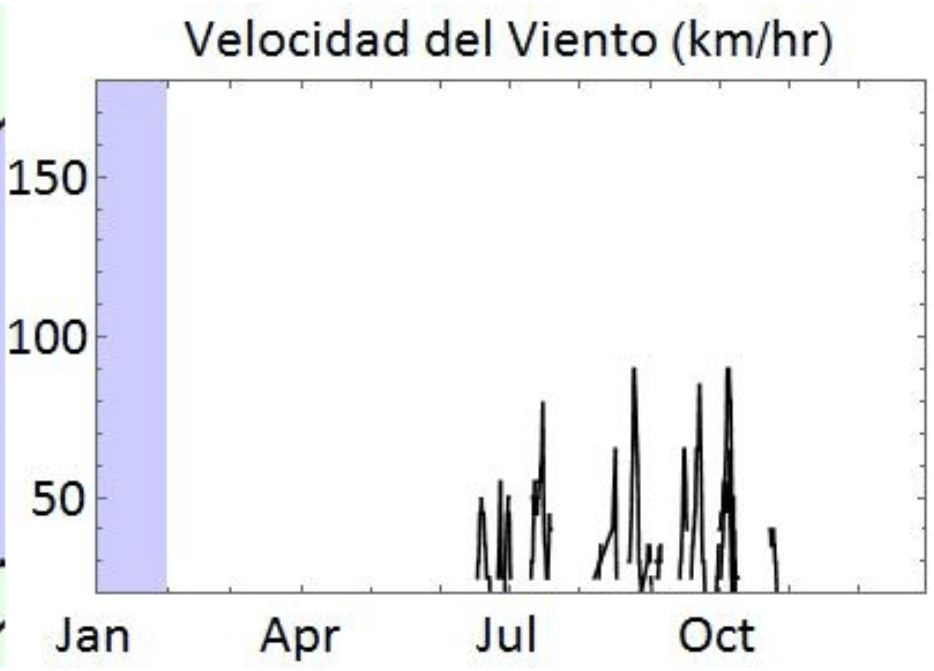
Impact of Hurricane Wilma on Economic Activity



Note: Quarterly Indicator of State Economic Activity (ITAEE).
Source: Own elaboration using seasonally adjusted series from the National Institute of Statistics and Geography (INEGI).

Stylized Facts

Trajectory and Wind Speed of Tropical Cyclones, 2003 - 2017

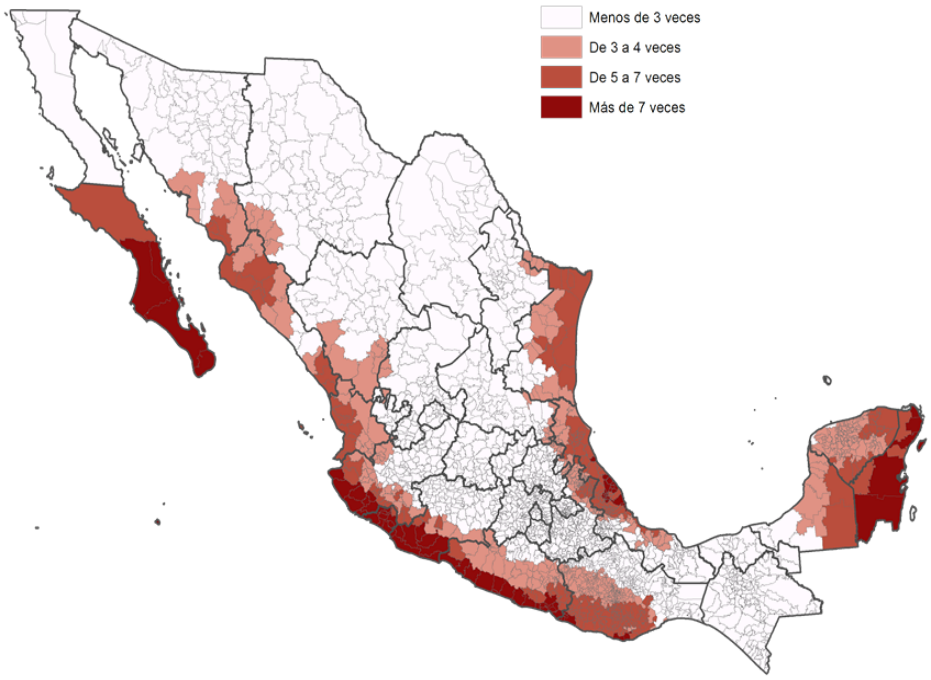


Source: Own elaboration using the IBTracs from NOAA.

Risk Map for Tropical Cyclones

- Number of times a municipality has been hit by TC during the period 1994-2017
- There are about 600 municipalities with high exposure to TC.
    - In the Pacific, these municipalities are located mainly in the entities of Baja California Sur, Colima, Jalisco, Michoacan, Guerrero and Oaxaca.
    - in the Atlantic, most of the municipalities with high exposure are in Veracruz, Tabasco, Campeche and Quintana Roo.

Maps of Exposure to TC Maximum Sustained Winds, 1994 – 2017
Frequency at Municipality level of TC of Hurricane Category 1 and Higher



Note: This indicator quantifies the number of times that all the localities that make up the municipalities have been exposed to the radius of influence of tropical cyclone winds.
Source: Own elaboration using the IBTrAC from NOAA.

Data and Sources

- TC trajectories and msw from the International Best Track Archive for Climate Stewardship (IBTrACS).
- We used Storm Wind Model package in R developed by Brook Anderson from Colorado State University. This algorithm allowed to us modeling wind speeds at grid points in the Mexican territory using the TC trajectory records data.
- Weather information of about 3,000 ground station data from the National Meteorological System that provides daily records of precipitation, maximum and minimum temperature located across all states.
- Monthly Industrial Survey covers the period 1994 - 2008 and considers 205 industries.
- Monthly Extended Survey of Manufacturing Industry 2005-2010 with 230 industries.
- Monthly Survey of Manufacturing Industry 2007-2017 representing 240 industries.
- Monthly Survey of Services 2008-2014 includes 105 economic classes.

Summary of Characteristics of Surveys

		NAICS 6-digit		Observations/Estab.	
Survey	Period	classes	Establishments	Minimum	Maximum
EIM	1994-2008	205	6,867	12	168
EIMA	2005-2010	230	7,238	12	72
EMIM	2007-2017	240	11,406	120	12
EMS	2005-2015	105	7,465	1	95

Source. INEGI, Microdata Laboratory.

Firm Level Estimation

- We use an Augmented Distributed Lagged Model

$$\Delta \ln(Firm_{i,j,t}) = \alpha_i + \sum_{M=0}^{4} [\beta_{iTC} TC_{j,t-M} + \beta_{iT} Temp_{j,t-M} + \beta_{iR} TC\_Rain_{j,t-M}] + \rho_t + \mu_j + \gamma_{ij} xt + \eta_{jt} + \lambda_t S + \varepsilon_{ijt}$$

For firm i in municipality j and month t; the β_i stand for the coefficients of the variables of interest that meaning the marginal effects of the TC exposure (β_{iTC}), average temperature during the month β_{iT})and the cumulative rain when a TC is present β_{iR}); α_i stands for the establishment fixed-effect, ρ_t is a month and year fixed-effect that controls for the different economic structures and stationarity patterns of the month and year affecting the economic activity, μ_j are municipality fixed-effects, γ_{ij} are municipality specific trends for each firm that captures the heterogeneity in the growth trend of every municipality and time; λ_t controls for specific dynamics of the subsectors of economic activity (3-digit SCIAN) and, finally $\varepsilon_{i,j,t}$ is the error term of the model.

Firm Level Results

Marginal Cumulative Effects of Sustained Wind of Tropical Cyclones (m/s) on Manufacturing Establishments for Highly Vulnerable Municipalities, 1994-2017

	Production Index 2008=100	Real Remuneration per worker	Worked Hours by Employed Personnel
$Tcyclones_{t}$	0.056 **	-0.053	0.042 ***
$Tcyclones_{t-1}$	-0.114 ***	-0.896 ***	-0.033 ***
$Tcyclones_{t-2}$	-0.013 ***	-2.033 ***	0.018 ***
$Tcyclones_{t-3}$	-0.025	-2.241	0.016
$Tcyclones_{t-4}$	0.050 *	-2.186	0.031
$Tcyclones_{t-5}$	0.108 *	-2.904 *	0.052 ***
$Tcyclones_{t-6}$	0.030	-2.773	0.046
$Tcyclones_{t-7}$	0.001	-3.599 *	-0.017
$Tcyclones_{t-8}$	0.149 *	-3.951	0.095
$Tcyclones_{t-9}$	0.095	-4.050	0.050
$Tcyclones_{t-10}$	0.063	-4.433	0.040
$Tcyclones_{t-11}$	0.191	-4.454	0.071
$Tcyclones_{t-12}$	0.205	-4.596	0.045
FE, YE, ME	Y	Y	Y
State trends	Y	Y	Y
NAICS 3-digit	Y	Y	Y
Observations	704,024	369,666	640,343

Source: Authors' estimations using the using the Monthly Industrial Survey (1994-2005), the Extended Monthly Industrial Survey (2005-2006) and the Monthly Survey of Manufacturing Industry class (2007-2017).

In these estimations, we controlled for mean temperature and cumulative precipitation by municipality, industry class specific trends (2-digit SCIAN activities), state-time-specific constants, month-specific constants and year-specific constants.

The high exposed municipalities are located in the following entities: Baja California Sur, Colima, Guerrero, Jalisco, Michoacan, Nayarit, Oaxaca, Puebla, Quintana Roo, Sinaloa, Tamaulipas, Veracruz and Yucatan.

***P < 0.01, **P < 0.05, *P < 0.1 stands for statistical significance at 1%, 5% and 10%, respectively; standard errors are robust to spatial correlation by state. Estimates for monthly temperature and cumulative precipitation are available upon request to the authors.

Firm Level Results

Marginal Cumulative Effects of Services Establishments of Sustained Winds (m/s) of Tropical Cyclones for Highly Vulnerable Municipalities 2008-2015

	Revenue Index 2008=100	Remunerations per worker	Operative Expenses
$Tcyclones_{t}$	0.001	-0.014	-0.026
$Tcyclones_{t-1}$	-0.004 ***	0.005	-0.120 **
$Tcyclones_{t-2}$	-0.011 ***	-0.037	0.057 ***
$Tcyclones_{t-3}$	-0.011	-0.044	0.064
$Tcyclones_{t-4}$	-0.010	-0.058	-0.026 *
$Tcyclones_{t-5}$	-0.008	-0.023	0.077
$Tcyclones_{t-6}$	-0.006 *	-0.012	-0.002
$Tcyclones_{t-7}$	-0.007	0.015	-0.090
$Tcyclones_{t-8}$	-0.012 ***	0.001	0.030
$Tcyclones_{t-9}$	-0.020 ***	0.033	-0.033
$Tcyclones_{t-10}$	-0.025 ***	0.014	-0.298
$Tcyclones_{t-11}$	-0.028	-0.012	-0.261
$Tcyclones_{t-12}$	-0.027 *	-0.006	-0.256
FE, YE, ME	Y	Y	Y
State trends	Y	Y	Y
NAICS 3-digit	Y	Y	Y
Observations	200,172	155,697	190,345

Source: Authors' estimations using the using the Monthly Services Survey (2008-2015).

We controlled for mean temperature and cumulative precipitation by municipality, sector specific trends (2-digit SCIAN sector), state-time-specific constants, month-specific constants and year-specific constants.

The high exposed municipalities are mainly located in the following entities: Baja California Sur, Colima, Guerrero, Jalisco, Michoacan, Nayarit, Oaxaca, Puebla, Quintana Roo, Sinaloa, Tamaulipas, Veracruz and Yucatan.

***P < 0.01, **P < 0.05, *P < 0.1 stands for statistical significance at 1%, 5% and 10%, respectively; Standard errors are robust to spatial correlation by state.. Estimates for monthly temperature and cumulative precipitation are available upon request to the authors.

Conclusion

- In line with the economic literature, controlling by climate, we found that firms from manufacturing and services in Mexico show negative effects of TC exposure. However, there exist heterogeneous results across sectors.
- For an average firm of the manufacturing sector located in the most vulnerable municipalities, the exposure to tropical cyclones, measured by the maximum sustained winds, generates negative and more persistent effects on production and real remuneration per worker.
- In contrast, services establishments show a short-run negative impact on revenue.
- The main contribution of this paper is based on the more disaggregated temporal and spatial character of its results, which allow identify how heterogeneity plays a role on the magnitude of the effect, which is especially useful for policy design.