



The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

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

Miriam Juárez-Torres,
Banco de México
mjuarez@banxico.org.mx

Jonathan Puigvert-Angulo
Banco de México
jpuigvert@banxico.org.mx

***Selected Paper prepared for presentation at the 2019 Agricultural & Applied Economics
Association Annual Meeting, Atlanta, GA, July 21 – July 23***

Copyright 2019 by Miriam Juarez-Torres and Jonathan Puigvert. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

Abstract

In this paper, we study the effects of weather and Tropical Cyclones on the economic activity at the firm level of the manufacturing and services sectors across Mexico. We use monthly firm observations and data of climate and TC at the municipality level to estimate their effects on the hours worked and employed personnel of firms from manufacturing sectors for the period 1994-2014. Similarly, for firms of services sector, we estimate their effects on income, operative expenditure, remunerations and employed personnel. While we observe increasing negative and persistent effects on firms of manufacturing sector; in contrast, firms of services show a higher short-run negative sensitivity but low persistence. 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.

Keywords: TC, Economic impact, losses, wind exposure

JEL codes: Q54, Q51, L60, O12, O14

1. Introduction

Tropical Cyclones (TC) are atmospheric phenomena with an important function in the hydrological cycle in tropical and subtropical regions of the earth since they are the mechanism to transfer heat and energy between the equator and the cooler regions toward the poles. In addition, for arid and semiarid regions, TC are an active source of water recharge for aquifers, rivers, lakes and dams (Aguilar-Benitez, 2011). TC have formation patterns within seven basins around the world at different seasons throughout the year. In the Northern hemisphere, TC are originated in the North Atlantic (NA) and Eastern North Pacific (EP), and their season goes from June to November with a peak in September.

However, TC are one of the most dangerous natural hazards for human life and economic activities. These events cause damage from a combination of intensity, size, forward speed, and rainfall. In particular, size and forward speed add to economic losses through the area affected and the length of time the wind blows. TC reach different intensities measured by their maximum sustained winds (msw), being storms and tropical depressions the lowest intensity events and hurricanes the most potential damaging events. Hurricanes are classified according to the Saffir-Simpson Hurricane Wind Scale from 1 to 5 rating, with category 3 and higher being considered as the major ones because of their potential for causing losses of life and damage¹.

Derived from the potential devastation produced by TC in recent years, the renovated interest in studying the effects of these unpredictable natural events is not astonishing. Furthermore, the general concern relies on the possibility about the increasing severity of TC due global warming. Around the world, since 1975 there has been a substantial and observable increase in the proportion of Category 4 to 5 hurricanes of 25–30 % per 1°C of anthropogenic global warming (Holland and Bruyere 2014). Extreme rain has amplified alongside hurricanes; weak storms have been scaling up into higher intensities by extracting moisture from the area surrounding the core of the hurricane, which results in higher volumes of net rain, mainly in the Atlantic basin (Mendelsohn et al., 2012). More frequent episodes of heavy rain associated to TC may increase its destructive power in economic activities, especially in developing countries. In the near future, these phenomena could bring devastating consequences for Mexican population that often dampen economic activity as a short term response to winds of hurricanes and severe storms.

In particular, since the record-breaking 2005 Atlantic season that included three of the ten most intense Atlantic hurricanes ever (Katrina, Wilma and Rita), TC have received increasing attention because their devastation power appears to be increasing. Katrina and Wilma were category 5 hurricanes, the second costliest and the most intense (by lowest barometric pressure) Atlantic hurricanes on record, respectively. More than a decade later, the 2017 Atlantic season was hyperactive and catastrophic by featuring 6 major hurricanes. For first time in records, three hurricanes were simultaneously active in the same basin, and two of them reached over 150 mph of

¹ A tropical depression shows msw of 38 mph or less and a tropical storm from 39 to 73 mph (34 to 63 km/h). A category 1 hurricane is characterized by msw from 74-95 mph (119-153 km/h) that usually produces some minor damage. Category 2 could produce some damage with mws of 96-110 mph (154-177 km/h). Category 3 is a major devastating damage event with 111-129 mph (178-208 km/h). Category 4 refers a sustained severe damage 130-156 mph (209-251 km/h). Category 5 (major) 157 mph or higher 252 km/h or higher indicates a catastrophic damage.

msw. In Houston, the Hurricane Harvey devastated parts of the Texas coastline and produced more rainfall than any U.S. hurricane on record. The Hurricane Irma had a record-breaking duration as a Category 5, and Maria was the tenth-most intense hurricane on record and the most intense tropical cyclone worldwide of 2017 causing important human life and economic losses across Puerto Rico, Dominica, the Dominican Republic, Haiti, Guadeloupe, Virgin Islands and mainland in the United States. Thus, empirical evidence has brought in to the arena, besides the wind intensity, the relevance of studying precipitation associated with this natural events. In economic literature, most of the economic impact of TC exposure has been assessed in terms of wind intensity, while the rain dimension remains still scarcely studied.

Although in the economic literature, the impact of these atmospheric events has been studied at a country level, this paper focuses on the more disaggregated approach of state for a highly exposed country (see Hsiang and Jina, 2014). We use panel data at the coastal state level with quarterly information by main sector of the economy and we constructed measures of exposure to TC using the records of the TC trajectories and wind speed to quantify the effect of hurricanes and tropical storms in economic sectors of coastal states for the period 2003 – 2016. We use a Distributive Lagged Model to estimate the effects of TC for a specification. We found short-term negative economic effect of TC on economic activity that disappears after the third quarter. However, the negative impact is heterogeneous across sectors. We find that the effect on tertiary activities is higher for activities directly related with climate, such as tourism and retailing, while other activities like construction (included in the secondary sector) show a positive effect derived from the reconstruction activities.

The rest of the paper is organized as follows. Section 2 reviews the literature about the impact of TC on economic activity. Section 3 presents some stylized facts of the TC in Mexico and economic activity. Section 4 cites data sources and describes data and construction of variables. Section 5 presents the model and the results of the econometric estimations. Finally, section 6 concludes and outlines the directions for future research.

2. Literature Review

The occurrence of more frequent extreme weather events around world and the more tangible climate change have increased the interest of the study of their consequences on the economic activities. One of the most important advantages of these kind of studies depend on its relatively strong identification properties based on exploiting the exogenous weather variation, which assembles random draws from complex atmospheric stochastic systems within a given spatial area. Thus, since weather randomly vary, the fixed effects of the defined geographical areas absorb the static spatial features, either observed or unobserved, separating the shock from many other sources of possible omitted variable bias (Dell et al., 2014). Under this approach, a broad research in economic literature has focused on studying agricultural yields, energy demand, mortality, labor productivity, exports, migration, social conflicts and violence, and economic growth (see Mendelsohn et al., 2004; Deschenes and Greenstone, 2007; Deschenes and Greenstone, 2011; Deschenes y Moretti, 2009; Dell, Jones and Olken, 2009; Jones and Olken, 2012).

However, the study of the destructive power of hurricanes and their impacts on the economy remained barely studied until 2005, when category 5 hurricane Katrina arrived in late August

making landfall on the Gulf coast from central Florida to Texas, and causing severe unexpected damages in property and economic activities in the coastal areas of Louisiana and Mississippi. The same year, hurricane Wilma made several landfalls, with the most destructive effects felt in the Yucatán Peninsula of Mexico. Thus, the perspective of progressive increasing potency of TC associated to climate change brought in the discussion arena the effects of TC on economic activity.

In this context, the seminal paper of Nordhaus (2010) examined the economic impacts of US hurricanes from 1900 to 2008. He used a damage function of the winds records of hurricanes and found high vulnerability to Atlantic hurricanes where damages appear to have a ninth power law respect to maximum wind speed. He also found that 2005 Atlantic season appears to have been a quadruple hurricane outlier. In addition, US hurricanes damages could increase by 0.08% due the intensification effect of a CO₂ equivalent doubling.

Moreover, Hsiang (2010) examined windstorms by constructing meteorological databases based on storm trajectories to document the response of economic activities in 28 countries of the Caribbean basin. He showed that temperature and TC are correlated, so explicitly controlling by TC, the output losses in nonagricultural production exceeds losses in agricultural sector. Average temperatures during September-October-November have an important effect on sectors such as retail, restaurants and hotels and transport and communication, while in manufacturing and construction the effects are negligible and non-significant.

Later, Hsiang and Narita (2012) documented the adaptation process of countries with different climatology using data from 1950 to 2008. They find that the most exposed countries response with a higher adaptive effort by running heavy investments in infrastructure, and reducing the impact of hurricanes along the time. Then, Hsiang and Jina (2014) study the long-term effects on growth of CT using annual fluctuations from windstorms and they found evidence of national incomes decline for all type of income countries and such negative effect decreases with TC historical experience of countries. They found that lower growth rates in the following fifteen year after the disaster generate a significant effect in the path of growth.

Other studies have focused on Central America and the Caribbean countries exploring the effects of hurricanes using synthetic tracks based on satellite images to proxy the economic activity levels to estimate expected risk and losses of similar events for the last 30 years (Bertinelli et al., 2016; Bertinelli et al., 2016; Ishizawa et al., 2018).

Given the identification properties, of the estimations, the main challenge in this economic literature heavily relies on figuring out the best techniques for better capturing the complex atmospheric processes at different geographical scales. In this sense, one of the main contributions of this paper to the economic literature relies on the more disaggregated scale and the periodicity of the estimations on economic activities.

3. Stylized Facts of Tropical Cyclones in Mexico

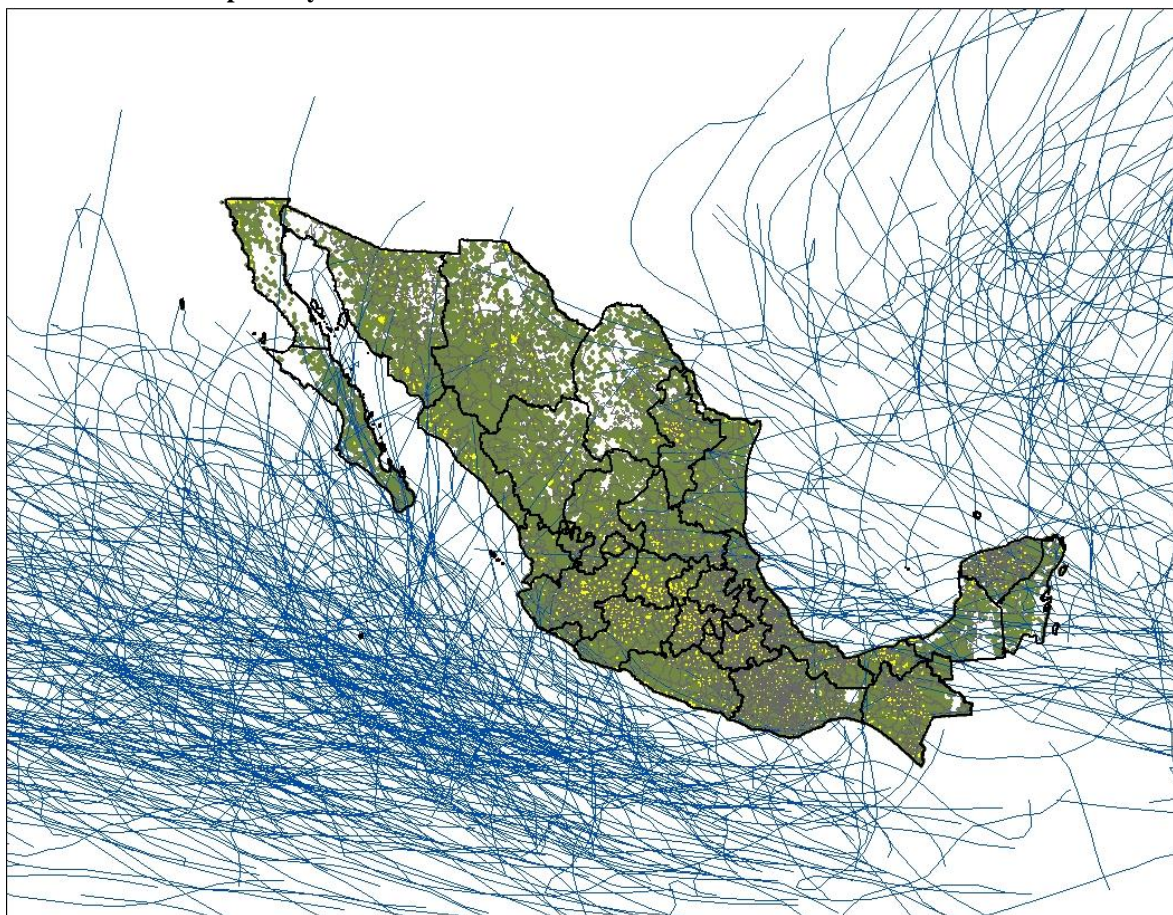
3.1. Exposure and Risk Map

Mexico is located at a middle latitude and in the vicinity of the Tropic of Cancer, which implies a highest exposure to TC on both of its shores (the North Atlantic and Eastern North Pacific), Hsiang

and Jina (2014) place Mexico as the number nine country in terms of its average exposure to TC. This country has 9,330 km of littorals with borders to the west with the Pacific Ocean and the Gulf of California; and to the east with the Gulf of Mexico and the Caribbean Sea; it has 17 coastal states (11 in the Pacific Ocean and 6 with the Gulf of Mexico, 153 municipalities constituted by 35,626 localities) that represent 56.3% of its mainland surface.,

Based on data from IBTrACs of the National Hurricanes Center (NHC), Figure 2 shows the trajectories of all TC in the NA basin and the EP basin occurred between 2003 and 2016, according to their intensity.

Figure 1
Tropical Cyclones Paths and its Maximum Sustained Winds 1994 – 2016



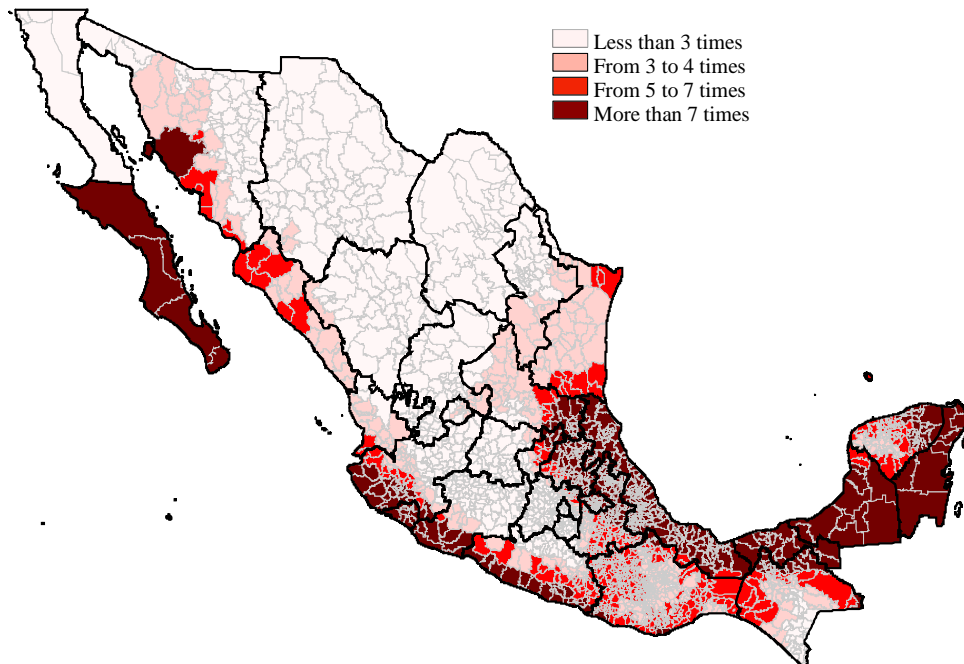
Source: Own elaboration using the IBTracs from NOAA, hurricanes from 1994 - 2016.

The map reveals the trajectories of a total of 842 TC developed in the two basins bordering Mexico.² Even when the EP basin has the highest number of hurricanes, the NA basin show a number of hurricanes with higher intensity. At a first glance, we can observe that the most of hurricanes' landfalls have occurred in states like Baja California Sur, Sonora, Tamaulipas, Jalisco, Yucatan and Quintana Roo.

² From 1950 to 2016, in the Eastern North Pacific basin recorded a total of 1,143 tropical storms and 1,026 tropical storms at the North Atlantic basin with about 10% of the TC reached category 3 and over in Saffir-Simpson scale.

Next, us, we counted the frequency of wind exposure at the municipality level. Figure 2 displays a map of exposure for illustrating the geographical distribution of such indicator. **Figure 2.**

Map of Exposure to the Radios of Influence of the TC Winds, 1994 - 2016



Source: Own elaboration using the IBTrACs from NOAA.

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.

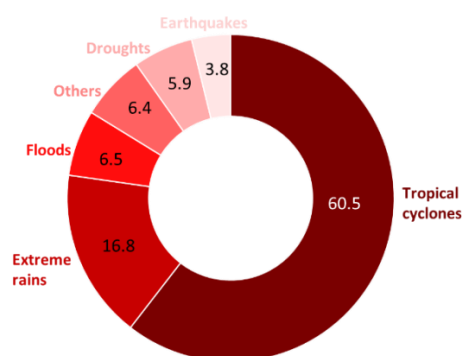
In particular, this figure displays the number of times that a municipality has been hit by the TC's winds, given the 150 km radius of influence. We observe about 600 municipalities in dark red that indicate a high frequency, more than 60% of those municipalities are in the Pacific shore in municipalities of the states of Baja California Sur, Jalisco, Colima, Michoacan, Guerrero and Oaxaca. While in the Atlantic shore, the most frequently affected municipalities are concentrated in the states of Veracruz, Tabasco, Campeche and Quintana Roo.

3.2 Economic Loss and Damage due TC in Mexico

TC may be one of the most potent sources of economic loss and the severity of the damage may differ according to the adaptation and the resilience developed typically by the most strike locations and the available resources to deal with these natural events. Derived of the magnitude of economic losses due TC, the Mexican government stablished the Mexico's Natural Disaster Fund (FONDEN, by its acronym in Spanish) as disaster risk management strategy to support disaster relief and reconstruction. This mechanism supports the recuperation of federal and state infrastructure affected by natural disasters. The objective of FONDEN is moderating the severity of the adverse social and economic costs from natural disasters that usually trigger supply interruptions during the post-disaster. The resources from the FONDEN are used for the rehabilitation and reconstruction of i) public infrastructure at the three levels of government (federal, state, and municipal); ii) low-income housing; and iii) specific components of the location.

Figure 3 shows the share of FONDEN's resources exercised by type of natural disaster for the period 2000 – 2015. Between 2000 and 2017, of the 9,007 municipalities declared as disaster areas by the FONDEN, 25% were due TC and 42% due extrema rain and flooding, most these associated to TC. The TC constitute the most important category of natural disaster causing the biggest economic losses in infrastructure like highways, communications and services like electricity, sewing and utilities, which bill about 60% available resources at the FONDEN. In frequency, in terms of municipalities with declaratory of natural disaster, extreme rains and floods are the main category of disaster.

Figure 3
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).

Next, Table 1 shows the details of the top seven declarations with the major funding from the FONDEN. For Mexico, 2005 and 2010 were two years with important economic losses associated to TC disasters. In 2005 the hurricanes Wilma and Stan caused important economic losses in Quintana Roo and Chiapas, respectively. In 2010, the extreme rain associated to hurricanes Karl and Mathew flooded the downtown of Veracruz capital, causing power outbreaks, while hurricane Alex occasioned major flooding in Nuevo León producing power outbreaks and damaging installations of manufacturing firms and affecting the regular operation of economic activity in the City of Monterrey for several weeks.

Table 1
Top Seven Disaster Declaratories by Amount of Resources Exercised from FONDEN

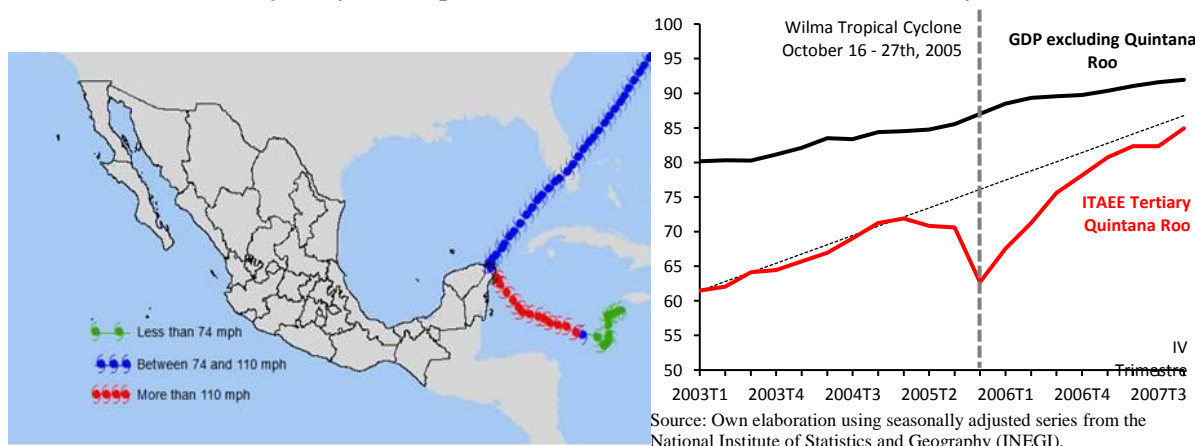
	Month/Year	Name	State	Total of resources exercised Percentages
1	September 2010	Karl and Matthew	Veracruz	11.1
2	September 2014	Odile	Baja California Sur	10.2

3	September 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).

In this section, we also analyze since a broad perspective the economic effects of the hurricane Wilma that made a first landfall on October 21st 2005 on the island of Cozumel, Quintana Roo with msw of 150 mph (240 km/h) and a second landfall on the north over the Yucatán Peninsula. On its path, Wilma struck Cancun causing a widespread damage on an important tourist Mexican destination and its adjacent localities. Several hotels, highways and electrical infrastructure were severely damaged for several weeks. Figure 4 (left) displays the geographical trajectory of hurricane Wilma, disturbing Yucatan Peninsula and Quintana Roo, where this hurricane reached its highest wind intensity of 150 mph (240 km/hr). The Figure 4 (right) shows the economic impact of the hurricane Wilma. It is remarkable that economic activity in Quintana Roo contracted especially in the tertiary sector during the quarter while this hurricane was active and no long-term effects are observed since this state recovered its growth path after three quarters. In contrast, such economic performance contrast with the rest of the states, where the aggregate indicator does not shoe evidence of any affectation, but remain under the same path of growth.

Figure 4
Trajectory and Impact of Hurricane Wilma on Economic Activity



4. Data and Sources

4.1 Tropical Cyclone Exposure Measurement

In the economic literature wind speed has been used as a proxy variable of the intensity (Emanuel, 2011, Hsiang and Jina, 2014, Ishizawa et al., 2017, Boose et al., 2004). We constructed an innovative database containing a measure of the tropical cyclone physical exposure based on wind speed with observations at the locality level for all Mexican territory. In order to calculate the exposure measure, we used detailed information of all the TC occurred in the North Atlantic (NA)

and East Pacific (EP) basins from 1994 to 2017 employing the trajectory records from the International Best Track Archive for Climate Stewardship (IBTrACS). This database (<http://www.ncdc.noaa.gov/oa/ibtracs/>) contains the most comprehensive records on 6-hour basis of georeferenced tracks, the msW, average wind speed at 10-m height above level ground, minimum pressure and other parameters for each TC. Although IBTrACS database contains information since 1850, records since 1987 and afterwards are more accurate since they are verified by satellite images.

Thus, we used Storm Wind Model package in R developed by Brook Anderson from Colorado State University based on Willoughby et al. (2006). This algorithm allowed to us modeling wind speeds at grid points in the Mexican territory based on IBTrACS trajectory records data. Basically, using population mean center locations in Mexico, this package interpolates TC tracks and maps wind speeds during the duration of the storm. For each locality center, the program estimates surface-level sustained wind and 3-second wind gusts at all storm observation points (i.e., all points along the interpolated storm track). These estimates measure distance to county from storm center (radius) calculating tangential gradient wind components at that grid point, gradient wind direction at that grid point; surface wind speed; surface wind direction, adding storm forward motion back into surface wind estimate.

The program determines for each locality the maximum sustained winds and wind gust speeds at any point on the storm's track; the duration of sustained and gust winds over a certain speed (i.e., how many minutes winds were above a cutoff). The wind exposure measurements generated for each grid point the maximum 10-m 1-minute gust wind experienced at the grid point during the storm are (vmax_gust); Maximum 10-m 1-minute sustained wind experienced at the grid point during the storm (vmax_sust); duration gust wind was at or above a specified speed (default is 20 m/s), in minutes (gust_dur) and duration sustained wind was at or above a specified speed (default is 20 m/s), in minutes (sust_dur).

As Hsiang and Jina (2014), the erogeneity of this kind of events can be established by constructing an index of disaster intensity that depends only on the geographical features of the disaster in terms of the affected area, wave height, or storm radii. Following Hsiang and Narita (2012) measures incidence with maximal wind exposure based on the idea that wind speed is necessary for predicting whether goods are heavily degraded. Thus, our index of TC exposure is based on the maximum wind speed (mws) occurred over the trajectory of all storms in a given month.

Next, we standardized the wind exposure indicator by every municipality, for the estimations, we used the normalized measure of 10 meters sustained wind, so we obtained the exposure measures as deviations from the mean at the municipality level. The resulting observations at the municipality level capture physically differentiated effect in municipalities, more densely populated municipalities show larger values of wind exposure. Since no correlation between the intensity of the storms and the probability that the most intense regions within that storm strike are the most economically active in the municipality. That means that the intensity across storms is not spatially correlated with the intensity of the economic activity.

In addition, we weighted the TC exposure by the population of both, urban and rural, localities in each municipality using information from the Geostatistical Framework of June 2017 and the

annual population data from 1994 to 2010 from extrapolated data from the Population Census 1990, 1995, 2000 and data population from the webpage from 2011 to 2017, both published by the INEGI. Thus, for every each point in the path of the TC, we got a resolution grid for each trajectory intersected with the land (smoothed) and then, we consider the overlaps of the trajectories at each point for accounting intensity of the effect.

4.2 Weather Database

In addition, we include weather information of ground station data from the National Meteorological System that provides daily records of precipitation, maximum and minimum temperature from about 3,000 weather stations located across all states of the country. So, we interpolate station information over a grid to provide gridded data that displays a comprehensive coverage. Since the distribution of weather stations is far from being uniform and some regions may have a sparse coverage, and in order to decrease measurement error, we carried out a control quality process of the weather stations and ruled out those stations with incomplete entries or frequent missing data. Then, we constructed a balanced panel data with monthly observations on precipitation, maximum and minimum temperatures for all municipalities across Mexico from January 1994 to November 2014.

4.3 Economic Surveys

We use the two representative surveys of the Mexican manufacturing sector carried out by the National Institute of Statistics and Geography (INEGI) for the period 1994-2014. While the questionnaire basically remained the same in every survey, its sampling design was continually updated with the Economic Census to improve the coverage of the surveyed activities and the states considered in the sample. From 1994 to 2008, the target population are manufacturing establishments and excludes those dedicated to maquila export and basic petrochemicals, oil refining, as well as corresponding to the micro-industry, which employed personnel goes from zero to fifteen people. Since 2007 and onwards target population are manufacturing establishments, including those dedicated to maquila export, and basic petrochemical and oil refining. The sampling design is a four-step based selection process of manufacturing establishments based on reported income as its main variable selection and secondly on occupied staff. In the first stage, based on a number of economic activities (4-digit NAICS), the selected establishments are those with the highest reported revenue value and taking into account the occupied personnel. Second: In each activity type, establishments which together provide at least 80% of the value of revenues were selected. Third: In general, establishments with 300 or more employed personnel and those who were not selected with the above procedure are included. Fourth: For activities where production is highly concentrated, all establishments were incorporated.

First, the Monthly Industrial Survey (*Encuesta Industrial Mensual*, EIM, by its acronym in Spanish) covers the period 1994 - 2008 and considers 205 industries (4-digit activities of the North American Industrial Classification System, NAICS). This survey has as framework the Economic Census of 1994 with records of 6,884 establishments that represent about 80% of the gross value added of the manufacturing sector. The EIM provides results for (19 of 32) states and the most important industrial states in the country: Aguascalientes, Coahuila, Chihuahua, Mexico City, Guanajuato, Jalisco, Estado de Mexico, Nuevo Leon, Puebla, Queretaro de Arteaga, San Luis Potosi, Sonora

and Veracruz (by subsector of economic activity) and Baja California, Durango, Morelos, Sinaloa, Tlaxcala and Yucatan (sector totals only).

Second, the most recent manufacturing survey used in this paper is the Monthly Survey of Manufacturing Industry (*Encuesta Mensual Industrial Manufacturera*, EMIM, by its acronym in Spanish) is based on the Economic Census 2009 with monthly information from January 2007 onwards of 11,406 establishments (in the design year 2008) representing 240 economic activities (4-digit SCIAN).

Finally, the Monthly Survey of Services (EMS, by its acronym in Spanish) aims to generate indicators of the private non-financial service sector. The sample design, according to the Economic Census 2004, is characterized by being deterministic for 45 branches of activity, with an average coverage of 82.34% of the value of the Census income, and a probabilistic design for 12 branches,. Currently the survey collects information about 7,475 economic units.

Table 2
Summary Statistics for Key Variables of the Manufacturing Surveys

Variable	Mean	Std. Dev.	Min	Max
Monthly Industrial Survey (1994-2008)				
Hours worked by the personnel	46.1	46.5	0.0	625.8
Hours worked by workers	32.1	33.8	0.0	403.8
Hours worked by employees	14.0	18.5	0.0	399.8
Total employed personnel	234.8	236.1	0.0	3,062.3
Total workers	163.0	173.0	0.0	1,878.8
Total employees	71.8	94.1	0.0	1,947.5
Monthly Survey of Manufacturing Industry (2008-2014)				
Hours worked by the personnel	49.1	55.2	0.3	1,111.0
Hours worked by workers	38.5	44.9	0.3	719.0
Hours worked by employees	10.6	15.3	0.0	411.3
Total employed personnel	248.9	280.7	1.8	4,861.5
Total workers	195.7	231.1	1.8	3,350.8
Total employees	53.2	76.2	0.0	1,733.8
Monthly Industrial Survey (1994-2008)				
Employed personnel	216.8	2,151.3	0.0	18,963.0
Remunerations	2.7	24.9	0.0	1,690.0
Expenses	3.6	71.4	0.0	8,560.0
Income	14.1	187.0	0.0	11,800.0

Source: INEGI, Microdata Laboratory.

Note: The hours are in thousands of hours worked per month; the employed personnel is in number of people; remunerations, expenses and income are in millions of pesos.

The manufacturing surveys show consistent indicators of hours worked by the personal, as expected workers have more hours cumulated by month. In terms of employees, workers are considerably more abundant in the manufacturing sector. The variables of services show higher variance in its composition, which implies high heterogeneity across the activities that are reported.

5. Model Specification

Because TC are random realizations of complex ocean and atmospheric systems, the stochastic timing, direction and their strength allows identifying the causal effect on an output variable using quasi-experimental techniques (Angrist and Pische, 2008). Thus, in this paper, we estimate the effects of TC on economic activity of firms, measured by production, worked hours and occupied personnel, from the manufacturing and services sectors by exploiting their random nature in the month to month within municipality variation in intensity and trajectories and we assume that our exposure measure variable is exogenous and uncorrelated.

However, as other authors suggest, temperature and precipitation are correlated with patterns of tropical cyclone exposure over time (see Hsiang, 2010; Auffhammer, 2014; Auffhammer, Hsiang, Schlenker and Sobel, 2013). Some research have focused on studying the influence of TC to rainfall in Mexico, they found that some regions of Mexico receive an important rainfall contribution from TC like the Baja California Peninsula in the Northwestern region that receive between 55 and 60% of the total mean annual precipitation; also, the Central Northern Pacific coasts and the Yucatan Peninsula that present a contribution about 20% (Brenia-Naranjo, et al., 2015). In consequence, the influence of TC should be simultaneously estimated in order to avoid that the omitted variables may bias the response estimate.

Given the structure of our data, we can estimate the causal effect of the TC and climatic variables using a multivariate panel and the differences-in-differences approach for modeling first differences logarithm of the output variable (worked hours, occupied personnel and production) of the firms as an impulse-response function that is linear in contemporaneous and historical area-average TC exposure, as in the model of Hsiang and Jina (2014) that uses an Augmented Distributed Lagged Autoregressive Model using Ordinary Least Squares (OLS)

$$\Delta \ln(Firm_{i,j,t}) = \sum_{M=0}^4 [\beta_{jTC} TC_{i,t-M} + \beta_{jT} Temp_{i,t-M} + \beta_{jR} Rain_{i,t-M}] + \mu_{ij} + \gamma_{ij}xt + \eta_{jt} + \lambda_t Act + \varepsilon_{i,t} \quad (1)$$

For firm i in municipality j and month t ; the β_j stand for the coefficients of the variables of interest that meaning the marginal effects of the of the TC exposure and climate variables on the output variables; i and the month t ; μ_{ij} y γ_{ij} are state-specific trends for each firm that captures the heterogeneity in the growth trend of every municipality; η_{jt} stand for the fixed effects for state and month, respectively, that control for the different economic structures in every state and stationarity patterns of the month affecting the economic activity; 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.

In the other hand, the $TC_{i,t}$ exposure measures the cumulative exposition to the 10-meters-sustained wind in every point of its trajectory for every locality for the municipality j in the period t . As other authors, such as Hsiang (2010), Hsiang (2012) and Hsiang y Jina (2014), we normalized the $TC_{i,t}$ in terms of their standard deviations for the period of study. Under this setup, the variable of interest are the coefficients β_j which represent the derivatives on economic activity with respect to fluctuations on tropical cyclone energy for the state j months after the shock of the TC with a $TC_{i,t}$

equivalent to a given number of standard deviations above the mean of the historical records of TC exposure experimented in the given municipality for the period of study.

5.1 Results of the Manufacturing Sector

In this section, we show the results of the estimations performed for the manufacturing sector using the three previously mentioned surveys using these as independent estimations.

Table 3 presents the cumulative effects of TC on the worked hours and employed personnel for the firms in the manufacturing sector relative to a firm situation before the event baseline trend.

Table 3
Marginal Cumulative Effects on Worked Hours and Employed Personnel on Firms of 1
Additional Standard Deviation in Sustained Wind of Tropical Cyclones using
the Monthly Industrial Survey 1994 – 2008

	Hours worked by the total personnel	Hours worked by the total of workers	Hours worked by the total of employees	Total employed personnel	Total workers	Total employees
Tcyclones _t	-0.2319 *** [0.006]	-0.2605 *** [0.007]	-0.1813 *** [0.009]	-0.0964 *** [0.006]	-0.1240 *** [0.006]	-0.0530 *** [0.013]
Tcyclones _{t-1}	-0.4832 *** [0.006]	-0.5402 *** [0.006]	-0.3511 *** [0.009]	-0.1634 *** [0.007]	-0.2083 *** [0.007]	-0.0754 *** [0.018]
Tcyclones _{t-2}	-0.2681 *** [0.014]	-0.3177 *** [0.016]	-0.1562 ** [0.032]	-0.2254 *** [0.008]	-0.2831 *** [0.008]	-0.1333 *** [0.016]
Tcyclones _{t-3}	-0.5530 *** [0.010]	-0.6265 *** [0.011]	-0.3890 *** [0.017]	-0.2661 *** [0.009]	-0.3228 *** [0.010]	-0.1636 *** [0.017]
Tcyclones _{t-4}	-0.5895 *** [0.012]	-0.6608 *** [0.013]	-0.4386 *** [0.019]	-0.3133 *** [0.009]	-0.3804 *** [0.011]	-0.1835 *** [0.019]
Tcyclones _{t-5}	-0.4610 *** [0.016]	-0.5520 *** [0.019]	-0.2448 *** [0.041]	-0.3404 *** [0.011]	-0.4463 *** [0.011]	-0.1560 *** [0.028]
Tcyclones _{t-6}	-0.5803 *** [0.016]	-0.6655 *** [0.018]	-0.3480 *** [0.033]	-0.3572 *** [0.012]	-0.4643 *** [0.012]	-0.1676 *** [0.030]
Tcyclones _{t-7}	-0.7072 *** [0.015]	-0.8018 *** [0.018]	-0.4668 *** [0.029]	-0.3541 *** [0.014]	-0.4539 *** [0.014]	-0.1634 *** [0.035]
Tcyclones _{t-8}	-0.4527 *** [0.026]	-0.5217 *** [0.030]	-0.2550 *** [0.059]	-0.3712 *** [0.015]	-0.4734 *** [0.015]	-0.1789 *** [0.036]
Tcyclones _{t-9}	-0.7572 *** [0.019]	-0.8544 *** [0.021]	-0.4888 *** [0.035]	-0.4151 *** [0.015]	-0.5407 *** [0.015]	-0.1866 *** [0.039]
Tcyclones _{t-10}	-0.7081 *** [0.021]	-0.8160 *** [0.024]	-0.4251 *** [0.044]	-0.4250 *** [0.016]	-0.5329 *** [0.017]	-0.2080 *** [0.039]
Tcyclones _{t-11}	-0.4658 *** [0.034]	-0.5464 *** [0.039]	-0.2331 *** [0.088]	-0.4443 *** [0.017]	-0.5579 *** [0.018]	-0.2348 *** [0.038]
Tcyclones _{t-12}	-0.9555 *** [0.020]	-1.0735 *** [0.022]	-0.6167 *** [0.037]	-0.4751 *** [0.017]	-0.6143 *** [0.018]	-0.2302 *** [0.042]
FE, YE, ME	Y	Y	Y	Y	Y	Y
State trends	Y	Y	Y	Y	Y	Y
3-digit NAIC	Y	Y	Y	Y	Y	Y
Observations	788,415	778,093	770,619	796,265	786,243	783,716

Source: Authors' estimations using the Monthly Industrial Survey 1994 – 2008.

In these estimations, we controlled for industry specific trends (2-digit SCIAN activities), state-time-specific constants, month-specific constants and year-specific constants.

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

The effects of TC on worked hours are statistically significant and appear to be persistent and increasing after the shock. The magnitude of the contemporaneous effect implies that one standard deviation increase in wind speed of the TC exposure in a given municipality where the firm is located, decreases the rate of growth of worked hours by 0.24 percentage points and such effect month to month increases after the shock almost reaching the 1 percentage point. This effect is particularly higher in the hours of workers and the cumulative effect is superior to one percentage point one year after the shock. This former result contrasts with the estimated impact for the hours worked by employees, whose magnitude after the fourth month is about the half of the effect on the hours worked by workers.

In terms of the total employed personnel, the effect is lower than the hours worked but also increasing, one year after the TC exposure, one standard deviation increase in wind speed decreases by 0.47 percentage points the employed personnel at the firms. This effect is substantially higher on workers, since the employees show a one-year cumulative impact lower than the half of the workers (-0.23).

Table 4 show the estimations of the TC effects on firms using the Monthly Survey of Manufacturing Industry with data from 2007 to 2014. It is important to mention an important change in the sample of the Survey since it included 1,537 additional firms dedicated to the maquila for exportation, as well as producing economic units of goods, regardless their participation to the program of the Manufacturing Industry, Maquiladora and Export Services (IMMEX).

Table 4
Marginal Cumulative Effects on Worked Hours and Employed Personnel on Firms of 1
Additional Standard Deviation in Sustained Wind of Tropical Cyclones using
the Monthly Survey of Manufacturing Industry 2007-2014

	Hours worked by the total personnel	Hours worked by the total of workers	Hours worked by the total of employees	Total employed personnel	Total workers	Total employees
Tcyclones _t	1.3171 *** [0.012]	1.2491 *** [0.016]	0.8935 *** [0.022]	0.0632 [0.150]	-0.1079 [0.110]	-0.1160 [0.097]
Tcyclones _{t-1}	-2.6502 *** [0.012]	-2.9730 *** [0.013]	-2.1610 *** [0.018]	-0.5331 *** [0.035]	-0.7878 *** [0.029]	-0.2463 [0.088]
Tcyclones _{t-2}	-0.3175 [0.151]	-0.6345 [0.097]	0.2789 [0.215]	-0.6765 *** [0.042]	-1.0552 *** [0.033]	-0.1390 [0.240]
Tcyclones _{t-3}	-1.1183 *** [0.060]	-1.4830 *** [0.058]	-0.7857 * [0.107]	-0.7405 *** [0.054]	-1.0631 *** [0.046]	-0.3975 [0.118]
Tcyclones _{t-4}	-3.1896 *** [0.027]	-3.5883 *** [0.031]	-2.7602 *** [0.039]	-0.7574 ** [0.068]	-1.1271 *** [0.056]	-0.4868 [0.124]
Tcyclones _{t-5}	0.4675 [0.234]	0.1165 [1.165]	0.8099 [0.169]	-0.7311 ** [0.089]	-1.1085 *** [0.072]	-0.4624 [0.164]
Tcyclones _{t-6}	-2.2295 *** [0.060]	-2.8195 *** [0.060]	-1.4050 ** [0.118]	-0.7728 * [0.103]	-1.1704 *** [0.083]	-0.4680 [0.197]
Tcyclones _{t-7}	-2.2639 *** [0.071]	-2.8257 *** [0.072]	-1.2103 * [0.165]	-0.8266 * [0.115]	-1.1358 ** [0.103]	-0.4998 [0.221]
Tcyclones _{t-8}	-1.6380 *** [0.115]	-2.2700 *** [0.106]	-0.5338 [0.445]	-0.8465 * [0.134]	-1.3186 ** [0.105]	-0.2524 [0.526]
Tcyclones _{t-9}	-0.6473 [0.341]	-1.2286 [0.229]	0.2099 [1.312]	-1.0208 ** [0.129]	-1.4563 ** [0.111]	-0.4224 [0.364]
Tcyclones _{t-10}	-3.2697 *** [0.079]	-3.9747 *** [0.083]	-1.9159 ** [0.169]	-1.0064 * [0.153]	-1.4245 ** [0.133]	-0.4233 [0.423]
Tcyclones _{t-11}	-0.5702 [0.483]	-1.0638 [0.332]	0.9278 [0.374]	-1.1585 ** [0.143]	-1.4680 ** [0.138]	-0.1628 [1.163]
Tcyclones _{t-12}	-1.0637 [0.286]	-1.3514 [0.288]	-0.0428 [3.000]	-1.1014 * [0.165]	-1.1813 * [0.189]	-0.4129 [0.516]
FE, YE, ME	Y	Y	Y	Y	Y	Y
State trends	Y	Y	Y	Y	Y	Y
3-digit NAIC	Y	Y	Y	Y	Y	Y
Observations	748,731	741,481	716,265	749,282	742,005	716,822

Source: Authors' estimations using the Monthly Industrial Survey 1994 – 2008, Monthly Survey of Manufacturing Industry 2007-2014.

In these estimations, we controlled for industry specific trends (2-digit SCIAN activities), state-time-specific constants, month-specific constants and year-specific constants.

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

The impact estimation of TC exposure on worked hours are statistically significant and positive in the contemporaneous month and it becomes negative after the second month of the shock and henceforth; however, some cumulative effects are not statistically significant. This change in the results can be explained by the introduction of the 1,537 additional maquila firms. Furthermore, in terms of the total personnel at the firm, the effect is increasing negative after the first month up to the twelfth month when it goes over 1 percentage point. It is important to point out that this impact is completely conducted by the effect on the total workers, since the employees show non-statistically significant effects.

In Table 5, we show the results of an additional exercise that allow us to follow most of the original sample since 1994 to 2014 using the Monthly Industrial Survey (1994-2014), the Extended Monthly

Industrial Survey (2005-2010) and the Monthly Survey of Manufacturing Industry (2007-2014). Presumably no maquila export industry firms are included in this sample. Also, it is worthy to mention that across these three surveys the variables are completely consistent since the questions in the questionnaire remain the same for the variables used for our estimations.

Table 5
Marginal Cumulative Effects on Worked Hours and Employed Personnel on Firms of 1
Additional Standard Deviation in Sustained Wind of Tropical Cyclones using
the Three Monthly Manufacturing Surveys 1994-2014

	Hours worked by the total personnel	Hours worked by the total of workers	Hours worked by the total of employees	Total employed personnel	Total workers
Tcyclones _t	-0.2477 *** [0.005]	-0.2992 *** [0.008]	-0.1817 *** [0.008]	-0.1395 *** [0.004]	-0.1978 *** [0.004]
Tcyclones _{t-1}	-0.5145 *** [0.004]	-0.5980 *** [0.007]	-0.3588 *** [0.007]	-0.2010 *** [0.005]	-0.2802 *** [0.005]
Tcyclones _{t-2}	-0.3647 *** [0.009]	-0.4518 *** [0.019]	-0.2133 ** [0.019]	-0.3005 *** [0.005]	-0.4203 *** [0.005]
Tcyclones _{t-3}	-0.4503 *** [0.010]	-0.5666 *** [0.017]	-0.3163 *** [0.017]	-0.3164 *** [0.006]	-0.4240 *** [0.006]
Tcyclones _{t-4}	-0.7807 *** [0.007]	-0.9070 *** [0.011]	-0.6146 *** [0.011]	-0.4093 *** [0.006]	-0.5405 *** [0.006]
Tcyclones _{t-5}	-0.6951 *** [0.010]	-0.8384 *** [0.018]	-0.4588 *** [0.018]	-0.4052 *** [0.008]	-0.6030 *** [0.007]
Tcyclones _{t-6}	-0.7727 *** [0.011]	-0.9063 *** [0.017]	-0.5597 *** [0.017]	-0.4079 *** [0.009]	-0.5896 *** [0.008]
Tcyclones _{t-7}	-1.0731 *** [0.009]	-1.2114 *** [0.014]	-0.8259 *** [0.014]	-0.3793 *** [0.011]	-0.5443 *** [0.010]
Tcyclones _{t-8}	-0.6359 *** [0.017]	-0.7345 *** [0.027]	-0.4813 *** [0.027]	-0.3302 *** [0.015]	-0.4939 *** [0.013]
Tcyclones _{t-9}	-0.7733 *** [0.016]	-0.9103 *** [0.025]	-0.5732 *** [0.025]	-0.3285 *** [0.017]	-0.5355 *** [0.014]
Tcyclones _{t-10}	-0.9317 *** [0.015]	-1.1026 *** [0.022]	-0.7229 *** [0.022]	-0.2898 *** [0.021]	-0.4588 *** [0.018]
Tcyclones _{t-11}	-0.4205 ** [0.036]	-0.5580 *** [0.062]	-0.2895 [0.062]	-0.2971 ** [0.023]	-0.4830 *** [0.018]
Tcyclones _{t-12}	-1.0276 *** [0.016]	-1.2231 *** [0.026]	-0.7653 *** [0.026]	-0.3325 *** [0.022]	-0.5695 *** [0.017]
FE, YE, ME	Y	Y	Y	Y	Y
State trends	Y	Y	Y	Y	Y
3-digit NAIC	Y	Y	Y	Y	Y
Observations	595,480	588,212	580,872	601,493	594,541

Source: Authors' estimations using the Monthly Industrial Survey (1994-2014), the Extended Monthly Industrial Survey (2005-2010) and the Monthly Survey of Manufacturing Industry (2007-2014).

In these estimations, we controlled for industry specific trends (2-digit SCIAN activities), state-time-specific constants, month-specific constants and year-specific constants.

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

Thus, under this assemble sample of 20 years of monthly observations, we obtained the estimates for the cumulative effect of TC wind exposure on firms hours worked and total employed

personnel. We found statistically significant negative effects since the contemporaneous month with an estimate of -0.25 percentage points, which continuously increase up to the twelfth month with a magnitude of -1.03 percentage points. Such impact is mainly conducted by the workers that show a more negative effect, in particular, one standard deviation increase in wind speed generates in that municipality where the firm is located a decrement of -1.22 percentage points of the hours run by workers. Similarly, the total employed personnel increasing negative effects since the contemporaneous month, and again the impact is considerably higher for the workers. At the twelfth month, one standard deviation increase in wind speed generates a decrease of 0.56 percentage points in the total workers of the firm.

5.2 Results of the Services Sector

Table 6 shows the estimated effects of TC on firms of the services sector for the available variables in the survey: employed personnel, remunerations, expenses and income. We observe no statistical significant effect on employed personnel and the significant impacts are concentrated in the contemporaneous and first month after the shock.

Table 6
Marginal Cumulative Effects on Firms of Services Sector for 1 Additional
Standard Deviation in Sustained Wind of Tropical Cyclones using
the Monthly Services Survey 2008-2014

	Employed personnel	Remunerations	Expenses	Income
Tcyclones _t	-0.0440 [0.039]	0.2013 * [0.030]	-0.4170 * [0.064]	-0.4609 *** [0.032]
Tcyclones _{t-1}	0.0087 [0.433]	-0.0674 [0.177]	-0.6780 ** [0.078]	-0.3970 * [0.073]
Tcyclones _{t-2}	0.0028 [0.300]	-0.3728 * [0.051]	-0.2054 [0.411]	-0.1109 [0.427]
Tcyclones _{t-3}	-0.0483 [0.161]	0.2398 [0.110]	-1.0076 ** [0.116]	-0.1202 [0.546]
Tcyclones _{t-4}	-0.1110 [0.089]	-1.1957 *** [0.029]	-1.3452 ** [0.113]	-0.5711 [0.146]
Tcyclones _{t-5}	-0.0781 [0.163]	-0.1988 [0.221]	-1.2696 ** [0.155]	-0.1633 [0.680]
Tcyclones _{t-6}	-0.0561 [0.280]	-0.3056 [0.180]	-1.3962 ** [0.175]	-0.6247 [0.215]
Tcyclones _{t-7}	-0.1569 [0.123]	-0.6039 * [0.111]	-1.7074 ** [0.175]	-0.9213 [0.178]
Tcyclones _{t-8}	-0.1174 [0.196]	-0.4821 [0.166]	-0.7827 [0.460]	-0.4896 [0.401]
Tcyclones _{t-9}	-0.1739 [0.158]	-0.5111 [0.185]	-1.3684 [0.310]	-0.4347 [0.530]
Tcyclones _{t-10}	-0.2272 [0.142]	-0.8716 * [0.129]	-2.6290 *** [0.191]	-1.5784 ** [0.174]
Tcyclones _{t-11}	-0.0890 [0.404]	-0.9964 ** [0.122]	-1.6273 [0.333]	-1.5047 * [0.197]
Tcyclones _{t-12}	-0.2800 [0.139]	-0.7617 [0.177]	-2.2023 [0.275]	-1.8477 ** [0.179]
FE, YE, ME	Y	Y	Y	Y
State trends	Y	Y	Y	Y
3-digit NAIC	Y	Y	Y	Y
Observations	271,787	271,634	290,831	312,308

Source: Authors' estimations using the using the Monthly Industrial Survey (1994-2014), the Extended Monthly Industrial Survey (2005-2010) and the Monthly Survey of Manufacturing Industry (2007-2014).

In these estimations, we controlled for industry specific trends (2-digit SCIAN activities), state-time-specific constants, month-specific constants and year-specific constants.

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

Results between variables are consistent, the income and the expenses of the firm show a negative impact during the contemporaneous and the first month after the shock. Thus, one standard deviation increase in wind speed of TC exposure decreases by 0.46 percentage points the growth of income and in 0.42 percentage points the expenses of the firm to operate. In the case of the expenses of the firm, it might be a direct result of a fall in the activity since the firms will need less inputs since they may not be operating normally after the shock of a TC. In addition, the remunerations for employed personnel increase in the same month of the shock, which may be reflecting the extra activities that that staff must carry out in order to recuperate the physical installations of the firm.

However, it is important to point out that even when the sensibility of this sector appears to be higher since the magnitude of the impact on firms' income is considerable; also, the capacity of these firms to recover the level of its activity is higher, especially for recovering the income.

6. Conclusions

In this paper, based on the identification properties of TC, we estimate their effects on economic activity taking advantage of a more disaggregated set of information for one of the most exposed countries in the world. In Mexico, TC are one of the primary causes of economic losses and large scale damage in infrastructure. The importance of this research relies on the positive relationship between global warming and severity of TC, so the expectation of deeper climate change rises concern about their policy challenges for supporting adaption and economic resilience in the most vulnerable areas.

In this context, using data of TC's trajectories from IBTrACs for both basins neighboring Mexico, we found about 600 municipalities show the highest levels of exposure. Nevertheless, the NA basin have been showing an increasing trend in the severity of hurricanes. The most exposed municipalities are mostly located in coastal states of the EP shore like Baja California Sur, Jalisco, Colima, Michoacan, Guerrero and Oaxaca an in the NA shore in Veracruz, Tabasco, Campeche, and Quintana Roo. Some of these states, in both shores, have the lowest levels of economic development.

All our findings are consistent with the international evidence (Hsiang, 2010; and Hsiang and Jina 2014). In Mexico, we found that firms from manufacturing and services show negative effects of TC exposure if the impacts appear to be transitory since it dissolves during one year after the shock, depending of the sector. However, there exist heterogeneous results across sectors, the tertiary sector shows a higher sensitivity and vulnerability but limited duration under these kind of events. In contrast, in secondary activities the effect is negative and appears to be persistent for one year.

We found that for the sector of manufacturing and the period 1994-2014, one standard deviation increase in wind speed decreases by 1 and 1.77 percentage points the growth of the hours worked and the employed personnel at the firms, respectively, being always of higher magnitude de effects on workers. For the sector of services, one standard deviation increase in wind speed of TC exposure decreases by 0.46 percentage points the growth of income and in 0.42 percentage points the expenses of the firm to operate. However, firms from services sector have a very quick recovery from this type of events.

Thus, we observe increasing negative and persistent effects on firms of manufacturing sector; in contrast, firms of services show a higher short-run negative sensitivity but low persistence. 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.

Even when our results are statistically significant, and show the expected signs, the structure of the data imposes some limitations in terms of the attrition that could question the validity of our results. For future research, it is imperative to carry out this analysis and prove other specifications, as well as estimate adaptation effects of the TC in the economic activity, in order to identify the most effective strategies to increase the economic resilience of the states and locations. In addition, it would be interesting to incorporate the climate change scenarios in to the estimations of impact for dimensioning the possible future risk.

7. References

- Dell M, Jones BF, Olken BA. 2009. Temperature and income: reconciling new cross-sectional and panel estimates. *Am. Econ. Rev. Pap. Proc.* 99:198–204
- Dell M, Jones BF, Olken BA. 2012. Temperature shocks and economic growth: evidence from the last half century. *Am. Econ. J. Macroecon.* 4:66–95
- Dell M, Jones BF, Olken BA. 2014. What do we learn from the weather? The new climate-economy literature. *J. Econ. Lit.* 52:740–98
- Deschenes O, Greenstone M. 2007. The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather. *American Economic Review* 97:354–85
- Deschenes O, Greenstone M. 2011. Climate change, mortality, and adaptation: evidence from annual fluctuations in weather in the US. *Am. Econ. J. Appl. Econ.* 3:152–85
- Deschenes O, Moretti E. 2009. Extreme weather events, mortality and migration. *Rev. Econ. Stat.* 91:659–81
- Desmet K, Rossi-Hansberg E. 2015. On the spatial economic impact of global warming. *J. Urban Econ.* 88:16–37.
- Domínguez C. y V. Magaña. 2018. “The Role of TC in Precipitation over the Tropical and Subtropical North America”, *Frontiers in Earth Sciences* 6:19.
- Emanuel, K. 2005. “Increasing destructiveness of TC over the Past 30 Years”, *Nature. Letters* 436:4.
- Holland, G. y C. Bruye`re. 2014. “Recent intense hurricane response to global climate change”, *Climate Dynamics*, 42:617–627. DOI 10.1007/s00382-013-1713-0.
- Hsiang SM. 2010. Temperatures and cyclones strongly associated with economic production in the Caribbean and Central America. *PNAS* 107:15367–72
- Hsiang S.M., Jina AS. 2014. The causal effect of environmental catastrophe on long-run economic growth: evidence from 6,700 cyclones. NBER Working Paper 20352.
- Hsiang, S. 2016. “Climate Econometrics”, *Annual Review in Resources Economics* vol. 8:43–75
- Jones, B. F. and B. A. Olken. 2010. Climate Shocks and Exports *American Economic Review: Papers & Proceedings* 100 (May 2010): 454–459.
- Mendelsohn R, Emanuel K, Chonabayashi S, Bakkensen L. 2012. The impact of climate change on global tropical cyclone damage. *Nature Climate Change* 2:205–9
- Nordhaus WD. 2010. “The economics of hurricanes and implications of global warming”, *Climate. Change Economics* 1:1–20