FONDATION POUR LES ÉTUDES ET RECHERCHES SUR LE DÉVELOPPEMENT INTERNATIONAL

Insuring Growth: The Impact of Disaster Funds on Economic Development

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Abstract

While a recent stream of papers has shown that natural disasters in developing economies have negative and persistent effects on economic development, it is still unclear whether *ex ante* budgeting allocations for post-disaster reconstruction provide a cost effective way of mitigating these losses. By taking advantage of the sharp rules that govern the municipal level eligibility to infrastructure reconstruction funds in Mexico, this paper provides some of the first estimates of the impact of disaster funds on local economic activity. Our main finding is that access to disaster funding increases local economic activity by as much as 2.57% one year after damage from heavy rainfall has occurred. We also find that the average benefit cost ratio of Mexico's disaster fund is 1.3.

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1. Introduction

While in developed economies there is considerable debate over the long run effects of natural disasters on economic performance (see Strobl (2011); Hsiang and Jina (2014)), in developing economies both micro and macro level empirical studies suggest that natural disasters can have particularly large and persistent effects on economic performance (see Anttila-Hughes and Hsiang (2013); Noy (2009)).

The estimated effects of natural disasters on economic performance are potentially large. At the top range of estimates, Hsiang and Jina (2014) argue that a percentile 90 hurricane can reduce per capita income by as much as 7.4%, and for as long as two decades. This loss is of considerable magnitude as it is roughly equivalent to undoing 3.7 years of average economic growth. Similarly, in a medium run scenario, Anttila-Hughes and Hsiang (2013) claim that the damage created by west pacific hurricanes one year after the event is 15 times larger than the immediate damages.

Given the scale of potential medium and long run losses in post-disaster economic outcomes, a key question is whether tools like national disaster funds provide developing economies with a cost effective way of mitigating the losses caused by natural disasters. Taking advantage of a unique natural experiment and dataset, this paper provides some of the first evidence on the causal impact of disaster funds on medium run economic development.

We circumvent endogeneity in the provision of rapid reconstruction funds by using a regression discontinuity design that exploits the sharp rules that determine whether a natural disaster has occurred in a Mexican municipality.[1] Since only officially affected municipalities can access disaster funds, we recover causal estimates of the impact of disaster funds on local economic activity by comparing municipalities that are just below and above the thresholds that define the occurrence of the disaster.

We measure changes in economic activity at the municipal level using high resolution satellite imagery that allows us to measure the intensity of light as observed from outer-space. Because our night light measure is strongly related to local economic activity we are able to track the differential economic performance created by the provision of rapid reconstruction funds.

Our main finding is that Mexico's disaster fund increased local economic activity by as much as 2.57%. Our point estimates are currently too noisy to precisely determine whether the program is cost effective. Nonetheless, taken at face value the estimates suggest that the benefit cost ratio of Mexico's disaster fund is 1.3.

The rest of the paper is organized as follows. Section 2 presents brief background information on the FONDEN disaster fund. Section 3 presents the identification strategy. Section 4 discusses the various datasets used. Section 5 presents the main results. Section 6 concludes.

2. Background

FONDEN is a fund setup by the Mexican government to manage the risk created by natural disasters. The program is funded by the government and through the placement of catastrophe bonds in the capital market. The program became operational in 1999 with the primary purpose of supporting the reconstruction of federal and state infrastructure destroyed by natural disasters. Over time the efforts of the federal government have evolved to finance interventions at all stages of the disaster risk management cycle. Currently, FONDEN funds short term emergency relief operations and the reconstruction of low-income housing and public infrastructure.

Mechanisms to mitigate the impact of disasters

The bulk of FONDEN expenditures are related to reconstruction efforts. These efforts include the

1. A municipality is a second level administrative unit in Mexico. There are currently 2461 municipalities.

reconstruction of federal and state roads, the provision of funds to reconstruct low-income housing, and the rebuilding of hydraulic, health, and educational infrastructure. These expenditures can provide a double gain to economic development. First, by mitigating the losses created by natural disasters. Second, by enabling local governments and households to reallocate resources from inefficient low risk-low return productive activities to more risky-higher yielding activities.

Our current analysis estimates the impact of FONDEN one year after the occurrence of a natural disaster, and focuses on the 2004-2011 period when road expenditures accounted for the bulk of overall expenditures.[2] Accordingly, we expect FONDEN to affect economic activity primarily by enabling municipalities to quickly rebuild their road network following a disaster.

3. Empirical Strategy

In order to estimate the impact of FONDEN we will take advantage of sharp physical event thresholds that determine whether a natural disaster has occurred, and therefore whether a municipality is eligible for FONDEN funding. The funding process begins with a request from the state governor. This request contains a list of municipalities that are believed to have experienced damages as a result of a natural disaster. The request is verified by an independent technical agency who compares measurements of the intensity of the disaster to the thresholds set out on FONDEN operational guidelines. For example, in the case of heavy rainfall, the technical agency CONAGUA[3] compares the rainfall at the weather station representative of the requested municipality to the FONDEN heavy rain threshold, that is, rainfall greater or equal to the percentile 90 of historic rain recorded at that weather station. CONAGUA will then list the municipalities that pass the threshold, and a declaration of disaster will be issued for this set of municipalities. A declaration of disaster is a necessary condition to receive FONDEN funding.

We will focus on rainfall related events because they account for the bulk of FONDEN expenditures. These events include: heavy rain, tropical storms, hurricanes, areal flooding, riverine flooding, landslides, and hail storms. The threshold for heavy rain, and areal flooding is rainfall greater than the percentile 90 of historic rainfall. Tropical storms, hurricanes, riverine flooding, landslides, and hail storms have other additional thresholds. In spite of the sharp rules, we use a fuzzy regression discontinuity design because we are currently unable to perfectly distinguish between different types of events, and because we are unable to fully match municipalities to the set of weather stations used for verification. Because of data restrictions, as previously mentioned, we will restrict the sample to the 2004 to 2011 period.

In the fuzzy regression discontinuity design to estimate two causal effects: the effect of crossing the percentile 90 threshold on the probability of receiving FONDEN, and the effect of crossing the percentile 90 threshold on local economic activity. Specifically we run the following regressions:

$$f_{mt} = \gamma_0 + \gamma_1 z_{mt} + \gamma_2 g(r_{mt} - c_{mt}) + y_3 g(r_{mt} - c_{mt}) * z_{mt} + \theta_t + v_{mt} \quad (1)$$

$$y_{mt} = \beta_0 + \beta_1 z_{mt} + \beta_2 g(r_{mt} - c_{mt}) + \beta_3 g(r_{mt} - c_{mt}) * z_{mt} + \theta_t + \varepsilon_{mt} \quad (2)$$

$$\hat{\pi}_1 = \frac{\hat{\beta}_1}{\hat{\gamma}_1} \quad (3)$$

Equation 1, the first stage, is estimated by regressing a dummy that takes the value of one when municipality m in year t receives FONDEN, f_{mt}, on an indicator variable that takes the

2. The share of expenditure by category vary year by year depending on the the type of damages that have occurred. During the period of analysis road expenditures account for 56% of overall expenditures, and for more than 70% of expenditures in three of the eight years analyzed.
3. CONAGUA is an agency of the government of Mexico charged with water conservation.

value of one when an observation falls above the threshold, z_{mt}. That is, $z_{mt} = 1(r_{mt} \geq c_{mt})$ where r_{mt} is the amount of rainfall on the day requested and c_{mt} is the percentile 90 threshold. The function $g(r_{mt} - c_{mt})$ represents the relationship between the outcome and the forcing variable, that is, millimeters of rainfall to the the percentile 90 threshold. We will consider various ways of modeling this relationship. First we will model $g(\cdot)$ as a flexible polynomial function on either side of the threshold and use the full sample to estimate it. Second, we will assume that $g(\cdot)$ is linear and use a sample that falls within an optimal bandwidth to estimate it. To determine the bandwidth we will use the methods proposed by Imbens and Kalyanaraman (2012) and Calonico et al. (2014b).

Equation 2, the reduced form, is derived by regressing our measure of local economic activity, y_{mt}, on z_{mt}. The estimation procedure is analogous to that of equation 1. Next, we derive the impact of FONDEN on local economic, π_1, by rescaling the reduced form coefficient of z_{mt} by its first stage coefficient.[4]

4. Data

For our analysis, we use data from several sources. We proxy changes in municipal level economic activity by using imagery from the DMSP-OLS satellite program. The imagery provided by NASA and NOAA is available in yearly frequency from 1992 to 2012. The digital number (DN) that can be derived from these images is a measure of the intensity of the light observed from outer-space. The DN is recorded at a spatial resolution of approximately one km square.[5] Given the high-resolution of these images we are able to construct meaningful measures of the change in economic activity at the subnational level. Specifically, we follow Henderson et al. (2011) and use as proxy the log of the sum of the DN over all pixels that fall within a municipality standardized by the area of the pixels. Consistent with past literature our own tests reveal that the change in log lights is a good predictor of changes in state level GDP, as well as other measures of economic activity at the municipal level.[6]

Data on historical rainfall at the weather station level, the rainfall thresholds used to verify the occurrence of a natural disaster, and the mapping between weather stations and municipalities is provided by CONAGUA. Data on FONDEN expenditures are provided by the Ministry of Finance. Data on municipal-level requests and approvals for disaster declarations are constructed from the archives of Mexico's official diary.

All in all, we have 7200 municipal disaster observation between 2004 and 2011. In our first pass at the data, we will restrict the sample to municipalities that experience a natural disaster related to heavy rain and for whom we have complete information. Table 1 below presents summary statistics of our key variables in this sample.

Table 1: Summary statistics

Variable	Obs	Mean	Std. Dev.	P5	P95
Δ log light	1745	-.04	.28	-.43	.48
Fonden = 1	1745	.58	.49	0	1
Above threshold	1745	.36	.48	0	1
Rainfall mm to threshold	1745	-13.09	74.94	-116.1	120.8

5. Results

Figure 1a plots the mean probability of receiving FONDEN relative to rainfall millimeters (mm) to the threshold. The figure reveals a potential jump in the probability of receiving FONDEN. Moving from just below to just above the threshold increases the likelihood of receiving

4. In order to derive standard errors for π_1 we will instead estimate the coefficient using 2SLS.
5. The actual spatial resolution is 30 arc seconds, that is, at the equator 0.86 km by 0.86 km grids.
6. See Henderson et al. (2011) for a discussion of using changes in night lights to predict changes in economic activity.

FONDEN from about 60% to 80%. In order to better visualize this jump, the figure additionally plots kernel-weighted local polynomial regression lines that are estimated separately on each side of the threshold. The figure further suggests that the underlying relationship between the probability of receiving FONDEN and mm to the threshold could be captured by a second or third order polynomial function of $g(\cdot)$.

Analogously, figure 1b plots the mean change in log lights between the year a disaster occurs and the following year. The figure reveals a clear jump in brightness at the threshold. Moving from just below to just above the threshold increases brightness by roughly 0.07 log points. As expected, the figure additionally reveals that in the absence of FONDEN, night lights become dimmer as the intensity of the disaster increases, that is, as the we move towards the threshold from the left. Interestingly, moving from the threshold to the right there appears to be no relationship between the brightness and the intensity of the disaster. These findings are consistent with the idea that our log lights proxy is in fact capable of measuring a reduction in economic activity caused by natural disasters, and that FONDEN is at least partly capable of mitigating the impact of natural disasters.

Table 2 presents the regression analog of figures 1a and 1b. Panel A present OLS estimates of equation 1. Panel B presents OLS estimates of equation 2, and 2SLS estimates of the impact of FONDEN on local economic activity π_1. Columns 1 to 4 present various specifications of the functions $g(\cdot)$. Specifically, in columns 1 and 2 we estimate using the full sample and assume that function $g(\cdot)$ is a second or a third order polynomial. In columns 3 and 4, we assume that $g(\cdot)$ is linear and restrict the sample to within 50.5 mm and 57.3 mm as determined by two optimal bandwidth calculations. Standard errors are clustered at the municipal level.

Consistent with figure 1a, the estimates of panel A reveal that crossing the threshold increases the probability of receiving FONDEN between 13% to 19% and that this jump is statistically significant in all cases. Similarly, the reduced form estimates of panel B reveal that municipalities above the threshold grew by roughy 0.04 log points more than municipalities below the threshold. Once we rescale these reduced form coefficients, we find that FONDEN led to an increase in the range of 0.196 to 0.37 log points. While these coefficients are only statistically significant at the margin, the estimated effect sizes are of considerable economic magnitude. In the last column of panel B we convert the changes in log light created by FONDEN to changes in economic activity using an elasticity of light to GDP of approximately 0.07.[7] These estimates of the impact of FONDEN suggest that the program could have increased local economic activity by as much as 2.57%.

Simulation

In order to get a better sense of the magnitude of the changes in economic activity generated by FONDEN, this section preforms a simple counterfactual simulation. The calculation is preformed in four steps. First, we approximate municipal GDP at baseline by calculating 2004 per capita GDP at the state level and then multiply this figure by the population of each municipality. Second, we convert the estimated change in log light to a change in economic activity using an estimated elasticity of light to state GDP. Specifically, we follow Henderson et al. (2011) and derive this elasticity by regressing the log of state level GDP on our log light proxy, year fixed effects, state fixed effects, and linear state trends. Third, we restrict the sample to municipalities that received FONDEN between 2004 and 2011, our sample period. Fourth we calculate the value of the economic activity generated by FONDEN by multiplying municipal GDP by the change in economic activity. The municipal figures are then summed up and converted to dollars using the current exchange rate.

To account for the uncertainty in the es-

7. See the next section for details on this calculation.

timated regression parameters, we perform the calculation described in the previous paragraph, using coefficients drawn from a normal distribution with mean equal to the estimated coefficient and a standard deviation equal to the standard error. This procedure is then repeated 1000 times, using a random draw of the coefficients each time.

The resulting simulation suggests that the increase in economic activity had an average value of USD $6.38 billion with a standard deviation of USD $5.63 billion. Given that the cost of FONDEN during this period is USD $4.9 billion,[8] these figures suggest that the average benefit-cost ratio is roughly 1.3. These figures seem to be of a reasonable magnitude, if we were to think of FONDEN as fiscal stimulus even when taking into account one standard deviation we would derive a Keynesian multiplier in the 0.15 to 2.45 range. When we replicate this simulation exercise for each year in our sample, we find that FONDEN provides an average increase in local economic activity of USD $1.69 billion, that in all years the multiplier is above one, and that the multiplier could be as large as 5.

All in all, while our estimates are too noisy to clearly pin-down the effect of FONDEN, they are still informative as they provide lower bounds of program impact. We are likely to be underestimating the impact of FONDEN. First, because, one year after a disaster occurs, municipalities without FONDEN funds are likely to have engaged in reconstruction efforts of their own. Second, because municipalities without FONDEN funds are likely to benefit indirectly from FONDEN reconstruction projects in neighboring municipalities. These spillover effects could be particularly important in the case of road reconstruction projects, which represent the bulk of FONDEN projects in our sample.

8. This cost figure refers to the money spent by FONDEN in reconstruction projects. Note that in the absence of FONDEN these reconstruction projects are likely to be undertaken by other government agencies, albeit at higher administrative costs and longer waiting times. The additional benefits created by the more effective FONDEN administration are not been taken into account in this analysis.

6. Conclusion

This paper exploits the sharp rules that govern eligibility to FONDEN funding, to derive some of the first estimates of the impact of disaster funds on local economic activity. On the whole, our results suggest that, in Mexico, FONDEN has provided cost-effective protection from the public service disruptions created by natural disasters. Given the scale of gains to local economic activity brought about by disaster funds, policy makers are encouraged to consider using disaster funds to extend their own response capabilities.

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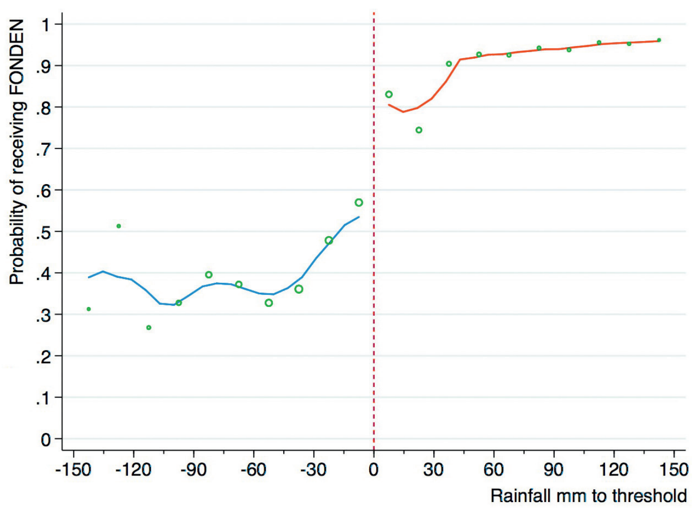
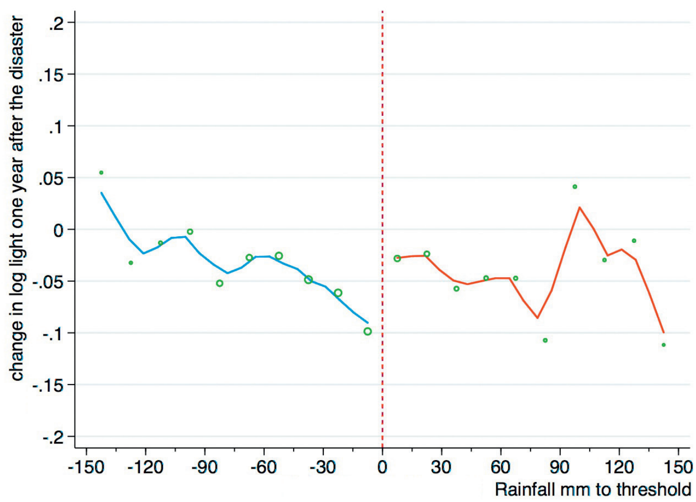
7. Figures and Tables

Figure 1: Probability of receiving FONDEN and change in lights by forcing variable



(a) First stage, twenty 15 mm bins



(b) Reduced form, twenty 15 mm bins

Note: The figures plot the local average of 15 mm bins, and triangular kernel-weighted local polynomial regression lines on each side of the threshold. The size of the markers is proportional to the number of observations used to estimate the local averages. The 15 mm bin width roughly corresponds to the optimal bin width derived when minimizing the integrated mean square error. See Calonico et al. (2014a) for details on deriving the optimal number of bins. The forcing variable is calculated by taking the difference between daily rainfall and the percentile 90 threshold, For disasters that span more than one day, the day with the maximum rainfall is used.

Table 2: The impact of FONDEN

	(1)	(2)	(3)	(4)
Panel A: First Stage				
Dep. Variable	Fonden=1	Fonden=1	Fonden=1	Fonden=1
Above threshold (γ_1)	0.194*** (0.042)	0.140*** (0.0510)	0.129** (0.0530)	0.157*** (0.0506)
Panel B: Reduced Form & 2SLS				
Dep. Variable	Δ log light	Δ log light	Δ log light	Δ log light
Above threshold (β_1)	0.038** (0.018)	0.0382 (0.0235)	0.0481** (0.0235)	0.0439** (0.0222)
$\widehat{\text{Fonden}}$ (π_1)	0.196* (0.104)	0.272 (0.199)	0.372 (0.238)	0.280* (0.167)
Impact on local GDP %	1.36	1.88	2.57	1.93
Observations	1,745	1,745	922	1,016
Specification	quadratic	cubic	linear	linear
Sample	Full	Full	Optimal bw IK: 50.5 mm	Optimal bw CCT: 57.3mm

Note: Standard errors clustered at the municipal level in parentheses. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels. All regressions include year fixed effects. Panel A presents OLS estimates of equation 1. Panel B presents OLS estimates of equation 2, and 2SLS estimates of the coefficient π_1. The label specification referrers to the polynomial order of the function $g(r_{mt} - c)$. In column 3, the optimal bandwidth was derived following Imbens and Kalyanaraman (2012). In column 4 the optimal bandwidth was derived following Calonico et al. (2014b). The impact on local GDP is derived by multiplying the 2SLS estimate by the elasticity of light to GDP, details on this calculation can be found in the simulation section.