The Impact of Hurricanes Katrina, Rita and Wilma on Business Establishments[1]

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Abstract

We show that GIS based estimates of the economic impact of the 2005 hurricanes provide a more accurate characterization of affected businesses than widely reported estimates constructed from county level data. Our methodology relies on mapping business establishments into damage zones defined by remote sensing information provided by FEMA. Our methodology is based on pre-storm data, so estimates can be made available very quickly to inform the public as well as policy makers. Our GIS-based estimates indicate significantly smaller impacts on business payroll than previous estimates using county level data. Tests using post-storm data support our GIS methodology.

KEYWORDS: natural disaster, economic impact, economic activity, Business Register

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1. Introduction

In the wake of large-scale disasters, such as Hurricanes Katrina, Rita and Wilma, the public and policy makers will want to quickly assess the damage and understand the impact.[2] A fully accurate assessment can take many months, perhaps years, as homeowners, businesses, insurance companies and government agencies clean up and rebuild damaged areas and structures. Except for those directly involved, however, the only source of information about the impact of a disaster is what they get from media and government sources in the period immediately after the event.

Estimates of the impact of disasters that come out in the days and weeks following the event, such as during the 2005 U.S. hurricane season, are necessarily based on pre-event data. In the case of the 2005 hurricanes, many of these estimates were based on publicly available data from the Census Bureau and other government statistical agencies. These data are commonly available at the county level and conveniently map into Federal Disaster Areas that are also defined at the county level. Thus, the media and statistical agencies often give what might be called "worst case scenarios" by reporting the population, number of business, employment or other statistics for the counties declared as Federal Disaster Areas. While easy to generate, these county level estimates from pre-event data are very likely to overstate the impact of a disaster since not all of the areas of declared counties will be equally affected.

Methodologies utilizing post-event data typically yield substantially lower impact estimates. These studies often show that disaster events are often associated with positive economic impacts in the longer run (see Ewing and Kruse [3], Ewing Kruse and Thompson [4] and Garber et. al. [7] for examples). However, these estimates almost exclusively appear well after the event and in publications intended for professional audiences rather than policymakers or the public. For example, Garber et. al. [7] provide estimates of the employment impact of hurricane Katrina in the same range as our using the Bureau of Labor Statistics Current Employment Survey and Quarterly Census of Employment and Wages, but not until a full year after the event.

In this paper, we develop estimates of the impact of hurricanes Katrina, Rita and Wilma on business establishments using both pre-storm and post-storm data. The estimates we develop are useful for assessing the number and payroll of

[2] Natural disasters inflict a host of social and economic impacts. Ewing, Kruse and Sutter [5] survey research on the effects of hurricanes and other disasters.

workers at businesses damaged by the 2005 hurricanes.[3] Our methodology, however, would also be useful for analyzing the impacts of disasters on housing units and public infrastructure. More generally the estimates and methodology developed in this paper can be used to help plan the type and level of response to an event in near real time.

To develop more accurate estimates, we use Geographic Information Systems (GIS) tools to merge information on areas affected by the 2005 hurricanes to the Census Bureau's Business Register (BR). We then classify business establishments by Federal Emergency Management Administration (FEMA) damage categories. We are thus able to address the magnitude of the error introduced by using county level information.

A key advantage in our approach to measuring the impact of disasters on businesses is that it can be used to generate estimates very quickly after the event. The interest in such estimates declines rapidly over time. Thus, measurement strategies that require statistical agencies to wait for new administrative or survey data will produce estimates for which there is little public interest. Our approach provides statistical agencies, like the Census Bureau, with the means to provide the public and decision makers with reliable estimates when they need them. In the case of hurricane Wilma, we were able to produce estimates only 3 days after landfall.

2. Determination of Affected Establishments

Statistical agencies released estimates of affected populations shortly after each of the 2005 hurricanes. These estimates were typically based on federal disaster declarations issued for specific counties or parishes. However, the issuance of a federal disaster declaration for a county does not require that the county suffer a large amount of damage.[4] In addition, hurricane damage does not equally affect all parts of a political jurisdiction such as a state or county. Estimates based on county-level federal disaster designations, thus, overstate the impact of such events. Ideally we want to precisely determine what businesses are located in affected areas and then measure their output, employment and so on. The use of GIS tools combined with FEMA digitized damage maps can accomplish the first

[3] We would also like to look at sales, but survey information on sales is not available for the frequency and level of geographic detail required for these purposes.

[4] Code of Federal Regulations (**Title 44, Chapter 1, Part 206.48**) establishes that a county is eligible for public assistance if it has countywide damages of at least $2.77 per capita.

part of this task – determining which businesses are located within an affected area.

FEMA provided, shortly after each hurricane, detailed PDF maps and ESRI shape files of affected areas based on remote sensing data (see FEMA [6]). In the case of hurricane Katrina, the remote sensing observations were obtained over the period from August 30 to September 10, 2005. The FEMA maps show levels of damage using the following categories[5]:

- Limited Damage: Generally superficial damage to solid structures (e.g., the loss of tiles or roof shingles), some mobile homes and light structures are damaged or displaced.
- Moderate Damage: Solid structures sustain exterior damage (e.g., missing roofs or roof segments), some mobile homes and light structures are destroyed, and many are damaged or displaced.
- Extensive Damage: Some solid structures are destroyed, most sustain exterior damage (e.g., roofs are missing, interior walls are exposed), most mobile homes and light structures are destroyed.
- Catastrophic Damage: Most solid and all light or mobile structures are destroyed.
- Flooded area: Area under water.
- Undamaged: Areas not covered by the above categories.

Figure 1 presents two views of the areas of Louisiana damaged by hurricane Katrina. The left panel depicts Louisiana parishes classified as federal disaster areas. The panel on the right shows the areas given one of the above FEMA damage classifications. One is immediately struck by the difference in the land area labeled as affected under the two methodologies. Note, however, that FEMA's remote sensing maps focus primarily on developed areas, so the area classified in one of the above FEMA categories must be, by definition, smaller than under the method of classifying an entire parish/county as damaged. Nevertheless, for our purposes of measuring the impact on businesses, we are bound to find fewer businesses in the affected areas depicted in the right panel than in the left panel.

The next step is to assign establishments in the Census Bureau's Business Register (BR) a FEMA damage classification. The BR contains the universe of business establishments with paid employees and contains basic information about the scale and type of business activity at each location. Thus, placing an accurate damage classification on each establishment in affected states would give

[5] These damage classifications refer to assessments of remote sensing data. See http://www.gismaps.fema.gov/attr.shtm#hurricane.

an accurate enumeration of the number and scale of activity at affected businesses.

Our approach is to use GIS tools to geocode businesses in the BR and then add FEMA GIS damage layers. Doing this gives us, for each (geocoded) establishment, the FEMA damage classification of the location containing the establishment. Critical to this approach are: 1) the accuracy of the FEMA damage classifications, 2) the availability and accuracy of detailed geocodes on the BR, and 3) the timeliness of the business data at our disposal.

On the first point, there is not much we can do. We take the FEMA GIS information as given. As you will see, in some cases FEMA may provide alternative estimates of the type of damage sustained at a given location. In the case of hurricane Katrina, FEMA provided two sets of GIS flood layers for New Orleans that showed significantly different patterns. From other information (e.g., news accounts, conversations with people in New Orleans), we have reason to believe that the GIS data showing more limited flooding was more accurate. As you will see, our analysis using post storm data confirms this. Nevertheless, we compute and present estimates under both scenarios.

The ability to place businesses within FEMA-designated affected areas depends on the completeness and accuracy of the geocodes available on the BR. The lowest unit of geography on the BR that is reliable for the entire universe of establishments is the county or parish.[6] Many establishments also have valid census block and tract codes. Our initial attempt to merge FEMA GIS damage data to Census Bureau business data was to map census blocks into FEMA damage areas. However, this proved too cumbersome as many blocks intersected with multiple damage areas (e.g., part of the block was flooded and part was undamaged). This resulted in a very large number of establishments that could not be assigned a unique FEMA damage classification.

More accurate establishment-level geocodes permit assigning BR establishments to a unique FEMA damage area. To accomplish this, we use street address information on the BR to assign latitude and longitude (lat/long) coordinates to as many establishments as possible.[7] Our ability to do this is dependent on the quality of the address information on the BR. This varies across space; address quality in the BR is higher for establishments in urban areas than it is for those in rural areas. For the three states affected by hurricane Katrina, we are able to assign detailed geocodes (i.e., latitude and longitude coordinates) to

[6] The Census is required to provide measures of business activity at the county level so it devotes additional resources to obtaining accurate codes.

[7] We used ArcGIS to attach latitude and longitude coordinates to BR street addresses.

between 61 percent (Alabama) and 73 percent (Louisiana) of the establishments in the BR.

Another shortcoming of the process by which we geocode establishments stems from the fact that, by using street address, we are only able to locate each business on a point on the map rather than delineate the polygon defined by the establishment's physical boundaries. We have no information about the extent of the business properties, the locations of buildings or other things that might help determine what lies inside a damage zone and what doesn't. This is probably not too problematic for small establishments, but could be troublesome for large establishments such as oil refineries and other large manufacturing plants.

Finally, the time required to collect, process and ready data for analysis necessarily dictates the type of analysis that can be conducted. Current survey data (from, for example, the Manufacturer's Shipments, Inventories and Orders Survey or the Monthly Retail Survey) provide a wealth of information on current business activity. However, these data are unsuitable for estimating the impact of localized events, such as hurricanes, as their samples are typically designed to provide national estimates only. Thus, very few survey units would be expected to be located in affected areas. In contrast, administrative data, while not as rich, provide universal coverage and have a lag time of approximately one quarter. Still, administrative data require considerable processing before they are useful for statistical and analytic uses. Thus, the only way to produce timely estimates of the impact of disaster events such as hurricanes is to use what's available at the time of the event. Hurricane season reaches its peak in the late summer. In the case of the Census Bureau, the most recently fully processed data from the BR will be for the reference year 2 years prior. Administrative data that have undergone only minimal processing are typically available for the period two quarters prior to an event.[8]

[8] Administrative data are not available at the establishment-level for multi-location companies. The Census Bureau's Annual Survey of Manufactures (ASM) and Company Organization Surveys (COS) are used to collect establishment-level information during years without an Economic Census. The Economic Census collects establishment-level data every five years. All these programs are used to update the BR. Importantly, for measuring the impact of hurricanes, the ASM/COS updates to the BR occur in the fall of the year after the reference year.

3. Measuring the Impact on Business Establishments

If all establishments were accurately geocoded on the Census Bureau's Business Register, assessing the potential impact using FEMA GIS damage layers would be a fairly straightforward exercise. Namely, one simply determines which establishment units are located within FEMA damage GIS polygons and then use information on the Business Register and other Census Bureau datasets to examine their characteristics.

As mentioned above, however, not all establishments on the Business Register have geocodes of the precision required to locate them accurately on a map. Depending on location (particularly urban vs. rural settings), between 27 percent and 39 percent of establishments will not have detailed (lat/long) geocodes. In these cases we are not able to accurately determine their location. Fortunately, most of the FEMA damage areas lie in areas where the BR contains better address information.

Because of the uncertainty introduced by missing geocodes, we develop a range of damage estimates. At the bottom of this range, we only count as damaged those business establishments that we are able to locate inside FEMA damage zones using GIS. At the top end of this range, we assume that all ungeocoded businesses in counties and parishes receiving federal disaster area designations are damaged.

Neither of these alternatives is satisfactory. Therefore, we employ a simple strategy that uses the share of geocoded businesses within a county or parish that lie in areas with a given FEMA damage classification to impute the total for the county. We can compute this since all establishments are geocoded to the county level and we know how many, within the each county, we are able to give latitude and longitude coordinates.

We multiply those shares by the number (or employment or payroll) of un-geocoded businesses. More precisely, for a given characteristic x (e.g., number of establishments, employees, payroll), the imputed total located within areas with FEMA damage classification d ($d \in$ {undamaged, limited, moderate, extensive, catastrophic, flooded}) is given by

$$(1) \qquad x_c^d = \frac{x_{gc}^d}{x_{gc}} x_{\sim gc} + x_{gc}^d$$

where c denotes the county, g denotes the total computed by summing across geocoded establishments, and $\sim g$ denotes the total computed by summing across ungeocoded establishments.

Recall that our main goal is to develop a GIS based measurement methodology that provides estimates of the impact of disasters on business establishments very quickly after the event. An implication of the need for timely estimates is that it requires us to use pre-storm data. In the present case, we use data from the 2004 snapshot files of the Census Bureau's Business Register (BR) to provide an assessment of activity lost due to damage from the hurricanes.[9] The earliest the Census Bureau would obtain updates of administrative data covering the period after the hurricanes (i.e., the 4th quarter of 2005) was early 2006. Although, we use this post-storm data in our analysis below, we choose not to employ it in our primary impact estimation strategy. This is because the demand for estimates of the impact of the storms on businesses and the economy was immediate, and waiting until early 2006 to provide those estimates would mean they would be of little use.

The BR has three items of interest in measuring the impact of the storm: number of affected establishments, employment at affected establishments, and payroll at affected establishments. Note that our analysis does not attempt to estimate the cost to businesses of physical damage from the storms. Nor does it factor in secondary effects on undamaged businesses that might arise from storm-related labor shortages or a lack of customers due to large scale and persistent evacuations (although these secondary impacts will be picked up by our regressions on post-storm data). Our goal is to simply estimate the impact on business activity due to damage sustained in the storm. These estimates can then be used to help determine the overall impact of the storm on the economy of the region and nation.

4. GIS Based Estimates Based On Pre-Storm Data

To see the utility of our GIS approach, we examine the impact of hurricane Katrina on business establishments in Alabama, Louisiana and Mississippi. Our most basic results are given in Table 1 that are updated versions of the estimates we developed for public release in late 2005. The three panels, A B and C, look respectively at the percent of establishments, employment, and payroll at geocoded businesses that were affected by hurricane Katrina for the states of

[9] This paper reports on a refined version of our initial methodology developed in the fall of 2005. At that time we utilized the 2003 BR as the Census Bureau had not yet completed processing of the version of the annual snapshot data brought to CES for analytical purposes. These initial estimates can be seen at http://www.census.gov/econ/www/hurricane/maps/hurricane_katrina_map_tables.htm. In the future, however, we would most likely make use of more current quarterly updates to the BR in order to get the most recent data possible.

Louisiana, Mississippi, and Alabama. Table 1 shows the level of damage implied using alternative definitions of affected areas. In the case of Louisiana we provide two sets of estimates since FEMA provided two alternative GIS layers of the scope of the flooding in New Orleans.[10] These alternative New Orleans (NOLA) flood layers can be seen in Figure 2. The area with a horizontal line pattern uses the FEMA GIS data indicating the maximum extent of flooded area. We denote this New Orleans Flood Definition I. The area with a crosshatch pattern uses the FEMA GIS data indicating less extensive flooding (it excludes areas where flood waters receded quickly). We refer to this as New Orleans Flood Definition II.

Recall that we can't determine the type of damage sustained by ungeocoded businesses. Thus, the table shows results only for the subset of the data for which we were able to assign latitude/longitude coordinates, thereby allowing us to determine the type of damage sustained from the storm. Because of this, all results are expressed as a percent of state totals for geocoded businesses only.

The main result of Table 1 is that employing crude levels of geography vastly overstates the direct impact of the storm on businesses. Nevertheless, these are precisely the types of estimates one sees from the news media and statistical agencies soon after the storm. Over 70 percent (row 3, panel A) of the geocoded establishments in Louisiana and Mississippi, the two hardest hit states, are located within counties or parishes that received a federal disaster declaration.

Many counties and parishes receiving federal disaster declaration may only sustain little damage or have damage contained within a very small area. Many federally declared disaster counties and parishes do not have any areas designated as damaged in the FEMA GIS data. If we use the presence of a FEMA damage area within a county or parish, as we do in the fourth row of table 1, to denote affected counties and parishes, we see the percentages of businesses, employment, and payroll affected by the storm drop dramatically. This is particularly true for Mississippi where the share of affected businesses drops from 70.5 to just fewer than 15 percent (row 4, panel A).

The percentage of affected businesses is reduced even further when using smaller geographic units such as census blocks. However, the most accurate method is to use only those establishments located in areas known to be

[10] We use the files dated September 10 and September 11. The first describes the maximum extent of damage inflicted by Katrina. The second describes receded flooding as of September 11 and appears to more accurately describe the extent of flooding in the city of New Orleans.

damaged.[11] These provide our "lower bound" estimates in that they only include those establishments that are directly observed in a FEMA damage zone. The rows in Table 1 labeled "In FEMA GIS Disaster Map" give the percentage of geocoded businesses, their employees and payroll, that we identified as being located inside a FEMA damage polygon.

Depending on what GIS source data we use, we find that between 5.9 and 18.5 percent of geocoded businesses in Louisiana lie within affected areas. These establishments account for between 6.2 and 21.0 percent of employment and between 7.1 and 23.7 percent of payroll at geocoded establishments in Louisiana. We also report the percent of establishments located within FEMA damage areas by damage classification. The primary class of damage sustained by Louisiana businesses is flooding followed by "limited" damage.

Mississippi also sustained heavy damage from Katrina. We identified 7.0 percent of geocoded businesses in Mississippi as being located within affected areas. These businesses accounted for 7.2 of employment and 6.7 percent of payroll at geocoded Mississippi businesses. Most interestingly, the predominant type of damage sustained by businesses in Mississippi was "catastrophic", mostly businesses near the coastline that bore the full impact of Katrina's winds and storm surge. Table 1, panel B (last row, third column) shows that 4.4 percent of the employees at geocoded establishments in Mississippi worked at establishments that sustained "catastrophic" damage. Recall that a "catastrophic" designation means that most structures within the area are destroyed.

A problem with the lower bound estimates, as stated earlier, is that they assume all ungeocoded establishments in the Census Bureau's register are undamaged. To address this problem we use the imputation formula given in equation (1) to compute the number of ungeocoded establishments that were damaged by the storm. We refer to this as our "Best GIS" methodology to obtain accurate estimates of damage to business quickly after a disaster event. Alternatively one can simply assume that all ungeocoded businesses are damaged. We refer to this methodology as the "Upper Bound" GIS based estimate.

We report our "Best GIS" based estimate, as well as the "upper" and "lower bound" GIS based estimates in Table 2. For convenience we also report the county/parish based estimates from Table 1 in Table 2. Consider first estimates of the number of affected business establishments given in the upper panel of Table 2. Depending on which FEMA New Orleans flood data are used, we see that even our upper bound GIS estimate of between 50,000 and 60,000 affected establishments is still far below the 131,000 establishments located in federally declared disaster areas in AL, LA and MS. However, just as not all

[11] Again, if there are damaged establishments located outside of FEMA GIS damage areas, we will not know they are damaged.

geocoded businesses are affected by the storms, not all ungeocoded businesses will be affected. Our imputation rule give in equation (1), assumes the same proportion of ungeocoded establishments will be damaged as for geocoded establishments. Applying these imputes gives us our "best" GIS based estimates. With this imputation strategy and the broad FEMA New Orleans (NOLA) flood definition (def. I), we see that 23,149 (8.6 percent) establishments sustained direct damage from hurricane Katrina. Using the narrow FEMA flood definition (def. II), we find that only about 10,300 (3.8 percent) establishments were directly affected by Katrina. The imputed "best" GIS estimates are much closer to our lower bound estimates than they are to the upper bound estimates, which are much smaller than those implied using county level data, as is often done in the media.

Table 2 shows that the impacts on business employment and payroll are similar in magnitude to the impact on the number of establishments. Establishments in LA, MS, and AL that lie inside FEMA disaster declared counties/parishes have approximately 2 million workers and are responsible for about $60 billion worth of annual payroll (roughly 50 percent of all payroll in those states). Our "best" estimate using the broad FEMA definition (def. I) suggests that establishments directly affected by hurricane Katrina have 380,737 employees and are responsible for approximately $12 billion in annual payroll. If we use the narrow FEMA definition (def. II), our "best" estimate yields only 158,113 employees and about $4.6 billion in annual payroll at affected business establishments.

The estimates shown in Tables 1 and 2 could be generated by statistical agencies, such as the Census Bureau, very quickly. In the case of hurricane Wilma, we were able to produce initial estimates of the number of affected businesses within three days of landfall in Florida[12]. Once FEMA releases remote sensing GIS data, analysts at the statistical agency can download the shape files and merge them with geocoded data on businesses (or housing units). In the case of the Census Bureau, this is most easily done with the Business Register (or Master Address File). This of course requires that detailed geocodes be maintained on the BR. This is not currently the case. Discussions are underway to have the Census Bureau's Geography Division provide latitude and longitude coordinates for as many establishments in the BR as possible.[13] Finally, note that

[12] Estimates using our GIS methodology were published on the Census Bureau's web page in late 2005 (see http://www.census.gov/econ/www/hurricane/maps/).

[13] The Census Bureau goes to much greater effort to geocode housing units than it does for business establishments. This is because the Census Bureau releases tabulations of household data at detailed levels of geography from the decennial census and does not for businesses due to disclosure concerns.

this methodology can be used to examine the impact of disasters on the housing stock and other fixed infrastructure and to aid in planning for future disasters.

5. Post-Storm Estimates

We now turn to an analysis of the accuracy of our GIS based estimates of disaster related damage to businesses. We are concerned with several potential sources of error. First, the FEMA GIS damage layers could be inaccurate. Next, detailed geocodes on the Census Bureau's Business Register can either be missing or inaccurate. Finally, in the case of quantities such as payroll or sales, our GIS methodology gives the impact on annual rates. The impact of the storm on most businesses is likely to be of considerably shorter duration. Thus, if we want accurate estimates of the impact on business payrolls or sales (not considered in this paper), we may need to develop a method to estimate the duration of a disaster's impact.

5.1. A Model to Estimate Damage Using Post Storm Data

We have no direct way to assess the accuracy of the GIS damage classifications made available by FEMA. In the case of the impact on business establishments, it is possible, however, to use administrative data from the Census Bureau's business register to compare quarterly business payrolls before and after the hurricanes hit.[14] Our measurement strategy is to use a simple regression model to compare one-year growth in quarterly payroll across establishments located in affected and unaffected areas, and to compare affected establishments before and after the hurricanes. We use data for all the Gulf States and include FEMA damage classifications from hurricanes Katrina, Rita and Wilma. We specify the following regression model:

$$\gamma_{it} = X_i\beta + \varepsilon_{it} \tag{2}$$

where the dependent variable is the annual growth rate of quarterly payroll given by

$$\gamma_{it} = \frac{pay_{it} - pay_{it-4}}{.5*(pay_{it} + pay_{it-4})}, \tag{3}$$

[14] Again, we would prefer to use a metric like sales, but it is not available on a quarterly basis.

and X_i is a matrix of dummy variables indicating the class of damage sustained by establishment i from the hurricanes. The FEMA damage classifications refer to particular locations. So, in essence, the *X* variables are customized location dummies that are unique for each disaster event. The regressions compare the performance of establishments in locations with different FEMA damage designations. We use the nominal quarterly administrative payroll data in the BR to measure pay_{it} as the payroll for establishment *i* in quarter *t*.

In addition, we run the regressions for all quarters in 2005 so that we can compare the performance of establishments within a given FEMA damage classification before and after the hurricanes. This requires quarterly payroll data for all establishments in each of the Gulf States (Alabama, Florida, Louisiana, Mississippi and Texas) for 2004 and 2005.

For the dependent variable, $\gamma_{it,}$ we employ the growth rate definition used in Davis, Haltiwanger, and Schuh [2] and given in equation (3). This specification has two advantages for our purposes. First, it is robust to entry and exit allowing an integrated treatment of establishment births, deaths, and continuers. Since it's likely that many businesses will not report payroll at all in the third or fourth quarters of 2005, this feature is quite appealing. Second, this specification controls for seasonal effects by using year to year changes in payroll rather than quarter to quarter.

Note that the growth rate specification given by (3) implies that births will have a value of 2 and deaths will have a value of -2. We expect to find that many establishments in the harder hit areas will not report payroll in the 4th quarter of 2005 since they may be shut down. So it could be that the distribution of fourth quarter one-year payroll growth rates will be skewed to the left (i.e., toward -2). However, we are also interested in seeing the impact of the hurricanes on businesses that don't shut down. For that reason, we estimate separate regressions on all establishments and the continuers only sample.

Since we are ultimately interested in the impact of the hurricanes on the economy at large, we estimate weighted regressions where each establishment is weighted by its average payroll over the 2004 and 2005 reference years. This means we are giving each dollar of payroll equal weight, rather than each establishment. Thus, larger establishments will receive more weight. Finally, we also estimate the one year payroll growth regressions under both of the New Orleans flood damage estimates provided by FEMA.

5.2. Results

The results obtained using the broad definition of flooding in New Orleans (NOLA Def. I) are given in Table 3, and those using the narrow definition (NOLA Def II.) are given in Table 4. We define the regressors such that the

estimated coefficients are interpreted as the weighted mean one-year change in quarterly payroll for each geographic classification. These geographic classifications describe the level of damage sustained from the 2005 hurricanes.

Tables 3 and 4 provide a rich description of the outcomes experienced by Gulf Coast establishments by class of hurricane damage. We first compare establishments located within federally declared disaster counties to those that aren't. The first column of coefficients gives the growth rates for establishments outside of affected counties/parishes. The remaining columns, (2) through (8), have the same information for various classes of establishments located within affected counties/parishes. Comparisons across rows highlight differences by quarter.

The first two rows of tables 3 and 4 compare the one year growth in quarterly payroll for the first and second quarters of 2005, respectively. The main finding here is that there are no large and systematic differences between establishments located in areas affected by the hurricanes and those that weren't, in the two quarters *before* the first hurricane (Katrina) hit. If anything, businesses located in the areas affected by the hurricanes were enjoying more growth (in payroll) prior to the storms, than were businesses located in areas unaffected by the storms. Table 3 shows that first quarter payroll was 4.9 percent higher in 2005 than 2004 for businesses located outside of federally declared disaster counties/parishes. Businesses located within undamaged areas of affected counties/parishes had either 6.9 or 6.7 percent increases in first quarter payroll depending on whether we use the broad (def. I) or narrow (def. II) definitions of flooding in New Orleans. Business located in FEMA damage areas experienced one year first quarter payroll growth between -7.4 percent and 10.9 percent (using the regression for Flood Def. II in table 4). The damaged areas are fairly small, containing between approximately 100 and 10,000 establishments depending on the damage classification. This explains why we see such varied outcomes for these classes.

We can also compare establishments within affected counties/parishes that lie in areas FEMA classified as undamaged to those that lie within damaged areas. The third column of coefficients gives the weighted mean one-year payroll growth rates for establishments located in undamaged areas within affected counties. Columns four through eight provide the coefficients for establishments located in areas receiving one of the FEMA classified damage classifications. Note that we provide a separate set of coefficient estimates for ungeocoded (i.e., where we can't identify the type of damage sustained) establishments located in affected counties/parishes. This allows us to cleanly compare the impact on areas we know are affected to those we know are not.

Hurricane Katrina occurred in the third quarter of 2005 and is partly reflected in the Q3 regressions in Tables 3 and 4. All the damaged areas show

sharply reduced growth in quarterly payroll, both relative to undamaged and unaffected areas, and relative to their own performance from the prior quarters. Comparing the growth rates for damaged businesses in the "all businesses" regressions for Q2 and Q3 in table 4 (i.e., subtract the Q3 growth rate from the Q2 growth rate), we see that business establishments experienced between a 1.4 and 7.5 percent reduction in payroll growth.

Turning to the regressions reported in the bottom half of Tables 3 and 4, we find that continuing businesses do not exhibit a reduction in Q3 payroll growth. Thus, the reductions in payroll growth observed for damaged areas in Q3 are coming from establishments that close immediately following hurricane Katrina or fail to report 3rd quarter payroll to the Internal Revenue Service (IRS), the supplier of most of the administrative data that underlie the BR.

A shortcoming of using quarterly payroll as our measure of impact is apparent at this point. Many businesses may have kept payrolls near normal levels even though sales were affected. There are several reasons they might do this including the expectation that business conditions would return to normal shortly, or to retain skilled workers.[15] Since we don't have quarterly sales data for a large enough sample of Gulf State businesses from survey data, we have no choice but to use payroll.

The impact of the hurricanes is vividly seen in the Q4 regressions which show the dramatic drop in payrolls for damaged areas. Moreover, the severity of the drop is clearly related to the extent of the damage in the FEMA data. Due to the small number of businesses observed in areas that sustained "extensive damage" the estimated coefficients for this category are never significant. Therefore, we will limit our discussion to the other damage categories. Panel A lists the results of the regressions for all businesses and captures the impact of both continuing and closing businesses. Here we see that businesses located in areas with "limited", "moderate" and "catastrophic" damage suffer reductions in payrolls of 16, 27 and 45 percent, respectively, in 2005:Q4 relative to 2004:Q4. Thus, businesses located in areas where FEMA GIS data show more severe damage suffer greater economic impacts. This finding gives us confidence that our GIS approach is a useful method to ascertain the impact of disasters on businesses.

Businesses in the broader flooded area (flood def. I) in New Orleans experienced a 32 percent reduction in payroll. Those in the smaller flooded area (flood def. 2) suffered a 49 percent decrease in payrolls relative to the same period one year prior. This finding indicates that FEMA GIS data showing more limited flooding better reflects the actual damage suffered from hurricane Katrina

[15] This is more likely the case in industries with high proportions of high skilled labor.

in New Orleans since the many unflooded businesses under Flood Definition I brought the estimated impact down.

Even if we look only at continuing businesses, we see large impacts from the storms in the Q4 regressions. Payrolls for continuing businesses in areas sustaining limited damage are not significantly different in 2005:Q4 than they were for 2004:Q4. Using the limited flood definition (def II – table 4), we see that businesses in areas that experienced "moderate" and "catastrophic" damage had reductions in payroll of 4.6 and 21.5 percent, respectively. Those in flooded areas had a 15 percent drop in payrolls relative to the same period a year before.

Comparing the results for all businesses to those for continuing establishments only suggests that much of the impact of the hurricanes on businesses occurs at those that cease operations. Had we been able to perform a similar analysis with sales data, we might find that continuers suffered more extensive losses and are simply trying to retain their employees in expectation of improved business conditions. In this sense, our regression estimates may understate the full impact of the hurricanes on businesses. The total loss of business payrolls due to the 2005 hurricanes will depend on how long business activity is slowed, either due to physical damage suffered by the businesses themselves or by lack of demand caused by customers who have relocated elsewhere. We can begin to get a sense of impact duration in the bottom row of tables 3 and 4 by looking at the annual change in payroll for the first quarter of 2006, more than 4 months after hurricane Katrina. We focus our comments here on the results in table 4 where we use the more conservative NOLA Flood Definition II. These estimates indicate that businesses located in the areas most affected by the storms are not recovering quickly, whereas those in less affected areas showed marked improvement.

Those businesses in areas where the damage was classified as catastrophic actually show bigger declines in payroll in 2006:Q1 than in 2005:Q4, and this holds true even for continuing businesses (or those at least that continue to report payroll). This is in stark contrast with the finding that continuing businesses (lower panel of table 4) in all other areas of the Gulf States actually have higher business payroll growth in 2006:Q1 relative to the same period a year prior. However, as the upper panel of table 4 shows, when we include all businesses, payrolls are lower in damaged areas compared to the same period a year prior, driven largely by businesses that are closed (or at least are not reporting quarterly payroll to the IRS).

While our focus in the paper is to determine which businesses have been affected by the hurricane and to estimate the extent of the impact on them and their employees, our results suggest that further study of the businesses in affected areas that exhibit little or even positive impacts from disaster events may be equally as informative. Policy responses to disasters should account for the

resiliency of the local economy to disasters. Rose [10] discusses issues associated with assessing the ability of local economies to cope with the affects of disasters. Data, such as those we use here, should be of great value to researchers seeking to provide empirical evidence on the resiliency of businesses affected by hurricane and other natural of man-made disasters.

6. GIS-Based Estimates with Pre-Storm Data vs. Post-Storm Estimates

We can use the estimated coefficients from the post-storm regressions to compute an estimate of the total impact of the storms on business payrolls. To do this, we simply multiply the coefficients of the Q4 regression in table 3 for each of the classifications in federally declared disaster counties/parishes net of the coefficient for unaffected areas outside these counties/parishes by their total quarterly payroll in 2004:Q4. Doing this shows a loss of $444 million in payroll for the 4th quarter of 2005 due to the storms with most of this due to Katrina. The total impact will depend on the amount of time the effects of the storms persist.

Our estimates using pre-storm data were expressed in annual rates. Thus, we annualize the $444 million in lost 2005:Q4 payroll and get a figure of $1.78 billion for all three storms. Recall from table 2 that the "lower bound" estimate of annual payroll at businesses affected by hurricane Katrina using the narrow (Def. II) definition of flooded area in New Orleans was $3.2 billion. From similar estimates reported in the appendix of Jarmin and Miranda [8], the "lower bound" estimate for hurricanes Rita and Wilma is approximately $1.1 billion. Thus, the "lower bound" estimate for all three storms is about $4.3. We refer to this number as the "lower bound", however, for it to be realized all the businesses in damaged areas would need to shut down for a full year. Clearly the actual impact on individual businesses will depend on the level of damage actually sustained. Those with limited damage may recover quickly. Our regression results suggest the actual losses suffered by businesses are nearly 60 percent lower than even our "lower bound" estimates.[16]

[16] Note that our regression results, by necessity, are based on administrative records that have not been fully processed. In the case of multi location companies, this means that the administrative payroll for establishments reporting under a single Employer Identification Number are shared out using weights from the most recent direct collection (the Company Organization Survey for larger companies, or the Economic Census). To the extent that these administrative data for multi unit companies report for both affected and unaffected establishments, we would expect to systematically underestimate the impact of the storms. That is, we would expect to find that single location businesses would exhibit a larger drop in payroll growth due to the storms that would multi location businesses. In

Burton and Hicks [1] estimated that Hurricane Katrina would result in $4.6 billion in lost business revenue using a regression based approach and publicly available Census data. The Economic Census is the only economy-wide source of establishment-level data on business revenues. It's conducted only every five years with the last one performed for reference year 2002 and, therefore, not timely for our purposes. We can, however, construct revenue to payroll ratios that can be used to re-scale our payroll based impact estimates. To do this, we computed a payroll-weighted average of revenue to payroll ratios across 2-digit NAICS sectors. This yields an economy-wide revenue to payroll ratio of approximately 5.7. Thus, our "lower bound" GIS based estimate suggests that the business revenue lost due to hurricane Katrina in the 4th quarter of 2005 would be just over $4.5 billion ((3.2/4)*5.7). Similarly, rescaling the 4th quarter payroll impact estimate from the regressions in Table 4 gives an estimate of lost revenue of just over $2.5 billion for all three storms. Thus, our "lower bound" is very close to the regression based estimates of Burton and Hicks. However, our results using realized 4th quarter payrolls suggest a more limited impact.

With estimates of the total cost of hurricane Katrina alone ranging between $100 and $200 billion, it's clear that costs associated with lost business revenues and payrolls are not a major component. The largest impact on business establishments is most likely to be physical damage to structures and equipment. Burton and Hicks [1] estimate this to be approximately $21.1 billion for commercial structures and $36.4 billion for commercial equipment for Katrina. These amount to just over a third of their $156.7 billion estimate for total Katrina related damages. Unfortunately, we don't have data on capital stocks at the establishment level that would allow us to assess estimates of losses of structures and equipment. Given that our GIS Bases and post-storm estimates find more limited impacts on business activity than previous estimates, additional scrutiny of other components of the total impact of the 2005 hurricanes and other disasters is appropriate.

7. Conclusions

In this paper, we provided a GIS based method that combines FEMA remote sensing information with Census Bureau Business Register files to determine which business establishments are affected by disaster events such as hurricanes. We also develop a methodology to estimate the number of employees and the payrolls at affected establishments.

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the case of flooded businesses in New Orleans, this appears to be the case. However, for those businesses in areas receiving catastrophic damage we found that multi unit businesses suffered greater payroll losses.

Estimates based on our GIS approach are more accurate and potentially of much greater utility to the public and decision makers than tabulations of data at the state or county level that often appear in the media and on statistical agency websites following disasters. Our GIS based estimates indicate significantly smaller impacts from the storms than do estimates constructed from publicly available county level data. Our preferred GIS based estimates indicated the just over 158 thousand workers were employed at businesses damaged by hurricane Katrina compared to the over 2 million workers in Federally declared disaster areas.

We tested the accuracy of our GIS based estimates by using post-storm data to measure the actual impact on business payrolls. The post-storm data showed even more limited impacts that did our GIS estimates using pre-storm information. The post-storm data suggests that most businesses bounce back from the immediate shock of the storm quite quickly and that much of the persistent (lasting longer that one quarter) impact is borne by businesses that shut down. More work is needed to understand why some businesses in heavily affected areas survive and even thrive while others do not recover.

Importantly, our methodology provides statistical agencies with the ability to provide more accurate estimates without waiting for post-event data to become available. GIS based estimates can be made available within days of a disaster with the proper preparations in advance. While we focus on the impact of the 2005 hurricanes on business establishments, our GIS methodology can be used to examine the impact of disasters on housing units[17] and other fixed infrastructure as well.

[17] See Richardson and Renner [9] who use GIS to examine damage to housing units in the aftermath of the 2005 hurricanes.

Figure 1

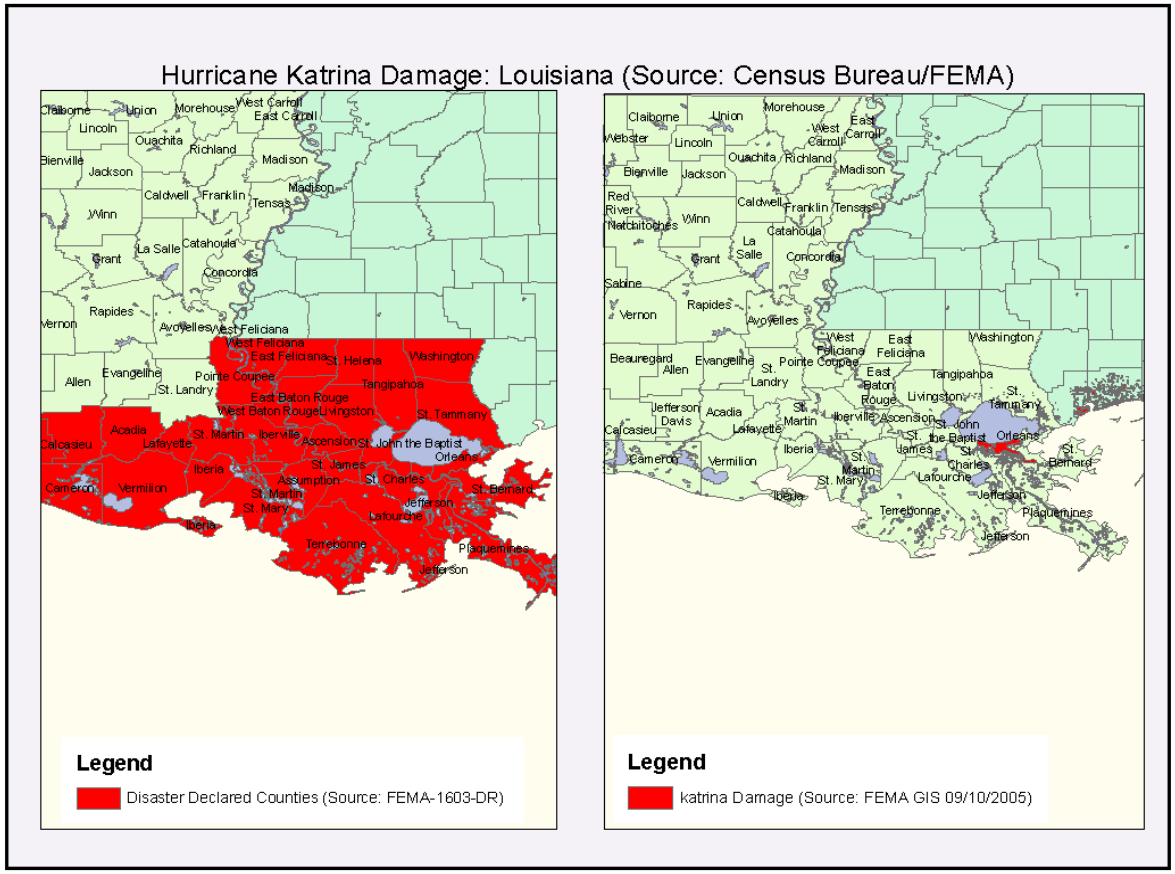
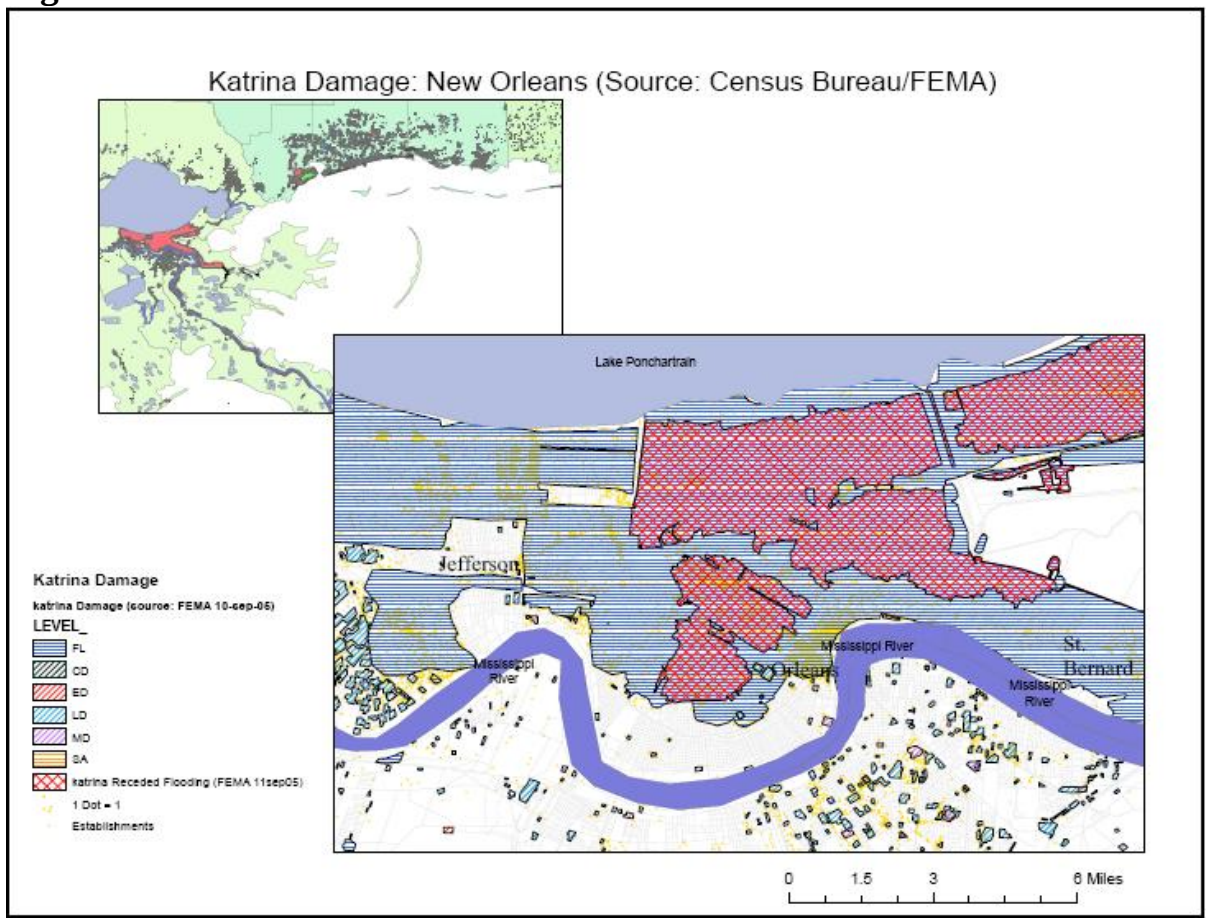

Hurricane Katrina Damage: Louisiana (Source: Census Bureau/FEMA)
Legend
Disaster Declared Counties (Source: FEMA-1603-DR)
Legend
katrina Damage (Source: FEMA GIS 09/10/2005)

Figure 2



Notes: FL=Flooded, CD=Catastrophic Damage, ED=Extensive Damage, MD=Moderate Damage, LD=Limited Damage, SA=Saturated Area.

Table 1A: Number of Business Affected by Katrina: by Type of Area (Percents of geocoded establishment, 2004 Business Register)

	Louisiana I	Louisiana II	Mississippi	Alabama
Number of Businesses	107,277		62,090	100,841
Number of Geocoded Businesses	75,518		38,538	61,429
In FEMA disaster declared Counties/Parishes [0]	73.39%	73.39%	70.51%	18.40%
In Counties/Parishes with some FEMA Damage Area	40.68%	35.95%	14.81%	13.65%
In Affected MSA/Place (%) [1]	32.12%	32.12%	14.03%	11.19%
In Affected Census Blocks (%) [2]	22.31%	12.13%	12.22%	1.76%
In FEMA GIS Disaster Map	18.49%	5.92%	7.01%	0.10%
FEMA Classification - Flooded	16.15%	3.58%	0.07%	0.00%
FEMA Classification - Limited Damage	2.16%	2.16%	2.81%	0.08%
FEMA Classification - Moderate Damage	0.14%	0.14%	1.29%	0.01%
FEMA Classification - Extensive Damage	0.02%	0.02%	0.17%	0.01%
FEMA Classification - Catastrophic Damage	0.02%	0.02%	2.67%	0.00%

0. As of 10/05/2005
1. List of Places/MSA is not comprehensive. Based on Census places in affected areas.
2. Affected Blocks are identified by overlaying FEMA GIS maps of affected areas with Census GIS Block maps.

Table 1B: Share of Employment Affected by Katrina: by Type of Area
(Percents of Geocoded Employment, 2004 Business Register)

	Louisiana I	Louisiana II	Mississippi	Alabama
Number of Employees	1,599,043	1,599,043	886,206	1,566,910
Number of Employees at Geocoded Establishments	1,100,735	1,100,735	540,796	921,506
In FEMA disaster declared Counties/Parishes [0]	75.72%	75.72%	69.94%	16.99%
In Counties/Parishes with some FEMA Damage Area	41.95%	41.95%	15.48%	12.82%
In Affected MSA/Place (%) [1]	34.59%	34.59%	15.32%	11.25%
In Affected Census Blocks (%) [2]	25.43%	25.43%	12.44%	1.69%
In FEMA GIS Disaster Map	21.03%	6.20%	7.22%	0.05%
FEMA Classification - Flooded	18.27%	3.44%	0.03%	0.00%
FEMA Classification - Limited Damage	2.64%	2.64%	1.88%	0.05%
FEMA Classification - Moderate Damage	0.10%	0.10%	0.88%	0.00%
FEMA Classification - Extensive Damage	0.01%	0.01%	0.07%	0.00%
FEMA Classification - Catastrophic Damage	0.01%	0.01%	4.36%	0.00%

0. As of 10/05/2005
1. List of Places/MSA is not comprehensive. Based on Census places in affected areas.
2. Affected Blocks are identified by overlaying FEMA GIS maps of affected areas with Census GIS Block maps.

Table 1C: Share of Annual Payroll Affected by Katrina: by Type of Area (Percents of geocoded Payroll, 2004 Business Register)

	Louisiana I	Louisiana II	Mississippi	Alabama
Total Payroll (millions)	47,476	47,476	23,790	48,427
Payroll at Geocoded Establishments (millions)	31,567	31,567	14,038	28,162
In FEMA disaster declared Counties/Parishes [0]	78.35%	78.35%	71.12%	15.56%
In Counties/Parishes with some FEMA Damage Area	44.13%	39.65%	13.81%	11.88%
In Affected MSA/Place (%) [1]	37.63%	37.63%	13.64%	10.63%
In Affected Census Blocks (%) [2]	27.69%	15.01%	11.13%	1.70%
In FEMA GIS Disaster Map	23.68%	7.09%	6.69%	0.03%
FEMA Classification - Flooded	20.17%	3.58%	0.03%	0.00%
FEMA Classification - Limited Damage	3.40%	3.40%	1.75%	0.03%
FEMA Classification - Moderate Damage	0.10%	0.10%	0.83%	0.00%
FEMA Classification - Extensive Damage	0.01%	0.01%	0.06%	0.00%
FEMA Classification - Catastrophic Damage	0.01%	0.01%	4.01%	0.00%

0. As of 10/05/2005
1. List of Places/MSA is not comprehensive. Based on Census places in affected areas.
2. Affected Blocks are identified by overlaying FEMA GIS maps of affected areas with Census GIS Block maps.

Table 2: Estimates of the Number and Annual Payroll of Business Establishments Affected by Hurricane Katrina

	Number of Affected Establishments	
Located in Federally declaraed Counties/Parishes	131,172	
	NOLA Flood Def. I	NOLA Flood Def. II
Lower Bound GIS (observed in FEMA GIS damage areas)	16,721	7,229
Best GIS Estimate (Lower Bound + Imputes)	23,149	10,321
Upper GIS Bound (all ungeocoded estabs assumed damaged)	59,999	50,502
	Employment at Affected Establishments	
Located in Federally declaraed Counties/Parishes	2,077,714	
	NOLA Flood Def. I	NOLA Flood Def. II
Lower Bound GIS (observed in FEMA GIS damage areas)	270,936	107,697
Best GIS Estimate (Lower Bound + Imputes)	380,732	158,113
Upper GIS Bound (all ungeocoded estabs assumed damaged)	980,431	786,811
	Annual Payroll at Affected Establishments (Billions)	
Located in Federally declaraed Counties/Parishes	$60.09	
	NOLA Flood Def. I	NOLA Flood Def. II
Lower Bound GIS (observed in FEMA GIS damage areas)	$8.42	$3.19
Best GIS Estimate (Lower Bound + Imputes)	$11.87	$4.64
Upper GIS Bound (all ungeocoded estabs assumed damaged)	$29.41	$29.44

Table 3. Annual Payroll Growth Rate Regressions (by Quarter): NOLA Flood Definition 1*

Sample	Annual Change Computed for	Outside Federally Declared County or Parish	Inside Federally Declare County or Parish						
				Geocoded					
			Un - Gecoded	Undamaged	Limited Damage	Moderate Damage	Extensive Damage	Catastrophic Damage	Flooded
All Establishments	2004-2005 Q1	0.049	0.069	0.069	0.056	0.113	0.181	0.035	0.001
		(0.0007)	(0.002)	(0.002)	(0.014)	(0.033)	(0.096)	(0.021)	(0.002)
	Q2	0.067	0.067	0.104	0.044	0.124	0.097	0.061	0.028
		(0.0007)	(0.002)	(0.002)	(0.014)	(0.031)	(0.093)	(0.020)	(0.006)
	Q3	0.085	0.078	0.124	0.003	0.100	0.016	0.047	-0.072
		(0.0007)	(0.002)	(0.002)	(0.014)	(0.032)	(0.093)	(0.020)	(0.006)
	Q4	0.028	0.024	0.039	-0.076	-0.073	-0.120	-0.357	-0.212
		(0.0008)	(0.002)	(0.002)	(0.014)	(0.033)	(0.097)	(0.022)	(0.006)
	2005-2006 Q1	0.028	0.026	0.034	-0.091	-0.066	-0.044	-0.581	-0.200
		(0.0007)	(0.002)	(0.002)	(0.013)	(0.030)	(0.086)	(0.021)	(0.006)
Continuers Only	2004-2005 Q1	0.057	0.089	0.075	0.075	0.070	0.243	0.048	0.005
		(0.0004)	(0.001)	(0.001)	(0.008)	(0.019)	(0.057)	(0.012)	(0.003)
	Q2	0.079	0.095	0.113	0.068	0.088	0.192	0.062	0.036
		(0.0004)	(0.001)	(0.001)	(0.008)	(0.018)	(0.054)	(0.011)	(0.003)
	Q3	0.112	0.115	0.140	0.074	0.077	0.166	0.106	0.017
		(0.0004)	(0.001)	(0.001)	(0.008)	(0.019)	(0.056)	(0.012)	(0.004)
	Q4	0.060	0.067	0.080	0.023	-0.011	0.022	-0.226	-0.082
		(0.0005)	(0.002)	(0.001)	(0.009)	(0.022)	(0.064)	(0.015)	(0.004)
	2005-2006 Q1	0.113	0.120	0.135	0.090	0.213	0.181	-0.231	0.005
		(0.0004)	(0.001)	(0.001)	(0.008)	(0.019)	(0.054)	(0.014)	(0.004)

* Standard errors in parentheses. NOLA Flood Definition 1 refers to FEMA GIS data showing largest area flooded.

Table 4. Annual Payroll Growth Regressions (by Quarter): NOLA Flood Definition 2*									
		Outside	Inside Federally Declare County or Parish						
				Geocoded					
Sample	Annual Change Computed for	Federally Declared County or Parish	Un - Gecoded	Undamaged	Limited Damage	Moderate Damage	Extensive Damage	Catastrophic Damage	Flooded
All Establishments	2004-2005 Q1	0.049 (0.0007)	0.069 (0.002)	0.067 (0.002)	0.056 (0.014)	0.114 (0.033)	0.181 (0.096)	0.035 (0.021)	-0.068 (0.011)
	Q2	0.067 (0.0007)	0.067 (0.002)	0.100 (0.002)	0.044 (0.014)	0.125 (0.031)	0.097 (0.093)	0.061 (0.020)	0.015 (0.012)
	Q3	0.085 (0.0007)	0.078 (0.002)	0.113 (0.002)	0.003 (0.014)	0.101 (0.032)	0.016 (0.093)	0.047 (0.020)	-0.060 (0.012)
	Q4	0.028 (0.0007)	0.024 (0.002)	0.024 (0.002)	-0.076 (0.014)	-0.073 (0.033)	-0.120 (0.097)	-0.357 (0.022)	-0.361 (0.012)
	2005-2006 Q1	0.028 (0.0007)	0.026 (0.002)	0.023 (0.002)	-0.091 (0.013)	-0.066 (0.030)	-0.044 (0.086)	-0.581 (0.021)	-0.246 (0.011)
Continuers Only	2004-2005 Q1	0.057 (0.0004)	0.089 (0.001)	0.072 (0.001)	0.075 (0.008)	0.070 (0.019)	0.243 (0.057)	0.048 (0.012)	-0.052 (0.001)
	Q2	0.079 (0.0004)	0.095 (0.001)	0.108 (0.001)	0.068 (0.008)	0.088 (0.018)	0.192 (0.054)	0.062 (0.011)	0.055 (0.003)
	Q3	0.112 (0.0004)	0.115 (0.001)	0.133 (0.001)	0.074 (0.008)	0.077 (0.019)	0.166 (0.056)	0.106 (0.012)	0.067 (0.007)
	Q4	0.060 (0.0005)	0.067 (0.002)	0.073 (0.001)	0.023 (0.009)	-0.011 (0.022)	0.022 (0.064)	-0.226 (0.015)	-0.167 (0.009)
	2005-2006 Q1	0.113 (0.0004)	0.120 (0.001)	0.128 (0.001)	0.090 (0.008)	0.213 (0.019)	0.181 (0.054)	-0.231 (0.014)	0.013 (0.007)

* Standard errors in parentheses. NOLA Flood Definition 2 refers to FEMA GIS data showing largest area flooded.

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