Impact of Low-Intensity Hurricanes on Regional Economic Activity

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Impact of Low-Intensity Hurricanes on Regional Economic Activity

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Abstract: Although low-intensity hurricanes cause far less structural damage than high-intensity hurricanes, these weaker hurricanes do impact regional economic activity through ''business interruption.'' Because the strike frequencies of low-intensity hurricanes are orders of magnitude greater than those of stronger storms, the cumulative impact of frequent ''business interruption'' may be significant. Using Chamber of Commerce survey data, we estimate industry-specific business interruption losses for three low-intensity hurricanes striking the Wilmington, N.C., region. The average, per-storm regional impacts of business interruption, including direct, indirect, and induced impacts, are equivalent to between 0.8 and 1.23% of annual regional output, between 1.11 and 1.63% of regional employment, and between 1.21 and 1.81% of annual indirect business taxes. While these per-storm losses may appear small, the high strike frequencies of low-intensity hurricanes produce a cumulative (in expectation) impact equivalent to a high-intensity hurricane strike causing approximately $3.7 billion in damage.

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Introduction

Although low-intensity hurricane strikes typically cause less physical property damage than high-intensity storm strikes, the *frequency* of low-intensity hurricane strikes is much greater (see, e.g., Table 1). [Tropical weather is classified based on the Saffir-Simpson (Simpson 1974) scale. Saffir-Simpson categories 0–2 are considered ''low-intensity'' storms, while categories 3–5 are considered ''high-intensity.''] As a result, low-intensity hurricanes may have significant *cumulative* impacts on regional economies and warrant further investigation. This study examines the industry-specific economic impacts of three low-intensity hurricanes (Bertha, Fran, and Bonnie) striking Wilmington, N.C., from 1996 to 1998. For comparison purposes, the study also calculates the equivalent (in expectation) high-intensity hurricane strike.

Most studies of the regional economic impacts of hurricanes consider high-intensity storms. These studies generally compare the immediate losses in property damage and municipal revenues with the income generated by subsequent reconstruction activity. Gillespie (1991) reports that total economic activity in South Carolina suffered little in the aftermath of Hurricane Hugo, as reconstruction funded by disaster relief programs compensated for output, wealth, jobs, and state tax revenues lost during the storm. Guimaraes et al. (1993) find that the post-Hugo growth trend of state-wide income returned to the pre-Hugo trend. Chang (1983) shows that long-run municipal revenues were enhanced in the aftermath of Hurricane Frederick as government recovery monies flowed into the coastal counties of Alabama. West and Lenze (1994) show that Hurricane Andrew had a positive short-run impact on jobs in Florida as destroyed structures were rebuilt. However, in the long run, West and Lenze's model predicts that Florida will lose jobs as persons migrate out of state. This result is supported by Smith and McCarty (1996), who estimate that 17,700 Dade County residents left Florida after Hurricane Andrew. Long-run migration effects aside, these studies indicate that the short- to medium-run impact of high-intensity storm damage on regional economic activity is ameliorated by reconstruction-related local spending (financed largely from extraregional sources, such as insurance claim payments and federal disaster funds).

In comparison to high-intensity hurricane strikes, low-intensity strikes cause only modest levels of structural damage but do disrupt regional economic activity for several days to several weeks through ''business interruption.'' Business interruption is a reduction in economic output due to temporary lack of utility service, employee absenteeism, supply chain interruption, and disruption of consumer access to businesses due to temporary flooding, etc. Business interruption has been found to have a significant impact on business losses following natural disasters (Webb et al. 2000). As the regional impacts of low-intensity storms arise mainly through business interruption rather than through structural damage, these impacts are not offset by large inflows of extraregional funds. The lack of offsetting reconstruction activity and the relatively high strike frequency of low-intensity storms raise the possibility that low-intensity hurricanes may have a significant impact on regional economies over time.

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Table 1. Tropical Weather Wind Speed Categories and Strike Probabilities, Wilmington, N.C.

Saffir-Simpson hurricane category	Maximum sustained wind speed ranges (mph)	Estimated annual probabilities of maximum sustained winds[a]
Tropical storm	39–73	0.15336
Category 1	74–95	0.02826
Category 2	96–110	0.00817
Category 3	111–130	0.00520
Category 4	131–154	0.00254
Category 5	155+	0.00010

[a]Source: National Weather Service HURISK Computer Model (Neumann 1991; Neumann, personal Communication, 2000).

Our study addresses two difficulties encountered by others in attempting to assess the economic impacts of natural disasters. First, as noted by West and Lenze (1994), many economic impact studies of natural disasters are based on *hypothetical* simulations, due to lack of data on actual events. [For example, Ellson et al. (1984) use a regional input-output model to examine the economic impacts of *hypothetical* earthquakes on the Charleston, S.C., economy.] These studies must guess the size of the initial, exogenous shock (direct impact) to the regional economy. Indeed, little information is available on the direct business interruption losses caused by hurricane strikes [National Research Council (NRC) 1999]. Our study uses new survey data on industry-specific business interruption times for three *actual* hurricanes striking Wilmington, N.C., from 1996 to 1998. Second, where regional impact data do exist, it is often difficult to disaggregate measures of total regional impact into *industry-specific* effects. The recent work of Webb et al. (2000) is notable in that it uses empirical survey data to assess the industry-specific impacts of a high-intensity hurricane strike (Hurricane Andrew). Our data allow us to determine the industry-specific impacts of business interruption due to low-intensity hurricane strikes.

The paper consists of five parts. In the following section, we discuss industry-specific business interruption data for three low-intensity hurricanes. The third section calculates upper and lower bounds for the economic impacts of business interruptions averaged over three low-intensity hurricanes using a regional input-output model. For comparison purposes, the fourth section estimates the expected damage caused by low-intensity hurricanes for Wilmington, N.C., and calculates the size of the equivalent (in expectation) high-intensity storm. The final section summarizes key findings and gives concluding commentary.

Methodology

Three named hurricanes, Bertha (July 12, 1996), Fran (September 5, 1996), and Bonnie (August 26, 1998), struck the Wilmington, N.C., region from 1996 to 1998. (Three additional hurricanes struck Wilmington, N.C., during 1999: Dennis, Irene, and Floyd. Unfortunately, comparable survey data for these storms are not available, as they struck after the survey was completed.) These storms were officially classified as a Category 1, a weak Category 3, and a Category 2 storm, respectively, as defined by the Saffir-Simpson tropical weather index. Hence, these storms span the range of low-intensity hurricanes.

The measurement of business interruption losses caused by natural disasters is difficult (NRC 1999). These losses are often proxied using data on unemployment insurance claims. Unfortunately, these data are often confounded by postdisaster reconstruction activity (Brady and Perkins 1991). Cho et al. (1999) estimate business interruption losses for earthquakes using a model of business closure times. Similarly, we use business interruption times to estimate business interruption losses due to low-intensity hurricanes.

Baseline economic data for the Wilmington, N.C., region (Brunswick, New Hanover, and Pender Counties) are provided in Table 2. A convenience sample survey was conducted in January 1999 to determine business interruption times in the Wilmington region due to Hurricanes Bonnie, Fran, and Bertha. The survey was included in a regular mailing of The Greater Wilmington Chamber of Commerce to its 1,200 members. Two hundred sixty businesses replied, for a survey response rate of 22%. This response rate falls toward the low end of survey response rates from several recent studies of businesses and natural disasters that ranged from 24 to 50% (Webb et al. 2000). The number of survey observations by industry is provided in Table 2.

Due to the nonrandom nature of the sample selection process, generalizing sample results to the regional population of businesses is problematic. Nonetheless, a comparison of the distribution of observations with the distribution of regional businesses in terms of output and employment (Table 2) indicates that the sample represents the diversity of businesses present in the region. Exceptions include agriculture, fisheries, and forestry, which were not included in the sample frame, and the motion picture and retail clothing industries. Impacts on natural resource industries, however, are commonly estimated by state and federal agriculture departments, and the contribution of the latter two industries to baseline regional output is small (less than one-half of one percent).

For each hurricane, businesses responded to the following question: ''How many days did it take you to return to 25%, 50%, 75%, and 100% of normal operations?'' The advantage of phrasing the question in this way is that it addresses the *net* effect of multiple factors that hinder the ability of businesses to sell products and services following storms: lack of supplies, lack of utility service, temporary employee absenteeism, etc. On the other hand, the disadvantage of the question is ambiguity concerning the phrase ''normal operations.'' Businesses may have interpreted ''normal operations'' as simply the *operational capability* to provide goods and services. Alternatively, ''normal operations'' may have been interpreted as *both* the operational capability to provide goods and services *and the return of customer demand to prehurricane levels*. We address this ambiguity by presenting results for each of the two interpretations.

For each hurricane, business interruption times for each respondent are measured by *full-day equivalents lost (FDEL)*. The percentages of normal operations, 25, 50, 75, and 100%, are converted to decimal form and denoted P_j, $j=1,\ldots,4$, respectively. The number of days reported by respondent i necessary to reach the percentage of normal operations indexed j is denoted D_{ij}. Hence, FDELs are defined by

$$\mathrm{FDEL}_i=(1.25-P_1)\cdot D_{i,1}+\sum_{j=2}^{4}(1.25-Pj)\cdot\max(0,D_{i,j}-D_{i,j-1}) \tag{1}$$

For example, suppose that company i takes 4, 6, 8, and 10 days to return to 25, 50, 75, and 100% of normal operations, respectively. In other words, the company is completely shut down for four days (four FDELs), operates at 25% of normal operations for the next two days (1.5 additional FDELs), operates at 50% of

Table 2. Regional Data for Wilmington, N.C., 1995 (1995 U.S. Dollars)

Aggregated IMPLAN model sectors	Disaggregated IMPLAN model sector numbers	Standard Industrial Classification (SIC) codes	Number of survey observations[a]	Annual industry output ($millions)	Industry employment (full- and part-time jobs)	Indirect business tax ($millions)
Agriculture	1–21,521	Most of 01 and 02	NA	64.57	759	3.38
Forestry	22–24,27,133–142, 145–147	0708, part of 01,08,09,24	NA	182.76	2,497	1.43
Fisheries	25,26	0910, part of 02,07,08,09	NA	2.39	222	0.08
Mining	28–47	10,12–14	1	7.55	74	0.13
Construction: residential	48,55,143,144,448,461	2451,2452,5200, part of 15,16,17	10	837.43	6,152	68.48
Construction: commercial	49–54,56,57	Part of 15,16,17	8	661.81	8,149	1.56
Manufacture: food	58–103	20	NA	47.95	304	0.42
Manufacture: textiles	108–132	22–23	3	57.66	841	0.22
Manufacture: furniture	148–160	25	NA	7.90	82	0.03
Manufacture: pulp and paper	161–173	26	2	77.02	368	0.62
Printing and publishing	174–185	27	3	52.33	687	0.24
Manufacture: chemicals	186–220	28–30	4	1,514.93	4,158	19.70
Manufacture: stone, glass, brick	230–253	32	2	280.85	1,912	2.48
Manufacture: primary metal products	254–272	33	NA	6.77	26	0.06
Manufacture: fabricated metal	273–306	34	3	57.13	509	0.39
Manufacture: machinery	307–338,346–354	35 (not computers)	4	118.43	803	0.83
Manufacture: computors	339–345	357	NA	1.28	6	0.01
Manufacture: electronics	355–383	36	1	46.76	354	0.35
Manufacture: auto, aircraft railcar	384–391,394–399	Part of 37	1	232.64	1,277	1.98
Manufacture: ship/boat	392–393	Part of 37	6	7.64	73	0.06
Manufacture: instruments	400–411,413,414	38	NA	7.56	68	0.04
Manufacture: miscellaneous	415–432,517	39	6	0.84	12	0.04
Transport	433–440,510	40–42,44–47	8	381.53	3,676	4.84
Communications	441,442	48	5	143.34	955	8.12
Utilities: electric and gas	443,444,511,514	49 (not water and sewer)	NA	599.12	1,509	50.45
Utilities: water and sewer	445,446	Part of 49	2	11.57	114	1.62
Wholesale trade	447	50,51	1	599.35	7,257	116.32
Retail other	449,455,518	53,59	17	213.16	7,911	35.35
Retail grocery	450	54	3	106.98	3,966	17.95
Retail automotive	451	55	5	144.79	2,270	23.60
Retail clothing	452	56	NA	32.77	1,163	5.09
Retail furniture	453	57	3	43.59	1,095	9.22
Retail restaurant	454	58	10	317.87	9,753	23.31
Banking and insurance	456–460	60–64,67	25	227.44	2,701	9.95
Real estate	462	65	17	614.60	4,738	62.13
Services: hotels	463	70	10	65.28	1,532	5.03
Services: miscellaneous consumer	464–468,481,525	72,7630,7640,88	3	91.25	3,862	3.09
Services: advertising	469	7310	7	5.57	81	0.05
Services: miscellaneous business	470–476,480,482	73,7620,7690	22	233.99	6,140	3.41
Services: auto repair	477–479	75	1	119.41	1,552	2.93
Motion pictures	483	78	NA	28.36	384	0.08
Services: recreation	484–489	79	11	70.77	2,559	1.00
Health: doctors and dentists	490	8010–8040	10	263.51	2,142	1.44
Health: hospitals	491–493	0740,8050–8090	5	184.95	3,935	1.25
Service: legal	494	81	4	44.37	795	0.17
Private education: K-12	495,497	8210,8230,8240,8290	5	13.78	379	0.13
Private education: colleges	496	8220	2	1.21	36	0.00
Services: child and elderly care	498–501	83	10	47.56	1,720	0.09
Services: Nonprofit	502–505	86,84,6732,8922	6	56.36	2,329	0.06
Services: engineering and research	506,509	Part of 87	6	153.70	2,403	0.57
Services: accounting	507,508	87 (except engineering and research),89	5	94.83	2,383	0.43
Government: state (including public education)	512,522,523	— — —	2	598.60	16,420	0.00
Government: Federal	513,515,519,520	43	1	145.26	2,553	0.00
Inventory valuation adjustment				−21.44	0	0.00
Total			260	9,907.64	127,646	490.20

[a]NA indicates no survey observations for sector.

Table 3. Industries with Full-Day Equivalents Lost (FDEL) Greater than One Week with Means over All Industrial Sectors, for Hurricanes Bertha, Fran, and Bonnie, 1996–1998, Wilmington, N.C.

Implan model sector	Two-digit 87 SIC sector	Sector name	Number of survey observations	Bertha FDEL	Fran FDEL	Bonnie FDEL	Average FDEL
393	37	Boat building and repairing	6	6.54	104.46	32.21	47.74
488	79	Amusement and recreation Services, N.E.C.	8	9.94	89.03	17.78	38.92
450	54	Food stores	3	12.92	23.25	27.08	21.08
500	83	Social Services, N.E.C.	1	0.00	51.75	6.25	19.33
48	15	New residential structures	6	12.96	34.25	6.33	17.85
480	76	Electrical repair service	1	1.00	42.50	4.00	15.83
453	57	Furniture and home furnishings stores	3	8.58	31.58	4.92	15.03
502	84	Other nonprofit organizations	4	16.75	13.13	14.56	14.81
462	65	Real estate	17	10.74	11.72	8.24	10.23
455	59	Miscellaneous retail	12	8.02	14.27	4.19	8.83
128	23	Canvas products	1	5.00	14.00	5.00	8.00
457	61	Credit agencies	13	6.31	14.35	2.88	7.85
442	48	Radio and TV broadcasting	2	2.00	12.38	8.75	7.71
463	70	Hotels and lodging places	10	0.83	21.35	0.60	7.59
Observation weighted means over all sectors				3.75	12.61	4.66	7.01

Note: Contact writers for full table.

normal operations for the next two days (one additional FDEL), and operates at 75% of normal operations for the final two days of business interruption (0.5 additional FDELs). In this case, FDEL_i equals $4+1.5+1+0.5$, or 7 days.

The average number of full-day equivalents lost for industry $n(\text{Ave.FDEL}_n)$ is defined as

$$\text{Ave.FDEL}_n=\frac{\sum_{i\in N}\text{FDEL}_i}{s} \tag{2}$$

where N denotes the set of observation index numbers for respondents from industry n and $s=$number of elements of N. The fourteen industries with Ave.FDEL over one week are reported in Table 3. These industries are generally characterized by dependence on tourism, new residential construction, and retail sales. Tourism and retail sales may recover slowly because evacuated tourists are not likely to return to the region within the season. The industries returning to normal operations relatively quickly (not given in the table) are generally characterized by manufacturing, health care, and commercial construction. [These findings are similar to those of Gillespie (1991).] These sectors are typically comprised of relatively large firms and institutions. Webb et al. (2000) find that larger businesses are more likely to prepare for disasters than small businesses. Given the slow recovery of tourism and retail sales, it is perhaps surprising that the food services sector also recovers relatively quickly. We suspect that food services recovers quickly because residents without electricity eat outside the home more frequently if restaurants are open, and electricity is generally restored to commercial areas (i.e., restaurants) before residential areas following storms.

Regional Economic Impacts of Business Interruption

In this section, we measure the impacts of business interruption on regional output, employment, and indirect business taxes. *Business interruption losses to output (BILO)* are calculated by multiplying business interruption times (Table 3) by average daily revenues (disaggregated) per industrial sector (Table 4). [Average daily revenues per industrial sector are obtained from the IMPLAN county-level input-output database for 1995 (MIG 1997).] These industry-specific impacts on output are reported in Table 4. Summed over industries, regional BILO totaled \$56.4 million for Bertha, \$127.3 million for Fran, and \$54.9 million for Bonnie. As a point of reference, property loss estimates for these storms averaged around \$550 million for the entire state of North Carolina. [Insurance Services Office, Inc.'s (ISO) Property Claim Services (PCS) unit estimates that North Carolina insured property damages for Bertha, Fran, and Bonnie were \$135 million, \$1.275 billion, and \$240 million, respectively (Dasgupta, personal communication, 2002; ISO 2002).]

In Table 4, the top ten industries in terms of average (across hurricanes) BILO are sorted in descending order. Industries with high FDEL do not necessarily generate high BILO, because the BILO calculation weights business interruption times by industry output levels. For example, the boat building and repair, social services, and electrical repair industries ranked in the top ten in terms of FDEL, but these industries ranked much lower in terms of BILO (rankings of 20, 23, and 24). On the other hand, the eating and drinking, doctors and dentists, and new industrial and commercial buildings sectors ranked relatively low in terms of FDEL, but large sector outputs placed these industries near the top in terms of BILO.

We present economic impact estimates for two alternative interpretations of the phrase ''normal operations'' used in the survey questionnaire. If one assumes that businesses interpreted ''normal operations'' as the *operational capability* to conduct normal business operations, BILO captures only the direct economic impacts of low intensity hurricanes. Under this assumption, we estimate indirect (''ripple'') and induced (''household spending feedback'') impacts on regional output using the IMPLAN input-output modeling software calibrated to 1995 for Wilmington, N.C. (MIG 1997). Indirect impacts (''ripple'' effects) are the reductions in regional economic output due to reduced purchases by businesses suffering direct impacts. Induced impacts (''household spending feedback'' effects) are reductions in regional output due to reductions in household spending caused by temporary reductions in

Table 4. Business Interruption Losses to Output (BILO), Top 10 Industrial Sectors, for Hurricanes Bertha, Fran, and Bonnie, 1996–1998, Wilmington, N.C. (1995 U.S. Dollars)

Implan model sector	Two-digit '87 SIC sector	Sector name	Average daily revenues ($)	Bertha BILO ($)	Fran BILO ($)	Bonnie BILO ($)	Average BILO ($)
462	65	Real estate	1,683,845	18,076,576	19,735,659	13,866,962	17,226,399
48	15	New residential structures	779,173	10,096,790	26,686,691	4,934,765	13,906,082
450	54	Food stores	293,092	3,785,769	6,814,385	7,937,904	6,179,353
447	50	Wholesale trade	1,642,054	3,284,109	9,852,326	1,642,054	4,926,163
488	79	Amusement and recreation services	124,355	1,235,777	11,071,478	2,211,187	4,839,481
455	59	Miscellaneous retail	355,648	2,852,597	5,075,400	1,489,278	3,139,092
451	55	Automotive dealers and service stations	396,689	694,206	3,748,712	2,142,121	2,195,013
454	58	Eating and drinking	870,877	1,524,034	2,852,121	1,959,473	2,111,876
453	57	Furniture and home furnishing stores	119,432	1,025,126	3,772,064	587,208	1,794,799
490	80	Doctors and dentists	721,959	1,137,085	2,274,170	1,750,750	1,720,668
		Total for all sectors		56,408,847	127,368,149	54,920,391	79,565,796

Note: Contact writers for full table.

household income. Given estimates of direct impacts on regional output (i.e., BILO), IMPLAN estimates direct impacts on regional employment and business taxes, and indirect and induced impacts on regional output, employment, and business taxes. To minimize aggregation bias, we run the model using the disaggregated industry data. Model output is then aggregated across industries and averaged across storms (Table 5).

Under the assumption that BILO reflects direct impacts only, Table 5 shows that the direct impact on regional output is $79.6 million, averaged across storms. All amounts are given in 1995 dollars. Indirect impacts are $19.5 million, and induced impacts equal $23.2 million. These values represent 65.1, 15.9, and 19.0%, of total output impacts ($122.3 million), respectively. The average impact of a low-intensity hurricane strike on regional output is equivalent to 1.23% of the baseline (1995) annual output level of $9.9 billion (Table 2).

Table 5 shows that direct impacts on regional employment are equivalent to 1,416 jobs lost (including both full- and part-time jobs). Indirect impacts equal 286 jobs lost, and induced impacts equal 381 jobs lost. These values represent 68.0, 13.7, and 18.3%, respectively, of total employment impacts (2,083 jobs lost). It follows that the average impact of a low-intensity hurricane strike is approximately 1.63% of the baseline (1995) regional employment level of 127,646 (Table 2).

Direct impacts on regional indirect business taxes are $5.9 million (Table 5). Indirect impacts equal $1.2 million, and induced impacts equal $1.8 million. These values represent 66.4, 13.1, and 20.5% of total business tax impacts ($8.9 million), respectively. In sum, the average impact of a low-intensity hurricane strike is equivalent to 1.81% of regional baseline (1995) annual indirect business tax revenues of $490.2 million (Table 2).

Table 6 lists the top 10 sectors experiencing various types of output, employment, and business tax impacts. The table reemphasizes the findings of Table 4; low-intensity hurricanes have relatively small *direct* impacts on heavy industry and relatively large impacts on services, construction, and real estate. Sectors that do not suffer large direct impacts but that do suffer large *indirect* impacts include the ''business support'' sectors such as miscellaneous business services, transport, utilities, commercial construction, banking, and accounting and management. *Induced* impacts affect similar sectors with the addition of health care. (When reviewing the industry coverage in Table 2, it is important to note that the economic impacts of low-intensity storms on electric utilities are *indirect* rather than *direct* impacts—i.e., no power plant was directly shut down due to these low-intensity hurricanes. However, the significant *indirect* impacts on electric utilities due to decreased electricity purchases by storm-affected business customers are captured by IMPLAN.)

Turning to the alternative assumption that business survey respondents interpreted ''normal operations'' as both the operational capability to supply goods and services *and the return of demand to prehurricane levels*, BILO reflects the total (combined direct, indirect, and induced) impacts of business interruption. Under this interpretation, total impacts on regional economic output total $79.5 million. Hence, the alternative interpretations of ''normal operations'' produce lower and upper bounds on regional economic output impacts of $79.5 million and $122.3 million, respectively. Similarly, depending on survey interpretation, total regional employment impacts range from 1,415.6 jobs lost to 2,081.8 jobs lost, and business tax losses range from $5.9 million to $8.9 million.

These estimates do not consider possible compensating rebounds in economic activity following low-intensity hurricane strikes. Such rebounds in economic activity have been found to mitigate economic losses following high-intensity hurricane strikes (Guimaraes et al. 1993; Gillespie 1994; West and Lenze 1994). However, seasonally adjusted taxable sales indices for the Wilmington region show no compensating increase in economic activity in months following low-intensity hurricane strikes. Many of the sectors with high business interruption losses follow-

Table 5. Direct, Indirect, and Induced Output, Employment, and Indirect Business Tax Impacts Averaged across Hurricanes (1995 U.S. Dollars)

Type of impact	Average direct	Average indirect	Average induced	Average total
Output	$79,565,796	$19,463,255	$23,224,131	$122,253,182
Employment	1,416 jobs	286 jobs	381 jobs	2,083 jobs
Indirect business taxes	$5,887,430	$1,160,949	$1,820,174	$8,868,552

Note: Contact writers for these impacts by industrial sector.

Table 6. Ten Most Heavily Impacted Sector by Impact Type ("1" Indicates Most Heavily Impacted Sector)

Impact rating	Direct	Indirect	Induced
		(a) Output impacts	
1	Real estate	Real estate	Construction, residential
2	Construction, residential	Wholesale trade	Doctors and Dentists
3	Retail grocery	Miscellaneous business services	Real estate
4	Recreation	Transport	Retail restaurant
5	Wholesale trade	Construction, commercial	Wholesale trade
6	Retail other	Electricity and natural gas	Retail other
7	Retail automotive	Communications	Hospitals, nursing, and other health
8	Retail restaurant	Accounting and management	Banking, finance, and insurance
9	Communications	Forestry and primary forest products	Electricity and natural gas
10	Retail furniture	Banking, finance, and insurance	Retail automotive
		(b) Employment impacts	
1	Retail grocery	Miscellaneous business services	Retail other
2	Recreation	Wholesale trade	Retail restaurant
3	Construction, residential	Real estate	Hospitals, nursing, and other health
4	Retail other	Construction, commercial	Retail grocery
5	Real estate	Accounting and management	Miscellaneous consumer services
6	Retail restaurant	Transport	Wholesale trade
7	Wholesale trade	Retail other	Doctors and dentists
8	Retail furniture	Forestry and primary forest products	Real estate
9	Retail automotive	Retail grocery	Recreation
10	Hotels	Construction, residential	Retail automotive
		(c) Business tax impacts	
1	Real estate	Wholesale trade	Construction, residential
2	Retail grocery	Real estate	Wholesale trade
3	Wholesale trade	Electricity and natural gas	Retail other
4	Retail other	Retail other	Real estate
5	Retail furniture	Retail automotive	Retail automotive
6	Retail automotive	Communications	Retail grocery
7	Retail restaurant	Retail grocery	Retail restaurant
8	Hotels	Banking, finance, and insurance	Electricity and natural gas
9	Communications	Hotels	Retail furniture
10	Construction, residential	Miscellaneous business services	Banking, finance, and insurance

ing low-intensity hurricane strikes (e.g., food stores, amusement, retail, eating and drinking, service stations) are, somewhat substantially, tourist-driven industries during the hurricane season. As tourists generally do not return to the region within the season following a hurricane strike, the rebound in economic activity following a low-intensity hurricane strike is limited.

Comparison with High-Intensity Hurricanes

Averaged across years (that is, in expected value terms), the impact of low-intensity tropical storms and hurricanes is comparable to the impact of a high-intensity hurricane strike. The key reason for this result is that the strike frequencies of low-intensity storms are much higher than the strike frequencies of high-intensity storms (Table 1).

Using Wilmington, N.C., as an example, if we define low-intensity storms as tropical storms, Category 1 hurricanes, Category 2 hurricanes, and low-intensity Category 3 hurricanes, then the annual probability of a low-intensity storm strike is 0.19239 (i.e., using the HURISK data in Table 1, $0.19239 = 0.15336 + 0.02826 + 0.00817 + 0.5*0.00520$, where we have assigned half the Category 3 strike probability to low-intensity storms). This corresponds to a low-intensity storm return period of 5.2 years—that is, on average over time, the Wilmington region will be struck by a low-intensity storm once every 5.2 years.

Similarly, if we define high-intensity storms as high-intensity Category 3 hurricanes, Category 4 hurricanes and Category 5 hurricanes, then the annual probability of a high-intensity storm strike is 0.00524 (i.e., using the data in Table 1, $0.00524 = 0.5*0.00520 + 0.00254 + 0.00010$, where we have assigned half the Category 3 strike probability to high-intensity storms). This corresponds to a high-intensity storm return period of 190.8 years—that is, on average over time, the Wilmington region will be struck by a high-intensity storm once every 190.8 years.

Comparing the strike probabilities of low- and high-intensity storms for the Wilmington, N.C., region, the annual chances of being struck by a low-intensity storm are 36.7 times higher than the chances of being struck by a high-intensity storm. On average over time (in expectation), the impact of low-intensity storms, in terms of output, is equivalent to a high-intensity storm that does approximately $3.7 billion in damage. (That is, the average of the upper and lower bounds for the impact of a low-intensity storm strike is, $100,909,489. Multiplying: 36.7*$100,909,489 =$3,703,378,246.)

Conclusion

This paper investigates industry-specific business interruption losses and related indirect and induced economic impacts caused by three low-intensity hurricanes striking Wilmington, N.C., from 1996 to 1998. Because the frequency of low-intensity hurricane strikes is approximately *thirty-seven times greater* than the frequency of high-intensity storm strikes, the cumulative impacts of low-intensity hurricanes can be significant. Calls for national data collection efforts to assess the economic impacts of high-intensity hurricanes (e.g., NRC 1999) should consider low-intensity storms as well.

Survey results indicate that low-intensity hurricanes striking Wilmington, N.C., interrupt regional business operations for several days to several weeks. The average business interruption time across industries is 7.01 days. Sectors dependent on tourism suffer the longest business interruption times as evacuated tourists do not generally return to the region immediately following a hurricane. In contrast, manufacturing, health care, and commercial construction characterize industries returning relatively quickly to normal operations. We suspect that institutionalized disaster recovery procedures more common among larger firms may facilitate swifter recovery (Webb et al. 2000).

Low-intensity hurricane strikes have substantial impacts on local economies. We find that the impact of a low-intensity hurricane is, on average, between 0.80 and 1.23% of annual regional output. If a region's average annual rate of growth is 4%, these potential impacts amount to approximately *one-fifth* to *one-third* of an average year's growth.

Indirect business tax-intensive sectors, i.e., real estate, auto sales, grocery, and miscellaneous retail, are hit relatively hard by low-intensity hurricanes. Hence, the impact of low-intensity storms on state and local tax revenues is disproportionately high relative to impacts on output.

Comparing the strike probabilities of low- and high-intensity storms for the Wilmington, N.C. region, the annual chances of being struck by a low-intensity storm are 36.7 times higher than the chances of being struck by a high-intensity storm. On average over time (in expectation), the impact of low-intensity storms is equivalent to a high intensity storm that does approximately \$3.7 billion in damage.

Businesses have several options for reducing business interruption losses. First, firms may purchase optional endorsements (at additional cost) to their property insurance policies to cover business interruption losses. Even so, business interruption insurance may not cover some types of perils commonly associated with low-intensity hurricane strikes. For example, although business interruption insurance commonly provides coverage for losses arising from physical property damage, coverage for losses associated with the inability of employees to reach the workplace (''ingress-egress'' coverage), losses due to emergency evacuations (''civil authority action'' coverage), or losses from utility service interruption are available only as optional policy endorsements at additional cost (Torpey, personal communication, 2002). To reduce the financial risk of business interruption, businesses should review their business interruption insurance and optional endorsements. Second, businesses may use the federal Small Business Administration's Economic Injury Disaster Loan program to obtain low interest loans to cover operating expenses until business returns to ''normal operations'' (FEMA 2002). However, business owners must have exhausted all reasonably available funds and be unable to obtain credit elsewhere in order to be eligible for Economic Injury Disaster Loans (U.S. SBA 2002). Furthermore, these loans do not compensate for lost revenues and profits; they only cover operating costs. Indeed, Webb et al. (2000) find that businesses that tried to take advantage of various sources of recovery assistance following Hurricane Andrew, including SBA loans, fared no better than those that utilized less assistance. Finally, businesses should consider adopting formal disaster recovery procedures to facilitate a more rapid return to normal operations. Although Webb et al. (2000) find that disaster experience improves disaster preparedness, a relatively small proportion of businesses (13–14%) have developed formal disaster recovery plans.

This study is based on data collected from a convenience sample of regional Chamber of Commerce members. Ideally, we would prefer to have a random sample from the population of all regional businesses. Due to the nonrandom nature of the sample selection process, generalizing sample results to the regional population of businesses is problematic due to possible sample selection bias. However, a comparison of sample coverage with the distribution of output across industries in the region indicates that the sample does represent the diversity of businesses present in the study area. A second caveat concerns possible nonresponse bias. If nonresponding businesses differ systematically from survey respondents, then our results may be biased.

Caution should also be used when generalizing our results to other geographical regions. Regions differ in terms of industry mix, shares of industry purchases produced locally, and indirect business tax types and rates. In addition, North Carolina has a relatively strict and well-enforced coastal building code that lessens the potential physical damage from low-intensity hurricanes. Other regions with weaker building code restrictions or enforcement may suffer magnified economic losses from similar strength storms. Regional differences aside, significant business interruption impacts and high strike frequencies suggest that coastal policymakers should consider low-intensity hurricanes during the natural disaster risk assessment process.

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