STRONG AND WELL-ENFORCED BUILDING CODES AS AN EFFECTIVE WIND DISASTER RISK REDUCTION TOOL

Jeffrey Czajkowski
jcza@wharton.upenn.edu

(joint work with Kevin Simmons and James Done & supported by the State of Florida Division of Emergency Management and Verisk, Inc.)

The Institute for Catastrophic Loss Reduction
Friday Forum Webinar – November 16, 2016
Talk Outline

- Research Context and Approach
- Methodology & Results
  - Florida statewide code implementation statistical loss estimation
  - Benefit-cost analysis of Florida statewide code
- Extensions including local enforcement
$\approx 3.2$ trillion of insured residential property is at risk of hurricane damage in the state of Florida.

Statewide annual average loss of $3$ billion and a 100 year hurricane loss estimated at $35$ billion, both for insured property only and net of deductibles (Hamid et al., 2011).

What hurricane risk reduction actions can be taken to reduce vulnerability and ultimately manage losses lower?

One well-encouraged notion is to vigilantly and vigorously promote and support advanced building codes.
Despite strong building codes frequently touted as a key natural disaster risk reduction strategy & cornerstone of resiliency … we often witness
Enhanced emphasis on movement toward uniform statewide codes using most current code edition

• For 1- and 2-family dwellings:
  - 32 states utilize the model International Residential Code (IRC) effective statewide
  - Or, **36 percent of states** do not adhere to uniform statewide residential building code standards

• As per May 2018, whether local or statewide IRC:
  - **51 percent of states** are using an IRC edition that is at least six years old

*Increased costs of construction are often the key argument against more stringent codes – thus, it is critical to highlight the economic effectiveness of a strong statewide code.*
Statewide Florida Building Code (FBC)

FBC Timeline
- 1992 – Hurricane Andrew exposes low standards of construction
- 1996 – Florida Building Code Commission begins to study enhanced statewide codes
- 1998 – Commission recommendations approved by the state legislature
- 2002 – After all legal challenges were exhausted, the FBC was implemented statewide on March 1, 2002

Isolate the impact of the implementation of statewide FBC
- Loss data accounts for decade of construction
- Estimate loss differences from pre vs. *post 2000 construction*
Methodology

1) From the ISO data, estimate series of statistical models relating the *impact of post-2000 construction on 2001 to 2010 windstorm losses* controlling for other relevant exposure and vulnerability aspects.

2) Given these loss FBC loss reductions, evaluate the *economic effectiveness of the FBC* assuming that the *homes built prior to 2000 had instead been constructed under the FBC*.
Empirical Risk Assessment Framework - Loss

Hazard

Exposure

Vulnerability

Loss

Aggregated at the zip code
Insurance Services Office (ISO)
property/casualty insurance
industry annualized claim data
for 2001 to 2010
Insurance Services Office (ISO) annualized ZIP Code (~ 950 per year) loss data from Florida over the period 2001-2010

Across all years, an average of $517 million in losses ($5.17 billion total) and 31,701 claims (317,005 total) are incurred each year from 836,935 exposures, with an average windstorm claim being $10,089 incurred at the rate of 32.4 claims per 1000 insured exposures.
Empirical Risk Assessment Framework - Hazard

- Wind speed
- Wind Duration
Tracks of 18 tropical cyclones that either made landfall in Florida or brought at least tropical storm strength winds to Florida during 2001 to 2010: Gabrielle (2001); Edouard (2002); Bonnie, Charley, Frances, Ivan and Jeanne (2004); Arlene, Dennis, Katrina, Rita, Tammy and Wilma (2005); Alberto and Ernesto (2006); Fay (2008); Claudette (2009); and Bonnie (2010).
Wind hazard data are sourced from the National Center for Environmental Prediction's North American Regional Reanalysis.

Data are available 3-hourly on a 32km grid and 45 vertical layers.

The 3-hourly wind data are interpolated from the 32-km grid to the zip-code level.

2004 FL Frequency of Strong Winds
(Annual count of 3-hourly data times with wind speed greater than the mean wind speed plus one standard deviation for 2004.)
Empirical Risk Assessment Framework – Exposure & Vulnerability

- **Exposure**
  - Housing unit density
  - Mobile homes
  - Income
  - Number of policies
  - Total premiums collected
  - Number of claims

- **Vulnerability**

- **Loss**

- **Hazard**

*Per ZIP code:*
- Zip risk factors – coastal, Citizens percent
- Year of construction decade*
General Model Form

\[
\text{Natural log of losses} = f(\text{hazard, exposure, and vulnerability factors + time & space fixed effects})
\]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EHY</td>
<td>Number of customers by ZIP, decade of construction and by year</td>
</tr>
<tr>
<td>Premiums</td>
<td>Natural log of total insurance premiums. Adjusted to 2010 dollars.</td>
</tr>
<tr>
<td>Brick/Masonry</td>
<td>The percent of brick and brick/masonry homes for the ZIP and year.</td>
</tr>
<tr>
<td>Income</td>
<td>Natural log of median household income for the ZIP and year. Adjusted to 2010 dollars.</td>
</tr>
<tr>
<td>Unit Density</td>
<td>Number of residential structures divided by the size of the ZIP code in miles, By ZIP and year.</td>
</tr>
<tr>
<td>Pop Density</td>
<td>Population divided by the size of the ZIP code in miles</td>
</tr>
<tr>
<td>CCCL</td>
<td>Equals 1 if the ZIP code has a construction control line.</td>
</tr>
<tr>
<td>Distance</td>
<td>Natural log of the mean distance in miles to the nearest coast.</td>
</tr>
<tr>
<td>Citizens</td>
<td>Percent of insurance customers using the state insurer, Citizens.</td>
</tr>
<tr>
<td>Max Wind</td>
<td>Maximum wind speed by year</td>
</tr>
<tr>
<td>Wind Duration</td>
<td>Number of times the wind speed exceeds the mean speed plus one standard deviation for 12 hours, by year.</td>
</tr>
<tr>
<td>Post FBC</td>
<td>Equals 1 if the observation was for homes built after implementation of the FBC</td>
</tr>
<tr>
<td>Age</td>
<td>Year minus the beginning of the decade of construction</td>
</tr>
<tr>
<td>Age Squared</td>
<td>Age Squared</td>
</tr>
</tbody>
</table>

Overall, our results show the strong effect the statewide FBC had on losses from wind storms during this timeframe with losses shown to be reduced by as much as 72 percent. The loss reduction is robust across multiple regression models & consistent with other previous findings.
Methodology

1) From the ISO data, estimate series of statistical models relating the *impact of post-2000 construction on 2001 to 2010 windstorm losses* controlling for other relevant exposure and vulnerability aspects.

2) Given these loss FBC loss reductions, evaluate the *economic effectiveness of the FBC* assuming that the *homes built prior to 2000 had instead been constructed under the FBC*.
That better construction practices lead to lower wind damage is not necessarily a surprise in Florida, but is it good public policy?

<table>
<thead>
<tr>
<th>Avg. Annual Loss (2010)</th>
<th>PV of Loss 50 Year</th>
<th>Reduced Loss Pct</th>
<th>Reduced Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO Data</td>
<td>$479 million</td>
<td>$22 billion</td>
<td>.29 $6.4 billion</td>
</tr>
</tbody>
</table>

- Total loss from our ISO data is $5.178 billion in 2010 dollars.
- **$4.79 billion is from homes built prior to 2000.**
- Our straightforward AAL then is $4.79 billion divided by the 10 years in our data.

- From this $479 million AAL with an inflation rate of 2% ...
- a discount rate of 2.25% (10-year Treasury) ...
- and an expected life of the home of 50 years ...
- we get a 2010 present value of future losses of $22 billion

- Conservative estimate of loss reduction = 29%
**Compare avoided damages to cost of FBC compliance**

<table>
<thead>
<tr>
<th>ISO Data</th>
<th>Avg. cost per square foot to meet FBC</th>
<th># of Pre-2000 Decade of construction residential units</th>
<th>Avg. square footage</th>
<th>Additional Cost to meet FBC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$1.50</td>
<td>828,047</td>
<td>2,287</td>
<td>$2.84 billion</td>
</tr>
</tbody>
</table>

- Cost data from ARA 2002 study of the enactment of the FBC for three related housing types constructed to FBC standards
- Weighted across wind-borne design regions and adjusted to 2010
- Cost compares favorably with a similar building code enhancement adopted by the City of Moore, OK - $1.00 per square foot

- **Comparing this $6.4 billion in benefits versus the added $2.84 billion in costs, gives a benefit-cost ratio of 2.25 for the FBC**
- **That is, for every dollar spent on the implementation of the statewide FBC, 2.25 dollars are saved in the form of reduced windstorm losses**
BC Ratios > 1 robust across multiple scenarios

<table>
<thead>
<tr>
<th></th>
<th>Per Unit Cost</th>
<th>FBC Direct Reduction 53%</th>
<th>FBC Full Reduction 72%</th>
<th>BCA 53% Reduction</th>
<th>BCA 72% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO Sample</td>
<td>3,254</td>
<td>11,381</td>
<td>15,461</td>
<td>3.50</td>
<td>4.75</td>
</tr>
<tr>
<td>With Deductibles</td>
<td>3,254</td>
<td>19,002</td>
<td>25,813</td>
<td>5.84</td>
<td>7.93</td>
</tr>
<tr>
<td>All Florida</td>
<td>3,254</td>
<td>8,695</td>
<td>11,812</td>
<td>2.67</td>
<td>3.63</td>
</tr>
<tr>
<td>With Deductibles</td>
<td>3,254</td>
<td>14,508</td>
<td>19,709</td>
<td>4.46</td>
<td>6.06</td>
</tr>
</tbody>
</table>

- Results are consistent with the multi-hazard mitigation council “6 to 1” BC ratio (our work highlighted in their updating process)

- Assuming a 72% reduction in loss and including deductibles, the BCA ratio of 6.06 translates to a payback of between 8 and 9 years.
Moore OK Building Code BC Results

• Engineering estimate of 30% reduction in damage from tornadoes
  • Direct reduction only – i.e., does not include effect of reduction in claims as the Florida study
  • Full reduction estimate would have been 41% reduction based on Florida study

• Benefit calculated on historic annual average loss for Oklahoma
  • Direct reduction BC Ratio of 3.2
  • Full reduction estimated BC Ratio would be 4.4

• A 2015 EF-2 tornado in Moore confirmed performance difference between pre and post code homes*

• This graph shows the change in weekly sales activity for Norman from pre and post code (Black line).
• Next it shows what the change in sales would have been in Moore if it followed the same pattern (Blue line).
• Finally, it shows the actual change in sales.
• The difference between what actually occurred and the estimate is small and not significant.
Research Extensions

- Examine how the BCA performs under different Florida wind regions. Additionally, consider how future varying climate change scenarios affects the BCA

- Quantify the effectiveness of the FBC against the different wind field parameters - wind speed, duration, and steadiness

- In addition to the impact of the statewide FBC on windstorm losses, analysis of the impact of the local implementation of stringent and well-enforced codes - Building Code Effectiveness Grading Schedule (BCEGS)©
Within State Variation in our BCA
Within State Variation in our BCA

BCA Range with Deductibles

<table>
<thead>
<tr>
<th>State</th>
<th>N-WBDR</th>
<th>WBDR-Cov</th>
<th>WBDR-Glz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7 historical hurricanes – more than just wind speed
Loss sensitive to wind speed, then steadiness, then duration.

Homes built in 2000s drive down losses by 68% compared to homes built in the 1990s.

### Model results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficient</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>Pr &gt;</td>
</tr>
<tr>
<td>major_hurricane</td>
<td>2.49</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>minor_hurricane</td>
<td>1.76</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>high_duration</td>
<td>0.50</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>high_steadiness</td>
<td>-0.78</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>built_2000s</td>
<td>-1.13</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>obs</td>
<td>10564</td>
<td></td>
</tr>
<tr>
<td>r²</td>
<td>0.34</td>
<td></td>
</tr>
</tbody>
</table>
Hurricane Andrew (1992)
• In South Florida, 25,000 homes were destroyed
• >700,000 insurance claims
• 11 Insurance Company Insolvencies


It is an **open question** as to how well a code is maintained and enforced at the local level?

Miami Herald
“Andrew’s winds leveled entire subdivisions, but left standing areas where developers built stronger than code requires”

Rick Hirsch, Miami Herald
“Andrew exposed how low standards for construction and poor enforcement by inspectors led to destruction and disaster.

Florida Senate President Phillip Lewis
“The drive-by inspections that came to light after Hurricane Andrew were an indication that it’s not just code that’s important, it’s making sure the code is enforced”
Identifying Building Code Benefits – Quantifying Avoided Windstorm Losses

- Utilize comprehensive – in number, space, and time – insured loss and policy data for the analysis
  - *FL insured windstorm losses totaling $5.178 billion dollars from 317,005 claims incurred during the time period of 2001 to 2010*

- Isolate the impact of both *extensive & intensive* components:
  1) Implementation of statewide FBC – decade year of construction data
  2) Local implementation of stringent and well-enforced codes - *Building Code Effectiveness Grading Schedule (BCEGS)* ©
Since 1995 ISO has primarily administered the BCEGS rating

- Today, evaluates more than 16,700 code jurisdictions
- Each jurisdiction is classified on a **scale of 1 to 10**, with a **rating of 1** representing exemplary enforcement of a model code

**Minimum BCEGS requirements** include:

- Building department must be permanently organized under state or local laws and a building code must be adopted
- Plan reviews must be conducted and field inspections must be made
- Training of code enforcement personnel must be done

**Beyond the minimum requirements** a community's classification is based on:

- **Administration of codes** – e.g., building-code edition in use, zoning provisions to mitigate natural hazards, training of code enforcers
- **Review of building plans** – e.g., staffing levels, qualifications
- **Field inspections** – e.g., level of detail of inspections, staffing

*Source: BUILDING CODE EFFECTIVENESS GRADING SCHEDULE (BCEGS®) - EXPLAINING THE CLASSIFICATIONS*
BCEGS personal line rating classifications (i.e., for building code adoption and enforcement for one- and two-family dwellings) from 1995 to 2015 were provided by ISO for the state of FL at the zip code level for 950 individual FL zip codes.
Geographic location of 126 high windstorm loss zip codes (>\$10 million in total losses) highlighted in blue in addition to 2005 BCEGS rated 1 to 3 zip codes in grey
Empirical Risk Assessment Framework – Exposure & Vulnerability

Per ZIP code:
- Zip risk factors – coastal, Citizens percent
- Year of construction decade*
- BCEGS ratings*

Hazard

Exposure

Vulnerability

Loss
Empirical Results Verify the Benefits of Building Codes at both Extensive & Intensive margins

- Results show the strong effect that the statewide FBC had on losses from wind storms during this timeframe.
  - Windstorm losses are shown to be reduced by as much as 72 percent due to the implementation of the FL statewide codes, consistent with other previous findings.

- BCEGS ratings perform as expected, i.e., better ratings translate into lower losses.
  - Compared to FL zip codes with low and missing BCEGS ratings, FL zip codes with more favorable BCEGS ratings reduce losses by 15 percent.
  - Some evidence that higher BCEGS ratings reduce windstorm losses more significantly in high wind environments.

- Results control for other exposure and vulnerability factors and are robust to a number of additional analyses.
For MO zip code incurring hail claim - Average ZIP Code BCEGS Rating Geographic Distribution

- BCEGS ≤ 4
- BCEGS ≥ 5
- BCEGS not rated
“The concept is simple: municipalities with effective, well-enforced codes should demonstrate better loss experience” (ISO BCEG Summary)

- Results across a number of industry and exposure-based specifications consistently indicate that more favorable building codes do in fact matter in reducing hail damage on the order of 10 to 20 percent.

  - Average losses per claim = $7,500 per home, a 20% reduction due to more favorable building codes being in place would save $1,500 per home on average.
  - $6 million annual savings across 4,000 impacted homes

- Moreover, we generally find that it is better to have some minimally effective and enforced code in place as opposed to none at all

- Results control for other exposure and vulnerability factors such as hail size and frequency, construction type, roof type, etc.
Concluding Comments

• Research confirms that building codes are not only effective in reducing natural disaster losses but also do this in an **economically effective way**, with the benefits of avoided losses outweighing the additional costs of the new code.

• Although not as substantial in terms of its loss reduction magnitude, **intensively implementing building codes at the local level** by ensuring codes are properly administered and enforced at this scale provides additional loss reduction value.

• Despite the demonstrated value and economic effectiveness of stronger building codes, uniform adoption of strong codes across the country as well as optimal enforcement at the local level have not been achieved, even in high-risk natural disaster areas.
A Coherent Approach to Modeling Vulnerability Better Captures the Impact of Interrelated Building Characteristics

Typical Approach

Overall Vulnerability
- Other Modifiers
- Feature Modifiers
- Year-built Modifiers
- Regional Modifiers

General Vulnerability Functions

AIR Enhanced Approach

- Individual Building Characteristics
- Local Building Codes and Enforcement
- Local Construction Practices
- Year-built

Source: CATASTROPHE INSURANCE (C) WORKING GROUP U.S. Hurricane Model Update
NAIC 2011 Spring National Meeting Austin, TX 28 March 20
Published Papers:

http://le.uwpress.org/content/90/3/482.full.pdf+html


https://muse.jhu.edu/article/690441

https://link.springer.com/epdf/10.1007/s11027-018-9808-x?author_access_token=3WSeSQQFnn5_uPDqmquqSF_e4RwlQNchNByi7wbcMAY6zC_6CAwk5Lafb-MOX2s6evKK5AlMqRFkooNcY32vmNVjJcdoNkqVjZWwDMtptZnI3bXcqHJdfgVeg8tWKseAOwkMf3JntYlc3F62JEpvCsA%3D%3D

https://doi.org/10.1175/WCAS-D-14-00032.1