Convective Storm Vulnerability: Quantifying the Role of Effective and Well-Enforced Building Codes in Minimizing Missouri Hail Property Damage

Jeffrey Czajkowski
Wharton School Risk Center
University of Pennsylvania

Kevin Simmons
Austin College

November 2013
Working Paper # 2013-08

Risk Management and Decision Processes Center
The Wharton School, University of Pennsylvania
3730 Walnut Street, Jon Huntsman Hall, Suite 500
Philadelphia, PA, 19104
USA
Phone: 215-898-5688
Fax: 215-573-2130
http://opim.wharton.upenn.edu/risk/

THE WHARTON RISK MANAGEMENT AND DECISION PROCESSES CENTER

Established in 1984, the Wharton Risk Management and Decision Processes Center develops and promotes effective corporate and public policies for low-probability events with potentially catastrophic consequences through the integration of risk assessment, and risk perception with risk management strategies. Natural disasters, technological hazards, and national and international security issues (e.g., terrorism risk insurance markets, protection of critical infrastructure, global security) are among the extreme events that are the focus of the Center's research.

The Risk Center's neutrality allows it to undertake large-scale projects in conjunction with other researchers and organizations in the public and private sectors. Building on the disciplines of economics, decision sciences, finance, insurance, marketing and psychology, the Center supports and undertakes field and experimental studies of risk and uncertainty to better understand how individuals and organizations make choices under conditions of risk and uncertainty. Risk Center research also investigates the effectiveness of strategies such as risk communication, information sharing, incentive systems, insurance, regulation and public-private collaborations at a national and international scale. From these findings, the Wharton Risk Center's research team – over 50 faculty, fellows and doctoral students – is able to design new approaches to enable individuals and organizations to make better decisions regarding risk under various regulatory and market conditions.

The Center is also concerned with training leading decision makers. It actively engages multiple viewpoints, including top-level representatives from industry, government, international organizations, interest groups and academics through its research and policy publications, and through sponsored seminars, roundtables and forums.

More information is available at http://wharton.upenn.edu/riskcenter

.

Convective Storm Vulnerability: Quantifying the Role of Effective and Well-Enforced Building Codes in Minimizing Missouri Hail Property Damage

Jeffrey Czajkowski[1] and Kevin M. Simmons[2]

[1] The Wharton Risk Management and Decision Processes Center, University of Pennsylvania

[2] Austin College

* We gratefully acknowledge research support provided by Eric Nelson and Bruce Stickley of the Travelers Companies, Inc., as well as William Raichle and Ralph Dorio at the Insurance Services Office[1]

November 11, 2013

Abstract:

Having strong building codes in place in a community is frequently touted as a critical component to reducing total property damage due to natural disaster occurrence. However, at the local level not all jurisdictions adopt equal codes nor properly enforce their codes once they have been adopted. In this study we empirically test whether zip code jurisdictions with effective and well-enforced building codes demonstrate better loss experience from the occurrence of a hail storm than those without. We model industry and exposure-based hail claim insurance data from 2008 to 2010 in the highly hail impacted state of Missouri. While the primary focus of the research is on building code effectiveness and enforcement ratings, the empirical model also controls for other relevant hazard, exposure, and vulnerability explanatory variables in the loss estimation. 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. Moreover, we generally find that it is better to have some minimally effective and enforced code in place as opposed to none at all.

---

[1] Information which is copyrighted and proprietary to Insurance Services Office, Inc., and information proprietary to Travelers Companies, Inc. is included in this publication. No consumer specific information was used in this study.

I. INTRODUCTION

Hail storms are a persistent and chronic source of property losses for United States homeowners and insurance companies (IBHS, 2003) with estimates of U.S. property insurer losses of $1.5 billion (Mills et al., 2005) to $1.6 billion (IBHS, 2013) per year.[2] A relatively recent example of a single hail storm's destructive potential occurred June 13, 2012 in Dallas, Texas where estimated damage from the baseball sized hail was $1.5 - $2.0 billion (Richter and Berkowitz, 2012). Usually they don't create the media attention associated with other natural hazards such as tornadoes as few people perish in these storms (Changnon et al., 2009), but property damage can be as high as tornadoes and more significantly hail storms happen much more frequently. With 75 percent of the cities in the continental U.S. experiencing at least one hailstorm per year (IBHS, 2013), homeowners and insurers welcome any evidence that mitigation measures taken before the hail storm strikes may diminish losses.

The focus of this study is to examine and quantify the role that effective and well-enforced building codes play in the mitigation of residential property damage from hail. Thus, we are trying to validate the simple concept championed by the Insurance Services Office (ISO) in reducing losses from natural disasters - "municipalities with effective, well-enforced codes should demonstrate better loss experience" (ISOa, 2012). Most hail damage on residential properties befalls the roof and the home supporting structures including windows and sidings. While large hail will damage almost any roof, proper installation and the quality of materials used to construct the roof and supporting structures are determinative of how much damage a structure will sustain if the structure is exposed to hail. Accordingly, adhering to local building codes as well as communities ensuring the proper licensing and enforcement of contractors plays a critical role in the mitigation of hail losses.

---

[2] Information shared with us by Travelers Companies, Inc. (insert source) suggests this annual amount may be on the low-end with combined hail/tornado insured losses from 1992 to 2012 ranging anywhere from approximately $4 billion to $30 billion per year, often equivalent with same-year hurricane losses during this timeframe

We employ 2008 to 2010 data on insured homes in Missouri (MO), which has the fifth highest rate of hail storms in the United States (Changnon et al., 2009)[3] and is also a state where building code adoption and enforcement is left up to individual municipalities/jurisdictions.[4] The property loss data comes in two forms: 1) Insurance Services Office (ISO) property/casualty insurance industry claim data aggregated at the zip code; and 2) more granular exposure-based data from the Travelers Companies, Inc.[5] The related building code data also is sourced from ISO as we utilize their Building Code Effectiveness Grading Schedule (BCEGS®) ratings provided to us at the zip code level. The BCEGS ratings provide a joint assessment of both the stringency/effectiveness of adopted codes in addition to how well these adopted codes are enforced. The ratings place a special emphasis on the mitigation of natural hazard losses. Our results across a number of industry and exposure-based specifications consistently show that effective and properly enforced building codes do reduce losses from hail by about 10 to 20 percent on average. Moreover, we generally find that it is better to have some minimally effective and enforced code in place as opposed to none at all.

Thus, the basic premise of our research is a test of building code mitigation, often touted as a critical component to reducing total property damage due to natural disaster occurrence (Board on Natural Disasters, 1999; Kunreuther and Michel-Kerjan, 2009; McHale and Leurig, 2012; Mills et al., 2005). Hail loss studies in the U.S. have focused on the role of impact resistant roofs (IBHS, 2003; RICOWI, 2011), while non-U.S. studies have focused primarily on the relationship between weather/climate and insured agricultural-based losses (Botzen et al, 2010; Dessens, 1995; McMaster, 2001; Vinet, 2001; Willemse, 1995). However, neither set of studies have incorporated the role of building codes in reducing hail losses as we do here. Furthermore, although there have been other natural disaster loss studies that investigate the role of adopted building codes in reducing losses (Fronstin and Holtmann, 1994; IBHS, 2004; Keith and

---

[3] The nation's second most damaging hailstorm since 1949, the Tri-State hailstorm which occurred on April 10, 2001, did the bulk of its damage through the state of Missouri (Changnon et al., 2009)

[4] http://www.disastersafety.org/building-codes/missouri/

[5] Thus the losses we are modeling are only insured losses. It is possible that was further non-insured damage that was incurred during these storms which we do not have access to and are therfore not including in our modeling.

Rose, 1994; Tsikoudakis, 2012), the issue of how well these codes have actually been enforced has been generally ignored. Thus our study expands the storm loss literature with the notable inclusion of investigating not only the role of effective but also well-enforced building codes in-place in a community in reducing associated losses. Quantifying the benefits of this type of mitigation is critical for decision makers (Kunreuther and Michel-Kerjan, 2009) weighing the costs of implementing more effective and well-enforced building standards. One particularly interesting outcome of our hail-oriented damage results is that building codes are not necessarily designed and applied specifically to hail as much as they are for wind and/or earthquake (although they still play a critical role in regard to hail as we discuss, and hail and wind damage often occur simultaneously). However, the idea behind maintaining effective and well-enforced building codes is that losses from other perils outside of wind and earthquake should also decrease (ISOb, 2012), as we show here. Thus it appears that effective and well-enforced building codes have a positive externality effect beyond the primary hazards they may be typically designed for. This is certainly an additional benefit decision makers need to account for in their implementation decision.

The paper will proceed as follows: Section 2 will discuss the incidence of hail damage in the U.S. as well as building code mitigation to reduce hail property damage. Section 3 will provide the empirical methods and the associated MO hail hazard and BCEGS ratings data. Also it describes the MO industry and exposure-based hail claims and the two associated damage loss models. Section 4 will provide the industry and exposure-based loss model results. Section 5 will serve as a discussion of the results and concluding remarks.

II. INCIDENCE AND PROPERTY MITIGATION OF HAIL VIA BUILDING CODES

Incidence of Hail and Associated Damage

U.S. property insurer losses due to hail storms are $1.5 billion (Mills et al., 2005) to $1.6 billion (IBHS, 2013) per year, with non-hurricane wind and hail losses estimated to represent 14 percent of total industry premiums collected, the 2nd highest catastrophe peril loss cost behind only fire (Karen Clark and Company, 2011). And while much of this damage occurs in the central U.S. (Mills et al., 2005), approximately 44 percent of the country is at average risk (2-3 hailstorms per year on average) or above of being hit by a hailstorm (Munson and Molina, 2012), with 75 percent of the cities in the continental U.S. experiencing at least one hailstorm per year (IBHS, 2013). Data collected from the Storm Prediction Center in Norman, OK (Table 1) estimates that between 1996 and 2011 total current dollar losses from hail alone were $14.5 billion from 203,665 storms (SPC, 2012)[6]. Further, the 203,665 hail storms are nearly ten times more frequent than the 20,910 tornadoes over the same time period. Finally, Table 1 also clearly identifies hail size (inches in diameter) as being an important determinant of damage, with almost 50% of the total $14.5 billion in damages stemming from hail as large as the June 2012 storm in Dallas, 2.5-3.0 inches, but accounting for just over 3% of the total storms that occurred.

Insert Table 1 Here

Missouri (MO), located in the central U.S. and the geographic location of our study, has the fifth highest rate of hail storms in the U.S. amongst all states (Changnon et al., 2009).[7] For the years 2008 to 2010 we collected MO property/casualty insurance industry data from ISO aggregated at the zip code. The ISO industry data represents 21% of total property/casualty insurance market share in MO, or aggregated data from over 200,000 customers. Figure 1 presents a summary of the ISO database industry losses split by classified hazard over this time period. We see that hail losses are the second largest cause of loss in MO from 2008 to 2010 totaling $94.4 million dollars in losses (27% of total hazard damage), as well as being the most frequent source of a loss claim with 12,329 claims incurred (32% of total hazard claims incurred). Clearly then, hail is a significant source of losses for property insurers in MO. For example, in 2010 the ISO database contains 211,527 policies in MO with $209 million in premiums collected. 2.3 percent of these policies had a hail claim in 2010 with the total hail damage from these claims being 18 percent of the total premiums collected. Thus, homeowners and insurers welcome any evidence that measures taken before the storm strikes may diminish losses.

Insert Figure 1 Here

---

[6] These losses are across property, auto, and crop. Starting in 2008, crop was split out from other damage types.

[7] The nation's second most damaging hailstorm since 1949, the Tri-State hailstorm which occurred on April 10, 2001, did the bulk of its damage through the state of Missouri (Changnon et al., 2009)

Building Codes as Hail Mitigation

The concept of mitigation is deceptively simple, actions taken before an event occurs to prepare for possible negative consequences (Arrow, 1996). In a seminal article on the topic, Ehrlich and Becker (1972) define mitigation in two ways; self-insurance and self-protection. Self-insurance is a reduction in the size of a loss when it occurs, while self-protection reduces the probability of a loss occurring in the first place. So what mitigation actions can be taken to reduce losses from natural disasters such as a hailstorm? Having strong building codes in place - a form of involuntary self-insurance imposed by the local jurisdiction, county or state - is frequently touted as a critical component to reducing total property damage due to natural disaster occurrence (Board on Natural Disaster, 1999; McHale and Leurig, 2012; Mills et al., 2005; Kunreuther and Michel-Kerjan, 2009). Along with homeowners whom share in the loss through payment of their deductible, the most obvious industry concerned with hazard mitigation is property insurers since it is they who pay claims when the eventual storm strikes. The Insurance Institute for Business and Home Safety (IBHS) conducted an ex-post study on Hurricane Charley which made landfall in Florida in 2004 (IBHS, 2004), and found that homes built after 1996, or when enhanced building codes in regard to wind were instituted in Florida, had lower claim frequency (60% less) and severity (42% less) as compared to homes built before the implementation of the new wind standard codes. These studies were conducted after the state of Florida enhanced their building codes in response to observed damages from Hurricane Andrew (Tsikoudakis, 2012). It became clear, unfortunately after Hurricane Andrew, that construction practices in place during the 1980's had not been sufficient to face a large windstorm (Sparks et al., 1994). After the storm, inspections detected the inferior construction practices which inflated the damage (Fronstin and Holtmann, 1994; Keith and Rose, 1994). In other words, even if more stringent building codes had been in place when Andrew happened, the lack of proper enforcement of these codes would likely still have been problematic in terms of the damages incurred (Board on Natural Disasters, 1999). Kunreuther and Michel-Kerjan (2009) also show from a probabilistic modeling perspective the significant loss reduction from future hurricanes in Florida, New York, South Carolina, and Texas due to building code mitigation, with loss reductions ranging from 31 to 61 percent.

Most hail damage on residential properties befalls the roof and the home supporting structures including windows and sidings. There is also evidence from the insurance industry in regard to Texas hail damage that roof type and impact resistant roofs matter in the amount of damage incurred and in reducing hail losses respectively (IBHS, 2003). For example, homes with impact-resistant asphalt shingle roofs were 40 to 60 percent less likely to have a loss claim (IBHS, 2003). The Roofing Industry Committee On Weather Issues, Inc. (RICOWI, 2011) also found reduced damages from impact-resistant roofs in their field study following the May 24, 2011 Dallas and Fort Worth hailstorm. Historically, however, roofing-related building codes have been primarily concerned with fire resistance and the structural loading of snow, wind, and drainage, while impact or hail resistance is not much of a concern (Crenshaw and Koontz, 2001). Accordingly, the International Building Code (IBC) does not require the consideration of impact resistance in the selection of roofing materials (IBHS, 2013).

Nonetheless, this apparent lack of impact and/or hail resistance concern in model building codes does not translate into enhanced building codes having little impact on reducing hail damage, especially when roofs in severe hail-prone areas of the U.S. (such as MO) are often replaced every seven to ten years (IBHS, 2013). Firstly, hail tends to cause more damage when more than one layer of shingles is present on a roof (IBHS, 2002), and building codes generally require all shingle layers to be removed prior to the installation of new roofing materials. For example, the 2006 International Residential Code (IRC) states that the layering of asphalt shingles is not allowed at all when the building is located in an area subject to moderate to severe hail exposure (Building and Housing Codes Dept., 2013). Secondly, replacing one's roof is not a do-it-yourself project. Proper installation and the quality of material used to construct the roof are determinative of how much damage a structure will sustain if the structure is exposed to hail (Homeowners Insurance Guide, 2013). Adhering to local building codes as well as communities ensuring the proper licensing and enforcement of roofing contractors therefore plays a critical role in this roof replacement (and thus hail damage minimization) process (IBHS, 2002). Communities that adopt and enforce codes ensure that the structure is built to international codes as well as ensuring that the products used in the construction of the home are A-rated.[8] Although the IBC does not require the consideration of impact resistance in the selection of roofing materials, the IBC[9] does include a provision that requires roofing systems to meet minimum impact resistance requirements (Crenshaw and Koontz, 2001). Lastly, although codes are predominantly designed and implemented for wind and/or earthquake, the idea behind maintaining building code best practices is that losses from other perils outside of wind and earthquake should also decrease (ISOb, 2012). This is certainly a plausible expectation for hail losses since hailstorms often coincide with a severe wind event. All told, effective and well-enforced building codes should matter in reducing hail damages.

Ranking the Adoption and Enforcement of Building Codes - Building Code Effectiveness Grade Schedule Ratings[10]

In the U.S. many states have no statewide building code in place; adoption is left up to individual municipalities/jurisdictions.[11] MO is one such state where building code adoption and enforcement is at the individual jurisdiction level.[12] Table 2 provides a summary of the building/dwelling and structural codes in place for eight of the main MO population localities (Reed Construction, 2013). What is illustrated from Table 2 is the lack of consistency across MO in regard to which code(s) is applied. For example, while each locality shown adheres to an IBC code, two use the 2009 version (Saint Louis City and Saint Louis County), four use the 2006 version (Columbia, Joplin, Kansas City, Springfield), and two use the 2003 version (Branson, Independence). Five of the eight supplement the IBC code with a similar year IRC

---

[8] Personal communication with Tim Reinhold, Sr. VP of Engineering, Insurance Institute for Business and Home Safety.

[9] As well as the BOCA national building code, the standard building code and the South Florida building code

[10] Material in regard to the ISO BCEGS ratings is sourced from the ISO's Building Code Effectiveness Grading Schedule (BCEGS®) http://www.isomitigation.com/bcegs/0000/bcegs0001.html For more detailed information on the BCEGS ratings please see the description on their website.

[11] As of December 2012 (http://www.iccsafe.org/gr/Documents/AdoptionToolkit/CodeAdoptionProcessState.pdf), 11 of the 50 states either have state codes that do not apply at the local level unless adopted by local jurisdictions, or codes are adopted at the local level rather than the state level. These states are AL, AZ, CO, DE, IL, KS, LA, MS, MO, NE, and SD. Further, according to IBHS Building Code Resources (http://www.disastersafety.org/wp-content/uploads/ibhs_building_code_kit.pdf) even if a statewide code exists, it is not uncommon to allow local jurisdictions to deviate from the statewide standard.

[12] http://www.disastersafety.org/building-codes/missouri/

code – which disallows layering of roof shingles as discussed - (Columbia, Joplin, Saint Louis City, Saint Louis County, Springfield), while only one has added specific city amendments (Joplin).

Insert Table 2 Here

Further, even if localities adopt similar building code standards, it is unlikely all jurisdictions would equally and/or properly enforce their codes once they have been adopted. And as we have discussed in the Florida case, it is not sufficient to simply have stringent building codes in place, these need to be properly enforced to ultimately have the intended mitigation effect (Board on Natural Disasters, 1999). Since 1995 ISO has primarily administered the Building Code Effectiveness Grading Schedule (BCEGS) ratings for the property/casualty insurance industry across the entire country.[13] The BCEGS ratings provide a joint assessment of both the stringency/effectiveness of adopted codes in addition to how well these adopted codes are enforced. There is a special emphasis placed on the mitigation of natural hazard losses, with the implied understanding that while building codes are often designed specifically for wind or earthquake natural hazards, the idea behind maintaining effective and well-enforced building codes is that losses from other perils outside of wind and earthquake should also decrease (ISOb, 2012). Today, the ISO BCEGS program evaluates more than 16,700 code jurisdictions serving more than 25,000 communities.

In order for a community to obtain a BCEGS rating, minimum building code requirements must first be met. These minimum BCEGS requirements include: a building department must be permanently organized under state or local laws; a building code must be adopted; plan reviews must be conducted; field inspections must be made; and training of code enforcement personnel must be done. Beyond these minimum requirements a community's BCEGS rating is based on their performance under three main classifications – all of which have relevancy to hail loss mitigation as we have discussed: 1) administration of codes; 2) review of building plans; and 3) field inspections. Specific criteria for the administration of codes includes amongst other items the building code edition in use (e.g., see Table 2), zoning provisions to mitigate natural hazards, the training and certification of code enforcers, the qualifications and licensing

---

[13] In the states of Hawaii, Idaho, Louisiana, Mississippi, and Washington an independent rating bureau administers the BCEGS ratings.

of building officials and contractors/builders, and public-awareness programs. Specific criteria for both review of building plans and field inspections include amongst other items the staffing levels, qualifications, and level of detail of plan reviews and inspections. Lastly, ISO collects information on natural hazards common to the area, number of inspection permits issued, number of inspections completed, the building department's funding mechanism and date of establishment, size of the jurisdiction and population, and fair market value of all buildings, all of which is used in the calculations to determine the BCEGS rating classification.

Each jurisdiction/community is classified on a scale of 1 to 10, with a class of 1 representing exemplary enforcement of a model code and a class 10 indicates the jurisdiction has earned very few points on many evaluation criteria. Additionally, a rating of 99 indicates that the jurisdiction/community is unclassified. Communities may have a class 99 if they have built properties prior to the implementation of BCEGS, the community does not meet the minimum requirements of the BCEGS program, or have not participated in a BCEGS survey. Points are accumulated by a particular jurisdiction/community for how well criteria are met for each of the above classifications. Each criterion has a certain number of points, and the points are totaled to arrive at the BCEGS rating class. For example, BCEGS rating class 1 has a point range of 93.00 to 100.0, while BCEGS rating class 5 has a point range of 56.00 to 64.99. The determined BCEGS rating class has a particularly strong emphasis placed on building code enforcement with one-third of the possible total points dedicated to effective enforcement related criteria of training, certification, and experience. Across the entire U.S., 18 percent of graded communities have a rating from 1 to 3, 67 percent have a rating from 4 to 6, and 15 percent have a rating from 7 to 10.

III. EMPIRICAL DATA, METHODS & REGRESSION MODELS

Empirical Data

In this study we empirically test whether zip codes with effective and well-enforced building codes demonstrate better loss experience from hail storms via a damage analysis. We have five sources of data, industry-based data provided by ISO, exposure-based data provided by Travelers, hail hazard data from the Storm Prediction Center, population data from the Census Bureau and data on community building code ratings (BCEGS) also provided by ISO. Specifically, in separate damage functions we utilize the 2008 to 2010 realized property loss data provided to us from ISO and Travelers to explain the observed damage while controlling for hazard, exposure, and vulnerability variables that can either increase or decrease loss, including the BCEGS ratings. The hazard, exposure, and vulnerability explanatory variables are described in detail below. We capture as many of the critical ones as we can collect like the size of the hail, construction attributes of the property, and the age of the structure. Our primary objective is to test for how hail damage varies with the enforcement of effective local building codes so our principal variable of interest is the BCEGS rating provided to us by ISO.

Hail Hazard Data

We collect hail storm data in MO for 2008 to 2010 from the hail archive compiled and maintained by the Storm Prediction Center (SPC) in Norman, OK (SPC, 2012). The SPC is an agency of the National Weather Service and maintains archives on hail storms, windstorms and tornadoes. Their archive for hail goes back to 1955 and contains data on over 350,000 storms. Storm information is collected based upon observed hail data. Each observed data point contains the following information: date and time of observed hail; size of the hail; losses – injuries, fatalities, and damages; and the longitude and latitude coordinates of the observed hail.[14] However, the observed SPC data do not represent the complete impacted area of the storm, just the relayed observed hail (Gall, Borden, Cutter, 2009).

Therefore, we construct a best practice buffer having a 25 mile diameter around each observed SPC hail observation point (Severe Thunderstorm Climatology, 2013). We then intersected the directly impacted zip codes having observed SPC hail claim data with the buffered observed storm data and took the average of all the intersected hail size and frequency data for each zip code for each year. While both of our property loss datasets provides us geographic identification of loss (zip code), they do not provide us specific and/or consistent enough date of loss information beyond the year of occurrence. Thus, as an outcome of our intersection methodology applied to the SPC hail hazard data we obtain for each impacted

---

[14] http://www.spc.noaa.gov/wcm/data/SPC_severe_database_description.pdf

zip code the number of storms occurring during the year and the average hail size for all hail storms during the year. Given the level of accuracy in the SPC data, this methodology is a suitable way of incorporating the SPC hail size and frequency data into both our industry and exposure-based models.[15]

Figure 2 provides an example of our zip code hail hazard assignment methodology. MO zip code 63005 had no observed 2010 SPC hail data (point observations in Figure 2), but did have 17 hail claims for that year based upon the supplied ISO property loss data. In order to associate 2010 hail size and frequency data to this zip code we collect the observed hail data from the 25 mile diameter buffered points that intersect zip code 63005. In total, there were 12 observed 25 mile diameter buffered points that intersected zip code 63005 in 2010 with an average hail size of 0.98 inch in diameter. These resulting values are the respective hail frequency (12) and hail size (0.98 inches) values assigned to zip code 63005 for the year 2010 for the loss analysis. We apply this methodology to all MO zip codes for the 2008, 2009, and 2010 SPC data

Insert Figure 2 Here

Missouri BCEGS Ratings

1,168 individual MO zip code BCEGS personal line rating classifications (i.e., addresses building code adoption and enforcement for one- and two-family dwellings) from 1997 to 2010 were provided by ISO. ISO administers the BCEGS personal line ratings by jurisdiction, or the area with defined political boundaries served by the building department. As zip codes are not organized by political boundaries, multiple jurisdictions and hence building code departments/BCEGS ratings may be contained within each zip code following population amounts. Further, jurisdiction ratings are reevaluated over time, typically every five years. Thus, each zip code may have more than one rating record over our 1997 to 2010 time period (to account for the rating revaluations over time), as well as per each individual year (to account for

---

[15] Verified methodology with personal communication with Harold Brooks from NOAA's NSSL. Location information in the SPC file gives a county and lat/long coordinates but does not account for the area covered by the storm. As a robustness check we also created buffers with a 7.5 mile, 15 mile, and 30 mile diameter around each observed SPC hail observation point. Empirical results using this varying buffer size data are consistent with the results from Table 7 and Table 9b reported in this paper and are available upon request from the authors.

the multiple jurisdictions in each zip code). There are 2,576 mutually exclusive BCEGS jurisdiction ratings for the 1,168 zip codes supplied, or an average of 2.2 rated jurisdictions per zip code. And on average, each of these 2,576 separate jurisdictions was rated approximately two times between 1997 and 2010. Lastly, the rating classification applies to any building receiving a certificate of occupancy in the year the classification goes into effect, or in later years. However, if a structure undergoes a major renovation and if the property owner must bring the building into compliance with current codes and receives a new certificate of occupancy or legal equivalent — the year of construction and hence the rating classification for that structure will change. This is especially relevant in MO where roofs in severe hail-prone areas of the U.S. (such as MO) are often replaced every seven to ten years (IBHS, 2013). So, even if the BCEGS rating was not applicable to existing structures in say 1997, by 2010 there was a good chance that this structure would have its roof renovated and the corresponding roof replacement inspections performed by the BCEGS classified building department.

Therefore, in order to achieve a relatively comprehensive 2010 snapshot view of each zip code's evolving rating classification over time, we assign an average BCEGS rating over all records from 1997 to 2010 to include in our analysis. If all rating records for a particular zip code were "99", i.e., unclassified, then an average rating of 99 was assigned to that zip code. However, for other zip codes having any rating records other than 99, the constructed averages excluded any 99 ratings, but were adjusted for different time periods associated with our 2008 to 2010 loss claim data. For example, zip code 63005 had 10 separate BCEGS rating records from 1997 to 2010 as shown in Table 3. These 10 separate rating records over time come from five separate jurisdictions, or an average of two ratings per jurisdiction from 1997 to 2010. Excluding the 99 ratings, zip code 63005 had an average 1997 to 2010 rating equal to 4. However, from 1997 to 2007 only, the average rating for this zip code is equal to 3. Thus for our analysis of 2008 to 2010 claim data, the rating to be used in the associated 2008 loss analysis is a 3, while the rating to be used in the associated 2009, 2010, and combined 2008 to 2010 analyses is a 4.

Figure 3 illustrates the overall distribution of average ratings we have assigned as an outcome of our methodology for each of the 1,168 MO zip codes. The number of zip codes with 99 ratings is approximately 60 percent of the overall ratings for MO. However, while the majority of our average ratings in MO are a 99 unclassified rating, from a geographic perspective (not shown) the more heavily populated areas of the state such as Kansas City, St. Louis, Joplin, Springfield, etc. have determined BCEGS ratings in place. Explicitly, 84% of the total population from the 1,168 utilized zip codes in our analysis is in non-99 rated zips. This is important for our analysis as the experience of claims and losses will be closely tied to population as would be expected. From our determined non-99 BCEGS ratings, 14%, 24%, 29%, 18%, 7%, 3%, 5%, and 1% of zip codes have an average rating of 3, 4, 5, 6, 7, 8, 9, and 10 respectively. These percentage values coincide well with the national figures discussed in section 2 where 67 percent of national communities have a rating from 4 to 6 compared to 71 percent of our zip codes, as well as to the publically available personal line values for MO (http://www.isomitigation.com/bcegs/1000/graphs/MO.html) where 73 percent of MO communities have a rating from 4 to 6, again compared to 71 percent of our zip codes. For our loss models we use a discrete group of BCEGS ratings in the empirical analysis of "more favorable" (average ratings 1 to 4), "less favorable" (average ratings 5 to 10), and unclassified (average rating 99) ratings as overlaid upon the Figure 3 distribution.[16]

Insert Figure 3 Here

ISO Hail Claim Data for 2008 to 2010 and Corresponding Hail Loss Model

ISO tracks annual loss data[17] within a total of 961 identified zip codes in MO. Table 4 presents MO hail claims and losses by the impacted zip codes for each year from 2008 to 2010 from the ISO database. Each year roughly 40 percent of the 961 tracked MO zip codes have at least one hail-related claim initiated, with each impacted zip code averaging 8 to 14 claims per year with an average loss of approximately $7,500 per claim for each of the three years (the Appendix provides pictures of hail losses relatively near to this average loss amount albeit from Oklahoma).

---

[16] We ran several iterations of ratings including continuous beginning with using each grade as individual dummies. The coefficients for the separate dummies were significant and decreased in magnitude as the grade went from 2 toward 10 losing significance for the less favorable grades. The natural break appeared to be between 4 and 5 and we tried both values for creating two discrete categories. From these estimations we determined that 4 was the most natural break.

[17] Loss data is only by year of occurrence, not by occurrence of specific storm

Insert Table 4 Here

Figure 4 shows the location of each of the 532 unique zip codes in MO with a hail loss in at least one of the three years from 2008 to 2010, overlaid with their determined average BCEGS rating. Among the 532 unique zip codes with at least one claim, 59 percent of these zip codes have at least some BCEGS rating – either more favorable (19%), or less favorable (40%). Thus, for our analysis conditional upon the occurrence of the hazard, only 41 percent of MO zip codes used in the loss analysis have an unclassified 99 BCEGS rating.

Insert Figure 4 Here

Our industry-based loss model is a semi-log OLS model with the natural log of damages for the zip code as reported by ISO against a vector of hazard, exposure, and vulnerability explanatory variables from ISO, SPC archive data and population from Census. A semi-log model is often used in a natural hazard damage analysis since damage approaches a limit. There are 29 variables and 3,090 observations. The explicit form is:

$$\begin{aligned}\text{LN Hail Losses}_i = {} & \beta_0 + \beta_{1\text{-}5}(\text{Construction Types})_{it} + \beta_{6\text{-}12}(\text{AOI})_{it} + \beta_{13\text{-}18}(\text{Construction Decade})_{it} + \\ & \beta_{19}\text{Hail\_Size}_{it} + \beta_{20}\text{Population}_{it} + \beta_{21}\text{Storms}_{it} + \beta_{22}\text{Claims}_{it} + \beta_{23}\text{EHY}_{it} + \beta_{24}\text{Premiums}_{it} + \\ & \beta_{25}\text{Cov\_A}_{it} + \beta_{26}\text{MoreFavorable\_BCEGS}_{it} + \beta_{27}\text{LessFavorable\_BCEGS}_{it} + \beta_{28}\text{Yr\_2009}_{it} + \\ & \beta_{29}\text{Yr\_2010}_{it} + \varepsilon_{it}\end{aligned}$$

The ISO data gives aggregate customer data by hail hazard, decade of construction and by zip code *i,* for each year *t*. The ISO database has some information about the dwellings themselves such as the percent of homes that are brick, veneer, frame etc. Knowledge of the exterior of the structure controls for how a home may handle the stress of being struck by a hail stone as not all hail damage is found on the roof. Many materials at ground level can also be damaged by hail including those parts of the home on the exterior walls, such as siding and trim, windows, doors, window well covers, and any other building components. Aluminum siding is the type of siding most easily damaged by hail, whereas vinyl siding is easily cracked and broken and wood siding can be cracked, dented and broken too (InterNACHI, 2013). It also provides information about the insurance coverage such as the amount of insurance (AOI)[18], number of claims, premiums, dwelling coverage (Cov A), and the number of customers (Earned House Years). Earned House Years is counted as a full amount if they have coverage for the entire year. Customers with less than one year of coverage would count as a fraction based on the number of months they had coverage during the year.[19] Finally, the data is sorted by decade of construction so we are able to use a separate entry for each decade of construction and zip code. The basis then for each observation is average hail damage for homes within a zip code and for a particular decade of construction in one of the 3 analysis years, 2008-2010. Our model then includes a dummy variable for each decade with post 2000 as the omitted category, thus having some information on the vintage of the homes in a particular zip code. Homes built during different time periods may create varying damage profiles. Older homes tend to have lower pitched roofs which react differently to hail stones than steeper roofs. Also, older homes are smaller on average which means there is less roof exposed.

To test for differences in claims that may arise from higher populated zip codes versus less populated ones, we use the population of the zip code from the U. S. Census. The BCEGS data we use for the model is a categorical dummy variables with three categories introduced earlier. "More favorable BECGS" is any zip code whose average BCEGS rating is 4 or less, "Less favorable BECGS" is a zip code whose average BCEGS rating is between 5 and 10 and a third category where the BCEGS score is missing or not scored ("BCEGS=99"). The omitted category is where the BCEGS equals 99. Finally, as we have claim and associated loss data for three separate years we include a categorical dummy variables for each year (2008-2010) with 2008 as the omitted category. A complete list and description of the variables used in the model is provided in Table 5.

Insert Table 5 Here

---

[18] Amount of insurance is a potential proxy for house size as larger, higher-valued homes should have more insurance coverage all else being equal

[19] Someone who had coverage for 6 months would count as ½ earned house year.

To further control for any potential omitted variable bias in our model, we also run a zip code fixed effect model. We use a three-digit zip code to perform this analysis as compared to five digits in order to allow each zip code group to have sufficient observations for the analysis. Results of this test will be discussed in Section IV along with our presentation of the results from the industry regression.

Travelers Hail Claim Data for 2008 to 2010 and Corresponding Hail Loss Model

The aggregated nature of the ISO data does not allow for a more detailed examination of specific housing attributes that potentially affect (positively or negatively) resulting hail losses. For example, IBHS (2003) and RICOWI (2011) found that roof type and impact resistant roofs matter in the amount of hail damage incurred. Thus, our second model uses exposure-based data from the Travelers Companies, Inc. that allow us to control for how hail damages may vary with the attributes of a specific home such as the roof type.

Travelers Companies, Inc. provided us with 109,173 non-identifiable customer files for the years 2008 to 2010. Of those, a total of 2,554 (2.4%) policy-holders experienced a hail-related loss during this timeframe. While we have access to the individual policy home attribute data we were not provided the actual address of the structure. The lowest level of policy location data provided was at the zip code. Travelers had policies in-force in 758 of the zip codes in MO, or approximately 79% of the 961 ISO identified zip codes. All zip codes represented in the Travelers database experienced at least one hail storm during the 3 year analysis period. Here we provide as an example, a more detailed overview of the Travelers Companies, Inc. policy raw data specific to 2010 focusing on the roof type attribute data and its relation to hail losses.

Figure 5 illustrates the location of the 166 zip codes with a Travelers hail loss claim in 2010 overlaid with the 2010 SPC hail observations (non-buffered) as well as the more favorable BCEGS rated zip codes highlighted in blue. As with the ISO industry data we see relatively good agreement between the location of a claim and the observed SPC hail data, as well as relatively good variety in the BCEGS rated zip codes incurring a claim. 96% of the 60,849 Travelers policies in 2010 had either composition or architectural shingles as their roof type. Of the total 60,849 policies 1,308 (2.1%) incurred a hail loss claim in 2010 with the vast majority of claims coming from either composition shingle homes (93.5%) or architectural shingle homes (3.2%) as would be expected given that these roof types comprise 96% of the policy base. However, as a percentage of the customer roof type, wood (7.4%) and wood shake (4.0%) had the largest number of claims per policies in-place. IBHS (2003) found a similar result for wood roof homes in their TX study. Wood and wood shake homes also had the largest average loss per claims at \$10,911 and \$10,341 respectively.

Insert Figure 5 Here

Figure 6 illustrates the average 2010 losses per the various roof types split by the BCEGS rated zip codes. As with the ISO industry data, the raw data points to reduced hail losses on average for more favorable BCEGS rated zip codes. This is certainly evident in the two largest roof types – composition and architectural shingles. For wood, we begin to see evidence again that having some rating is significant in reducing losses compared to the average losses for the 99 rated zip codes.

Insert Figure 6 Here

To model the exposure-based data, we run two separate models for the pooled 2008 to 2010 loss data. The first model is a hurdle model in two stages with the first stage being a probit regression where the dependent variable equals 1 if a claim was experienced, zero otherwise. Explanatory variables in the first stage are limited to the number of storms during the year, hail size, and the insurance premium as a proxy for the size of the home. These are variables that would help determine the likelihood of the home sustaining damage. The second stage is similar to the industry level single stage model where we use a semi-log regression with the natural log of damage as the dependent variable against a vector of explanatory variables. Here though, each observation is an individual policy *i* in year *t* instead of aggregated as the industry model was. Only observations that sustained damage are included in the second stage. There are 109,173 in the first stage observations with 3 explanatory variables. The specification is:

First Stage:

$$\text{Damage or no Damage}_i = \beta_0 + \beta_1\text{Large Hail}_{it} + \beta_2\text{Storms}_{it} + \beta_3\text{Premium}_{it} + \varepsilon_{it}$$

The second stage has 2,554 observations and 34 variables. Its form is:

Second Stage:

$$\text{LN Hail Losses}_i = \beta_0 + \beta_{1\text{-}6}(\text{Construction Type})_{it} + \beta_{7\text{-}11}(\text{Shingle})_{it} + \beta_{11\text{-}16}(\text{Shingle*Age})_{it} + \beta_{17\text{-}22}(\text{Construction Decade})_{it} + \beta_{23}\text{High Season}_{it} + \beta_{24}\text{New Roof}_{it} + \beta_{25}\text{Home Age}_{it} + \beta_{26}\text{Hail Size}_{it} + \beta_{27}\text{Storms}_{it} + \beta_{28}\text{Premium}_{it} + \beta_{29}\text{Coverage Limit}_{it} + \beta_{30}\text{More Favorable BCEGS}_{it} + \beta_{31}\text{Less Favorable BCEGS}_{it} + \beta_{32}2009_{it} + \beta_{33}2010_{it} + \varepsilon_{it}$$

For the second model we employ a sample selection technique pioneered by James Heckman (Heckman, 1976, 1979). The model is also in two stages with the first stage the same as in the hurdle model described above. An output of the first stage is the Inverse Mills Ratio[20] which is found from the probability distribution of whether or not a home experienced hail damage. The Inverse Mills Ratio is passed to the second stage as one of the explanatory variables. The second stage is a semi-log OLS equation with the natural log of losses regressed against a vector of explanatory variables containing the housing attributes described below, the hail hazard data, and the BCEGS rating for the zip code where the home resides. There are 109,173 observations and 3 explanatory variables in the first stage.[21] The form is:

First Stage:

$$\text{Damage or no Damage}_i = \beta_0 + \beta_1\text{Large Hail}_{it} + \beta_2\text{Storms}_{it} + \beta_3\text{Premium}_{it} + \varepsilon_{it}$$

The second stage has 2,554 observations and 34 variables. Its form is:

Second Stage:

$$\text{LN Hail Losses}_i = \beta_0 + \beta_{1\text{-}6}(\text{Construction Type})_{it} + \beta_{7\text{-}11}(\text{Shingle})_{it} + \beta_{11\text{-}16}(\text{Shingle*Age})_{it} + \beta_{17\text{-}22}(\text{Construction Decade})_{it} + \beta_{23}\text{High Season}_{it} + \beta_{24}\text{New Roof}_{it} + \beta_{25}\text{Home Age}_{it} + \beta_{26}\text{Hail Size}_{it} + \beta_{27}\text{Storms}_{it} + \beta_{28}\text{Premium}_{it} + \beta_{29}\text{Coverage Limit}_{it} + \beta_{30}\text{More Favorable BCEGS}_{it} + \beta_{31}\text{Less Favorable BCEGS}_{it} + \beta_{32}2009_{it} + \beta_{33}2010_{it} + \beta_{34}\text{IMR}_{it} + \varepsilon_{it}$$

Given that the lowest level of policy location data is at the zip code, in both models we utilize the hail hazard (size and frequency), year of construction dummies, and BCEGS rating explanatory variables

---

[20] The Inverse Mills Ratio is the ratio of the probability distribution function divided by the cumulative distribution functions.

[21] As a robustness test, we also performed a Tobit/Hurdle model using the same variables in each stage. Results mirror those from the Hurdle model and the Heckman sample selection model that we use to report our results.

used in the industry model. Additionally, we incorporate other relevant policy specific attributes such as the exterior construction type; aluminum siding, masonry and several types of veneer, and the roof type which includes commonly used types such as composition (omitted category) and architectural shingles as well as wood and wood shake. On both the type of construction and type of roofing the data had several classifications which had few observations. Those were combined into one category. We also have the month the claim was filed, amount of the claim, insurance premium, limit of coverage, age of the home, and age of the current roof. We use the claim's file month to match to the high hail season which is equal to 1 if the claim occurred in a month from April, through September and which typically has more intense hailstorms bringing larger damages (Botzen et al, 2010).[22] A complete list and description of the variables used in the exposure-based models is provided in Table 6.

Insert Table 6 Here

Similar to the industry loss model, to further control for any potential omitted variable bias in our model, we also run a zip code fixed effect model using 3 digit zip code dummy variables. Results are discussed in Section 4.

IV. HAIL LOSS MODEL RESULTS

Industry Loss Model Results

Regression results using the aggregated industry data are shown in Table 7. The table has four regressions, one for all three years pooled together with our year dummies and then separate regressions for each year.[23] From the table, it is clear that more favorable BCEGS ratings are statistically significant estimators of reduced hail losses in comparison to less favorable and unclassified BCEGS 99 ratings (the

---

[22] While the exposure-based data has more specific date of loss/filing information than the annual loss data at the industry level, a direct match to specific SPC storm data was not possible. Therefore, we control for the seasonal aspect of the claim through our high hail season dummy, and continue to use the annual hail size and frequency information specific to the zip code in which the loss occurred as described in section III.

[23] As a robustness check we ran a series of parsimonious regressions using subsets of the explanatory variables. The intent of this exercise is to observe how the BCEGS ratings performed as additional variables are added to the model. The subsets were chosen in categories beginning with variables associated with the storm, then roof materials, roof interacted with age and finally exterior materials and the vintage of the home. In each regression, the More Favorable rating remained significant and the coefficient remained stable.

omitted dummy variable). For example, the coefficient values from the pooled year regression illustrate that losses in more favorable BCEGS rated zip codes are 20% less than those in unclassified BCEGS rated zip codes, as well as four times greater in loss reduction magnitude than less favorable BCEGS rated zip codes (-0.2034 vs. -0.05205). That said, it is still better, in general, to have some rating than none as less favorable ratings have negative coefficient values in comparison to the unclassified BCEGS 99 rated zip codes in three of the four regressions shown.

Insert Table 7 Here

Hail size, as expected, matters more to increased hail damages than the frequency of being impacted by hail with coefficient values ranging anywhere from 8 to 67 times larger. Hail damage in the RICOWI (2011) study found that the threshold for roof damage from hailstone impact to most materials was between 1.25 and 2.0 inches. To illustrate this jump in the ISO data Figure 7 shows average damage for the ISO data with a breakpoint of 1.25 inches. Also as expected, larger zip code population, policies (EHY) and claims experienced all significantly increase damages per zip code as evidenced by their positive and statistically significant coefficient estimates. Somewhat surprisingly, construction type and age of homes have limited significance on explanation of damages. Pre-1950 homes do have significantly lower loss estimates and has a coefficient that rivals strong enforcement of codes. One possible explanation for this result is that the size of homes has increased over the last 60 years. Home sizes have more than doubled since 1950.[24] Superior construction does increase loss but accounts for less than 1% of the homes in the sample.

Insert Figure 7 Here

We can further use our model coefficient point estimates to illustrate expected damages across various levels of our independent variables using the mean value for all independent variables. For example, Figure 8 shows estimated losses for various categories of hail sizes. More significantly though

---

[24] http://www.npr.org/templates/story/story.php?storyId=5525283

from this figure is the lower average damage estimates for more favorable BCEGS ratings across all hail sizes.

Insert Figure 8 Here

The results from our test for omitted variable bias using a 3 digit zip code fixed effects model is presented in Table 8. We find again that having any BCEGS grade is better than not, and that the more favorable grades provide lower losses from hail storms. However, while the most favorable BCEGS rating remains significant, it does show a decrease in reduction on damages magnitude to 12%. The sign and magnitude of the other variables remain stable between the two specifications.

Insert Table 8 Here

Exposure-based Model Results

The first model (a two stage hurdle model) with the first stage a probit regression using all Travelers Companies, Inc. customers in MO is shown in Table 9a and has five separate regressions each with different subsets of explanatory variable categories. The first of these five regressions uses only the age of the home, BCEGS ratings, year dummies and variables regarding the storm itself, hail size, number of storms and season. The second regression additionally brings roof type, the third regression adds roof type interacted with roof age. Regression four adds exterior construction type and home vintage. The final regression adds two variables about the policy itself, premium and coverage limit. The second model, shown in Table 9b is the two stage Heckman sample selection model . Observations that experienced a claim are then passed to the second stageand includes the Inverse Mills Ratio (IMR).

Insert Table 9a Here

Insert Table 9b Here

In both exposure-based models, BCEGS ratings perform as they did in the industry-based results showing significantly reduced damages from hail. The coefficients on both More Favorable and Less Favorable ratings are consistent across all parsimonious models and maintain significance in each. More Favorable ratings reduce hail damage by 21% in the hurdle model and by 19% in the Heckman model compared to zip codes with no rating. Additionally, the More Favorable rating reduces losses (.135 to .211, Hurdle model) (.117 to .192, Multi Stage model) by about 7% compared to the Less Favorable rating. This result is stronger than the presence of a new roof, and while several roof types had coefficients that exceeded that of the rating, only one type of roof shingle had a significant result that exceed enforcement of codes, wood shake shingle, and that was limited to the final model. Other significant results are that damages are significantly higher in the high hail season as expected. And composition shingles interacted with roof age shows a small but significant reduction in damages.

Similar to the industry loss model our results from the 3 digit zip code fixed effects model is presented in Table 10. As we saw in the industry-based analysis, our BCEGS grade categories perform as they have in our other regressions. More favorable BCEGS scores significantly reduce damages, in this specification, by almost 17%. As we observed when we performed this same test for the industry loss model, the signs and magnitudes of the other variables remained stable between the two specifications.

Insert Table 10 Here

V. DISCUSSION OF RESULTS AND CONCLUDING COMMENTS

Our study confirms that the enforcement of more favorable building codes does reduce damage from hail. The result is significant in both the industry and exposure-based models that we run and has similar coefficients on the BCEGS rating categories. Further, in the exposure-based model we show that this enforcement reduces damage comparatively to the type of roof used on the home. Our overall results provides empirical support for the common sense notion that the quality of construction matters when the home is under the stress of a potentially damaging event and that it pays to ensure that the proper construction quality is enforced.

More specifically though for hail, most hail damage on residential properties befalls the roof and the home supporting structures including windows and sidings. While large hail will damage almost any roof, proper installation (e.g., only one layer of shingles) and the quality of materials used to construct the roof and supporting structures are determinative of how much damage a structure will sustain if the structure is exposed to hail. Accordingly, adhering to local building codes as well as communities ensuring the proper licensing and enforcement of contractors plays a critical role in the mitigation of hail losses. To further approach why they matter we posed the question to Tim Reinhold who is the Senior VP of Engineering for the Insurance Institute for Business and Home Safety. IBHS has a large testing facility in South Carolina where they build entire structures and then subject them to common hazards like wind, fire, and hail. This allows them to observe, in a laboratory setting, the effect that hazards have on structures. Dr. Reinhold's response was that our results make intuitive sense given that communities that adopt and enforce codes ensure that the structure is built to international codes as well as ensuring that the products used in the construction of the home are A-rated.

In conclusion, we have not only shown that effective and well-enforced building codes matter in reducing damage from hail, but also significantly by how much they matter. Based upon our various industry and exposure-based model runs, effective and well-enforced building codes significantly reduce damage from hail from 12 % to 28% on average. With average losses per claim from hail being approximately $7,500 per home (Table 3), a 20% reduction due to more favorable building codes being in place would save $1,500 per home on average, a non-trivial amount considering the number of homes impacted per year. For example, for 4,000 impacted homes, a reasonable estimate from our MO ISO data (Table 4), this would equate to a savings of $6 million dollars annually. And remember, this amount is for roughly only 20% of the total property insurance market ISO data represents in MO. Highlighting this type of substantial mitigation savings is critical for decision makers weighing the costs of implementing more effective and well-enforced building standards. Particularly motivating is the supplementary mitigation benefits achieved by the more favorable codes for hazards such as hail as we have shown here, for which the codes are not predominantly designed and implemented for as they are for wind and/or earthquake. These positive externalities need to be factored into the decision making process against the building code costs. Especially recently where in all geographic regions of the U.S. there has been a decrease from previous years in the percentage of building code departments adopting the latest edition of the code (http://www.isomitigation.com/building-codes/building-code-effectiveness.html).

Finally, we do note that these conclusions are partially dependent upon on how reliable the BCEGS rating data actually is. Given its existence for eighteen years having conducted over 31,000 surveys in over

20,000 communities nationwide, by a well-trained staff with a rigorous quality control program, as well as the level of detail ISO collects, we believe the rating does capture the enforcement of effective codes. However, a better understanding of the accuracy of these ratings as well as whether there are particular components of the ratings that are more important than others (e.g., stringency vs. enforcement) is certainly something to be explored in future research. Moreover, investigating the role of these ratings in reducing losses from other hazards is also something to be analyzed in future work.

REFERENCES

Arrow, Kenneth (1996), “The Theory of Risk Bearing: Small and Great Risks”, Journal of Risk and Uncertainty, Vol. 12, No. 2/3, pp. 103-111.

Board on Natural Disasters, 1999. Mitigation Emerges as Major Strategy for Reducing Losses Caused by Natural Disasters. Science. 284:1943-1947.

Botzen, W., Bouwer, L., Van den Bergh, J., 2010. Climate change and hailstorm damage: Empirical evidence and implications for agriculture and insurance, Resource and Energy Economics. 32:341-362.

Building and Housing Codes Department, City of Jackson Tennessee, 2013. Available at http://www.cityofjackson.net/departments/buildingcodes/faq.html (last accessed, July 2013)

Changnon, S., Changnon, D., Hilberg, S., 2009. Hailstorms Across the Nation: An Atlas about Hail and its Damages. Illinois State Water Survey Contract Report 2009-12.

Crenshaw, V., Koontz, J., 2001. Simulated Hail Damage and Impact Resistance Test Procedures for Roof Coverings and Membranes. RCI Interface, 19(5), 5-10.

Dessens, J., 1995, Severe convective weather in the context of a nighttime global warming. Geophysical Research Letters, 22 (10) pp. 1241–1244

Ehrlich, Issac, Becker, Gary (1972), “Market Insurance, Self-Insurance and Self-Protection”, Journal of Political Economy, Vol. 80, No. 4, pp. 623-648.

Fronstin, Paul, Holtmann, Alphonse G., (1994) “The Determinants of Residential Property Damage from Hurricane Andrew”, Southern Economic Journal, Vol. 61, No. 2, pp., 387-397, Oct. 1994.

Gall, Melanie, Borden, Kevin , Cutter, Susan (2009) “When Do Losses Count? Six Fallacies of Natural Hazards Loss Data” Bulletin of the American Meteorological Society, pp. 709-809, June, 2009.

Heckman, James (1976), “The Common Structure of Statistical Models of Truncation, Sample Selection and Limited Dependent Variables and a Simple Estimator for Such Models”, Annals of Economic and Social Measurement, Vol. 5, No. 4, National Bureau of Economic Research, Cambridge MA, pp. 475-492, October 1976.

Heckman, James (1979), “Sample Selection as a Specification Error”, Econometrica, Vol. 47, No. 1, pp. 153-161, January 1979.

Homeowners Insurance Guide: Reduce Potential Damages and Premiums, 2013. Available at http://homeownersinsuranceguide.flash.org/reducepotentialdamages.htm (last accessed, July 2013)

Insurance Institute for Business and Home Safety (IBHS), 2002. Is Your Home Protected from Hail Damage? A Homeowner’s Guide to Hail Retrofit. Available at http://www.anpac.com/safety/home/IBHS/ProtectHomeAgainstHail.pdf (last accessed July 10, 2013)

Insurance Institute for Business and Home Safety (IBHS), 2003. Hail Storm Investigation. Investigation into Insured Losses and Damages to Single-Family Homes Resulting from the April 5, 2003 North Texas Hailstorms. IBHS Technical Report

Insurance Institute for Business and Home Safety (IBHS), 2004. Hurricane Charley Executive Summary. Available at http://www.disastersafety.org/wp-content/uploads/hurricane_charley.pdf (last accessed, February 14, 2013)

Insurance Institute for Business and Home Safety (IBHS), 2013. Hail Loss Fact Sheet. Available at http://ofb.ibhs.org/content/data/file/IBHS_HailLossFactSheet.pdf (last accessed July 10, 2013)

Insurance Services Office a. (ISOa). 2012. ISO's Building Code Effectiveness Grading Schedule (BCEGS®)
http://www.isomitigation.com/bcegs/0000/bcegs0001.html (last accessed, October 2012)

Insurance Services Office b. (ISOb). 2012. What? Why? When? And What Do I Do? BCEGS Summary - http://www.isomitigation.com/bcegs/0000/bcegs0002.html. (last accessed, October 2012)

International Association of Certified Home Inspectors (InterNACHI), 2013 From Mastering Roof Inspections: Hail Damage, Part 9 - InterNACHI Available at http://www.nachi.org/hail-damage-part9-36.htm#ixzz2Ykpt1s3b (last accessed July 2013)

Karen Clark and Company, 2011. Presentation to the National Association of Insurance Commissioners Public Hearing on Catastrophe Models.
http://www.naic.org/documents/committees_c_catastrophe_110328_presentation_karen_clark.pdf

Keith, E., Rose, J. (1994), "Hurricane Andrew – Structural Performance of Buildings in South Florida, Journal of Performance of Constructed Facilities, Vol. 8, No. 3, pp. 178-191.

Kunreuther, H., and E. Michel-Kerjan, At War with the Weather: Managing Large-scale Risks in a New Era of Catastrophes, New York, NY: MIT Press, pp.416, 2009.

McHale, C., Leurig, S., 2012. Stormy Future for U.S. Property/Casualty Insurers: The Growing Costs and Risks of Extreme Weather Events. A Ceres Report

McMaster, H.J., 2001. Hailstorm risk assessment in rural New South Wales, Natural Hazards, 24 (2) pp. 187–196

Mills, E., Roth, R., Lecomte, E., 2005. Availability and Affordability of Insurance Under Climate Change: A Growing Challenge for the U.S. A Ceres Report

Munson, D., Molina, G., 2012, CDS Business Mapping 2012 Hail Model: Model Overview and Results http://www.riskmeter.com/Resources/RiskMeter-Hail-Model-Study-July-03-2012-FINAL.pdf CDS Business Mapping /RiskMeter.Com report

Reed Construction, 2013. http://www.reedconstructiondata.com/building-codes/missouri/ (last accessed, July 2013)

Richter, Maurice, Berkowitz, Ben (2012), "Dallas Hailstorm Insured Losses Could Reach $2 Billion", *Insurance Journal*, June 18, 2012. Article can be found at: http://www.insurancejournal.com/news/southcentral/2012/06/18/251965.htm

Roofing Industry Committee On Weather Issues, Inc. (RICOWI) 2011. Hailstorm Investigation Dallas/Fort Worth, TX May 24, 2011. Technical Report.

Severe Thunderstorm Climatology, 2013. Available at http://www.nssl.noaa.gov/projects/hazard/

Sparks, P. R., Schiff, S. D., Reinhold, T. A. (1994), "Wind Damage to Envelopes of Houses and Consequent Insurance Losses", Journal of Wind Engineering and Industrial Aerodynamics, Vol. 53, No. 1-2, pp. 145-155, Nov. 1994.

Storm Prediction Center (SPC), 2012 - http://www.spc.noaa.gov/wcm/

Tsikoudakis, John, "Hurricane Andrew Prompted Better Building Code Requirements", Business Insurance, website article, posted August 12, 2012.

Vinet, F. 2001. Climatology of hail in France. Atmospheric Research, 56 (1–4) pp. 309–323

Willemse, S., 1995. A statistical analysis and climatological interpretation of hailstorms in Switzerland, Doctor of Natural Sciences Thesis Dissertation No. 11137. Swiss Federal Institute of Technology, Zurich. pp. 176

TABLES

Table 1: SPC Hail Statistics from 1996 to 2011

Hail Size	Storms	Storm Percent	Average Damage	CPI Adj Average Damage	Total Damage	Total Damage Percent	CPI Adj Total Damage	CPI Adj Total Damage Percent
0 - .5	51	0.03%	6,666.67	7,265.48	340,000	0.003%	370,539	0.003%
.5 - 1.0	99,535	48.87%	2,494.08	2,968.35	248,248,600	2.038%	295,454,516	2.041%
1.0 - 1.5	60,616	29.76%	26,717.27	30,834.72	1,619,493,900	13.296%	1,869,077,545	12.909%
1.5 - 2.0	34,014	16.70%	95,507.62	113,146.84	3,248,596,350	26.671%	3,848,576,464	26.580%
2.0 - 2.5	3,136	1.54%	315,882.16	370,718.04	990,606,450	8.133%	1,162,571,773	8.029%
2.5 - 3.0	4,831	2.37%	720,323.53	886,346.44	3,479,882,960	28.570%	4,281,939,676	29.573%
3.0 - 3.5	573	0.28%	1,681,229.06	1,861,031.56	963,344,250	7.909%	1,066,371,083	7.365%
3.5 - 4.0	116	0.06%	1,171,982.76	1,476,257.91	135,950,000	1.116%	171,245,918	1.183%
> 4	793	0.39%	1,883,668.03	2,249,201.08	1,493,748,750	12.264%	1,783,616,460	12.318%
Totals	203,665	100%			12,180,211,260	100%	14,479,223,973	100%

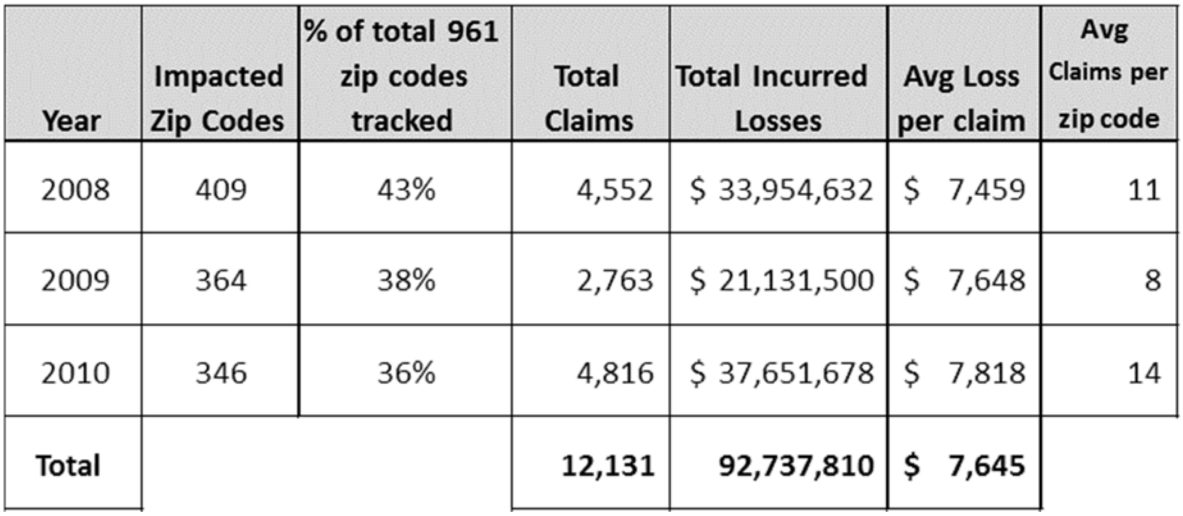
Table 2. Summary of Existing Codes in MO for Select Localities

Locality	**Building/Dwelling Code**	**Structural Code**
Branson	2003 IBC	2003 IBC
Columbia	2006 IBC 2006 IRC	2006 IBC 2006 IRC
Independence	2003 IBC	2003 IBC
Joplin	2006 IBC 2006 IRC City Amendments	2006 IBC City Amendments
Kansas City	2006 IBC	2006 IBC
Saint Louis City	2009 IBC (Ordinance 68788) 2009 IRC (Ordinance 68789)	2009 IBC (Ordinance 68788) 2009 IRC (Ordinance 68789)
Saint Louis County	2009 IBC 2009 IRC Int’l Existing Bldg. Code	2009 IBC 2009 IRC Int’l Existing Bldg. Code
Springfield	2006 IBC 2006 IRC	2006 IBC

Table 3. BCEGS Rating Example for Zip Code 63005

State	Zip Code	Personal Line Rating	YEAR
MO	63005	3	1997
MO	63005	4	1997
MO	63005	4	1998
MO	63005	99	1999
MO	63005	3	2002
MO	63005	4	2002
MO	63005	99	2004
MO	63005	4	2006
MO	63005	2	2007
MO	63005	5	2008

Table 4. ISO Database MO hail claims and losses by the impacted zip codes for each year from 2008 to 2010



Year	Impacted Zip Codes	% of total 961 zip codes tracked	Total Claims	Total Incurred Losses	Avg Loss per claim	Avg Claims per zip code
2008	409	43%	4,552	$ 33,954,632	$ 7,459	11
2009	364	38%	2,763	$ 21,131,500	$ 7,648	8
2010	346	36%	4,816	$ 37,651,678	$ 7,818	14
Total			**12,131**	**92,737,810**	**$ 7,645**	

Table 5: Industry Loss Model Variables

Dependent	**Description**	
ln_hail_losses	Natural log of loss by Year of Construction and Zip Code (ISO)	
Independent		
brick_pct	Percent of Claims that are brick construction (ISO)	
brick_veneer_pct	Percent of claims that are brick veneer construction (ISO)	
frame_pct	Percent of claims that are frame construction (ISO)	
siding_pct	Percent of claims that are siding construction (ISO)	
superior_pct	Percent of claims that are superior construction (ISO)	
aoi100_pct	Percent of claims that have insurance up to $100K (ISO)	
aoi200_pct	Percent of claims that have insurance from $100K to $200K (ISO)	
aoi300_pct	Percent of claims that have insurance from $200K to $300K (ISO)	
aoi400_pct	Percent of claims that have insurance from $300K to $400K (ISO)	
aoi500_pct	Percent of claims that have insurance from $400K to $500K (ISO)	
aoi600_pct	Percent of claims that have insurance from $500K to $600K (ISO)	
aoi600up_pct	Percent of claims that have insurance over $600K (ISO)	
pre_1950	Dummy variable to indicate year of construction is before 1950 (ISO)	
Y1950	Dummy variable to indicate year of construction is between 1950 and 1959 (ISO)	
Y1960	Dummy variable to indicate year of construction is between 1960 and 1969 (ISO)	
Y1970	Dummy variable to indicate year of construction is between 1970 and 1979 (ISO)	
Y1980	Dummy variable to indicate year of construction is between 1980 and 1989 (ISO)	
Y1990	Dummy variable to indicate year of construction is between 1990 and 1999 (ISO)	
Y2000	Dummy variable to indicate year of construction is between 2000 and 2009 (ISO)	Omitted
Y2010	Dummy variable to indicate year of construction is 2010 (ISO)	
size	Average annual Hail Stone Size in inches (SPC)	
pop2004	Population in 2004 (Census)	
storms	Number of storms in that year and that zip code (SPC)	
Claims	Number of claims for this observations Year of Construction decade and Zip Code (ISO)	
EHY	Earned House years for this observations Year of Construction decade and Zip Code (ISO)	
Premium	Premiums paid for this observations Year of Construction decade and Zip Code (ISO)	
CovA	Percent of single family homes in this zip code (ISO)	
MoreFavorable_BCEGS	Dummy variable to indicate the average BCEGS rating is 4 or below (BCEGS)	
LessFavorable_BCEGS	Dummy variable to indicate the average BCEGS rating is 5 or higher (BCEGS)	
BCEGS_99	Dummy variable to indicate the average BCEGS rating is 99 (BCEGS)	Omitted
Yr_2008	Dummy variable to indicate that this observation is from 2008	Omitted
Yr_2009	Dummy variable to indicate that this observation is from 2009	
Yr_2010	Dummy variable to indicate that this observation is from 2010	

Table 6. Exposure-based Model Variables

Dependent	**Description**	
ln_hail_losses	Natural Log of Damage to a given policy holder.	
Independent		
Almn	Aluminum Siding	
Frme	Frame Siding	Omitted
Masn	Brick/Masonry Siding	
Vnr2	Brick or stone veneer with smallest percentage of veneer	
Vnr6	Brick or stone veneer with larger percentage of veneer	
Vnr7	Brick or stone veneer with largest percentage of veneer	
Constr_Other	Other Siding	
Arshg	Architectural Shingles	
Shgcm	Composition Shingles	Omitted
Shgwd	Wood Shingles	
Shkwd	Wood Shake	
Targr	Tar and Glue	
Roof_Other	Other Shingles	
ARSHG_Age	Arshg * Roof Age	
SHGCM_Age	Composition Shingles * Roof Age	
SHGWD_Age	Wood Shingles * Roof Age	
SHKWD_Age	Wood Shake * Roof Age	
TARGR_Age	Tar and Glue * Roof Age	
pre_1950	Dummy variable to indicate year of construction is before 1950	
Y1950	Dummy variable to indicate year of construction is between 1950 and 1959	
Y1960	Dummy variable to indicate year of construction is between 1960 and 1969	
Y1970	Dummy variable to indicate year of construction is between 1970 and 1979	
Y1980	Dummy variable to indicate year of construction is between 1980 and 1989	
Y1990	Dummy variable to indicate year of construction is between 1990 and 1999	Omitted
Y2000	Dummy variable to indicate year of construction is between 2000 and 2009	Omitted
Y2010	Dummy variable to indicate year of construction is 2010	
High_Season	Hail storm occurring between April and September	
New_Roof	Roof Age less than 10 years	
Age	Age of the Home	
size	Average annual Hail Stone Size in inches (SPC) for a zip code	
storms	Number of Hail Storms for a zip code this year (SPC)	
Premium	Premium Amount	
Prim_Cov_Limit	Coverage Limit	
More Favorable	Dummy variable to indicate the average BCEGS rating is 4 or below (BCEGS)	
Less Favorable	Dummy variable to indicate the average BCEGS rating is 5 or higher (BCEGS)	
BCEGS_99	Dummy variable to indicate the average BCEGS rating is 99 (BCEGS)	Omitted
Yr_2008	Dummy variable to indicate that this observation is from 2008	Omitted
Yr_2009	Dummy variable to indicate that this observation is from 2009	
Yr_2010	Dummy variable to indicate that this observation is from 2010	

Table 7. Industry Hail Loss Model Results
(3,090 Observations)

Variable	2008-2010		Std Err	2008		Std Err	2009		Std Err	2010		Std Err
Intercept	5.024	***	1.652	1.456		2.484	10.260	***	3.084	5.209		3.231
brick_pct	0.654		0.439	0.574		0.544	-1.058		1.391	0.675		0.955
brick_veneer_pct	1.026	**	0.444	1.018	*	0.556	-0.633		1.389	0.999		0.979
frame_pct	0.954	**	0.430	0.879	*	0.523	-0.681		1.385	0.890		0.941
siding_pct	0.746	*	0.442	0.562		0.542	-1.202		1.425	1.046		0.958
superior_pct	6.674	***	1.738	3.591		3.272	8.217	**	3.396	6.374	**	2.707
aoi100_pct	-1.034	**	0.459	-0.898		0.562	0.465		1.415	-0.761		1.060
aoi200_pct	-1.127	**	0.453	-0.956	*	0.562	0.311		1.412	-0.896		0.990
aoi300_pct	-0.784	*	0.453	-0.463		0.570	0.687		1.412	-0.698		0.977
aoi400_pct	-0.705		0.468	-0.437		0.611	0.791		1.418	-0.625		1.008
aoi500_pct	-0.448		0.482	-0.543		0.622	1.240		1.451	-0.234		1.041
aoi600_pct	-0.478		0.523	-0.746		0.682	0.943		1.478	0.076		1.163
aoi600up_pct	0.177		0.552	0.661		0.863	0.837		1.509	0.762		1.109
pre_1950	-0.179	***	0.064	-0.193	*	0.104	-0.205	**	0.112	-0.197	*	0.113
Y1950	-0.117	*	0.069	-0.067		0.114	0.001		0.118	-0.290	**	0.120
Y1960	-0.108	*	0.061	-0.056		0.100	-0.049		0.106	-0.217	**	0.110
Y1970	0.072		0.059	0.049		0.096	0.196	*	0.101	-0.040		0.107
Y1980	0.177	***	0.062	0.070		0.100	0.402	***	0.111	0.086		0.108
Y1990	0.277	***	0.056	0.387	***	0.093	0.295	***	0.099	0.062		0.101
size	0.340	***	0.092	0.678	***	0.188	0.080		0.125	0.329		0.207
pop2004	0.000	***	0.000	0.000		0.000	0.000		0.000	0.000	*	0.000
storms	0.010	***	0.001	0.011	***	0.002	0.018	***	0.005	0.009	***	0.002
Claims	0.079	***	0.002	0.076	***	0.004	0.130	***	0.006	0.071	***	0.003
EHY	0.001	**	0.000	0.000		0.001	0.001		0.001	0.001		0.001
Premium	0.000		0.000	0.000		0.000	0.000		0.000	0.000		0.000
CovA	3.319	**	1.650	6.328	**	2.487	-1.568		3.086	3.270		3.212
MoreFavorable_BCEGS	-0.203	***	0.057	-0.139		0.092	-0.277	***	0.104	-0.249	**	0.108
LessFavorable_ BCEGS	-0.052		0.044	0.037		0.068	-0.148	*	0.076	-0.065		0.086
Yr_2009	0.085	**	0.044									
Yr_2010	0.066		0.042									
Scaled Deviance/DF	1.0098			1.0245			1.0311			1.0295		
R Squared	0.476			0.497			0.482			0.508		

*, **, *** denotes significance at the 10%, 5%, and 1% levels respectively

Table 8: Fixed Effects Industry Model (3 Digit Zip Code)

Variable	Estimate		Std Err
Intercept	4.038	**	1.685
brick_pct	0.43		0.45
brick_veneer_pct	0.815	*	0.452
frame_pct	0.588		0.439
siding_pct	0.439		0.452
superior_pct	6.057	***	1.739
aoi100_pct	-0.832	*	0.467
aoi200_pct	-0.84	*	0.461
aoi300_pct	-0.454		0.461
aoi400_pct	-0.399		0.476
aoi500_pct	-0.127		0.49
aoi600_pct	-0.116		0.533
aoi600up_pct	0.42		0.559
pre_1950	-0.209	***	0.064
Y1950	-0.117	*	0.069
Y1960	-0.107	*	0.061
Y1970	0.079		0.059
Y1980	0.19	**	0.061
Y1990	0.29	***	0.056
size	0.355	***	0.097
pop2004	0.00000447	**	0.000002
storms	0.011	***	0.001
Claims	0.077	***	0.002
EHY	0.001	**	0.0005
Premium	6.48E-08		4.82E-07
CovA	4.366	*	1.683
More Favorable	-0.123	*	0.069
Less Favorable	-0.04		0.052
Yr_2009	0.087	*	0.046
Yr_2010	0.05		0.043
zip_630	-0.167		0.115
zip_631	-0.257	**	0.118
zip_633	-0.18		0.127
zip_634	0.234		0.17
zip_635	0.168		0.18
zip_636	-0.01		0.171
zip_637	-0.488	***	0.184
zip_638	-0.729	***	0.237
zip_639	-0.106		0.228
zip_640	-0.053		0.105
zip_641	-0.034		0.111
zip_644	-0.028		0.129
zip_645	0.334	**	0.135
zip_646	-0.193		0.154
zip_647	0.015		0.149
zip_648	-0.097		0.122
zip_650	0.175		0.137
zip_651	0.169		0.176
zip_652	0.13		0.124
zip_653	-0.123		0.156
zip_654	-0.252		0.186
zip_655	-0.072		0.144
zip_656	-0.182		0.126
zip_657	-0.142		0.113
R Squared	0.4886		

*, **, *** denotes significance at the 10%, 5%, and 1% levels respectively

Table 9a. Exposure-based Model – Two Stage Hurdle model - Results
(109,173 Observations)

First Stage	Model 1			Model 2			Model 3			Model 4			Model 5		
Variable	Est		Std Err	Est		Std Err	Est		Std Err	Est		Std Err	Est		Std Err
Intercept	-3.874	***	0.059	-3.874	***	0.059	-3.874	***	0.059	-3.874	***	0.059	-4.007	***	0.064
Hail Size	1.369	***	0.056	1.369	***	0.056	1.369	***	0.056	1.369	***	0.056	1.408	***	0.057
Storms	0.017	***	0.001	0.017	***	0.001	0.017	***	0.001	0.017	***	0.001	0.017	***	0.001
Premium													0.081	***	0.014
Second Stage Variable	Est		Std Err	Est		Std Err	Est		Std Err	Est		Std Err	Est		Std Err
Intercept	8.592	***	1.211	8.581	***	1.211	8.723	***	1.171	8.603	***	1.112	8.021	***	1.633
Almn										-0.099		0.063	-0.080		0.060
Masn										-0.031		0.058	-0.118	**	0.056
Vnr2										0.192	***	0.046	0.093	**	0.045
Vnr6										0.042		0.058	-0.048		0.056
Vnr7										0.005		0.103	-0.193	*	0.100
Constr_Other										0.134		0.172	0.248		0.165
Arshg				0.111		0.072	0.010		0.135	0.030		0.135	-0.060		0.129
Shgwd				0.124		0.167	-0.432		0.550	-0.472		0.546	-0.483		0.524
Shkwd				0.040		0.131	0.043		0.354	-0.027		0.352	-0.688	**	0.341
Targr				0.095		0.198	-0.336		0.549	-0.360		0.544	-0.380		0.523
Roof_Other				0.162		0.113	0.063		0.116	0.060		0.115	-0.013		0.111
ARSHG_Age							0.002		0.013	0.001		0.013	0.003		0.012
SHGCM_Age							-0.008	***	0.002	-0.007	***	0.002	-0.007	***	0.002
SHGWD_Age							0.036		0.042	0.041		0.041	0.034		0.040
SHKWD_Age							-0.008		0.027	0.001		0.027	0.033		0.026
TARGR_Age							0.028		0.042	0.031		0.042	0.033		0.040
pre_1950										-0.453	***	0.162	-0.213		0.157
Y1950										-0.361	***	0.112	-0.107		0.108
Y1960										-0.330	***	0.093	-0.122		0.090
Y1970										-0.303	***	0.075	-0.130	*	0.073
Y1980										-0.218	***	0.064	-0.098		0.062
Y1990										-0.044		0.050	0.035		0.049
High_Season	0.164	***	0.040	0.164	***	0.040	0.163	***	0.040	0.163	***	0.039	0.145	***	0.038
New_Roof	-0.009		0.026	-0.013		0.026	-0.084	**	0.034	-0.075	**	0.038	-0.059		0.037
Age	-0.004	***	0.001	-0.004	***	0.001	-0.004	***	0.001	0.003		0.002	0.002		0.002
Size	0.346		0.370	0.346		0.369	0.328		0.358	0.385		0.340	0.531		0.491
Storms	-0.003		0.004	-0.003		0.004	-0.002		0.004	-0.002		0.004	-0.002		0.006
Premium													-0.051		0.041
Prim_Cov_Limit													0.017	***	0.001
More Favorable	-0.165	***	0.051	-0.165	***	0.051	-0.173	***	0.051	-0.147	***	0.052	-0.212	***	0.050
Less Favorable	-0.137	***	0.048	-0.138	***	0.048	-0.142	***	0.048	-0.125	***	0.048	-0.135	***	0.046
Yr_2009	-0.089	**	0.042	-0.085	**	0.042	-0.080	**	0.042	-0.082	*	0.042	-0.095	**	0.040
Yr_2010	-0.040		0.030	-0.040		0.030	-0.043		0.030	-0.041		0.031	-0.052	*	0.030
AIC	26535			26539			26535			26512			26269		

*, **, *** denotes significance at the 10%, 5%, and 1% levels respectively

Table 9b. Exposure-based Model - two stage Heckman Sample Selection model - Results (109,173 Observations)

	Model 1			Model 2			Model 3			Model 4			Model 5		
First Stage															
Variable	Est		Std Err	Est		Std Err	Est		Std Err	Est		Std Err	Est		Std Err
Intercept	-3.874	***	0.059	-3.874	***	0.059	-3.874	***	0.059	-3.874	***	0.059	-4.007	***	0.064
Hail Size	1.369	***	0.056	1.369	***	0.056	1.369	***	0.056	1.369	***	0.056	1.408	***	0.057
Storms	0.017	***	0.001	0.017	***	0.001	0.017	***	0.001	0.017	***	0.001	0.017	***	0.001
Premium													0.081	***	0.014
Second Stage															
Variable	Est		Std Err	Est		Std Err	Est		Std Err	Est		Std Err	Est		Std Err
Intercept	-6.215		8.847	-6.037		8.857	-6.011		8.837	-2.604		8.851	-3.758		8.347
Almn										-0.103	*	0.063	-0.084		0.060
Masn										-0.034		0.058	-0.123	**	0.056
Vnr2										0.185	***	0.046	0.086	*	0.045
Vnr6										0.040		0.058	-0.050		0.056
Vnr7										0.001		0.103	-0.198	**	0.100
Constr_Other										0.139		0.172	0.251		0.165
Arshg				0.105		0.072	0.005		0.135	0.026		0.135	-0.066		0.129
Shgwd				0.131		0.167	-0.444		0.550	-0.481		0.546	-0.490		0.524
Shkwd				0.043		0.130	0.047		0.354	-0.023		0.352	-0.692	**	0.341
Targr				0.102		0.198	-0.348		0.549	-0.369		0.544	-0.390		0.522
Roof_Other				0.165		0.112	0.066		0.116	0.063		0.115	-0.009		0.111
ARSHG_Age							0.002		0.013	0.001		0.013	0.003		0.012
SHGCM_Age							-0.008	***	0.002	-0.007	***	0.002	-0.007	***	0.002
SHGWD_Age							0.037		0.042	0.042		0.041	0.035		0.040
SHKWD_Age							-0.008		0.027	0.001		0.027	0.033		0.026
TARGR_Age							0.029		0.042	0.032		0.042	0.035		0.040
pre_1950										-0.454	***	0.162	-0.215		0.157
Y1950										-0.362	***	0.111	-0.108		0.108
Y1960										-0.329	***	0.093	-0.122		0.090
Y1970										-0.304	***	0.075	-0.131	*	0.073
Y1980										-0.219	***	0.064	-0.099		0.062
Y1990										-0.047		0.050	0.032		0.049
High_Season	0.187	***	0.042	0.186	***	0.042	0.185	***	0.042	0.179	***	0.042	0.162	***	0.040
New_Roof	-0.010		0.026	-0.013		0.026	-0.083	**	0.034	-0.076	**	0.038	-0.059		0.037
Age	-0.004	***	0.000	-0.004	***	0.000	-0.004	***	0.000	0.003		0.002	0.002		0.002
Size	4.746	*	2.629	4.689	*	2.633	4.705	*	2.626	3.715		2.631	4.029		2.479
Storms	0.051		0.032	0.051		0.032	0.051		0.032	0.038		0.032	0.040		0.030
Premium													0.149		0.145
Prim_Cov_Limit													0.017	***	0.001
More Favorable	-0.141	***	0.053	-0.142	***	0.053	-0.149	***	0.053	-0.129	**	0.053	-0.192	***	0.051
Less Favorable	-0.113	**	0.050	-0.114	**	0.050	-0.118	**	0.050	-0.107	**	0.050	-0.117	**	0.048
Yr_2009	-0.101	**	0.043	-0.097	**	0.043	-0.093	**	0.043	-0.092	**	0.043	-0.105	**	0.041
Yr_2010	-0.042		0.030	-0.042		0.030	-0.045		0.030	-0.043		0.031	-0.055	*	0.030
IMR	3.684	*	2.201	3.637	*	2.203	3.666	*	2.198	2.790		2.203	2.850		2.019
AIC	4845			4850			4845			4826			4618		

*, **, *** denotes significance at the 10%, 5%, and 1% levels respectively

Table 10. Fixed Effects Exposure-based Model (3 Digit Zip Code)

Hurdle Model				Heckman Sample Selection Model			
First Stage				First Stage			
Variable	Estimate		Std Err	Variable	Estimate		Std Err
Intercept	-4.007	***	0.064	Intercept	-4.007	***	0.064
size	1.408	***	0.057	size	1.408	***	0.057
storms	0.017	***	0.001	storms	0.017	***	0.001
premium	0.081	***	0.014	premium	0.081	***	0.014
Second Stage				Second Stage			
Variable	Estimate		Std Err	Variable	Estimate		Std Err
Intercept	7.973	***	1.515	Intercept	-2.089		9.730
Almn	-0.066		0.060	Almn	-0.068		0.060
Masn	-0.116	**	0.056	Masn	-0.117	**	0.056
Vnr2	0.103	**	0.047	Vnr2	0.102	**	0.047
Vnr6	-0.058		0.055	Vnr6	-0.057		0.055
Vnr7	-0.197	**	0.099	Vnr7	-0.196	**	0.099
Constr_Other	0.213		0.167	Constr_Other	0.219		0.167
Arshg	-0.055		0.129	Arshg	-0.059		0.129
Shgwd	-0.488		0.520	Shgwd	-0.496		0.520
Shkwd	-0.760	**	0.338	Shkwd	-0.765	**	0.338
Targr	-0.352		0.518	Targr	-0.364		0.518
Roof_Other	-0.012		0.110	Roof_Other	-0.010		0.110
ARSHG_Age	0.000		0.012	ARSHG_Age	0.000		0.012
SHGCM_Age	-0.007	***	0.002	SHGCM_Age	-0.007	***	0.002
SHGWD_Age	0.037		0.040	SHGWD_Age	0.038		0.040
SHKWD_Age	0.039		0.026	SHKWD_Age	0.039		0.026
TARGR_Age	0.033		0.040	TARGR_Age	0.034		0.040
pre_1950	-0.176		0.159	pre_1950	-0.178		0.159
Y1950	-0.070		0.110	Y1950	-0.071		0.110
Y1960	-0.088		0.093	Y1960	-0.088		0.092
Y1970	-0.114		0.074	Y1970	-0.114		0.074
Y1980	-0.090		0.062	Y1980	-0.091		0.062
Y1990	0.039		0.049	Y1990	0.038		0.049
High_Season	0.198	***	0.041	High_Season	0.206	***	0.041
New_Roof	-0.064	*	0.036	New_Roof	-0.064	*	0.036
Age	0.002		0.002	Age	0.002		0.002
size	0.231		0.459	size	3.209		2.881
storms	-0.002		0.005	storms	0.033		0.035
Premium	-0.063		0.040	Premium	0.108		0.169
Prim_Cov_Limit	0.018	***	0.001	Prim_Cov_Limit	0.019	***	0.001
More Favorable	-0.165	**	0.067	More Favorable	-0.156	**	0.067
Less Favorable	-0.114	*	0.061	Less Favorable	-0.106	*	0.061
Yr_2009	-0.052		0.045	Yr_2009	-0.067		0.047
Yr_2010	0.023		0.034	Yr_2010	0.017		0.035
zip_630	0.174		0.118	zip_630	0.183		0.118
zip_631	0.109		0.120	zip_631	0.122		0.121
zip_633	0.247	*	0.144	zip_633	0.259	*	0.145
zip_634	-0.170		0.269	zip_634	-0.145		0.270
zip_636	0.350		0.358	zip_636	0.369		0.358
zip_640	0.253	**	0.121	zip_640	0.284	**	0.125
zip_641	0.187		0.124	zip_641	0.223	*	0.128
zip_644	0.151		0.169	zip_644	0.189		0.173
zip_645	0.175		0.184	zip_645	0.186		0.184
zip_646	0.560	***	0.216	zip_646	0.606	***	0.220
zip_647	0.218		0.226	zip_647	0.237		0.227
zip_648	0.349	***	0.134	zip_648	0.380	***	0.137
zip_650	0.405	***	0.145	zip_650	0.419	***	0.145
zip_652	0.268	**	0.127	zip_652	0.278	**	0.127
zip_653	-0.226		0.263	zip_653	-0.234		0.263
zip_654	0.232		0.283	zip_654	0.230		0.283
zip_656	0.711	***	0.164	zip_656	0.719	***	0.165
zip_657	0.498	***	0.129	zip_657	0.512	***	0.129
zip_658	0.389	***	0.123	zip_658	0.405	***	0.124
				IMR	2.438		2.357
AIC	26264			AIC	4603		

*, **, *** denotes significance at the 10%, 5%, and 1% levels respectively

FIGURES

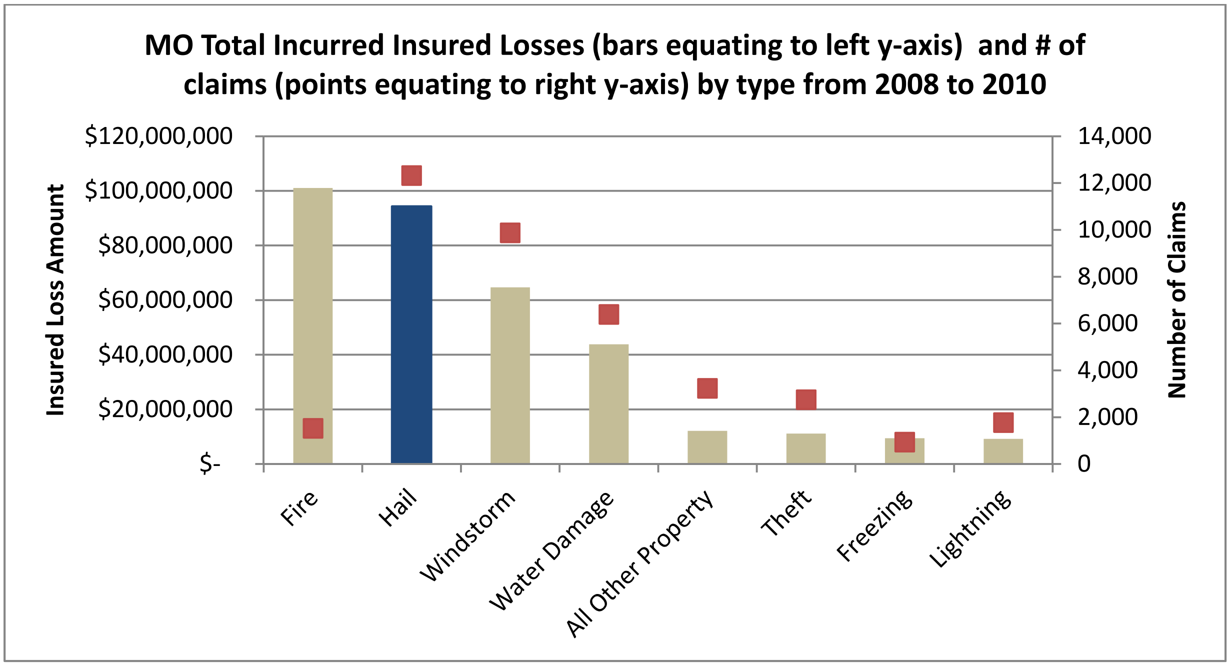
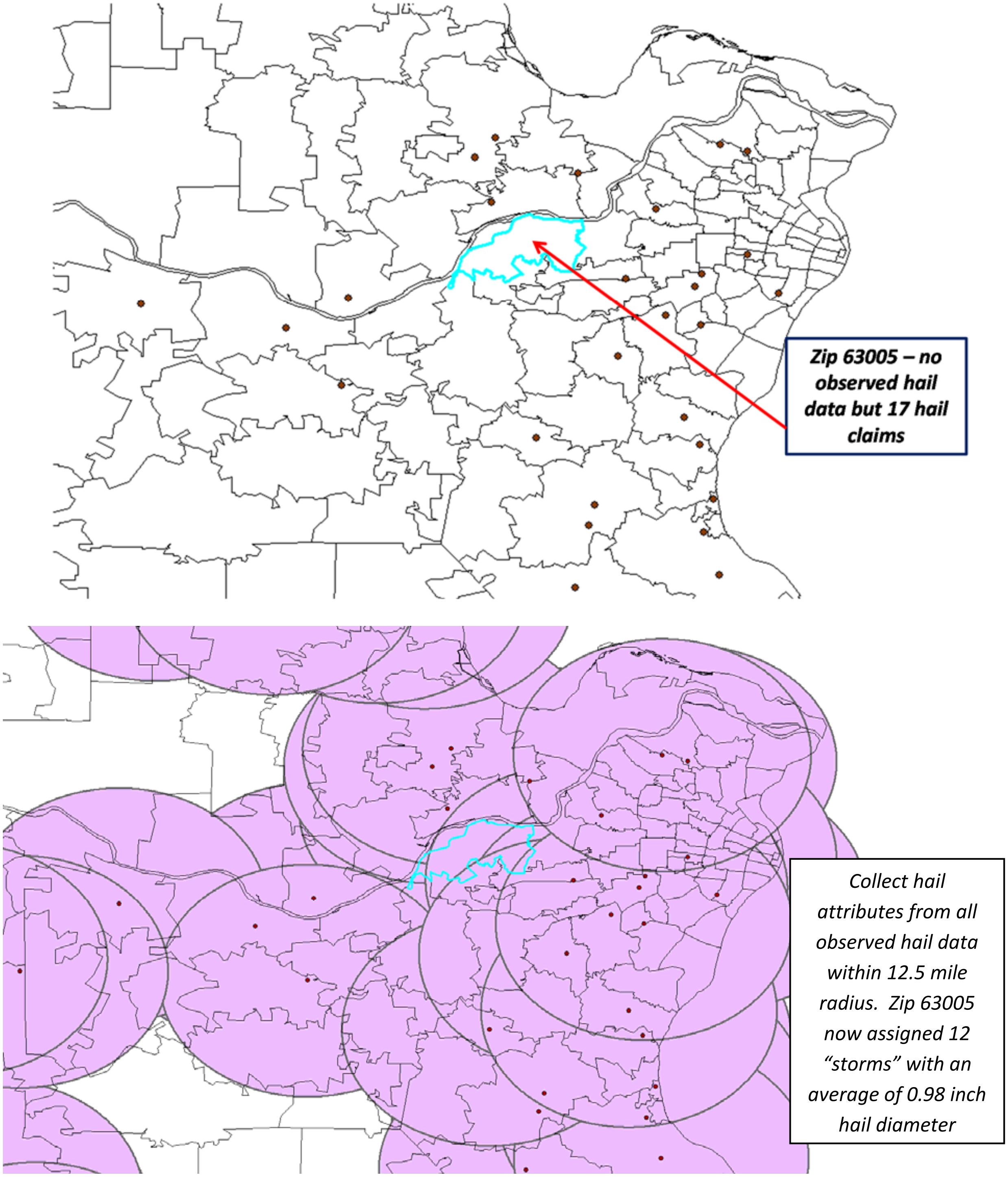


Figure 1. MO Total Incurred Losses (bars, left y-axis) and # of claims (points, right y-axis) by type from 2008 to 2010



Zip 63005 – no observed hail data but 17 hail claims

Collect hail attributes from all observed hail data within 12.5 mile radius. Zip 63005 now assigned 12 “storms” with an average of 0.98 inch hail diameter

Figure 2. Buffered SPC Hail Data Example

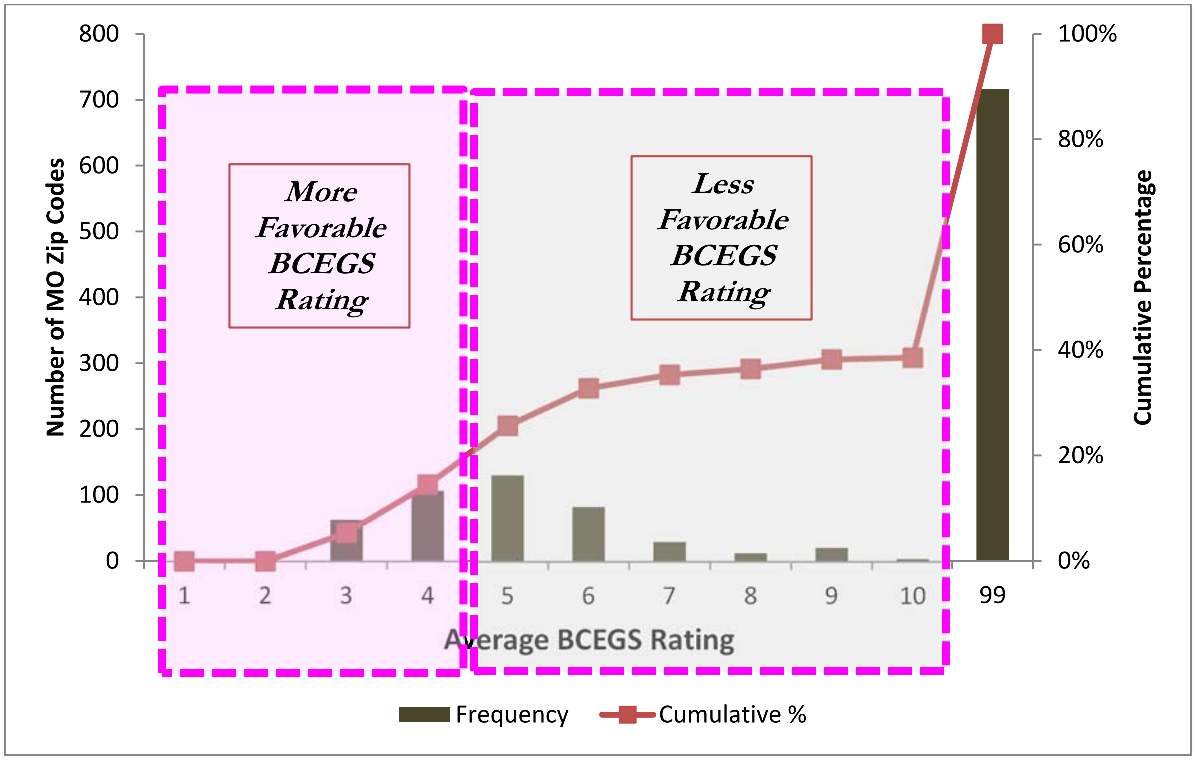


Figure 3. Distribution of MO zip code Average BCEGS Ratings

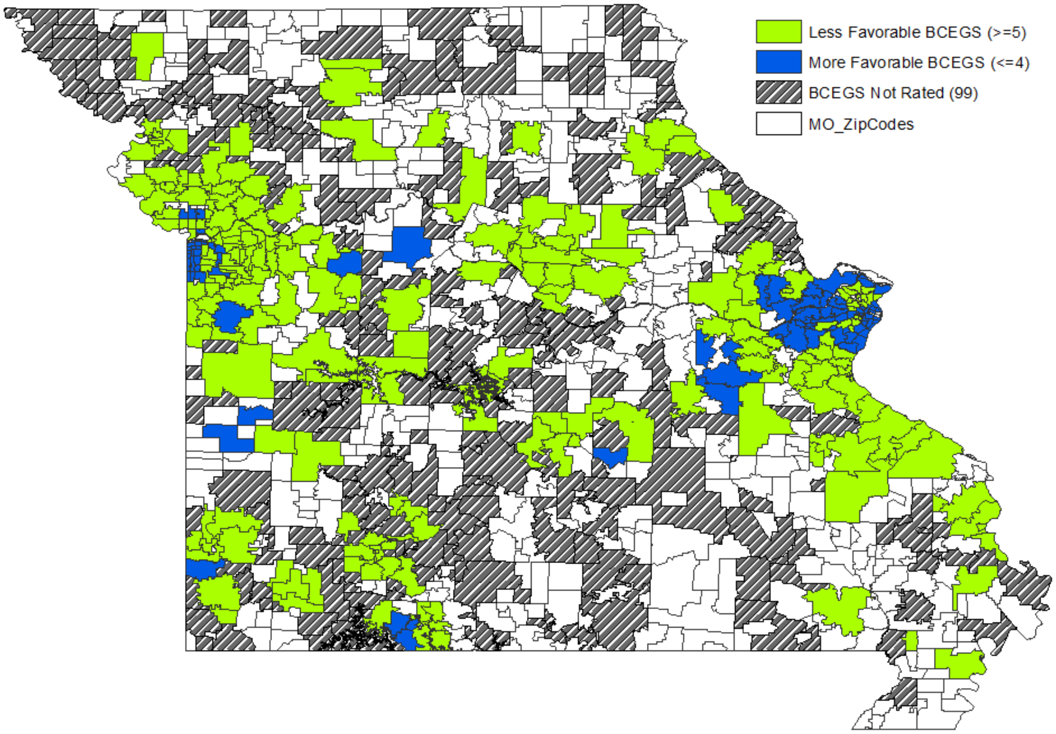


Figure 4. 532 unique zip codes in MO with a hail loss in at least one of the three years from 2008 to 2010 with Associated BCEGS Rating

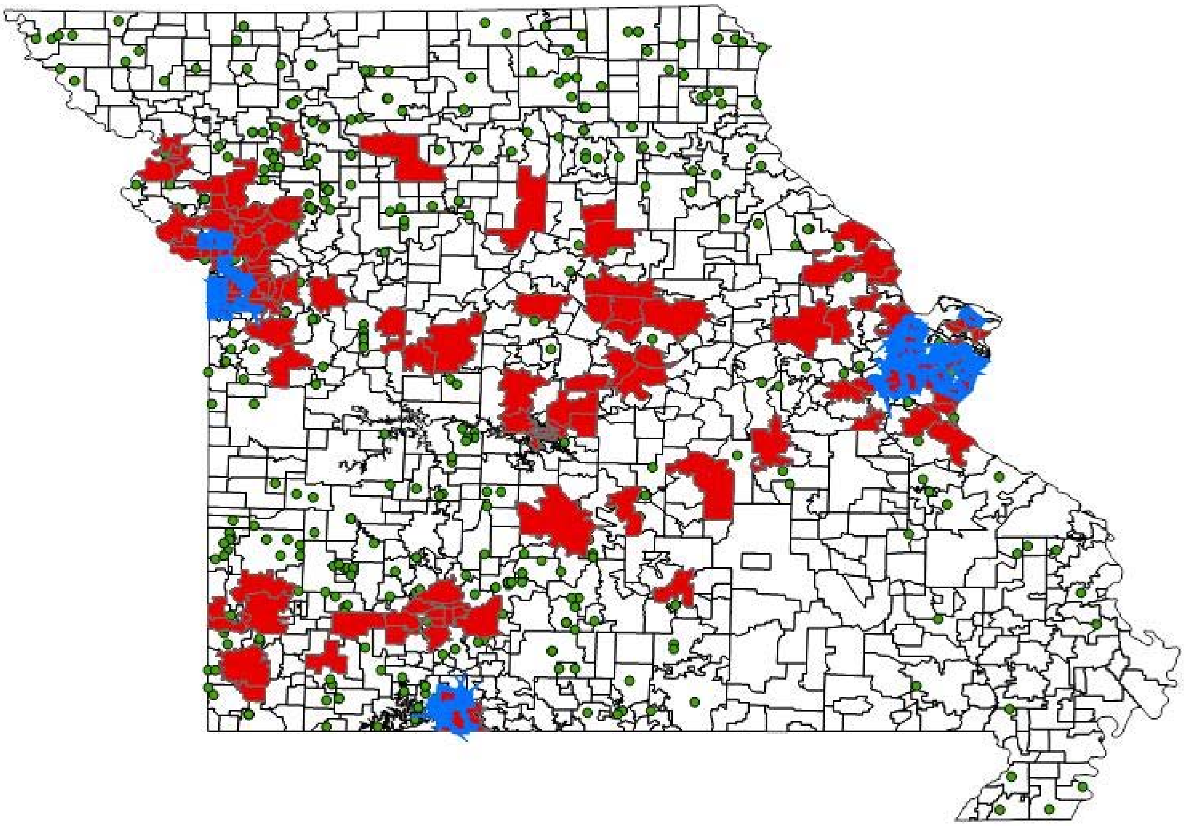


Figure 5. Location of 166 zip codes with Travelers hail claims in 2010 overlaid with 2010 SPC Hail Observations and zip codes with BCEGS <= 4 (highlighted in blue)

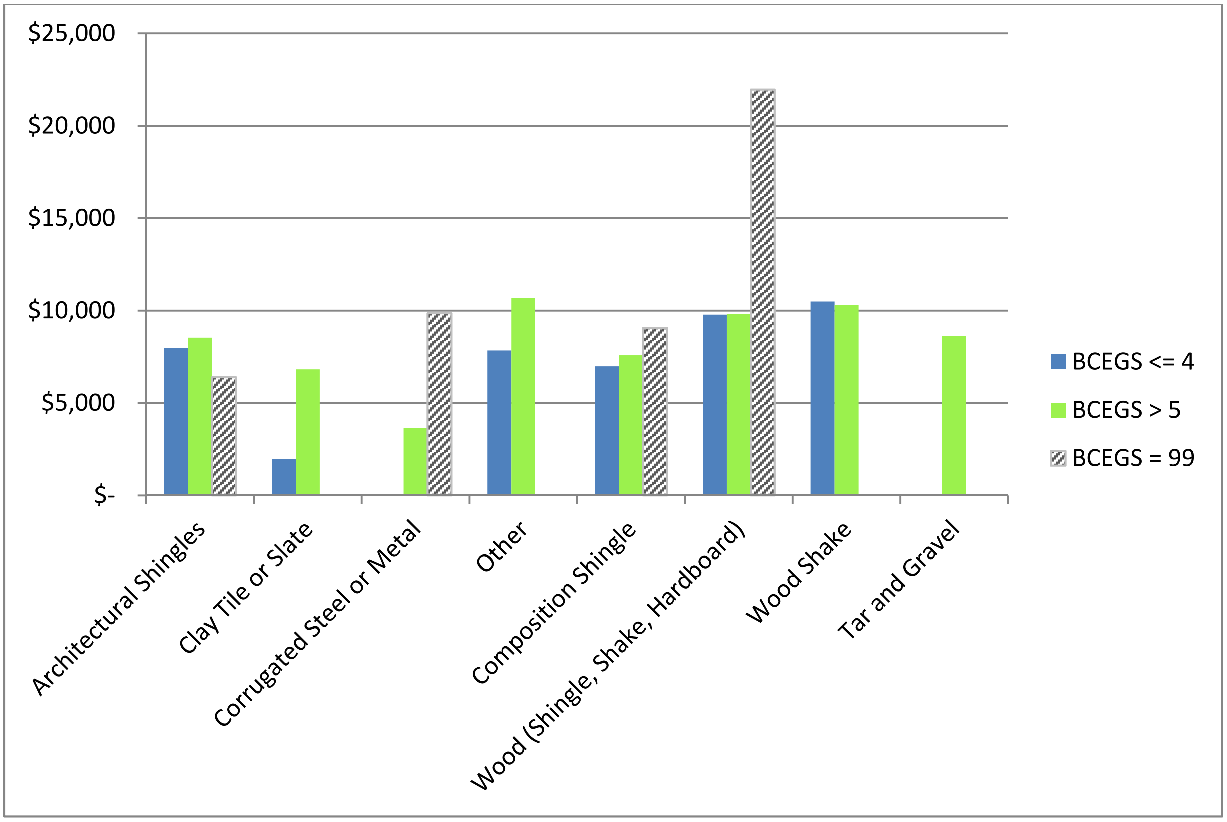


Figure 6. 2010 Average Loss per Claim by BCEGS Rating

7

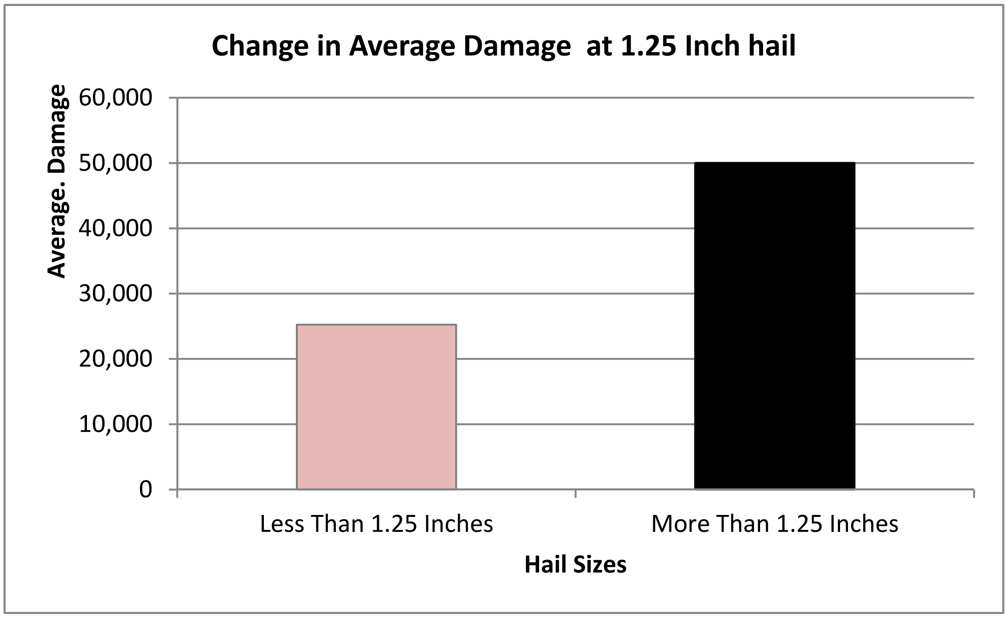


Figure 7: Average Damage for average hail size Less Than 1.25”

and Greater Than 1.25

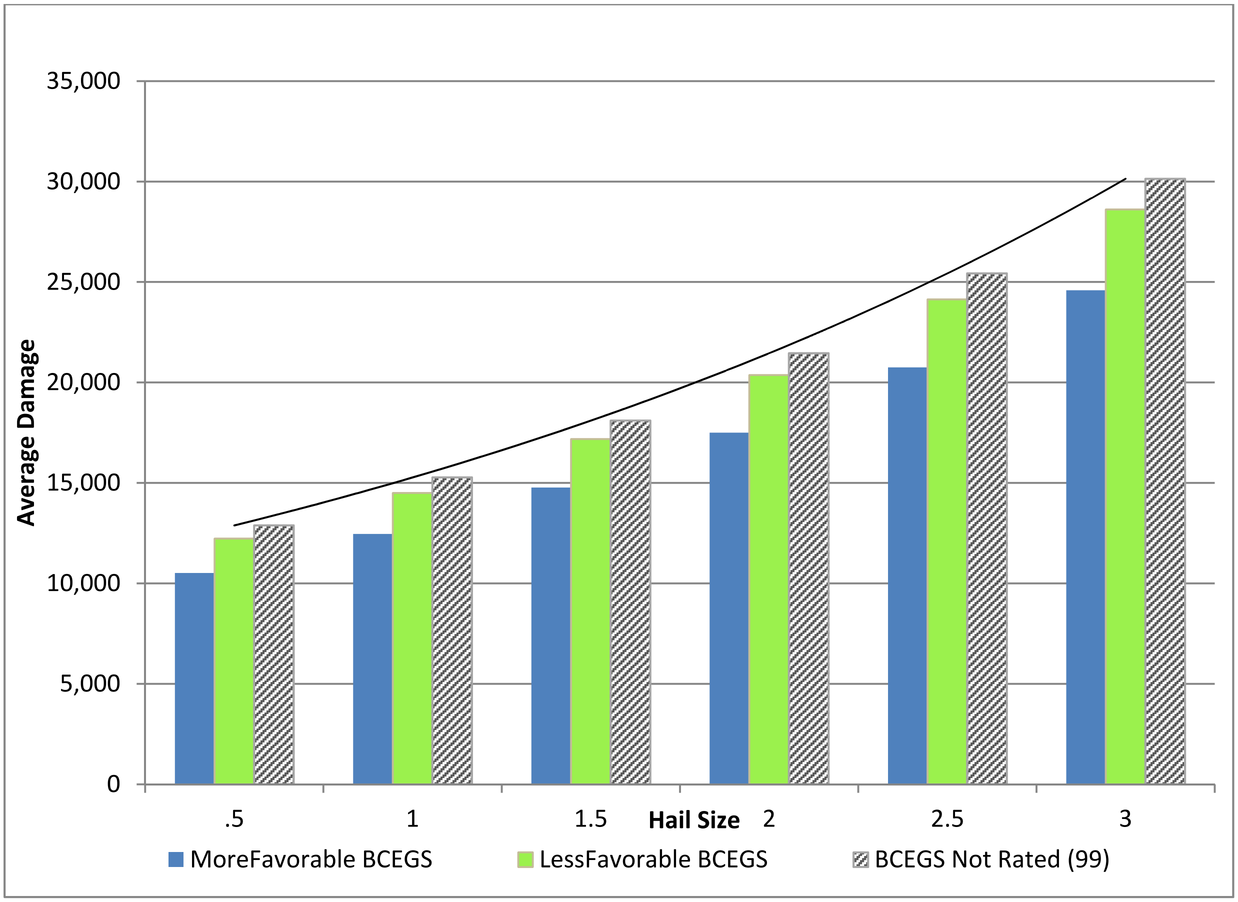


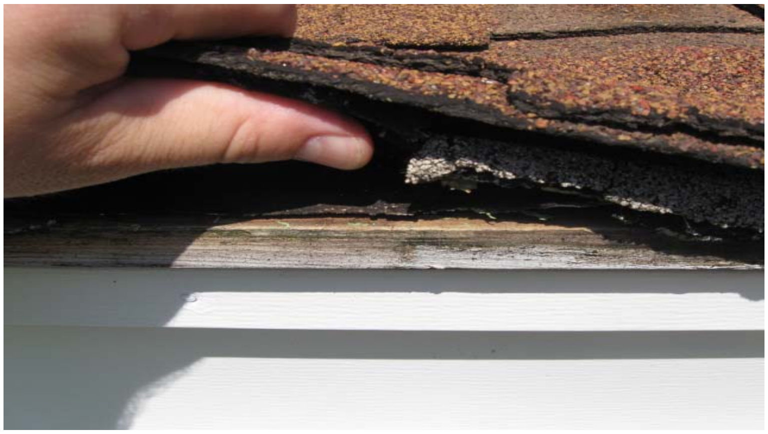
Figure 8. Expected Hail Damage by Hail Size and BCEGS ratings

APPENDIX

Representative hail losses from Oklahoma:

1) Damage: asphalt shingles over 15 years old, with two layers of shingles, an air conditioner unit, and one dented vent on the roof

Incurred Loss: $9,000 Roof replaced at rc, two layers removed



2) Damage: 13.5 year old asphalt roof with two layers, roof vents

Incurred Loss: $10,000 Roof replaced at rc, two layers removed

3) Damage: Asphalt shingles four years old, decking, minor contents, gutters and shed roof

Incurred Loss: $14,500 Roof, shed roof, gutters and decking replaced at rc