A Cost-Benefit Analysis of Fortified Homes in North Carolina

By Walter J. Wessels[1]

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Abstract: Owing to their size and intensity, hurricanes are a major source of damage to North Carolina. One way to mitigate this damage is to fortify homes. This paper analyses the costs and benefits of fortified homes in North Carolina. For the purposes of this paper, a fortified home can withstand F2 and Category 3 tornadoes and hurricanes (130 mph sustained winds). It finds that from a social point of view, fortifying homes in the eastern part of the state is economically viable: the benefits of fortifying homes exceed its costs.

Keywords: fortified homes, cost benefit analysis, hurricane, North Carolina, hazard analysis, risk-aversion

Introduction

This paper analyzes the cost and benefits of fortifying homes to reduce damage from hurricanes and other wind-related events. The potential savings could be large. While the economic costs of hurricanes in the 1990's appear high in contrast to those of the two previous decades, Pielke and Landsea 1998 found that the 1990's costs reflect the norm and there is good reason to expect future damages to be even greater. In addition, cost estimates from Hurricane Andrew suggest that over half of the costs came from damages to common insured private property.[2] A fortified home is defined as a home designed that will withstand F2 and Category 3 tornadoes and hurricanes (130 mph sustained winds). In recorded history, North Carolina has rarely suffered a hurricane above Category 3 (Hazel being the exception) and only a few tornadoes above F2. Consequently, a fortified home will withstand almost all wind damage[3].

Fortifying a new home increases its cost of being built by 6.25%[4]. Fortifying an existing structure costs relatively more, but how much is unknown at this point as it is dependent upon the individual structure. As fortified homes become more popular, both new technologies and economies of scale will likely reduce these costs.

The key issue is whether the benefit from fortifying a home covers these costs. This paper analyzes this issue from both the private and social point of view. When a home suffers damages, insurance compensates the owner for some of the damages. The owner pays the remaining costs, what we will call 'uncompensated costs.' These include the cost in time and anguish as well as the costs to the structure and its contents not covered by insurance. The private benefit of fortifying a home is the savings to the owner in uncompensated costs. The social benefit is the savings in all costs, compensated and uncompensated, to all members of society, including the insurance company and the government.

This paper accounts for the savings in wind damage only. There are several reasons for this. First, the data for wind damages is of sufficiently high quality that policy makers can rely upon it. Second, another major saving, the saving of life, is difficult to estimate. Third, and for the same reason, we do not include the value to households of enhanced personal safety in event the they cannot evacuated, their enhanced peace of mind, and their value of a higher probability of returning to an intact home (above and beyond the out-of-pocket of rebuilding the home). Finally, any such estimate depends upon what future policy will be. If the government continues to depend upon evacuation of threatened areas, most of these savings are likely to be small.

While the data reports compensated costs, uncompensated costs are estimated. Data from what people are willing to pay for living outside a flood plane is used for this purpose. The logic is that living out of flood plane protects a home from floods in much the same way a fortified home protects the home from most hurricanes.

The present value of the savings, both public and private, will be expressed as a percent of the home's structural cost. This allows for a direct comparison to the cost of fortifying the home.

One Estimate of the Value of Fortifying A Home

Burrus et al. 2000 compared the value to an owner of fortifying a home and compared this with buying insurance. The authors examined alternative strategies of reducing hurricane damage costs. Each strategy consists of the level of deduction for insurance (including no insurance at all) and some level of structural improvement (including no improvement). The authors then calculate the present value of the expected costs, including uncompensated costs due to hurricanes, for each strategy under alternative hurricane probability scenarios for a $140,000 home located 5 miles from shore in Wilmington, North Carolina. The alternative hurricane scenarios include historical probabilities (with zero probability of Category 4 or 5 hurricanes in this area[5]) and a simulated National Weather Service HURISK model (with a 0.00252 chance of a Category 4 hurricane and a 0.0001 chance of a Category 5 hurricane). The authors then compare the costs of these alternative strategies and choose the one with the lowest expected cost. The authors made several assumptions worth noting. First, they assume a discount rate of 7%, which makes an annual insurance payment more attractive that an up front expenditure on structural improvements. Second and most importantly, they assume that the only uncompensated cost is due to the absence of a deductible. This assumption will tend to undervalue the benefit of fortifying a home. Third, they assumed an unfortified home would be destroyed in Category 3 or higher hurricane while a fortified home would be destroyed in a Category 4 or higher hurricane.

Their results are that, in their model, owners would almost never structurally improve their homes when insurance is available. Even if insurance premiums were doubled or increased ten times, insurance only is the most cost-effective strategy. For example, using historical probabilities for hurricanes, the expected cost for a hypothetical home with insurance only is $3469. The expected cost to the owner who makes the optimal level of structural improvements and has no insurance is $5155. The owner would choose insurance over structural improvement or, as the report shows, any other combination of insurance and structural improvements.

On the other hand, from a social point of view, one that accounts for all costs to all persons including the insurance company, fortifying homes is very cost effective (note that the authors did not examine this point of view; these are my calculations from their sturdy).   Using the author's assumptions that without structural defenses the property and its contents will be destroyed in a category 3 or higher storm, the present value of damages will be $34,000 using the historic probabilities[6], and $26,657 with the HURISK model. Structural fortification of the home reduces these costs to $5155 and $10,143 respectively. Fortifying homes easily pays for itself several times over in reduced damages.

While fortifying a home has a positive net benefit to society, individuals will not fortify their homes because doing mainly benefits the insurance company. This suggests that insurance companies should offer some form of deduction for fortifying homes. Government also directly benefits from reducing the amount of public funds spent on home damage clean up and sheltering displace people, and from having the local economy and tax base recover quickly. This suggests that local taxation and impact fees are areas where government might also help encourage fortification.

Estimating Uncompensated Losses

One problem with these estimates is that the uncompensated losses to homeowners most likely exceed the uncovered deductible in the insurance policy. In addition to the uncovered deductibles are the opportunity cost of time spent rebuilding the home, the costs of alternative living arrangement during repair not covered by insurance, the psychic costs of losing items of personal significance, and the cost of added anguish and worry.

To estimate these costs, one can use the premium people are willing to pay for a safer home that is above a flood plane. Fortifying a home in a hurricane prone area and living above the flood plane are similar ways of reducing risk. Both involve up front costs made to avoid an uncertain but large loss.[7]

MacDonald et al. 1990 investigated property values in Monroe, Louisiana. According to the authors, "The flooding hazard exists because of the low elevation of the entire urban area. …The flooding damage occurs in the lower areas and does not necessarily occur in the same place, since the pumps and drains can fail in any area. The event of a flooding hazard is truly probabilistic, but the likelihood of greatest potential damage is to the lower lying areas. Insurance premium differentials reflect this because they are based on elevation." (p. 656). Most homes subject to flooding were located in a one-hundred year flood plane.

The authors ran a regression on property value of individual homes sold between

January and July 1988. Real estate agents were required to reveal the flood hazard before closing. The explanatory variables consisted of housing traits (such as square feet and number of baths) and area related variables (such as tax zones, neighborhoods, and fire district). The key explanatory variable was a dummy variable indicating if the home was in the flood hazard zone. A separate regression was run over a select neighborhood of older, homogenous homes (this area had suffered floods in 1978 and 1983).

If markets are efficient and buyers are risk-neutral, then the price differential for the "safe" home – the difference between its sales price and that of similar homes in the flood hazard zone -- should equal:

1) $$\text{Diffential} = \frac{IP + pUC}{r},$$

where IP is the annual insurance premiums, UC is the uncompensated cost caused by a flood, and p is the annual probability that a flood occurs[8]. The discount rate, r, is the inflation-adjusted interest rate. Note that this equation is used for the purposes of this paper and was not employed by the authors.

Equation 1 assumes the home lasts forever. If not, r has to be adjusted upwards. To illustrate the magnitude of the necessary adjustment, assume the real interest rate is 4 percent. If the home lasts 75 years, 50 years, 25 years, or 12.5 years, the corrected r would be 4.22 percent, 4.66 percent, 6.40 percent, and 10.32 percent. The life span of a home is the number of years before it is likely to be replaced (assuming it is maintained and not subject to flood damage). How long this will be is suggested by census data. The 1990 census found that nearly half the units that existed in 1940 are still in existence today. This suggests that the life span of the median home in 1940 exceeded 50 years. Given the improvement in building methods since 1940, most homes today will last well beyond fifty years (Ahluwalia and Shackford, 1999). The same paper estimates that poured footings and foundations can be expected to last 200 years while concrete blocks, floor systems, and walls will last 100 years. Wood flooring will last the life of the home, as will masonry. In addition, the Department of Commerce puts the useful life of a home at 80 years. It seems reasonable to assume that new homes and many older homes will last at least 75 years.[9] Therefore, in this case, the appropriate interest rate is 4.22 percent, which is likely conservative.

Another assumption is that the insurance premiums and uncompensated costs, once inflation is accounted for, will not grow over time. This seems to be a reasonable assumption for the insurance premium since what it covers, the value of the structure and its contents, is likely to grow at the rate of inflation. On the other hand, as people's wages and income are likely to grow faster than inflation over time, one would expect uncompensated losses, which include times costs, to also rise relative to inflation. If the rate of growth in the inflation-adjusted uncompensated costs is g, then the appropriate discount rate for uncompensated losses is r – g. Between 1973 and 1994, real wage growth was 0.3%; between 1973 and 1990, real per capita income growth was 1.6%. Assuming the growth in uncompensated losses grows in proportion to one of these measures, this suggests that g falls between 0.3 and 1.6 percent.[10]

The authors calculated the expected differential for three categories of home structures: below average ($25,000), average ($65,000), and above average ($99,000). Table One shows the estimated differential as well as its value expressed as a percent of the home structure cost in the Monroe, Louisiana study. The latter statistic shows what people are willing to pay to make their home safe.

TABLE ONE HERE

There are several points worth noting.

First, the premium paid, expressed as a percent, falls as the home becomes more valuable. Without the existence of uncompensated losses, it is difficult to explain this smaller percent differential. One would expect richer persons who buy the more expensive homes to have a lower discount rate since they have greater access to capital markets and because they have the wealth to alternatively choose to self-insure. In this case, equation 1 implies that the rich should be willing to pay a larger differential to be safe – a result contradicted by Table One. On the other hand, with the existence of uncompensated losses, the rich could pay a smaller percent differential if they are less risk-adverse (this effectively increases the discount rate r).

The second point to note is that the differential for older homes (in the sub-sample) is substantially larger. Most likely, newer homes in the flood hazard zone have greater protection from flooding (for example, by being built on a taller base), making the property value differential smaller.

Table One suggests that people are willing to pay between 6 to 20% of the value of the structure to be safe. This buys them a lower insurance premium and lower uncompensated cost in case of a flood. Since the authors know the insurance premiums similar homes pay, it is possible to estimate the annual expected uncompensated cost (p x UC) if the real discount rate is also known. In 1989, the mortgage rate was 10.13% while the inflation rate was 4.2% (using the implicit GDP deflator). This yields a real rate of about 6%. Table Two shows the resulting estimate of the annual expected uncompensated cost (p x UC).

TABLE TWO HERE

The apply equation one to calculate UC (uncompensated losses), the probability of a flood needs to be known. Unfortunately, this is not reported in the paper. Conversations with Monroe officials suggest the most homes at risk were, at the time of the study, located in a one-hundred year flood plane. Thus, we can let p = 0.01 so that UC is 100 times the figures in Table Two. In addition, we assumed a real interest rate of 6%. In this case, UC for average and above average homes is between 14% and 36% of its structure's cost.[11]

Table Two suggests that annualized uncompensated losses, expressed as a percent of home value, decrease as homes become more valuable. It seems reasonable that the older homes (in the sub-sample) are also the less protected homes and thus have higher uncompensated losses. It was suggested above that the discount rate for unexpected losses should be lower than that for property premiums. Incorporating this would decrease the figures in Table Two (p x UC).

These estimates of annualized uncompensated cost (p x UC) depend upon the interest rate used. One way to verify the reasonableness of these estimates is to assume instead that UC equals zero and solve for the discount rate. The estimated rates range from 1.5% to 3.8%. These are very low private interest rates, even if one takes into account the likely growth in the inflation-adjusted value of uncompensated costs. While the use of the 6% figure for r is open to debate, it is reasonable to assert that uncompensated costs do exist and that they are significantly greater than zero. Using the 6% figure results in the estimated compensated loss increasing with the cost of the home Rates below 5% result in the uncompensated loss decreasing with the cost of the home in all categories. Using the 6% figure gives reasonable results.

The Social and Private Discount Rate

It is necessary to determine the appropriate social discount rate to use to discount the future benefits of fortifying a home to society. We will follow the standard analysis presented in Broadman et al. 1996.

The social discount rate differs from the private discount rate in part because it includes taxes paid on investments. Since mortgage rates are tax-deductible and are used to finance fortifying homes, this would reflect the appropriate marginal private rate of return on housing-related investment (an inflation-adjusted return between 5 and 6%). The appropriate social rate of return reflects the collective risk to society and thus nullifies risks to individuals (Arrow and Lind 1968). Consequently, the social rate of return is likely to be less than the private rate of return on housing investment. This is because mortgage interest rates include a premium that compensates lenders for the risk that individuals will default on the loan. This is a cost to the bank but not to society since someone still consumes the services of the home.

An alternative rate of return is the before-tax returns on assets of equivalent risk. The before-tax return to capital is generally agreed upon to be around 10% (the rate used by the Office of Management and Budget). In the context of the Capital Asset Pricing Model, this is the historic real rate to capital invested in the stock market. The use of the 10% rate of return assumes the return on the investment varies directly with the stock market (has a beta of one). The beta for real estate is smaller than unity and is close to zero[12]. This implies that the risk-free inflation-adjusted rate of interest is more appropriate, such as the real rate of return on one-month treasury bills. This suggests a real social discount rate of return of 2 to 4% for discounting the stream of benefits from fortifying a home.

From a social point of view, the risks of hurricanes cannot be fully diversified. According to Elsner and Kara 1999, the ability of society to diversify the cost of hurricanes over a ten-year period are restricted if one is limited to the North American basin (pp. 439-440). In addition, the number of hurricanes experienced in a period depends on the number of hurricanes in past periods (see Elsner and Kara 1999, Chapter 16). Consequently, hurricanes come in clusters. This suggests that it is not be possible even for society to fully diversify away from the risks of hurricanes. If this is the case, the social discounting of fortifying homes should use a lower discount rate, although this adjustment is likely to be small, as the cost of hurricanes is small relative to GDP.

In addition, when risk-adverse individuals cannot fully diversify their losses through insurance, they should be willing to pay a premium to reduce these uncompensated losses. This premium should be added to the social value of fortifying a home. To calculate what this premium might be, a model was created assuming (1) constant absolute risk aversion, (2) uncompensated costs can be financed and distributed over time, (3) each year has the same independent chance of a hurricane, (4) hurricanes impose a given fixed loss, (5) real income is the same in all periods, and (6), when a hurricane occurs, the home will be rebuilt. The result is the following equation:

(2) $$f = -1/d \sum \log\{1 + \frac{p}{r}(1 - \exp[d \sum r \sum s])\}$$

where f is the annual option price (expressed as a fraction of income) the person is willing to pay to have no damage in the event of a hurricane, p is the annual probability of a hurricane, r is the real interest rate, δ is the relative risk aversion of the person, and s is the uncompensated cost in the event of a hurricane (expressed as a fraction of income). This equation is derived in the appendix.

Empirical studies (see Freeman 1984) suggest that 2.0 is a reasonable value for the degree of absolute risk aversion (δ). The other values used were r = 0.05, s = 0.5, and p = 0.01. The value of s is derived from Table Two (where C equals the number in the Table

Two divided by p), assumed to be about 20% of the structure's cost, and from the assumption that the value of the structure is 2.5 times the person's income. Therefore, s equals 0.5: the uncompensated cost of a hurricane equals 50% of the owner's income.

In the absence of risk aversion, the annualized unexpected loss is p s, or 0.005 of income. To avoid this loss, the risk adverse person in equation two is willing to pay 0.00515 percent of income per year. That is, the risk adverse person is willing to pay a premium of 3% over the saved unexpected losses. To make this result concrete, suppose the unexpected annual loss was $1000 a year. This has a present value of $20,000 if the discount rate is 5%. If the person is risk adverse, they would be willing to pay $20,600 to have the home fortified. The correct interest rate to discount the $1000 annual savings would be 4.85%. Because this adjustment is small, it will be ignored in accounting for the social benefit of fortifying a home.

This paper uses 4% as the social discount rate. Lower rates would yield a greater benefit.

The Benefits of Fortifying A Home

The wind damage to homes that hurricanes are likely to cause can be estimated from insurance claims. Rosowky et al. 1999 use insurance claims data and a model of wind speed to predict hurricane damage for most zip codes for North Carolina. Using data on individual homes from a large insurance company, the authors correlated damage claims for Hurricane Hugo and Andrew to local wind speeds. Next, they generated a model of wind speed for various locations. Then, using historical data, they were able to derive the expected damage by zip codes. The expected damage was expressed as a percent of the value of the insured structure.

Because conventional policies do not cover flood damage, the damage claims reflect mainly wind damage. Since the fortified home is designed to reduce wind damage, this data set is ideal for estimating the value of a fortified home.

The annualized damage ratio from this study can be used to estimate the social benefit of a fortified home. This value will be expressed as a percent of the value of the home's structure, so that it can be compared to the cost of a fortifying a home. We make the assumption that a fortified home will not suffer any wind damage.[13] This is true under historical wind conditions for the last one hundred years, when no category four or five hurricane have been experienced in North Carolina.

The social value of a fortified home is its present value to society, whether the beneficiaries are the insurance company or the owner. The estimate given here is most likely understates the true social benefits from fortified homes. One reason is that several major external benefits are not accounted for here. These including the amelioration of an economic downturn in areas affect by storms,[14] the reduction of external costs due to injuries from flying objects (such as from roof singles), and the savings to the government and other aid agencies from the reduction in services they need to supply to an impacted area if homes in that area are fortified. Insufficient data prevents us from making a reasonable estimate of the other benefits. The second reason that the social benefit estimated here most likely understates the true benefit of fortified homes is that only savings to the insurance company is included. To rectify this second problem, we use the estimates for uncompensated losses from Table Two to generate a second set of estimates (this will be identified as “including estimated uncompensated losses.”)

Some of the damage claims paid out by insurance companies would have occurred even if the home were fortified. In particular, damages due to falling limbs and flying projectiles will still occur, although to a lesser extent. For example, the stronger roof structure of the fortified home is likely to mitigate the worst of the damages caused by falling limbs. To the extent damages will still occur, using damage claims overstates the savings due to fortifying a home. On the other hand, as stated above, other benefits are not being accounted for, such as the saving of life, the saving of injury to bystanders, and the savings to society in public rescue and recovery costs.

Table Three shows the present value of the benefits to society of fortifying a home using the damage claim figures from Rosowky et al. 1999. In general, the towns go from west to east. The discount rate used is 4%. All numbers are expressed as a percent of the home’s structural cost. The first percent given assumes UC equals 0, the second assumes it equals 20% of the structure’s cost. For example, in Kitty Hawk, the benefit of fortifying a home equals 14.6% of the structure’s cost when UC equals zero and 17.6% of its costs when UC equals 20% of the structure’s cost. These are the present values of fortifying a home. If the cost of fortifying a home is less than this, then fortifying the home is worthwhile. If fortifying a home represents 6.25% of the structure's cost, fortification is justified starting east of Raleigh.

TABLE THREE HERE

The private benefit of fortifying a home comes from the avoiding uncompensated costs. The math is such that this equals the uncompensated cost's share, which is assumed to be 20%, times the first column in Table Three. This is shown in Table Four.

TABLE FOUR HERE

Table Four suggests that, without added incentives, only persons in the most vulnerable areas are likely build fortified homes. Unless insurance firms offer deductions off their premiums or government provides reduced tax or impact incentives, fewer homes than is optimal will be fortified. Since people vary in the value they place on peace of mind and avoidance of risk, some homes will be fortified even if the costs exceed the benefits as calculated here. Melcher 1999 found that people would spend money to reduce risk when the probability of death moves into the one in a ten thousand and even one in a thousand range for a period of time. Some hurricanes meet this criterion.

These figures depend upon the assumptions made here. The net value of fortifying an existing home is smaller because of its shorter life span and because of the greater cost of fortifying an existing home. The social value of fortifying a new home will be less than suggested here if the social discount rate is higher, if the damages prevented are smaller than calculated, or if storm activity is expected to be less than the past (as these figures are based upon the historical patterns). The social value will be greater to the degree that these homes reduce the rescue and recovery expenses of social agencies and to the degree they reduce the injury as neither of these benefits were accounted for. Finally, one would expect with time and scale that the cost of fortifying a home will fall.

Summary

From a social point of view, fortifying homes in the eastern part of the state is economically viable: its benefits exceed its costs (using a social discount rate of 4% and assuming uncompensated costs equal to 20% of the structure's cost). This paper takes into account only the wind damage to structures. Since it does not consider the savings in life and injury, benefits accrued for other hazards (seismic, snow, security, fire and personal safety) or the external savings to the economy, the actual benefits most likely are greater than estimated here.

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Appendix

A Formula for Deriving the Value of Fortifying A Home

It is assumed that the home structure exists long enough to make the assumption that it exists forever a useful approximation. In the absence of a destructive hurricane, the net utility the homeowner enjoys is:

A1) $U = U(Y)$,

where Y is their annual real income. We assume annual real income is constant. If a hurricane occurs, it has an uncompensated cost to the owner of C, which they finance at interest rate r to smooth out their future net utility, which will be:

A2) $U=U(Y - r C)$.

After the hurricane, the home is rebuilt.

If, after this, another hurricane occurs, the new net utility will be

A3) $U(Y - 2 r C)$,

with a "-3rC" for the third hurricane, and so forth.

It is assumed that the annual probability of a hurricane is p. At most, only one destructive hurricane per season is assumed (that is, if the home is destroyed, it is not fixed until the new year: the cost of waiting for the new home to be build is included in C).

The present value of $X a period, paid period after period, until some random event occurs with probability p, is[15]:

A4) $$PV = \frac{X}{1+r} + \frac{(1-p)X}{(1+r)^2} + \frac{(1-p)^2 X}{(1+r)^3} + \ldots = \frac{X}{r+p}.$$

If, when X terminates, the person gets paid V, the present value becomes:

A5) $$PV = \frac{X + pV}{r+p}.$$

Using this framework, begin with a new home subject to the risk of hurricane. The present value of owning the home that has had no hurricane hit it (PV_0) is:

A6) $$PV_0 = \frac{U(Y) + pPV_1}{r+p},$$

where PV_1 is the present value of owning the home after one hurricane:

A7) $$PV_1 = \frac{U(Y-rC) + pPV_2}{r+p},$$

where PV_2 is the present value of owning the home after two hurricanes (with U = U(Y – 2rC). Combining terms, A8 results:

A8) $$PV_0 = \frac{U(Y)}{r+p} + \frac{p}{(r+p)^2} U(Y - rC) + \frac{p^2}{(r+p)^3} U(Y - 2rC) + ...$$

With constant absolute risk aversion,

A9) U(Y – n r C) = -exp [-b(Y-n r C)] = - exp [-b Y] x exp [b n r C],

where n is the number of hurricanes. Combining A8 and A9, we have:

A10) $$PV_0 = \frac{-\exp(-bY)}{r+p} \left[1 + \frac{p}{r+p}\gamma + \left(\frac{p}{r+p}\right)^2 \gamma^2 + ... \right] = \frac{-\exp(-bY)}{r+p(1-\gamma)},$$

where γ = exp (b r C). The right-hand term can be interpreted as follows. The denominator is then the discount rate. If there were no uncompensated costs, the discount rate would simply be the interest rate r. If there are uncompensated costs, the discount rate is lower (since 1-γ is less than zero for reasonable values of bC), reflecting the increased risk to the owner (note that the exponential utility will be a negative term, so a higher “prevent value” here means a lower net utility).

Let OP be the amount the person pays per period to have a fortified home. Assuming the fortified home survives all hurricanes with no damage, its present value is

A11) $$PV_F = \frac{U(Y - OP)}{r} = \frac{-\exp(-bY)}{r} \exp(b\,OP).$$

If we set A10 equal to A11, OP/r is what the consumer is willing to pay for fortifying the home. It is the option price of fortifying the home. In the absence of risk aversion, OP =

p C, the avoided expected annual cost due to exposure to hurricanes.

Let δ = aY. This is the degree of relative risk aversion. Letting A10 equal A11 and canceling terms,

A12) $$\frac{1}{r + p(1 - \gamma)} = \frac{\exp(\delta OP / Y)}{r},$$

where γ can be written as exp(δ C/Y).

Multiply both sides by r and take the log of both sides. The result is:

A13) $$OP/Y = \frac{1}{\delta}\frac{1}{\log(1 + \frac{p}{r}[1 - \gamma])}.$$

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TABLE ONE

Differential in Property Values for Homes Not In Flood Hazard Zones

and Differential Expressed as a Percent of Structure's Cost

Type of Home	City	Parish	Sub-Sample
Below Average	$3114 12.5%	$2837 11.3%	$5067 20.3%
Average	$5413 7.4%	$5127 7.9%	$7334 11.3%
Above Average	$6779 6.8%	$6344 6.4%	$8947 9.0%

TABLE TWO

Estimated Expected Uncompensated Loss (p x UC)

As a Percent of Property Value

Type of Home	City	Parish	Sub-Sample
Below Average	$109.84 0.439%	$93.22 0.373%	$227.02 0.908%
Average	$132.78 0.192%	$115.62 0.168%	$248.04 0.359%
Above Average	$166.74 0.168%	$140.64 0.142%	$296.82 0.300%

Table Three

Present Value of Benefits To Society of Fortifying A Home

As A Percent of the Structure's Cost

Area	Not Including Uncompensated Losses	Including Uncompensated Losses
Raleigh	4.125%	4.95%
Lumberton	4.125%	4.95%
Wilson	4.88%	5.85%
Rocky Mount	5.25%	6.3%
Greenville	5.63%	6.75%
Kinston	6.0%	7.2%
New Bern	7.13%	8.6%
Wilmington	6.4% to 13.5%	7.7% to 16.2%
Kitty Hawk	14.6%	17.6%
Nags Head	18.4%	22.1%
Carolina Beach	48.8%	58.5%
Harkers Island	57.8%	69.3%

Table Four

Present Value of Private Benefits To Individual of Fortifying A Home

As A Percent of the Structure's Cost

Area	Private Benefit
Raleigh	0.83%
Lumberton	0.83%
Wilson	0.98%
Rocky Mount	1.05%
Greenville	1.13%
Kinston	1.2%
New Bern	1.43%
Wilmington	1.28% to 2.7%
Kitty Hawk	2.92%
Nags Head	3.68%
Carolina Beach	9.76%
Harkers Island	11.6%

1. Professor of Economics, Department of Economics, College of Management, North Carolina State University, Box 8110, Raleigh, N.C. 27695-8110.

2. Pielke 1995 estimates the total cost was 30 billion dollars. 16.5 billion was to private property. Another 6.5 billion was from Federal disaster funds. The cost to agriculture was 1.42 billion. The remainder is the rescue and recovery costs to private and public agencies.

3. It will help but not fully protect a home from falling debris (such as trees) and penetration by airborne missiles. It would protect a significant proportion of homes from complete destruction in a Category 4 hurricane.

4. From a discussion with Jeff Sciaudone, Institute for Home and Business Safety. This is for a fortified home using shutters. Using impact resistant doors and windows increases this to 13%.

5. Hurricane Hazel was a Category 4 hurricane at landfall in North Carolina but was of Category 3 strength by the time it hit Wilmington.

6. This implies that insurance rates understate the expected cost of hurricanes.

7. To estimate the premium paid for being 'safe' requires that other characteristics of the home be controlled for. This is easier when the homes are in a similar area, as they are for a given flood prone area. This is more difficult for comparing homes in and out of hurricane prone areas since hurricanes affect much larger areas. In addition, comparison is difficult in this case since being near the ocean is a major amenity available only in hurricane prone areas.

8. This equation assumes that all floods have the same damage (if not, then the p UC should be replaced by the expected annual loss), that the home will continue to command the same premium when resold, and that the home will last forever. The validity of the last assumption is discussed in the text of this paper; it is a useful a useful approximation if the house is expected to last more than several decades.

9. This assumption is supported by the fact that in the older homes above the flood plane commanded a larger differential, when comparing the differential for all homes in the survey over that from the subsample of older established homes. If the older homes were expected to last a substantially shorter

time, they should have commanded a smaller premium.

10. The fact that property values usually appreciate over time is immaterial to these calculations as what increases in value is the property, not the structures on it. In particular, the differential between homes in and out of the flood plane reflects the differences in insurance premiums and expected uncompensated losses and it is the appreciation of these items which is relevant.

11. If the discount rate for uncompensated losses is lower than that for insurance (which would occur if real uncompensated losses grow faster than insurance cost), the estimated UC would be larger. For example, if insurance premiums were discounted at 6% while UC costs were discounted at 4% (which would be the case if UC was expected to grow by 2% more per year than insurance premiums), the estimated UC would be 50% larger (the ratio is insurance discount rate divided by the UC discount rate).

12. Using the Russell-NCREIF Property Index (a value-weighted index of total returns on a large portfolio of unleveraged real estate, Giliberto 1989 founds an insignificant correlation with the stock market of –0.15. Geltner 1989 founds systematic risk of various real estate indices to be close to zero. The results match those of Liu et. al. 1992 who found a zero beta for real estate.

13. The fortified home is designed to protect the home and its content from major damage from a category 3 hurricane. Most likely, it would suffer some but not complete damage from a category 4 hurricane. It would be destroyed should a category five hurricane occur. Since this would be a 1 in a thousand-year event, the annual expected cost for a $140,000 home is only $140 in this case.

14. Burris et. al. (July 2000) found that a low-intensity hurricane reduced regional output by 1.23%.

15. Multiply PV by (1-p)/(1+r), subtract this sum from A4, collect terms, and solve for PV to get the expression on the right.