Residual Risk Accounting: A Pilot Study of the Coastal Sector

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Abstract

Risks continue near the coasts such as flooding, oil spills, deaths and unemployment despite numerous policies to prevent and mitigate their effects. Such policies are typically analyzed in their natural units, such as jobs, and so comparisons are difficult across risk categories. An approach similar to supplemental national income and product accounting allows direct comparison of the relative importance and variability of these residual risks. Results for the coastal sector highlight the stability and large expected annual costs associated with some activities such as recreational boating fatalities. In contrast, other categories such as oil spills and flooding exhibit high variability and in the case of flooding, a high level of damages. The results are useful in the strategic development of regulations, causal models and policy design.

JEL codes: E01, D60, Q00

Key words: Risk accounting, shadow price, flood, VSL, unemployment

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1. Introduction

The onshore and offshore coastal environment is a microcosm of a society as numerous uncertain events occur. Undesirable events, whether variability in good outcomes or unambiguously bad outcomes, are identified as risks which numerous policies seek to prevent, mitigate or transfer. Policies include those designed to prevent flooding, oil spills and drowning deaths. Other policies seek to transfer the financial risk as through insurance against flood damage and unemployment. Debates about such policies often focus on the natural units of these risks such as unemployment, fatalities, barrels spilled, and damages to the built infrastructure. Without a common unit of measurement, it is difficult to compare and contrast such risks except by asking individuals or groups to rank various categories.

While not without controversy, monetizing normally incomparable risks facilitates comparison, regulatory design, and causal modeling of the risks. In the regular market economy, the National Income and Product Accounts (NIPA) have a long history of accounting for economic activity (Berndt and Triplett, 1990). The National Research Council (1999, 2005) has reported on the usefulness of expanding NIPAs to include supplements to the core accounts. Such supplemental accounts are not complete, integrated alternative to the NIPAs such as those suggested by Nordhaus and Tobin (1972), Daly and Cobb (1994) or the extended issues that the social indicators movement has considered (Cobb and Rixford, 1998). Similarly, the residual risk accounts developed here are neither a sector specific supplement nor a complete alternative. Instead, the accounts cut across sectors using the theme of policy relevant residual risks in the coastal zone. This both adds complexity, due to separate conceptual issues that arise in each subject area, and reduces complexity as complete sector accounts are not developed. These residual risk accounts can also be considered an expansion across risk categories of research by Muller, Mendelsohn and Nordhaus (2011) which focused on air pollution. In contrast to that application, complexities such as concentration-response functions and non-constant marginal damages are less important here.

One way to conceptualize risks is that they change income flows or measures of wealth. For instance, a flood damages built capital and fatalities are the ultimate destruction of human capital. Implicitly it is the change in accounts, the realized risk, which is to be measured here. While many risks are not traded in markets and so have no obvious price, the tools of benefit-cost analysis can be applied to estimate a "shadow price" or value as if a market existed. A large body of literature exists on general principles for developing these shadow prices, as well as specific examples such as the value of a statistical life (Farrow and Zerbe, 2013). These shadow prices and the quantities to which they are applied contrasts with the more normally traded elements of economic activity as are reported in NIPAs or for the US coastal sector by the National Ocean Economics Program (Monterey Institute, 2013).

Eight initial residual risk accounts are created for the coastal zone: flooding, unemployment, oil spills and five causes of fatalities; boating, swimming, occupational hurricane and marine weather. These individual categories are grouped into the three broader categories of natural hazards, recreational, and occupational outcomes. There are numerous conceptual and empirical challenges to creating such time series so results presented here should be recognized for their limitations in data availability, varying degrees of precision in the measurement of shadow prices, and limitations in allocating events to the coastal zone. In this case, a pilot study in a limited geographic area creates empirical challenges not present in a national level analysis.

The paper proceeds with sections on concepts, data and estimation, results and discussion.

2. Conceptual issues

2.1 Which risks ?

Risks occur too numerous to count. The analysis covers an illustrative but not exhaustive set of coastal risks for which government, especially the federal government, takes direct or indirect responsibility. While not a complete set of coastal accounts, they illustrate the variety of outcomes that might be placed in monetary terms.

Risk in particular has a variety of meanings in the literature. From a forecasting perspective, risk is typically considered a probabilistic statement about an undesirable outcome either in direction or variability. From the retrospective perspective taken here, one observes the realization of the undesirable, "risky" outcome for that period and so the risk has occurred (perhaps with measurement error) and is not probabilistic in the sense of whether or not it occurred. The term "residual" thus represents the risk incurred by elements of society after efforts to avoid or mitigate risk.

Individuals, organizations and governments manage risks in a variety of ways such as avoidance, mitigation, transference, and acceptance or, in the case of Government, by imposing regulations that may mandate such actions on other sectors. The residual element of risk is what occurs given the management choices which were in place at the time of measurement. Consequently, risks that are avoided or mitigated are not residual risks and do not appear in the data. However, risks that are financially transferred are included initially in the data and then analyzed in a later section for the degree of transference.

2.2 Whose risks count: the issue of standing

The coastal sector has been defined in different ways by researchers. Although the ocean is the typical common link, this "sector" contains elements both in common with other sectors and elements which are unique. For instance, Pontecorvo, et al. (1980) defined the sector rather narrowly; while extensions of that work as through the National Ocean Economics Program define the sector as either depending on the ocean or its products; or adjacent to the ocean (Kildow, Colgon and Scorse, 2007). Similar to Pontecorvo's approach, this study focuses on coastal and marine activities directly related to the marine aspects of the coastal zone. For some categories such as flooding , natural hazard deaths, or oil spills; it does not matter who incurred the risk, whether a coastal tourist or commercial fisher. However, in the risk categories linked to industry definitions, such as occupational fatalities or unemployment, more generic industries such as retail trade in the coastal zone are not included. Industry data come from a variety of sources ranging from the North American Industry Classification System (NAICS) to unique reports prepared by federal agencies. For instance, NAICS accounts included in some components are: oil and gas extraction, ship building, water transportation, and fishing, hunting and trapping. In general, the data require some allocation to the coastal and non-coastal sectors. Although details are provided below, the preferred allocation was based on the activity occurring in or seaward of a coastal county as defined by the U.S. Coastal Zone Management Act (including the Great Lakes). Some data sets required a cruder allocation. Consequently, the impact allocations for this study are only approximate although elements of these allocations are discussed in each individual item below. Examples of non-industry data sources are county specific claims from the National Flood Insurance Program, NOAA's natural hazard statistics, US Coast Guard Boating Statistics; US Lifesaving reports, the Bureau of the Census Current Population Survey and the Bureau of Labor Statistics Census of Fatal Occupational Injuries. The time period covered is from 1995 to 2010. This period was chosen as one in which few major changes in data definitions occurred and which was subjectively viewed as long enough to display elements of year to year variability.

2.3 Shadow prices for risk

Microeconomic theory links values held by individual consumers with market prices to allocate goods and services. Welfare economics and its empirical application, benefit-cost analysis, uses prices to infer whether society is potentially better off from taking a policy action or maintaining the status quo (subject to several key assumptions). Strongly motivated by the environmental movement, goods and services that are not traded in the market have also been incorporated into welfare economics. Numerous empirical methods exist to value activities such as coastal recreation, ecosystem services, the value of a statistical life and other goods and services (Boardman, et al., 2011). The term "shadow price" is often used for a non-market but monetary valuation as they are not directly observed in a market. In the simplest approach to benefit-cost analysis and consistent with NIPAs (BEA 1985, 2006), a change in quantity due to a policy is multiplied by its shadow price in order to put impacts into monetary terms. Such is the approach taken here. Shadow prices existing in the literature are used to value risky outcomes in the coastal zone. Numerous methodologies exist to estimate shadow prices (Boardman, 2011). Some of these prices have a long history of estimation, and continuing controversy, such as the value of a statistical life, VSL, (Banzhoff, 2013; Viscusi and Aldy, 2003). The VSL measures how much people value small changes in risk, such as the risk of dying from air pollution or from an accident in the workplace which is aggregated to represent the value of avoiding one statistical death. Other shadow prices, such as those for unemployment (Masur and Posner, 2012; Bartik, 2012) and oil spills (Carson, et al. 2003; Hausman, 1993) are less resolved in the economics literature but substantial research and estimation has occurred as will be discussed in context.

As might be expected, important framing issues exist for shadow prices. One is in regard to how people value risk itself. If one wishes to estimate a shadow price in advance of the risk occurring, should one use the mathematical expectation of damages if measurable, or a measure which incorporates preferences to avoid risk such as option price, or a more behavioral approach that distinguishes gains from losses such as cumulative prospect theory? Those approaches may not be as divergent in practice as they are in theory (Farrow and Scott, 2013) but the approach taken here is to use the shadow price in standard usage for the category. Thus expected damages are most frequently used for to assess floods, while a willingness to accept measure underlies the shadow price of the VSL. Similarly, debates exist about the extent of indirect effects of a risk and whether to include what are often called secondary or general equilibrium effects which result from an impact rippling through many markets. The approach taken here is that most common in benefit-cost analysis, a partial equilibrium approach which may include a number of effects, as from oil spills, although not pursue their effect through the entire economy where they may thought to be de minimis.

2.4 Uses for residual risk data

Residual risk estimates, while measuring costs can be interpreted as the potential benefit of additional policies or action which reduces the risk. Some programs may also yield indirect benefits by causing reductions in other impact areas and by reducing costs associated with avoidance, mitigation, or transfer. Comparing these residual risks across policy areas can be a rough guide to the potential benefits of budgetary and investment decisions to reduce or mitigate risks. However, knowing the actualized residual risk does not say anything about the potential costs or net benefit of any additional policy which is likely to be partial in nature and implemented in a future environment. This accounting of what occurs also does not imply market failure, a "need" for a Government program, that any program targeted at such risks would be cost-beneficial or that a program has retrospectively failed or succeeded. What the risk accounting might do is to provide comparable data about which such questions could be asked and which might be incorporated into more detailed causal models. The Historical Statistics of the U.S. (Carter, et al., 2005) are just one illustration of the importance of providing credible time series data as the foundation for a broad set of researchers to use in ways that the original researchers could not have foreseen. Similarly, the original data collection of carbon dioxide measurements from Hawaii could not have foreseen how those data could have inspired so many other investigations and fed into so many scientific investigations about climate change. In assessing future risk or the impacts of policy, researchers look to various sources to characterize the distribution of risks. While elicitation approaches are in frequent use; many, perhaps even most researchers would prefer to have a historical record along with conditioning factors on which to base their estimates of future risk.

Finally, basic descriptive statistics of the residual risk can inform alternative policy designs. For instance, highly variable outcomes may suggest that individual insurance approaches may not be appropriate while less variable aggregate outcomes may suggest the usefulness of an insurance approach.

3. Data and Estimation for Prevention and Mitigation

Individual risk components and their measurement are discussed below as organized into the three broad categories of natural hazards, recreation and occupational. This section quantities and monetizes risks without consideration of the effect of insurance which transfers at least some of the monetary risk to other parties.

3.1 Natural Hazards

Storms such as Katrina in 2005 and Sandy in 2012 vividly illustrate coastal risks due to ocean driven flooding as well as riverine flooding. Whether due to named hurricanes or other weather events, building and content damage occurs and lives are lost.

The US National Flood Insurance Program (NFIP) is a useful point to begin coastal sector accounting for risk as claims for damages are "naturally" denominated in dollars. The NFIP implements legislation which requires that mortgages supported by federally insured institutions be insured if they are within the 100 year flood plain, that is, with an annual flood risk of at least 1% of being flooded every year. Among the claims submitted to the NFIP, the coastal damages must be distinguished here and an adjustment made for total damages compared with claimed damages under that one, albeit large, program.

Flooding claims are to be identified within the coastal sector. Claims for building and content damage occurring in those counties identified as Coastal Zone Management counties, essentially adjacent to oceans or the Great Lakes, are included (US Census Bureau, 2012). Valuation issues remain however. First, claims are not the total value of damages. Numerous properties are not insured, and there are deductibles and limits on coverage. However, the NFIP has carried out detailed post-event studies which indicate that total damages are remarkably close to two times the claimed damages (Dixon, et al., 2006). The benefit-cost analysis literature is also concerned whether damages represent an appropriate measure of welfare loss or whether measures such as option price should be used (Freeman, 2003). Recent literature suggests that ex-post damages have an ex-ante welfare interpretation (Freeman, 2001) and other work (Farrow and Scott, 2012) indicates that the distinction between damages and option price may not be significant in flooding applications. Table 1 presents the real value of NFIP claims (in 2010 dollars) in coastal counties and the estimated total damages for 1995 to 2010 as well as the value of natural hazard fatalities to be discussed below.

Within Table 1, the year 2005 stands out, years in which Hurricanes Katrina and Rita occurred. Damages from Hurricane Sandy in 2013 are likely to be of at least the same magnitude. The mean annual damage from flooding, $ 3.8 billion per year, and standard deviation are reported below the data. The standard deviation is about 2.4 times the mean value indicating a relatively large variation for building and content damages.

Natural hazard fatalities in the coastal zone are associated with weather events identified by the National Oceanic and Atmospheric Administration (NOAA, 2013) stemming from hurricanes, coastal storms, tsunamis, and rip currents. Fatalities from hurricanes are dominated by those from Hurricane Katrina in 2005; coastal fatalities are not able to be distinguished from hurricane caused fatalities further inland. In particular, fatalities associated with Hurricane Katrina were recorded by NOAA as due to a hurricane but 98 percent of 1,106 hurricane fatalities in 2005 had the cause of death identified as "unknown" (for instance, excluding "in water" or "boat") based on lack of evidence. Other weather fatalities are the sum of coastal storm, tsunami and rip tide causes. Fatalities from rip-tides are reported only after 2002 but there is a sharp decline in coastal storm fatalities beginning in the same year potentially indicating a change in the categorization of fatalities and not a dramatic change in their number.

The monetization for policy purposes of a life lost, a difficult concept, multiplies the VSL times the number of fatalities. The VSL is a key shadow price in the benefit-cost literature (Viscusi and Hamilton, 1992; Viscusi and Aldy, 2003). Consequently the valuation approach is now relatively standard; use a VSL measure as a measure of the willingness to pay to avoid one statistical death. There are however, numerous VSL measures and often stated in either real or nominal terms. The VSL used here is $7.9

million in 2010 dollars as used by the EPA (2010)[1]. Other US agencies may use different values; recently the Department of Transportation revised the nominal value used for VSL from $6 to $9.1 million (DOT, 2013).

Table 1: Estimated Natural Hazard Risks in 2010 $: 1995-2010

Year	**Coastal Flood Damage**		**Marine Weather Fatalities and VSL**			
	NFIP Covered	Total Flood	Hurricane Fatalities	Hurricane Fatal VSL	Other Weather Fatalities	Other Weather-Fatal VSL
1995	$1,549	$3,098	17	$134	1	$8
1996	$533	$1,067	37	$292	38	$300
1997	$126	$252	1	$8	22	$174
1998	$718	$1,436	9	$71	23	$182
1999	$510	$1,019	19	$150	28	$221
2000	$237	$473	0	$0	29	$229
2001	$1,317	$2,635	24	$190	53	$419
2002	$334	$667	51	$403	54	$427
2003	$657	$1,314	14	$111	55	$435
2004	$1,887	$3,775	34	$269	62	$490
2005	$19,000	$37,999	1,016	$8,026	41	$324
2006	$279	$559	0	$0	30	$237
2007	$195	$389	1	$8	57	$450
2008	$2,328	$4,657	12	$95	83	$656
2009	$424	$848	2	$16	87	$687
2010	$192	$385	0	$0	64	$506
Real mean	$1,893	$3,786	77	$611	45	$359
Std-dev	$4,610	$9,220	251	$1,981	23	$183

Sources: see text

The monetized value of natural hazard fatalities is substantial, in the hundreds of millions of dollar each year on average as reported in Table 1. However, the variability for fatalities due to hurricanes is much larger than that due to other weather causes. The vast majority of hurricane deaths occurred in one year, 2005, during Katrina.

[1] Nominal series were also created which included an adjustment for inflation and an income elasticity of the VSL of .5 .

3.2. Recreation

Even pleasurable activities have risks. Millions of people engage in water based recreation in the coastal zone whether simply bathing or numerous kinds of boating activity. Yet recreational fatalities are a major element of risk in the coastal zone.

The US Coast Guard (CG) reports recreational boating fatalities annually (USCG; 2013a) and maintains the Boating Accident Report Database (BARD). These data originate from reports to state authorities when a death occurs in a recreational boating accident (and for other criteria as well). The CG also identifies deaths which are reported in the media but which appear to have not been reported to the states. The geographic unit for the public record is the state although county specific data were provided by the US Coast Guard for this study (USCG, 2013b).

In addition to deaths associated with recreational boating, swimming accidents occur. Coastal swimming fatalities are not collected by a federal agency, presumably due to the large number of local and seasonal jurisdictions involved[2]. However, the US Lifesaving Association (USLA) whose membership includes agencies involved with open water (as opposed to pool) safety grew out of the Surf Lifesaving Association and has a long record of collecting data from its member chapters. In regard to coverage, the USLA states that the data they publish are not "a comprehensive list of all statistics generated by all beach lifeguard agencies, but the statistics of most major agencies are included". Consequently the USLA (2013) data for drowning from guarded and unguarded open water sites are used as an estimate of coastal recreational swimming fatalities. Data for death due to rip-tides are excluded from the USLA data as they are included since 2002 in natural hazard data reported by NOAA.

Table 2 presents the number of fatalities and the monetary estimate for coastal recreational deaths using the VSL as discussed in the previous section. While both recreational boating and swimming fatalities trend slightly downward (based on a time-

[2] The natural hazard fatalities reported earlier based on data from NOAA do include an item for "rip tide" caused deaths.

trend regression not reported here), the quantity can be seen to be relatively stable. The standard deviations are much less than the mean.

Table 2: Recreational Fatalities and VSL in 2010 $: 1995-2010

Year	Boating Fatalities	Boating VSL (Mil $)	Ocean Swimming Fatalities	Swimming VSL ($ Mil)	Recreational Total VSL ($ Mil)
1995	280	$2,212	120	$948	$3,160
1996	233	$1,841	110	$869	$2,710
1997	285	$2,252	83	$656	$2,907
1998	300	$2,370	119	$940	$3,310
1999	245	$1,936	108	$853	$2,789
2000	232	$1,833	74	$585	$2,417
2001	251	$1,983	90	$711	$2,694
2002	279	$2,204	75	$593	$2,797
2003	270	$2,133	79	$624	$2,757
2004	243	$1,920	84	$664	$2,583
2005	249	$1,967	71	$561	$2,528
2006	257	$2,030	72	$569	$2,599
2007	257	$2,030	56	$442	$2,473
2008	268	$2,117	71	$561	$2,678
2009	262	$2,070	113	$893	$2,963
2010	248	$1,959	55	$435	$2,394
Real mean	260	$ 2,054	86	$ 681	$ 2,735
std dev	19	$ 152	21	$ 169	$ 255

Source: USCG, 2013; USLA, 2013

3.3 Occupational risks

Risks broadly related to occupation are the final category. Occupational fatalities, unemployment and oil spills comprise the individual elements of this category representing the highly diverse kinds of outcomes potentially monetizable.

Annual occupational fatalities as reported by the Bureau of Labor Statistics (BLS, 2013a) are monetized using the VSL as above. The determination of what industries have standing as discussed in section 2.2 can be subject to dispute. Prior literature and the industry codes were reviewed. A narrow construction of coastal industries resulted in the following four industries being selected as coastal and marine focused with the method of coastal allocation in parentheses: 1) Hunting, fishing, and trapping (100 percent attributed to coastal fishing), 2) Oil and gas extraction and support activities (attribution ranged from 10 to 21 percent based on annual share of oil and gas production), 3) Ship and boat building (100 percent attributed), and 4) Water transportation (49 percent attributed based on coastal, lake and deep ocean employment relative to total employment, US Maritime Administration (2009)). Clearly the set of industries defines the scope of fatalities and unemployment. For instance, the data do not include the self-employed, an important aspect of coastal fishing. Similarly, a broader set of industries potentially related to the coastal zone would expand the magnitudes of risk.

The same industries analyzed for occupational fatalities are analyzed for the social cost of unemployment. Industry specific unemployment data based on the Current Population Survey (BLS, 2013b) are used for the number of unemployed. The industry level of publicly available data was insufficient to identify the desired industries but the Bureau of Labor Statistics provided additional data at the level of the identified industries (BLS Personal communication, 2012). The results are data for the number of unemployed in each industry by year.

There is less agreement on the social cost of a year of unemployment. Current research such as that by Bartik (2012) and Masur and Posner (2012) pursue increasingly sophisticated analyses taking into account the duration of spells of unemployment and earnings, if any, on return to employment. The valuation method used here is recommended by Boardman, et. al (2011) as an approximation when workers have reservation wages randomly and uniformly distributed between zero and the market wage and the market supply curve of labor is linear. In that case it can be shown that one-half the market wage is an estimate of the social cost of unemployed labor. Alternatively, the lost benefit to employees from unemployment is then the wage less the social cost. Given the estimate for social cost; its complement is the lost benefit to workers (Haveman and Farrow, 2011). Private sector hourly wages and average weekly hours worked were used for each industry (BLS, 2013c).

Oil spills are the last coastal category to be analyzed. Both quantity and a shadow price per unit of oil spilled are required. Both are only available as estimates with less precision than may occur in some other categories. Coastal and marine oil and gas production is overseen by states in near-shore waters and by the Federal government on the more distant Outer Continental Shelf Lands. Federal oversight has evolved from 1995 to the current time as a result of the Gulf of Mexico spill of 2010. The Bureau of Ocean Energy Management (BOEM) has continued the reporting of oil spills greater than 1 barrel of oil from platforms, pipelines, and vessels on the Outer Continental Shelf (BOEM, 2013) although the size of the Gulf of Mexico oil spill of 2010 remains in dispute. The shadow price or social cost of a barrel of spilled oil is also the subject of much controversy (Farrow, et al, 1990; BOEM, 2011). Although categories of impacts such as control costs, tourism, fishing, recreation and so on are reasonably well established; the time and location specific nature of an oil spill makes generalization difficult with one of the largest factors being the quantity of oil which hits land. Recent analyses tend not to report damages on a per unit basis (BOEM, 2011). The approach taken here is to use earlier estimates reported on a per barrel basis (Farrow, et al, 1990) and assume there is a ten percent chance that each barrel will hit shore (with correspondingly higher shadow price). The resulting values are $1,040; $1,210 and $1,380 in 2010 dollars for spills from pipelines, tankers, and platforms respectively.

The monetized values for occupational fatalities, unemployment and oil spills are presented in Table 3. Although the annual mean of the occupational fatalities are about twice that of the other categories in Table 3, the variability in oil spills is dramatic due to the Gulf of Mexico spill in 2010 where the standard deviation is about four times the annual mean value of oil spills.

. Table 3: Occupational Monetized Risks in 2010 dollars, 1995-2010

Year	Occupational Fatalities	Unemployment	OCS spills
1995	$883	$517	$2
1996	$1,107	$503	$1
1997	$714	$491	$1
1998	$1,106	$485	$13

Year	Occupational Fatalities	Unemployment	OCS spills
1999	$1,082	$473	$4
2000	$794	$462	$3
2001	$832	$446	$0
2002	$664	$441	$2
2003	$753	$432	$1
2004	$900	$418	$6
2005	$729	$405	$18
2006	$788	$393	$3
2007	$616	$381	$0
2008	$754	$367	$8
2009	$714	$370	$2
2010	$511	$364	$5,662
Real mean	$809	$434	$358
Std-dev	$172	$51	$1,414

4. Risk Transfer through Insurance

Risks such as flood damages, job losses and fatalities occur and represent a cost to someone. However, the direct cost may be at least partially offset by transferring the risk to others as through flood or unemployment insurance. Such transference has its own resource cost and distributional impact which has been detailed for the NIPA accounts by Chen and Fixler (2003). The shadow price when insurance exists can be complex (Boardman, et. al, 2011). In addition to insurance, liability may be assigned, as for oil spills, such that those initially incurring costs are intended to be compensated for their loss. Consequently, although the preceding tables do not account for insurance, they do represent economic measures of risk prior to any distributional effect resulting from insurance or liability coverage. None-the-less, policy makers may be interested in the extent of monetized but uninsured risks.

Table 4 summarizes the results in the major categories after adjusting for estimates of insurance. The adjustments made here are only approximate and are described below:

- Flood insurance: Only estimated damages not covered by the NFIP are included as reported in Table 1 (total damages less NFIP claims paid).

- Fatalities: Based on industry reports such as that by Prudential (2011), about 60 percent of adults in the United States have life insurance with mean coverage in 2010 of about $115,000. Consequently, the expected value of life insurance coverage is somewhat less than 1 percent of the VSL leaving 99 percent as uncovered.
- Oil spills: risk costs are assumed offset by liability for the spill based on the Oil Pollution Act of 1990 (Sump, 2011)[3].
- Unemployment: the average fraction of earning paid by Federal unemployment insurance is subtracted from the estimated cost (Employment and Training Administration, 2013) to compute the uncovered portion[4]. While the value varies somewhat by year, a value of .46 was used based on data from 2009 to 2013.
- The existence of government insurance for risks such as flooding and unemployment and the assignment of liability for oil spills reduce the annual expected value each of these categories. The existence of life insurance coverage for many individuals only slightly reduces the social costs of fatalities compared to data in previous sections.

Table 4: Monetized Risks Net of Insurance or Liability Coverage, real 2010 dollars

Year	Flood Uncovered	Hurricane Fatal VSL	Other Weather -Fatal VSL	Recreational -Fatal	Occupational Fatalities	Un-employment	OCS spills
1995	$1,549	$133	$8	$3,128	$874	$36	$0
1996	$533	$289	$297	$2,683	$1,096	$31	$0
1997	$126	$8	$172	$2,878	$707	$25	$0
1998	$718	$70	$180	$3,277	$1,095	$24	$0
1999	$510	$149	$219	$2,761	$1,071	$22	$0
2000	$237	$0	$227	$2,393	$786	$18	$0
2001	$1,317	$188	$415	$2,667	$823	$20	$0
2002	$334	$399	$422	$2,769	$658	$20	$0
2003	$657	$109	$430	$2,730	$745	$17	$0

[3] Limitations to liability may apply under certain conditions although such limitations have not been operative in the largest of recent spills, the Gulf of Mexico spill and the Exxon Valdez spill.
[4] Alternative computation methods and limitations on the duration of unemployment benefits exist which can vary depending on state and national conditions and legislation existing at the particular time. No adjustment is made if the unemployment extends past the period when unemployment benefits are made.

Year	Flood Uncovered	Hurricane Fatal VSL	Other Weather -Fatal VSL	Recreational -Fatal	Occupational Fatalities	Un-employment	OCS spills
2004	$1,887	$266	$485	$2,557	$891	$18	$0
2005	$19,000	$7,946	$321	$2,503	$721	$13	$0
2006	$279	$0	$235	$2,573	$781	$18	$0
2007	$195	$8	$446	$2,448	$610	$17	$0
2008	$2,328	$94	$649	$2,651	$747	$27	$0
2009	$424	$16	$680	$2,933	$707	$29	$0
2010	$192	$0	$501	$2,370	$506	$35	$0
Real mean	$1,893	$605	$355	$2,708	$801	$23	$0
Std-dev	$4,610	$1,961	$181	$253	$170	$7	$0

5. Synthesis

The main results of this monetization of coastal risk prior to any adjustment for insurance coverage can be represented by three figures. Figure 1 plots the core data from Tables 1, 2 and 3 as a time trend. The impact of the 2005 flooding and hurricane related deaths immediately stand out. On closer observation the steady but relatively high level of recreational fatalities may come as a surprise to some analysts.

Figure 1: Time Trend of Monetized Coastal Risks

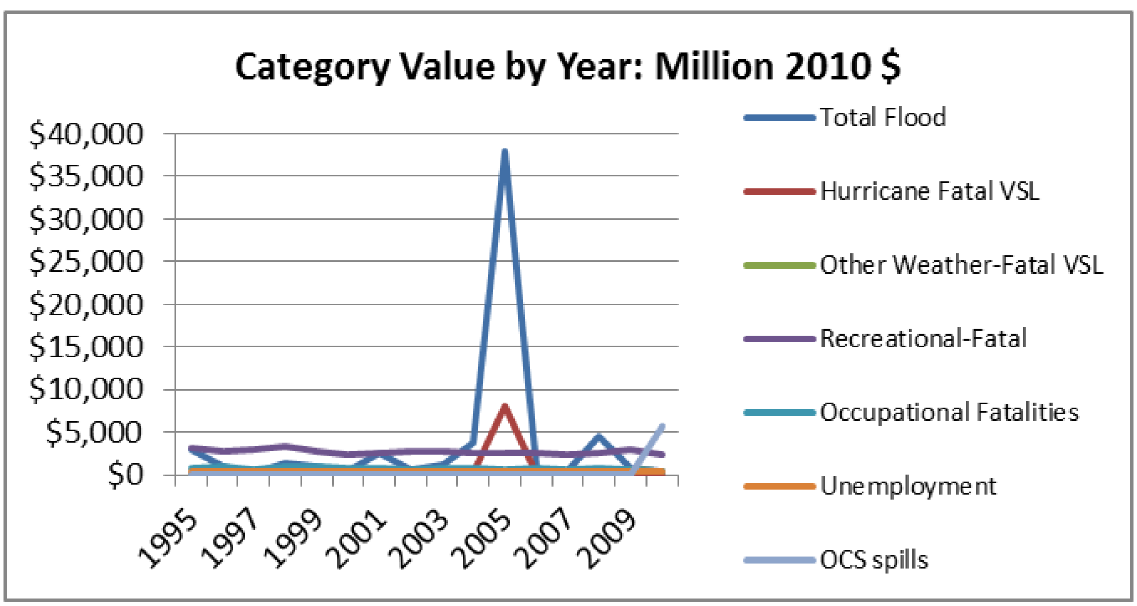
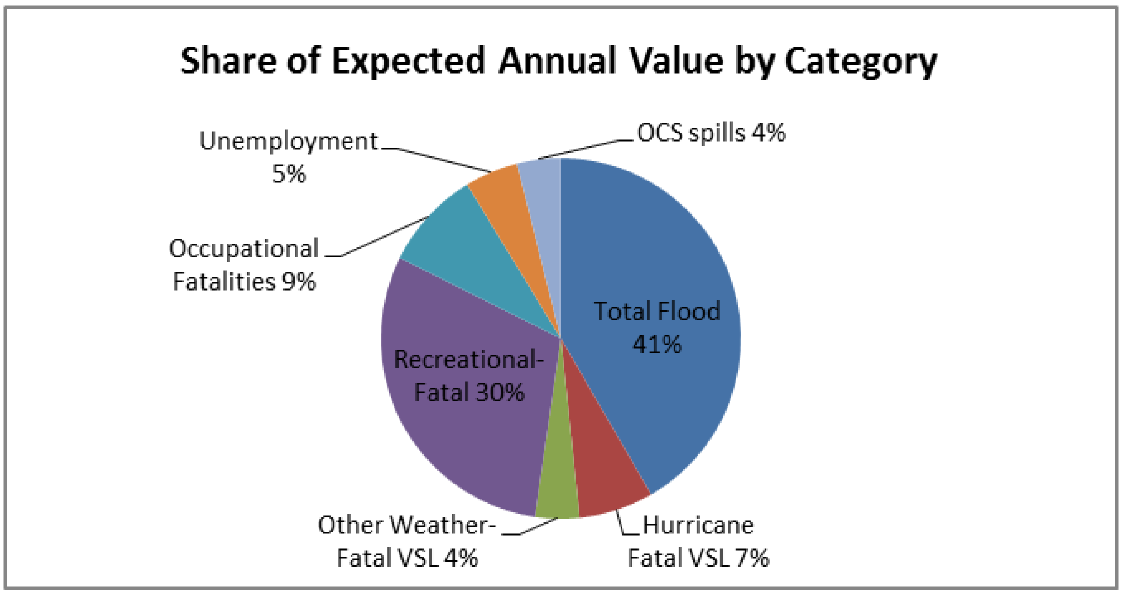


Figure 2 presents the shares of the expected value across the categories. While costs due to flooding are clearly large in expected value, recreational fatalities from boating and swimming accidents represent close to one-third of the annual expected risk in the coastal zone as measured here. The expected values of unemployment and occupational fatalities in the identified industries, oil spills, and hurricane fatalities are similar in magnitude with each accounting for a share between 4 and 9 percent of the aggregate value of residual risk.

Figure 2: Annual Value Shares by Risk Category

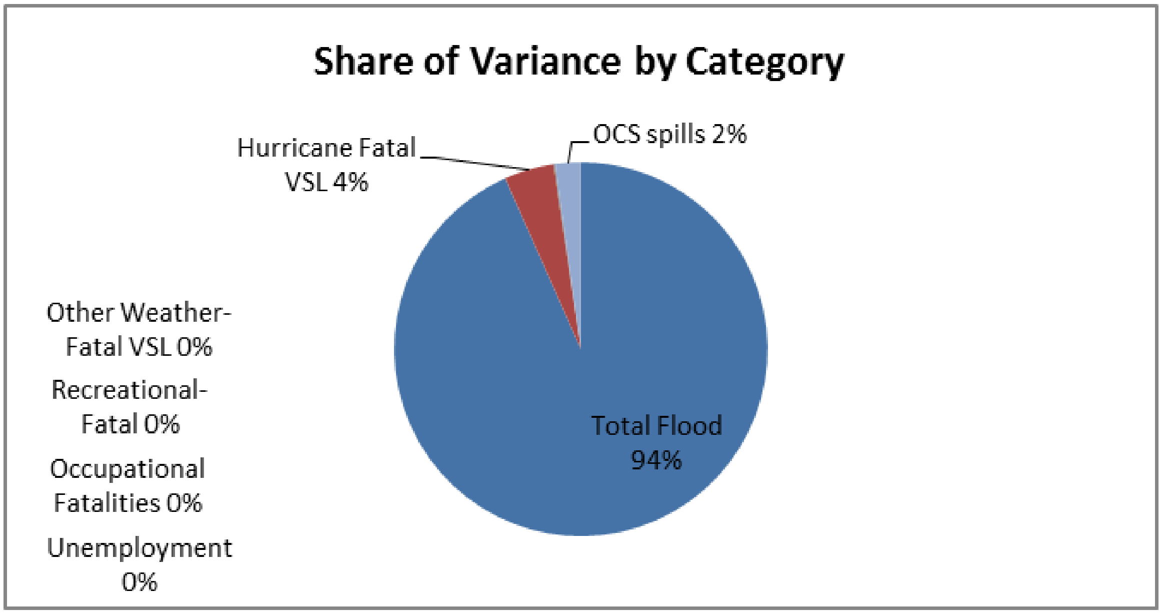


Source: Tables 1, 2, 3.

Figure 3 identifies the categories with the largest variation. Flooding, hurricane fatalities, and oil spills account for virtually the entire variability in the outcomes as measured by the variance of the several data series.   The other categories are relatively stable and contribute little to the variability in coastal residual risk.

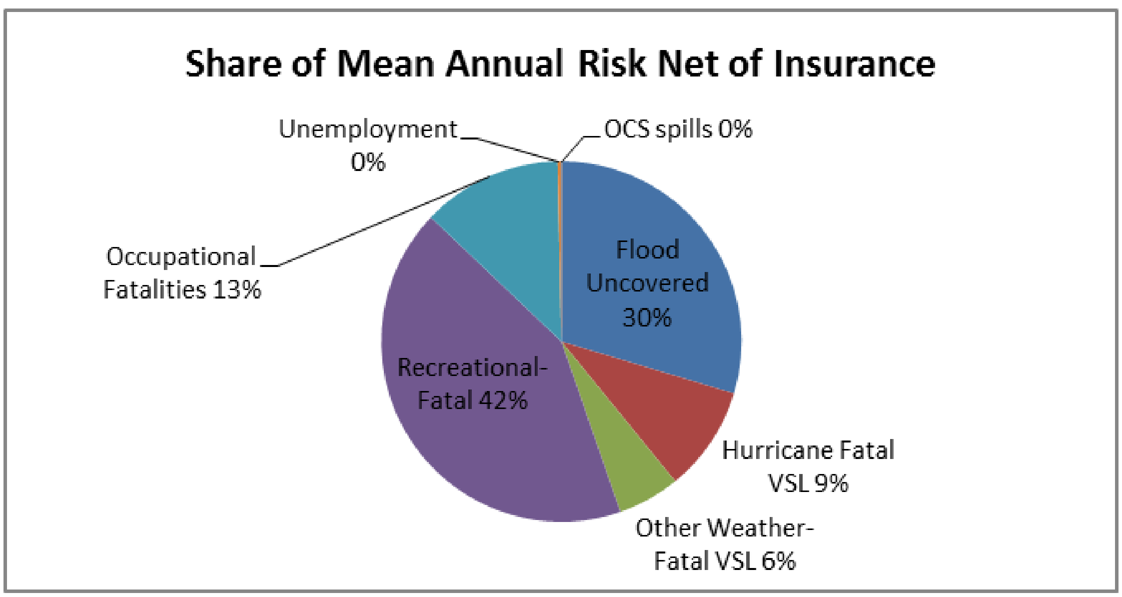
In contrast, the effect of insurance (and liability) coverage has a dramatic impact on the expected annual losses as can be seen in Figure 4. For instance, the uninsured portions of flooding and recreational deaths have similar annual expected shares of the total risk cost. The expected share of oil spills and unemployment are reduced to close to zero. The exact value of these results can be disputed, but the existence of risk transfer policies clearly has a larger impact on some categories than others. A chart of the share of the variance for the insurance and liability adjusted series would show that flooding and hurricane fatalities accounted for almost all the variability. In contrast to Figure 3, the variability due to oil spills become negligible as the assignment of liability essentially removes that category.

Figure 3: Variance by Risk Category



Source: Tables 1, 2, 3

Figure 4: Annual Risk Categories, Net of Insurance



6. Summary and directions for further research

Major residual risks are analyzed in comparable terms for the coastal zone. Monetization of previously non-comparable categories yields insight into both the relative level and variability in the outcomes. Recreational fatalities are revealed to be a relatively large source of risk in the coastal zone with very little variation. In contrast, flooding is revealed to be large both with respect to its annual expected risk and to its variability. Risks such as unemployment, occupational and hurricane fatalities and oil spills represent similar shares of the average coastal risk but the variability of these risks is quite different. Risk transfer as from insurance and liability does not change damage from the risks, but shifts it to an identified party such as those who pay flood premiums, unemployment claims, taxpayers and those parties who are liable for specific oil spills. Insurance adjusted data reduce the importance of flooding, unemployment and oil spills while having little effect on fatalities.

The absolute and relative magnitude of these accounts is importantly influenced by both the geographic definition and the substantive definition of activities related to the coastal and marine environment. For instance, a broader definition of coastal unemployment might include dining and lodging establishments which would expand the importance of that category without a concurrent expansion of damages such as those due to flooding. Some data are missing, such as unemployment data for self-employed fishers. Except for flooding, somewhat less data are available for annual elements of insurance coverage.

More generally, further research might consider residual risks on a nation-wide basis and using a broader set of risk categories. Examples of additional, nationally important risk categories might include but not be limited to: 1) less than a high school education, 2) early age pregnancy, 3) poverty, 4) premature mortality due to various disease and other accidental causes, 5) crime and 6) environmental damages. The framework of residual risk accounting illustrated here allows cross-category comparisons based on the monetization of impacts. The comparisons facilitated here may help inform policy and regulation.

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