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Assessing the Risk of Terrorism Using Extreme Value Statistics

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My research which is funded by the Dept. of Homeland Security (DHS) through the National Center for Food Protection and Defense (NCFPD) at the Univ. of Minnesota, deals with the question of how to assess the risk of terrorism. To do that, we adopt a novel statistical technique known as extreme value theory. We find some very interesting results that I will share with you today. My collaborator in this research is assistant professor Antu Murshid who could not attend today. So I will present this material on both our behalves.

An important question in discussing terrorism risk is: How can we understand the behavior of terrorists? To the extent that terrorism is aimed at disrupting the normal activity of society, a second important question is how to understand society's response-that is the reaction of economic actors such as consumers and investors to terrorism risk? Answering the first question leads to the kind of analysis that involves the behavioral aspects of terrorism. The new DHS Center at the Univ. of Maryland, known as START, is charged with this task.

Interest in the second question, however, relates to the type of issues that were discussed by Dr. Tom Stinson earlier, such as gauging the sentiment of consumer and investors. These could have immense impact on the level of economic activity in the long run and therefore it is very important to understand them. A part of gauging the sentiments of consumers and investors in their response to terrorism threat, involves evaluating the actual *risk* of terrorism. This is the area that I will focus on today.

Let me elaborate on each of these 2 points. On the understanding of the behavior of terrorists, economics adopts game theory approach which focuses on how terrorists adjust their action to counter terrorism policies, which in itself might be a response to a previous terrorist attack, and so on. One key person who has taken this approach is Dr. Todd Sandler at the Univ. of Southern California. Among industry researchers, one finds the works of John Major, a Senior VP at Guy Carpenter and Company.

On the second point, that is the understanding of the citizen response to terrorism threat, here there are two somewhat competing of views. The typical rationalist (or neoclassical) economic perspective is that consumer, citizens, and economic actors in general, adjust their behavior over time to any shock including threats of a terrorist nature. In this perspective, it would follow that the more adaptable the economy is, the more easily citizens can adjust their behavior, and the more resilient the economy would be to terrorism shocks and threats. This related to the point that Dr. Susan Offutt brought up earlier in her keynote speech and also to a very interesting recent study by the Nobel Laureate Gary Becker who focuses on citizen adaptability by considering the possibilities of substitution in consumption in response to terrorism threats.

An alternative view comes from behavioral economics and focuses on *regime shifts* where the frame of reference changes from before an attack to after an attack. In this view for example a response based on panic or fear is also considered feasible. So these are somewhat competing ways of looking at society's reaction. But either way, understanding society's response and its reaction to the threat of terrorism, involves the evaluation of the risk itself. This is what we focus on. First note that terrorism is a form of extreme risk, defined by that fact that it is rare in its occurrence but extreme in its magnitude, whether measured in casualties or in financial or economic loss. The methodology that we apply has been developed in finance and statistics and in some other areas where extreme risk applies (for example earthquakes), but we are the first to apply this methodology to terrorism risk. The key concept is estimating the probabilities of such extreme events. If these probabilities can be measured, then one can develop the concept of *value at risk* and this is related to what Dr. Tom Stinson mentioned in his talk. In essence one would combine the probability of an attack with the severity of the consequence of that attack to arrive at an expected value measure.

Before we go into the details of this approach, I want to ask how different stakeholders view the concept of risk when it comes to terrorism events. First is the government. Government has been instrumental in getting the insurance industry to provide terrorism coverage especially right after 9/11. As a result, Terrorism Risk Insurance ACT (TRIA) was born in 2002. This is a temporary measure that is supposed to be phased out in December of '05, but some insurance experts are rather concerned about this phase out. For example Dr. Howard Kuhnreuther of Wharton School has been a leading voice for either extending the phase-out or allowing for a gradual phase-out in order to give the insurance industry the time to adjust.

A second financial instrument is catastrophic bonds. This is an important new financial instrument that is being developed to address the markets' response to terrorism risk. The finance industry uses extreme value frequently in trying to figure out risk of default and other forms of extreme risks. However, the Insurance industry has had some reluctance in using catastrophic bonds to cover insurance risk. If the insurance industry is not forthcoming in providing for the coverage of extreme risks, then measures aimed at *self-insurance* become more important. This applies to the food industry as well as to other industries.

What it means is that firms are likely to commit to investments that protect themselves against terrorism risk. That is not of course to say that with insurance you do not need self-protection. Certainly your insurance rates would be much higher if you didn't, but this issue of-self insurance or self-protection becomes more important when markets are incomplete, as economists call it.

The philosophical question is whether terrorism risk is really a catastrophic or a deterministic event. I suggest several reasons why terrorism maybe viewed as a catastrophic event. First of all, you can view terrorism the way you would think about a crime; to the terrorist, the act is premeditated and deterministic – the terrorist knows when he wants to hit, what he wants to hit, by what means and so on. But to the victim there is an asymmetry of information about what, if anything at all, is going to happen, and where, when and how it is going to happen. Therefore, there is a certain "disconnect" between the deterministic aspects of terrorist behavior at the micro level, on the other hand, and the broad macro effects of terrorism on the other hand. This is a bit similar to thinking about *explaining* criminal behavior versus crime *statistics.* There is a second reason why terrorism may be viewed as a random process. Consider counterterrorism. If you think about counterterrorism, it may succeed in preventing some X fraction of terrorist attacks; and fail in preventing the other 1-X fraction. This way of thinking about terrorism risk is similar to the concept of failure in engineering systems; a successful terrorist attack is analogous to system failure and therefore can be addressed in the same way as engineers look at system failure, which is by statistical tools.

To illustrate, as I was first writing this segment of the talk for a conference at the Univ. of Southern California, I watched a piece at PBS which described that for the 2 incidences of terrorist attacks that shook London and Madrid last year, numerous others had been thwarted by counter-terrorist agencies. One can again appreciate how probabilities approach is involved here.

Finally a new approach that has been adopted to understand and even predict conflict and terrorism is the "complexity" approach advanced by Johnson, Spagat, and others (Johnson is a mathematical physicist at Oxford; Spagat is an economist at the Univ. of London.) The basis of their Approach revolves around the question of how "Attack Units" (whether in the instance of terrorism or war) come to coalesce or fragment. It turns out that their work leads to results that are similar to our estimates of the probability of terrorism events.

Finally a word on the US versus European perspective in viewing terrorism risk: Back in 2003 the U.S. and Europe had somewhat different perspectives of this issue. We tended to focus on the consequences of major events; Europeans tended to focus more on probabilities. Yet, our approaches now seem to be converging. This is seen in the new Secretary of Homeland Security Chertoff's emphasis on estimating and analyzing the risk approach to the issue of terrorism, and in thinking about how to direct scarce resources to high probability or high risk events, rather than ranking events solely based on their consequences, no matter what their probability might be.

Now we come to discussing our own estimation method. The challenge from an analytical perspective is how to go about measuring events that are rare and yet of extreme magnitude, because normal statistical procedures are not well suited to address this issue. Mathematical statistics provides an answer to this type of question. The answer is the extreme value theory, which is basically a limiting theory, and is similar to the famous Central Limit Theory that is used to derive normal distributions, except that Extreme Value Theory looks at the distribution of the *maxima* (or minima) of events. So people have used this approach to study extreme weather patterns, earthquakes, global warming, and so on. We are among the first to apply this approach to the estimation of the probabilities of events.

Now I will provide a little detail: Suppose that you have a random variable X that stands for the number of causalities associated with, say, a terrorist event. If the distribution of X is *F(X)*, then calculating the probability that *X* exceeds some threshold value is a trivial task. But if we don't know *F(X)* and would like to estimate the probability of it, that is more challenging. The question is: Can we still estimate this probability? The answer is: maybe yes, maybe no. Because suppose you have an estimate of this distribution that's G(X). It turns out that G(X) is close to F(X) only around the mid-part of your distribution. That is small errors in estimating *F(X)* in the mid part of the distribution lead to very imprecise predictions of the tail quartiles. Why the interest in the tail? The reason is that basically we are interested in extreme events. For instance, when a random terrorist event takes a large number of casualties, that event belongs to the tail of the distribution. That is where the extreme value theory becomes very useful.

Extreme value theory states that the maximum draws from independent samples belong to a certain class distribution regardless of where the origin of the distribution comes from. These distributions tend to have heavier tails. I will suggest an example: This is a typical distribution; this other one is a typical extreme value distribution. This 2nd distribution says that rare, extreme events are actually more likely than would be predicted by the normal distribution. For instance in the finance literature, people apply this to probability of a stock price falling more than, say 3 standards deviations from the mean. The data to calibrate these distributions and to estimate these tail effects are based on our own collection. We looked at a numbers of existing datasets and found that none contained data on the types of agents for which *food* would be a suitable medium. These potential agents fall in one of these four categories; chemical, biological, radioactive, or nuclear. That is why they are designated in the literature by the acronym CBRN. We analyze this data separately but also in combination with another important data set, the MIPT dataset that in itself has rather limited set of CBRN data but it has a lot more observations on non-CBRN events. In the future we might be able to work jointly with the Univ. of Maryland's START center which also has a great dataset on non-CBRN events.

Here are some examples of the history of some more prominent attacks on the food sector. The major one was the attack in 1984 by the Rajneeshee cult in which 751 people were injured but none died. A number of other ones occurred in Asia, many of them in China or Taiwan. These are just a few examples of the kinds of data that one finds specifically focusing on the food sector.

Here are some of the trends that we find. We see evidence of an upward over time, whether focusing on attacks on the food or water supply, or attacks using CBRN agents; whether attacks are measured by the number of events or they are measured by the number of casualties. In the case of the MIPT data that encompasses all forms of terrorist attacks including a few (I think about 50) of the more significant CBRN events, you see 3 that are marked in red: 2 of them (the 1984 and 1994 attacks) are outliers and 1 of them (the 1995 attack) is right on the trend line. The 1984 attack is the one I mentioned earlier (the Rajeeshee attack), but the 1995 and 1994 attacks are chemical attacks but not related to food. They are the 2 Tokyo subway attacks involving the release of sarin case.

So we must take these trends in account in our estimation procedure. This is very important because we don't know if an event is particularly "fat-tailed," that is whether it belongs to an extreme value distribution, or whether there are simply more attacks that are happening over time. So we have to account for that; when we correct for these trends in the estimation of the parameters of our distribution, we can then develop predictions of the recurrence of attacks or by the number of its victims. Here are some examples; we find the recurrence period for an event of the size of the Tokyo subway attack of 5,000 casualties (death or injury). Notice that as time goes by the recurrence period shortens! As of today, in 3-1/2 y we should be expecting on the average an attack of that size somewhere in the world. By the year 2020, the time period for recurrence shortens to 2-1/2 y. Now what is interesting is that for other types of attacks the trend is even steeper, that is, the period of time within which you would expect an attack to occur is initially longer, but falls faster over time.

Now when we combine our CBRN data with these generalized 21,000 MIPT data we get some interesting results. We break down our combined data to CBRN versus non-CBRN-type attacks, including firearms, explosives and so on and then study how the probability changes with different time horizons. One then observes that the probability for certain types of weapons such as explosives or CBRN attacks rise over time while those for firearms fall over time. If we forecast the probability by the *type* of tactic, such as arson, assassinations, suicide attacks, and so on, we see that some types of attacks such as suicide and bombings attacks seem to be on the rise (not surprisingly as our experience over the past few years has suggested), while others such as hijacking remain flat over the course of time. I will say a few words at the end about whether policy interventions could alter these trends. For now, let us consider another important angle on this issue.

This is the issue of *conditional* probabilities. The question is this: Given an attack with a certain number of casualties is to occur, what is the probability that the attack is of a particular type? Obviously this is a critically important question because it would have key application for various areas of national concern, including transportation, logistics, food supply chain, and so on. So it would be great to be able to say for example, "Look, we know something is going to happen. We can further tell whether food sector or the infrastructure is more vulnerable." Conditional probability makes an attempt to answer that question. The estimation of conditional probability is a bit tricky here because one is using extreme value statistics, not normal statistics. Here's an example; The conditional probability of an attack of any kind with potential number of 5000 casualties is given by the left column at 18% now to 22% in 5 y to 26% in 10 y to 35% in 25 y. However, the conditional probabilities of CBRN attacks, given that an attack is imminent, are much *higher* at first but then they seem to *decline* in time instead of rising.

The same thing is also depicted in the graph. Here, blue signifies unconditional probability which seems to rise; red signifies conditional probability which is initially higher but falling. Why is that? The reason seems to be-and I have not presented you with the result of our statistical analysis—related to the fact that there is a much greater upward *trend* associated with the generalized attack such as explosives or suicide attacks. On the other hand, with CBRN attacks we get a lot more tail end effects; that is effects that are high because we've had many low key events and very few high-impact effects, such as the Tokyo subway attack. So rather than instead of a trend, we have very few massive CBRN attacks but they happen, they are critically devastating. This bolsters the tail effect, which is the classic application of extreme value theory but not so much. At the same time the existence of a single major event suggests the lack of a trend effect. As far as the food sector is concerned, on the one hand, we should take assurance that this sector is less and less likely to be subject of an attack as time goes by, but the existence of a tail effect points to the potentially devastating nature of a potential attack on this sector, should one occur.

I would like to spend a few minutes discussing some of the tasks ahead. First, we are adding new data. We'd like to be able have enough CBRN data that we could isolate the data by regions, lets say the US versus for example the rest of the world. We'd also like to be able to have enough data to break this down further into commodities and agents. However, too much specificity in this direction may not yield valuable information. One reason is that terrorists might be entirely indifferent between two products, say a fresh produce X, and another fresh produce Y. Thus by using past data on fresh produce X to infer the future probability of an attack on X one overlooks the flexibility of terrorist "technology" and the fact that the next time, they may substitute fresh produce Y for X. In this case, this possibility of substitutability implies that the aggregated data set should include a composite of X and Y for a more accurate estimate of the probability, rather treat X and Y separately.

Another challenge is how to estimate the effects of policy intervention. There are two problems here. First, if a successful counterterrorism activity results in foiling a potential terrorist attack, then that event will not be observed. This would lead to *censored* data. But this is only a problem if analysis is based on short-run micro data attempting to establish a one to one causality between policy and terrorism events. However, at a macro level and over long-run, this is not a problem, since a successful policy would mean reduced future terrorist attacks, leading to a decline in the trend lines after the establishment of a given policy. Thus, censored data is not an obstacle for analysis based on a long-run aggregate horizon.

A second challenge is to establish a time frame that is specific enough to correspond to the establishment of specific policies. That may require for example monthly rather than yearly data which may be a challenge for terrorism events, though it is not impossible to overcome. We have carried out such a monthly data analysis, using extreme value theory, to examine the effects of policies in the UK to counter the spread of BSE or mad cow disease.

Another question is: What are other suitable applications of extreme value theory that involve natural disasters instead of intentional terrorist attacks. Within the context of the food sector, some candidates would be contagious diseases that would affect the food sector rapidly and would have disastrous consequences. Several candidates might be, bird flu, Foot and Mouth Disease (FMD), that Dr. Bernstein discussed.

In conclusion, terrorism risk can be a viewed as an "extreme value event" that can be measured. This would be a first step towards rationalizing the use of scare resources to rare but catastrophic events such as terrorism.

Assessing the risk of Terrorism using Extreme Value Statistics

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1. How can we understand the behavior of terrorist?

2. How can we understand the society's reaction to terrorism risk?

3. How can we evaluate the risk of terrorism?

1. Understanding the Behavior of Terrorists

- ❖ Game Theory
  - – Analyzes the strategic interactions of terrorists adjusting their behavior to the defensive acts by anti-terror groups (police, military, etc.) (e.g., T. Sandler and W. Enders, 2004, J, Major, 2001, others).
  - – The new START center at the U. of Maryland

2. Understanding Citizen Response to a Threat

- ❖ Behavioral Economics
  - – The "Frame" problem: Regime shifts in consumption and investment (e.g., David Laibson 2001)
- ❖ Neoclassical Economists
  - – The Adoption/Substitution principle (Gary Becker, 2005)

3. Evaluating the risk of terrorism

- Terrorism risk is a form of "extreme risk"
- Extreme risk: Measures probability of events that are rare in occurrence but extreme in magnitude
- Key role of a probability approach
- Methodology uses developments in statistics and finance
- How do different players view this approach?

Different Players in the risk valuation approach

- Government:
  - Terrorism Risk Insurance Act of 2002 (TRIA): A temporary measure to make risk insurance available (expired December of 05)
  - Cat bonds (Catastrophic bonds): For example see the GAO testimony before a House Subcommittee, October 8, 2002)
- Industry:
  - Finance: Extreme value approach is used in determining risks of default and other risks.
  - Insurance and Reinsurance: A Probabilistic valuation of extreme risk is being accepted with some resistance.
  - Implications for the need for self-insurance in food and other industries through investments that mitigate risk

Is Terrorism risk compatible with a probability approach?

Is terrorism a stochastic or a deterministic event?

Three reasons why terrorism can be viewed as a stochastic event

1. Terrorism is a classic case of asymmetric information between the terrorist and his victims: intentional and deterministic to the terrorist, but probabilistic to its victims. Deterministic at the micro level but random at the macro level.

Similar to explaining criminal behavior versus crime statistics

2. Counter-terrorism may succeed X fraction of time and fail 1-X fraction of time. Thus, a successful attack represents a random "system failure" (in the sense of operations management)

Example: In Europe numerous successes in disrupting terrorist plots over the past 5 years, but only two failures, Madrid and London (PBS Frontline, July 05).

3. The “complexity” approach advanced by Johnson, Spagat, et. al.

(Johnson is a mathematical physicist at Oxford; Spagat is an economist at U. of London. There work was covered in the Economist, July 21, 2005)

Basis of Approach: Coalescence and Fragmentation of “Attack Units”.

Leads to the statistical view of terrorism that is similar, but not identical, to our approach.

In 2003 US and Europe had differing Perspectives:

- U.S. focused on evaluating the consequences of terrorist events.
- Europe focused on evaluating the probabilities of terrorist events.

(Source: Jonathan Stevenson, Foreign Affairs, March/April 2003)

In 2005 these perspectives are converging:

Excerpts from Remarks by Secretary Chertoff, (Washington, D.C. July 13, 05)

- "…DHS must base its work on priorities that are driven by risk. Our goal is to maximize our security, but not security 'at any price.' "
- "We must increase preparedness with particular focus on catastrophic events"
- "Although we have substantial resources to provide security, these resources are not unlimited. Therefore, as a nation, we must make tough choices about how to invest finite human and financial capital to attain the optimal state of preparedness. To do this we will focus preparedness on objective measures of risk and performance." (emphasis added in red).

The Challenge is:

How does one measure the chance of an event that is rare in its occurrence and extreme in its magnitude?

- Mathematical Statistics provides an answer to this type of question: The extreme value theory

- It is a limiting theorem (similar to Central Limit Theory) that allows for measuring the distribution of maxima of events.

- This approach has been adopted in calculating weather patterns, earthquakes, global warming, etc.

- We are among the first to apply it to terrorist events.

Lets get a little in details

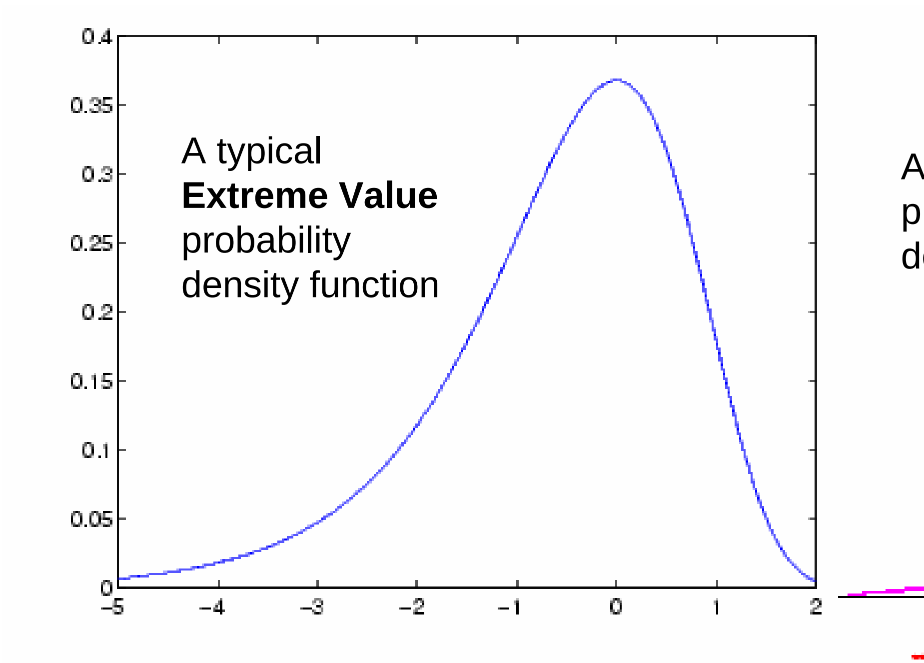
- Suppose X is a random variable that stands for the number of causalities associated with an event, say a terrorist event.

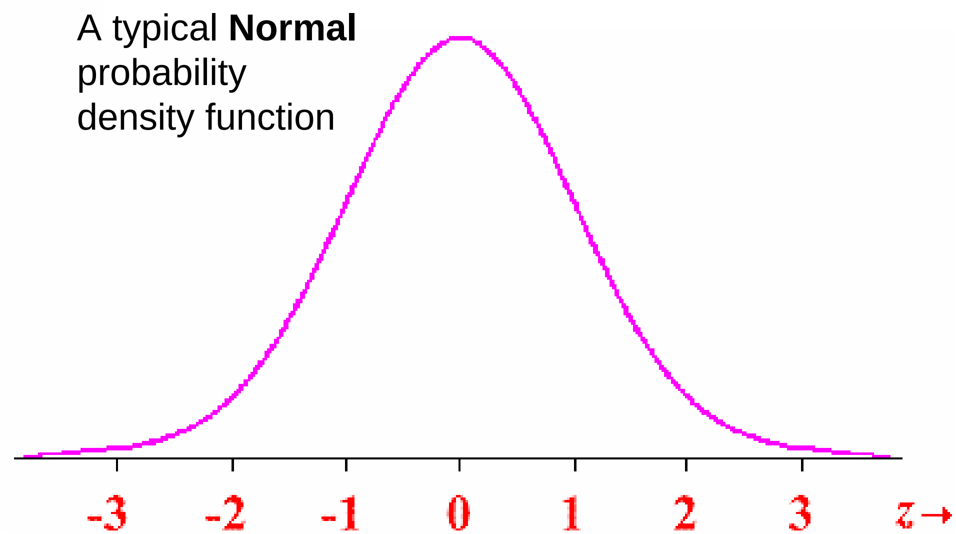
- If the distribution of X, say *F(X)*, is known calculating the probability that *X* exceeds some threshold value is a trivial task.

- But in general we don't know *F(X)*

- Can we estimate *F(X)*?
- Yes and No
- Suppose we estimate *F(X)* by *G(X)*. In general *G(X) is close to F(X) only* near the mode of the distribution.
- But even smallest errors in estimating *F(X)* in the mid part lead to very imprecise predictions of the tail quintiles.
- How do we solve this dilemma?

- By utilizing a theory (Fisher-Tippett theorem) that says,
  - The maxima draws from an independent sample of draws belongs to a specific class of distributions (with fatter tails than normal) regardless of the distribution of the original draws. These are known as the Extreme Value (EV) distributions.
- This lets us estimate the distribution of *Xmax, say h(Xmax),* from which we can predict *Pr(Xmax>x)*





- Note that the Extreme Value density function is skewed to the left.

- Implies that extreme events are more likely to occur than are predicted by a normal density function.

Data

- Our own data: 330 (growing to 600) incidents of chemical nuclear, biological radioactive or nuclear agents (CBRN).

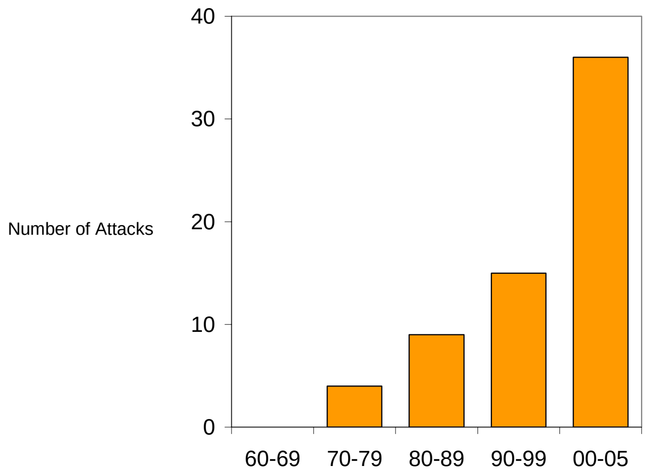
- We analyze this data separately *and* in combination with another data set:
  - MIPT (National Memorial Institute for the Prevention of Terrorism) that has very limited CBRN data but has over 21,000 observations of domestic and international terrorism.

The Most Serious Attacks on Food Chain: 1961-2005

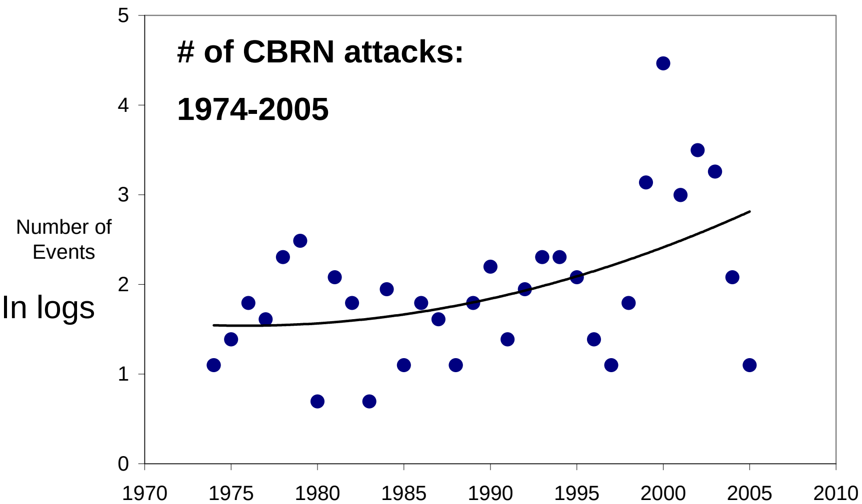
11/19/2003	0	50	About fifty people in more than 20 cities in Italy had to be treated for a variety of ailments including stomach pains, after they drank bottled water that had been injected with either bleach acetone or ammonia.
10/1/2003	0	64	Cao Qianjin threw 500 ml of a pesticide into the reservoir in Ruyang County, Henan. Province, China. Approximately 64 residents were poisoned.
9/23/2003	0	241	Several hundred (317) students and staff at an elementary school in Yueyang, Hunan Province, China, were sent to hospitals, after eating breakfast that had been laced with rat poison. Investigators stated that 241 students and staff showed some signs of poisoning.
12/31/2002	0	111	A supermarket employee in the US poisoned about 250 pounds of ground beef with an insecticide. At least 111 people who fell ill after eating the meat.
June, 2002	0	60	In June 60 students and teachers at a school in Volgograd, Russia, were hospitalized after being poisoned with the salmonella typhi toxin.
5/19/2002	7	47	Seven members of the Johanne Marange Apostolic Church, a Christian fundamentalist group, died and another 47 were taken ill after drinking a tea that had been poisoned.
1/30/2002	unknown	92	In Linxiang city, in China's Hunan Province, 92 children at the Yucai Private (primary) School fell ill after eating their school lunch which had been laced with rat poison. Of the 92, 40 were in serious condition.
8/8/2001	0	120	At least 120 patrons in 16 restaurants were made ill after eating noodles that had been contaminated with rat poison in Ningxiang, Hunan Province, China.
3/8/2000	2	60	Poisoned food was served to hundreds of students at a religious school in Jalaludin, Afghanistan. Two students died and sixty others lost consciousness.
11/3/1999	unknown	48	Approximately 48 people fell ill after eating meat rolls that had been laced with rat poison at a fast food restaurant in Deyang City, Sichuan Province, China.
3/8/1999	0	148	Five people were arrested in China, after putting nitric acid in a popular restaurant's specialty donkey meat soup, poisoning 148 people.
7/25/1998	4	60	Four people died and approximately 60 were hospitalized during a summer festival in Wakayama, Japan, in a case of mass food poisoning that possibly involved the use of cyanide.
1/1/1994	15	53	On New Year's day nine Russian soldiers and at least six civilians died after drinking champagne that had been laced with cyanide. The cyanide-laced champagne was being sold outside of the Russian compounds. Another 53 people, including 11 civilians, were hospitalized.
9/6/1987	19	140	Several fatalities resulted when members of the Philippine Constabulary were poisoned after accepting bags of ice water from an individual during a "fun run." As a result 19 people died and 140 fell ill.
Sep. 1984	0	751	Sometime early in September 1984, members of a religious cult known as the Rajneeshees contaminated salad dressing at ten restaurants in a small town in Oregon, USA. As a result 751 people became sick, there were no fatalities.

Trends in the incidence of Terrorism

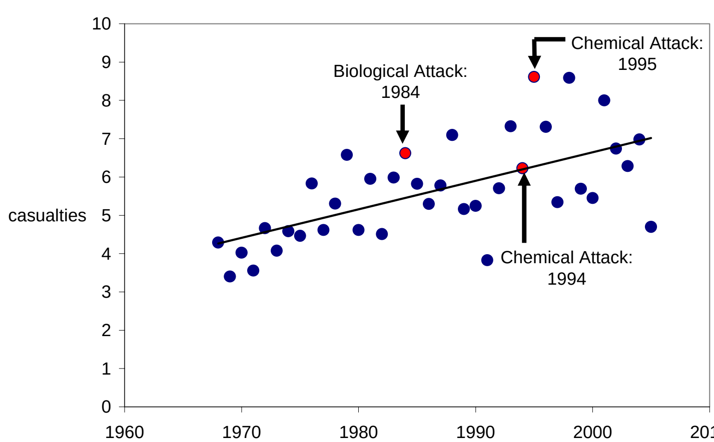
Frequency of Attacks on Food or Water Supply



Number of CBRN Events 1974-2005

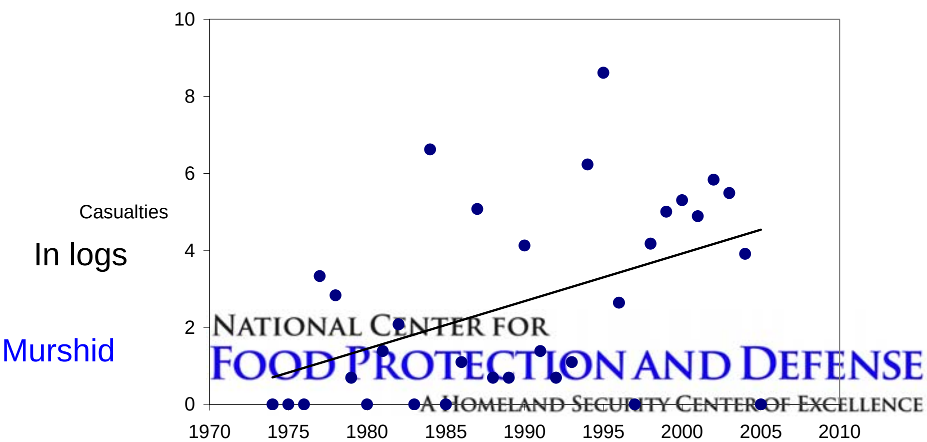


Casualties Resulting From Terrorist Attacks



Max # of casualties on a single day from CBRN attacks: 1974-2005

Maximum Number of Casualties on a Single Day 1974-2005



Source: authors' data and MIPT data

Model Estimation using EVT

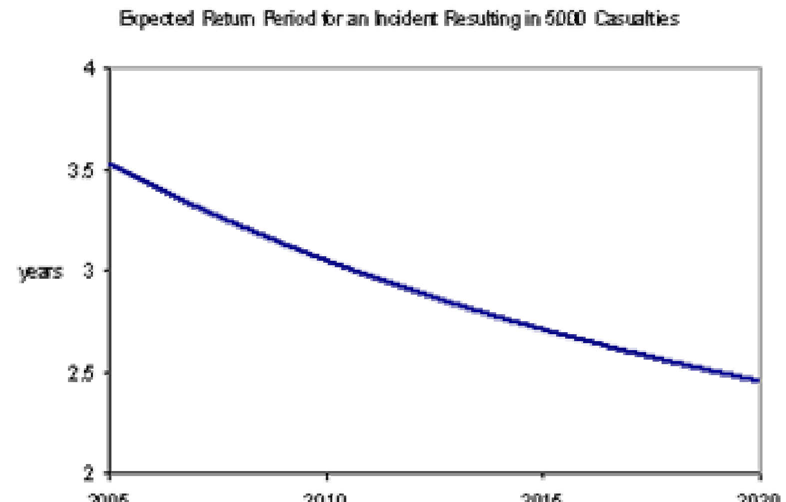
Since there is a trend in the data, estimating the probabilities must take account of this.

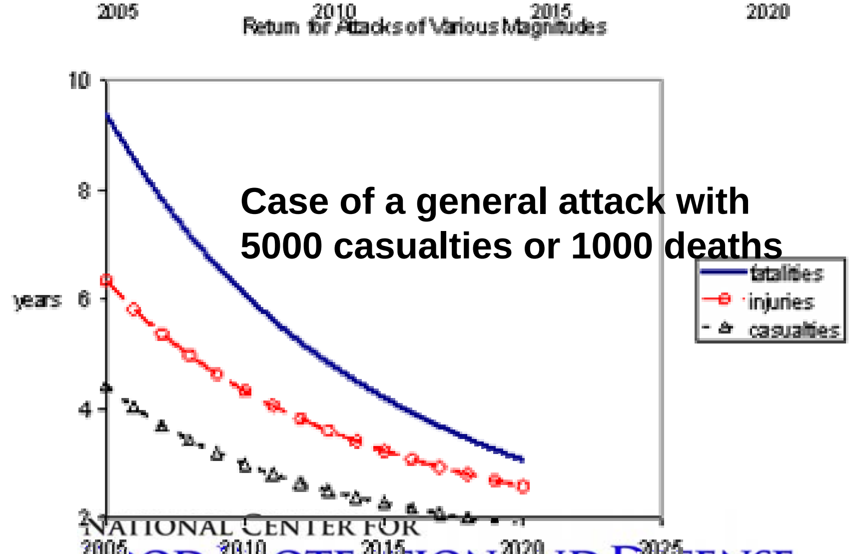
Thus, we allow for parameters of the distribution to depend on time.

Recurrence Period of terrorist events

Case of CBRN attack with 5000 casualties

- Based on our estimated model, we calculate the expected "reoccurrence period" for a catastrophic event.
- **For a CBRN Attack:**
- An event of the scale of Tokyo subway attack (with 5000 casualties) could occur by 2009.
- Note that reoccurrence period is decreasing with time. By 2020 an attack of that magnitude could occur about every 2 ½ years.
- **For a General Attack:**
- The results are even more extreme

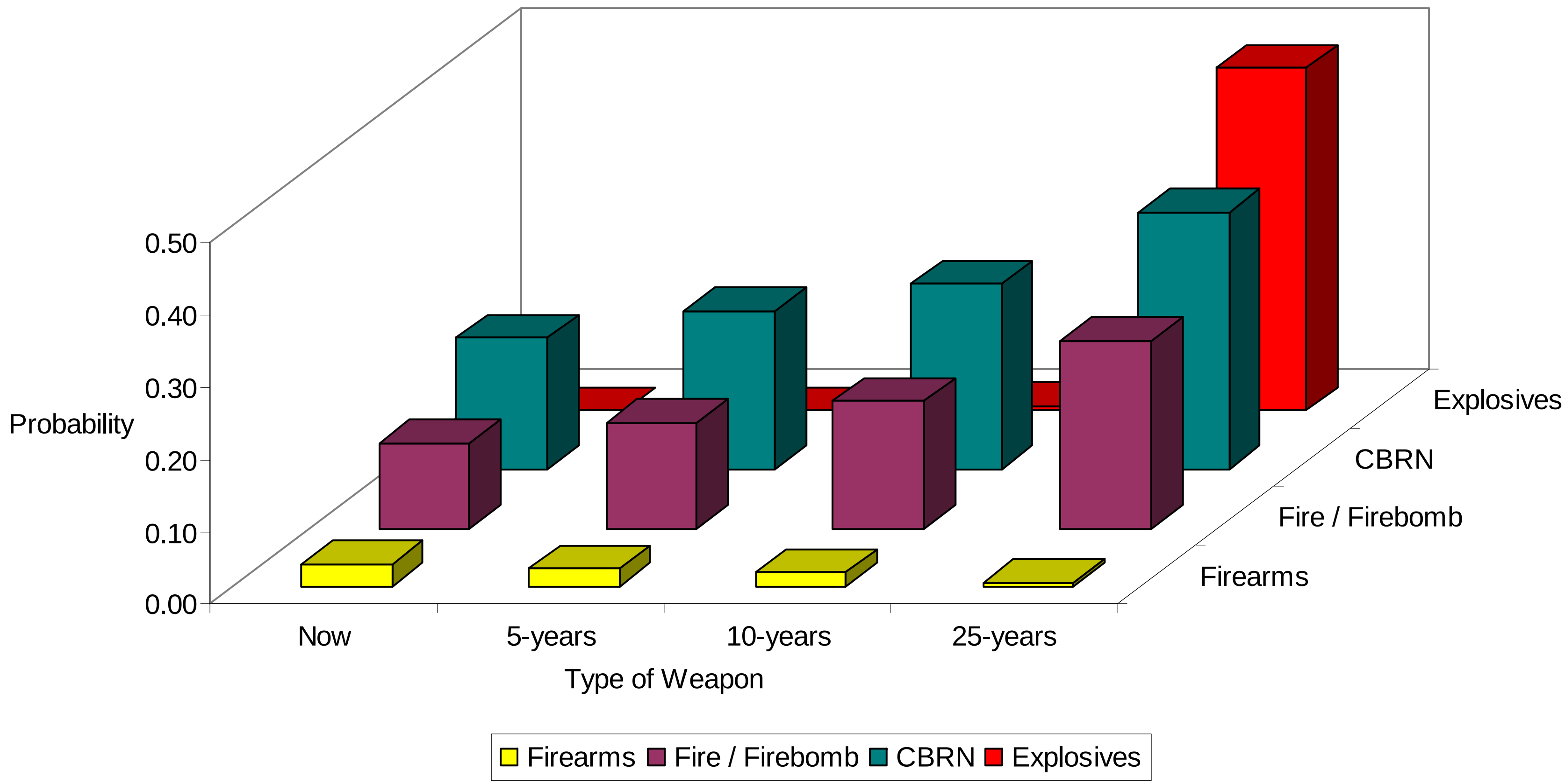




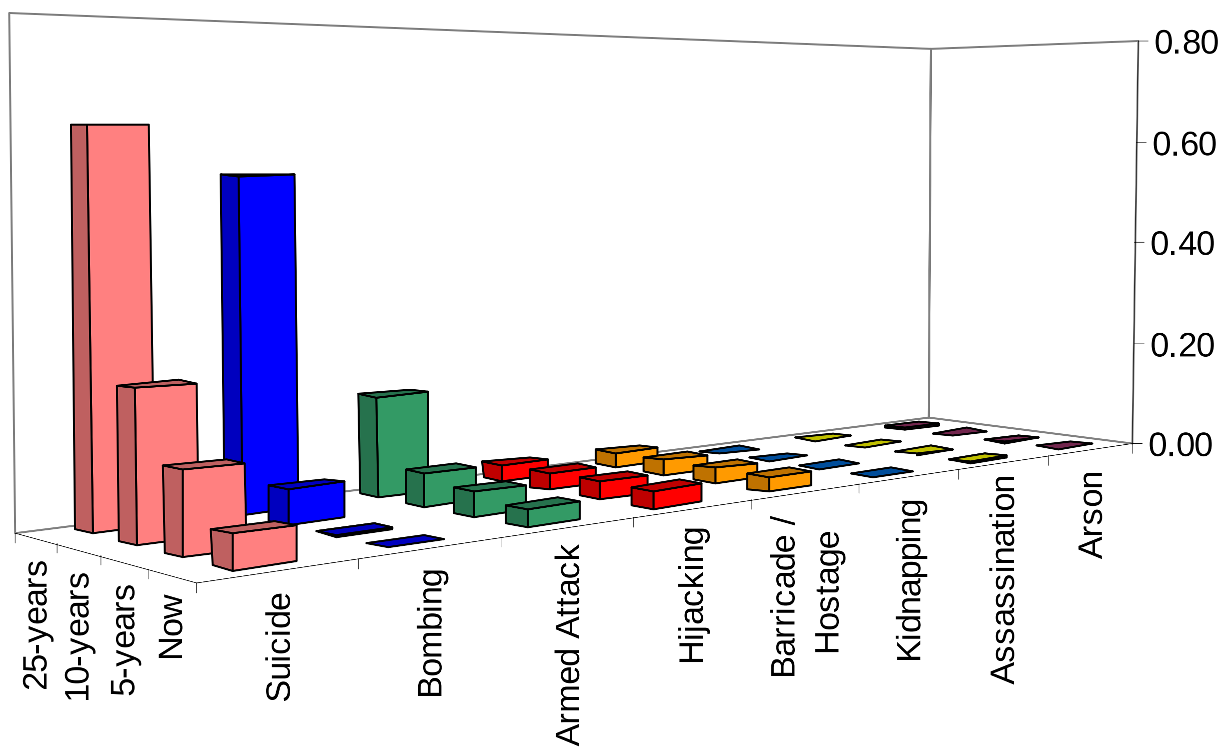
Case of a general attack with 5000 casualties or 1000 deaths

Combining CBRN with MIPT data sets

Forecasted Probability of an Attack at Various Horizons: Attacks Grouped by Type of Weapon



Forecasted Probability of an Attack at Various Horizons; Attacks Grouped by Tactic



Conditional Probabilities

An important question is:

- Given that an Attack with a certain number of casualties would occur, what is the probability that it is of a particular type?

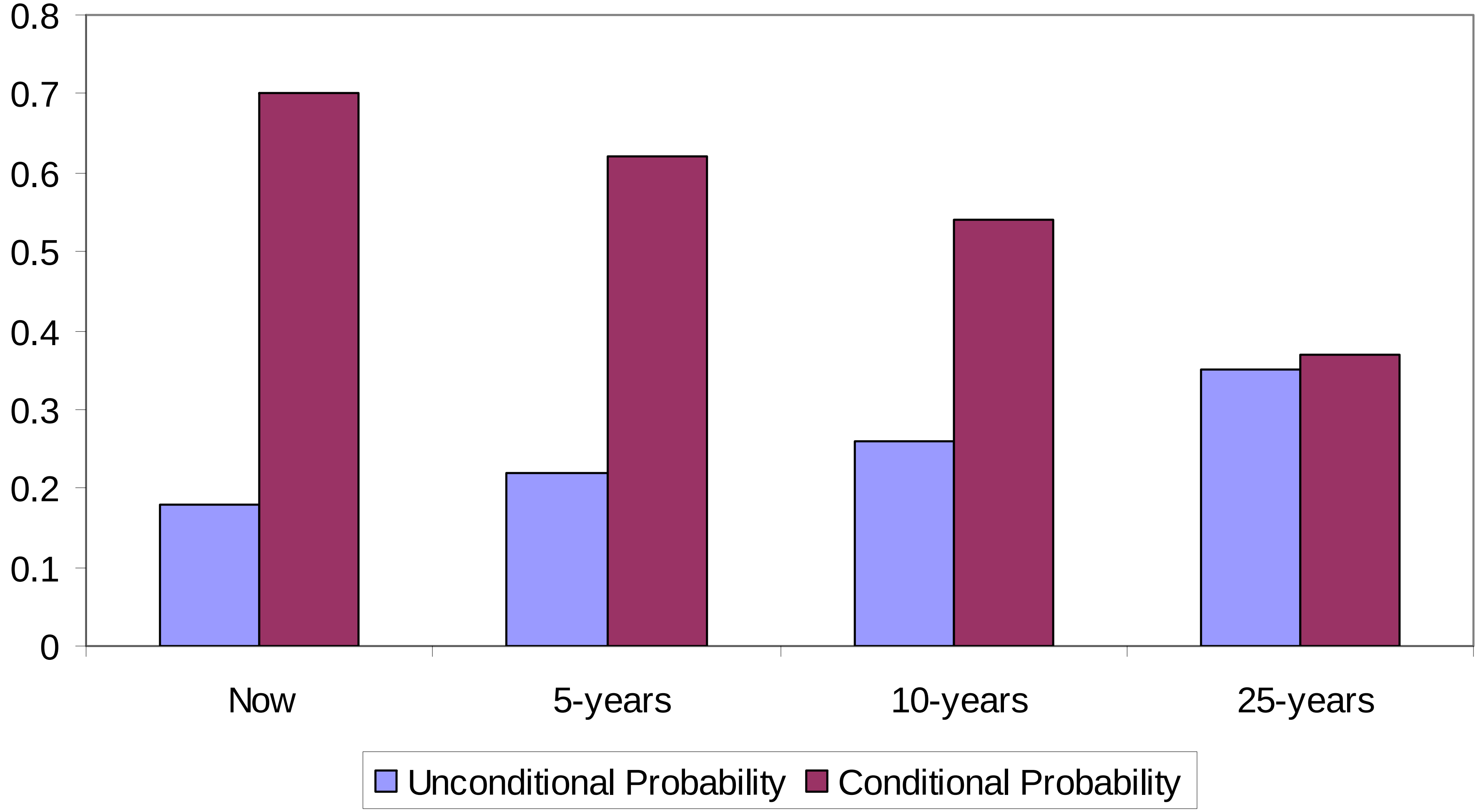
- Question has critical application to other areas of DHS concern, e.g., transportation, logistics, infrastructure.

- But doing conditional probabilities with extreme value distribution is somewhat tricky.

Probability of a CBRN Attack with 5000 casualties at Various Horizons: Conditional vs. Unconditional

	Unconditional Probability	Conditional Probability
Now	0.18	0.70
5-years	0.22	0.62
10-years	0.26	0.54
25-years	0.35	0.37

Probability of a CBRN Attack at Various Horizons: Conditional vs. Unconditional



- Unconditional probability rising, but conditional probability steadily declining.
- Why?
- The time trends in traditional weapons e.g. explosives data is more dominant.
- For CBRN, there is more weight on rare events (e.g. Tokyo subway attack) (heavy right tail) and weaker trend.
- Pattern may change, if distribution of CBRN-attacks show stronger upward trend.

Extensions and Remaining Issues

- We are adding new data (we will have near 600 data on CBRN observations)
- More data may allow us to focus on more specific agents. Yet, can't become too agent-specific!!
  - Reason: Targets substitutability by terrorist.
- Effect of Policy Intervention
  - Our estimates assume continuation of current trends. This may or may not be true.
  - What about the effect of intervention?
  - Have done EV analysis on the spread of BSE in UK. Find significant effects of policy intervention.
  - But BSE data is monthly. Terrorist data is annual. Cannot do the same with annual data.
  - Instead, try cross country analysis of the effect of policy on probability of attacks.

Extensions and Remaining Issues - Continued

- What are the best analogies to study?
  - The event must have the potential to lead to crisis, e.g. large economic or human impact of a rapidly spreading disease (so they simulate terrorist or catastrophic scenarios)
  - Must have data on the event, so we can study it.
  - Must have data on health policy response so we can see how effective policy has been in stopping it.
  - The agent must mutate in short periods of time, so it can simulate the adoptability of terrorists.
- A few potential candidates are:
- SARS? Bird Flu? FMD?

Conclusion

- Acts of terrorism **can** be viewed as probabilistic events.
- Such probabilities **can** be measured even if they occur seldom and are of extreme type.
- Measuring these probabilities is a first step towards rationalizing the use of scarce resources in defending against rare but catastrophic risks such as terrorism.