# Decision making under uncertainty

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*The aim of this seminar is to discuss how decisions are made both individually and collectively, and how uncertainty can be dealt with in this process. It is intended to be different to the lecture, which focussed more strongly on the statistical sides of uncertainty. Here we will look at how decision making is made, and why this can dramatically impact our choice of decisions in simple areas, and by extension in climate change.*

## 1. Individual decisions under uncertainty

We will start with some questions. We want you to answer these alone, without input from others. Please use Socrative to provide your answers (these are anonymous). Note that the probabilities below are the fraction of the time an outcome will happen, so 0.33 means 1 time in 3, or 33 %. These are questions taken (with minimal changes) from a seminal paper by Daniel Kahneman and Amos Tversky (Econometrica 47, p 263, 1979).

In each of questions 1-8 you are talking about *gaining* something, and you should view numerical values as being in UK pounds sterling.

1) Choose between the following

**A:** 2500 with probability 0.33
2400 with probability 0.66
0 with probability 0.01

**B:** 2400 with certainty

2) Now choose between

**C:** 2500 with probability 0.33
0 with probability 0.67

**D:** 2400 with probability 0.34
0 with probability 0.66

3) Now make the choice between

**A:** 4000 with probability 0.8 **B:** 3000 with certainty

4) Choose between

**C:** 4000 with probability 0.2 **D:** 3000 with probability 0.25

5) Would you opt for

**A:** 3 week tour of the USA (p=0.5), Canada and Mexico

**B:** One week tour of the USA (p=1)

6) Would your choice change if you were given these choices

**A:** 3 week tour of the USA (p=0.05), Canada and Mexico

**B:** One week tour of the USA (p=0.1)

7) Now consider how you would decide between

**A:** 6000 with probability 0.45 **B:** 3000 with probability 0.90

8) Or
**C:** 6000 with probability 0.001 **D:** 3000 with probability 0.002

Now lets turn the scenario around a talk about the possibility of losses. In questions 9-12 you are talking about the loss of money.

9) Now make the choice between loosing
**A:** 4000 with probability 0.8 **B:** 3000 with certainty

10) and
**C:** 4000 with probability 0.2 **D:** 3000 with probability 0.25

11) Now decide between the option of loosing
**A:** 6000 with probability 0.45 **B:** 3000 with probability 0.90

12) Or
**C:** 6000 with probability 0.001 **D:** 3000 with probability 0.002

## 1.1. Rational utility in payoffs

Each of the questions above is interesting, because for most of them you can calculate the expected payoff (excepting than in 5 & 6 you might or might not want to visit different places). The standard expectation is that you would take the option that gave you the largest payoff (on average). Lets look at these.

For q1, the expected payoff in A ($P_A$) is

$$P_A = 0{,}33 \times 2500 + 0{,}66 \times 2400 = 2409 \tag{1}$$

and in B is

$$P_B = 2400 \tag{2}$$

That is to say that the payoff in A is larger than B. For Q2 The payoff is

$$P_C = 0{,}33 \times 2500 = 825 \tag{3}$$

and in B is

$$P_D = 0{,}34 \times 2400 = 816 \tag{4}$$

The interesting thing is that in most cases people chose option A in Q1 and option C in Q2. In one case they have made the choice that yields the largest payoff (C), in the other they have not.

However, we can go further than this by talking about the utility of the value that you receive. In particular, if we look at Q1, lets call the utility (essentially the value you place on the return) $u$. The decision to chose B over A says[1]

$$u(2400) > 0{,}33 \times u(2500) + 0{,}66 \times u(2400). \tag{5}$$

The decision to chose C over D tells you that

$$0{,}34 \times u(2400) < 0{,}33 \times u(2500). \tag{6}$$

[1]If you can't recall, in the inequalities below the $>$ symbol means greater than, and the $<$ means less than. The wider side of the symbol always points towards the side that is greater.

Notice that you can rewrite equation 5 by subtraction $0{,}66 \times u(2400)$ from both sides. That means that in the first case you conclude

$$0{,}34 \times u(2400) > 0{,}33 \times u(2500). \tag{7}$$

This means that in the two scenarios you have made exactly the reverse choices. You were not logical (OK, perhaps in the seminar you were logical, but in the original experiments 82 % chose B and 83 % chose C). This does not look like rational decision making!

Now lets look at questions 3 & 4. In this case the 80 % of people chose option B and 65 % chose option C. The utilities can be written as

$$0{,}8 \times u(4000) < u(3000) \tag{8}$$

and

$$0{,}2 \times u(4000) > 0{,}25 \times u(3000) \tag{9}$$

But remember that multiplying both sides of an equation by the same number doesn't change the equation, so if I multiply equation 9 by 4 it simply becomes

$$0{,}8 \times u(4000) > u(3000) \tag{10}$$

In other words, again the scenario is one in which people make completely different choices, even when notionally the underlying utility is the same.

Both of these questions give an example of what is known as the **certainty effect**, that is to see that individuals weight highly a certainty. This may well be a perfectly rational perspective, but it isn't necessarily the one that would be expected. Indeed, while the certainty effect appears at first sight to be a good explanation of the choices people make when faced with gains, it seems to reverse when considering losses.

## 1.2. Rational utility in losses

Questions 9-12 are exactly the same as 3-4 and 7-8, but with the gains converted into losses. If the certainty effect was the explanation for the choices that were made in the earlier questions then we would expect to observe exactly the same patterns when losses are observed. In fact, the complete opposite is observed (and therefore with the same apparent lack of rationality). People are more risk averse when faced with gains, and more risk taking when faced with losses.

# 2. Insurance

Insurance is in an excellent example of a decision taken under uncertainty. We don't know if we will suffer significant losses, but we chose to insure ourself against them anyway. In general we will again pay for certainty. That is to say we will seek to indemnify ourselves almost totally against adverse effects. This is possible (aside from policy excesses) in many cases, but not all.

Here is another hypothetical question from Kahneman & Tversky.

13) You decide that there is no clear preference between insuring your house or not (based on the risks and the premium you pay). i.e. in the above parlance you find the utility of the two outcomes to be equal.

There is then an option to purchase *probabilistic insurance*. This enables you to pay half the premium. If an accident occurs on an odd day of the month, you pay the remainder of the premium, and the accident is covered. If it occurs on an even day of the month then you get your premium back, but must cover the cost yourself.

Remembering that the insurance that costs twice the price but covers 100 % of the time is only marginally valuable, would you purchase this insurance?

# 3. Back to Climate Change

So what has this got to do with Climate Change? At first sight you may think rather little, but actually these experiments provide important insight into decisions that may be made in the climate arena.

In particular, mitigating Climate Change is an example of probabilistic insurance. We must pay money to do it, and in doing so we reduce the chances of catastrophic consequences, but we don't have certainty in obtaining them. We could spend a large quantity of money (or other resources) in mitigating climate, and still have major costs of adaptation in addition. The example given above suggests that we will therefore prefer *not* to pay for the insurance, even if the utility of doing so is greater. This may explain a lot about why it is difficult to convince governments and other agencies to act against climate change.

Coupled with this, Climate Change is presented as a loss. It will cost money to mitigate against it, and it will cost money to adapt to it. Money for mitigation must be spent now, money for adaptation can be committed later. This means that we are faced with a straight probability gamble; *pay 2 % of GDP now with 100 % probability of pay 5 % of GDP later with a 70 % probability* for example (these numbers aren't necessarily accurate, they are just used to make a point). Given the uncertainties here it is easy to take the gamble. There is also evidence **XXX I need to find a reference for this** that individuals tend to prefer immediate gratification, that is that we value the present more highly than the future. This is also where ideas related to the *discount rate* enter the discussion, and this will be covered more in future lectures.

# 4. Forecasting

# 5. False choices

There is also a significant social and political element to choices relating to Climate Change and environmental protection. It is generally acknowledged for example that poor air quality kills tens of thousands of individuals in the UK each year. There are clearly efforts in place to improve this, but they are slow, and have relatively little cost. In contrast, a smaller number of people killed through terrorist incidents often yields rapid, large scale and expensive responses.

As another example, after the horrific events in New York on Tuesday night, president Trump tweated this morning that "We must not allow ISIS to return, or enter, our country after defeating them in the Middle East and elsewhere. Enough!" and "I have just ordered Homeland Security to step up our already Extreme Vetting Program. Being politically correct is fine, but not for this!". This suggests a large scale response to the attack. Indeed, stopping attacks like this has been used as a motivation for the banning of large demographics of individuals from entering the USA. In contrast, after at US Citizen shot hundreds of individuals is Las Vegas, the response was more muted, in particular, while there was outrage and sympathy, there appeared to be little prospect of action.

It is notable that when pollution or guns kill thousands our response is not to ban cars or (in the case of the USA) guns, but when terrorists kill tens to hundreds of people much more dramatic actions are launched. Indeed, the war on terror could have cost in excess of 5 trillions dollars [2].

These again are good examples where are values (or utilities) don't lead to apparently rational choices. Indeed, lives don't seem to have equal worth in the value of protecting them. There may be some rational action in this. For example, air pollution, or extreme weather events tend to take those who are already vulnerable, often with less life left to them. Alternatively, random events, such as gun violence or terrorism cut people down without discrimination. Indeed, in a lecture two years ago the Oxford Philosopher John Broome, argued that when faced with decisions we were using the wrong ruler for value in assessing a financial impact. He suggested that we should use *years of life* instead.

[2] http://nation.time.com/2011/06/29/the-5-trillion-war-on-terror/