

Bayesian Networks for Food Security

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Food security is influenced by a wide variety of factors, e.g. climate, farming and subsidies, business practice, energy costs, politics, etc. When designing policies to promote food security, it is necessary to take account of all the relevant factors. A decision support system needs to be capable of combining these in a coherent way.

Motivation

- Decisions may need to be made under uncertainty, e.g. crop yield, price. *"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"* (FAO, 1996)
- Many elements of the system depend on and affect each other.
- It is impossible for a single decision-maker to be expert in all the topics

What and Why Bayesian Networks?

A Bayesian network is a representation of some parts of a world which allows for the fact that some parts of it are uncertain, and that those uncertainties change depending on other parts of the system. For example, if it is cloudy, the chances of rain are higher.

Construction of a Bayesian network:

Stage one: First define what are the outcomes we are interested in. If there are several, this is called a multi-attribute objective. Then discover precisely where the important sources of the decision maker's uncertainty lie. Experts agree a representation of the system called an **influence diagram**. This shows all the important elements that influence the outcome of interest.

Stage two: Experts views are elicited on how the system is affected by various possible changes, e.g. "if oil prices rise from moderate to high, what do you expect to be the affect on sugar prices?" "I am 90% sure that sugar prices would be high as well. They certainly wouldn't be low." These are called **subjective conditional probabilities**.

Stage three:

The conditional probabilities are added to the network to form a **Bayesian network** – so called after Thomas Bayes, an English mathematician and Presbyterian minister who developed Bayes Theorem which is of mathematical importance in the manipulation of conditional probabilities.

The sugar industry example

Sugar can be used for food or biofuel production, and is grown as beet in the UK and as cane abroad, making it an interesting example.

Influence diagram

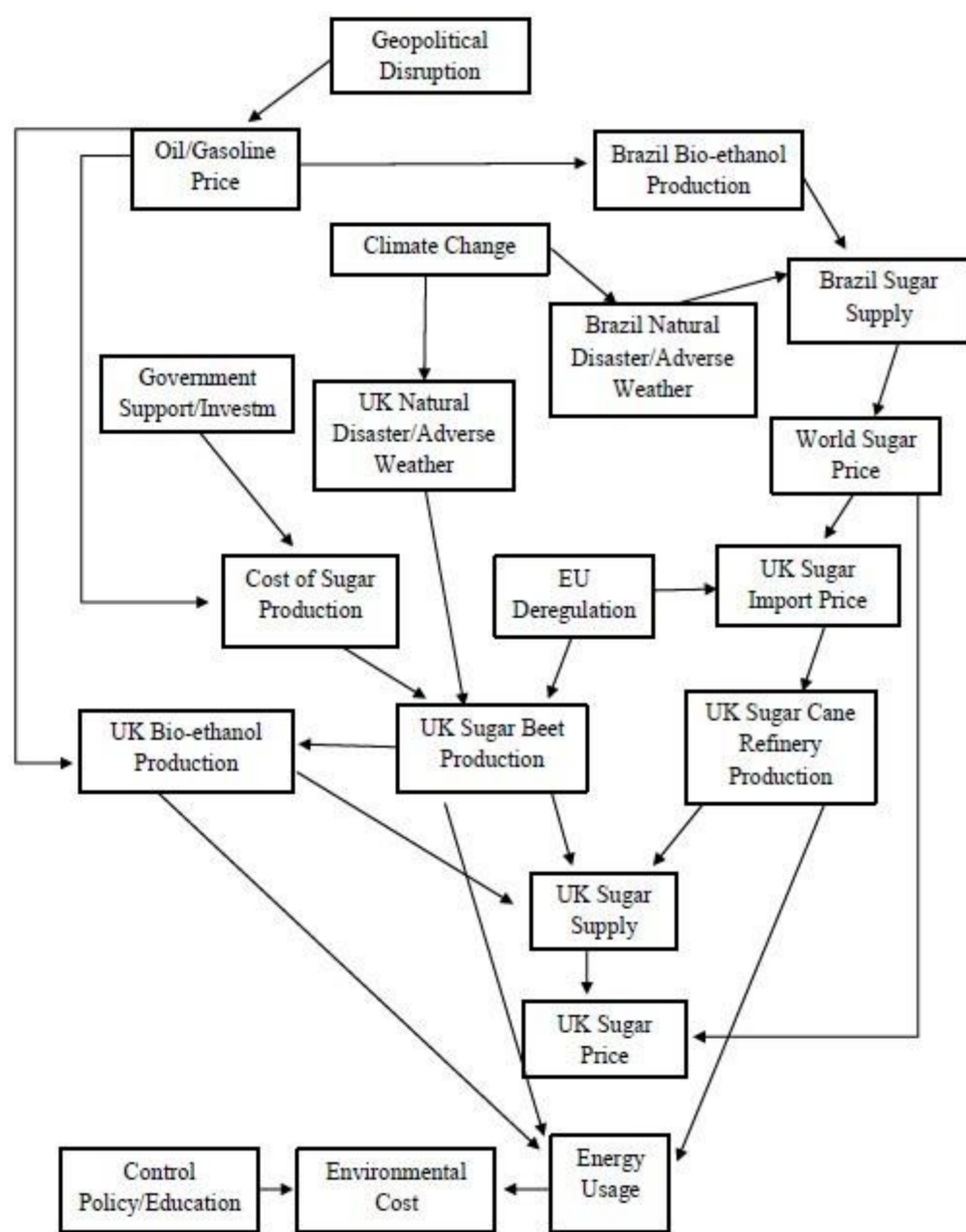


Fig 1: Influence diagram for the UK sugar price.

An influence diagram was drawn up from the publications of Defra and others, and the most important elements were identified with the help of sugar industry experts.

Elicitation

UK food security depends on natural systems, political decisions, business practice, cultural and societal elements. The relationship between some of the elements can be quantified using historic data, e.g. how much price is changed by changes in price of a particular good. In many cases, the best source of information about relationships is given by experts in the particular part of the industry under scrutiny.

This Bayesian network was built using the experts' opinions about how much changes in one variable would affect another. Professor Ben Richardson is an expert in the sugar industry and was a valuable source of information along with several experts from China, giving an international perspective.



Bayesian network

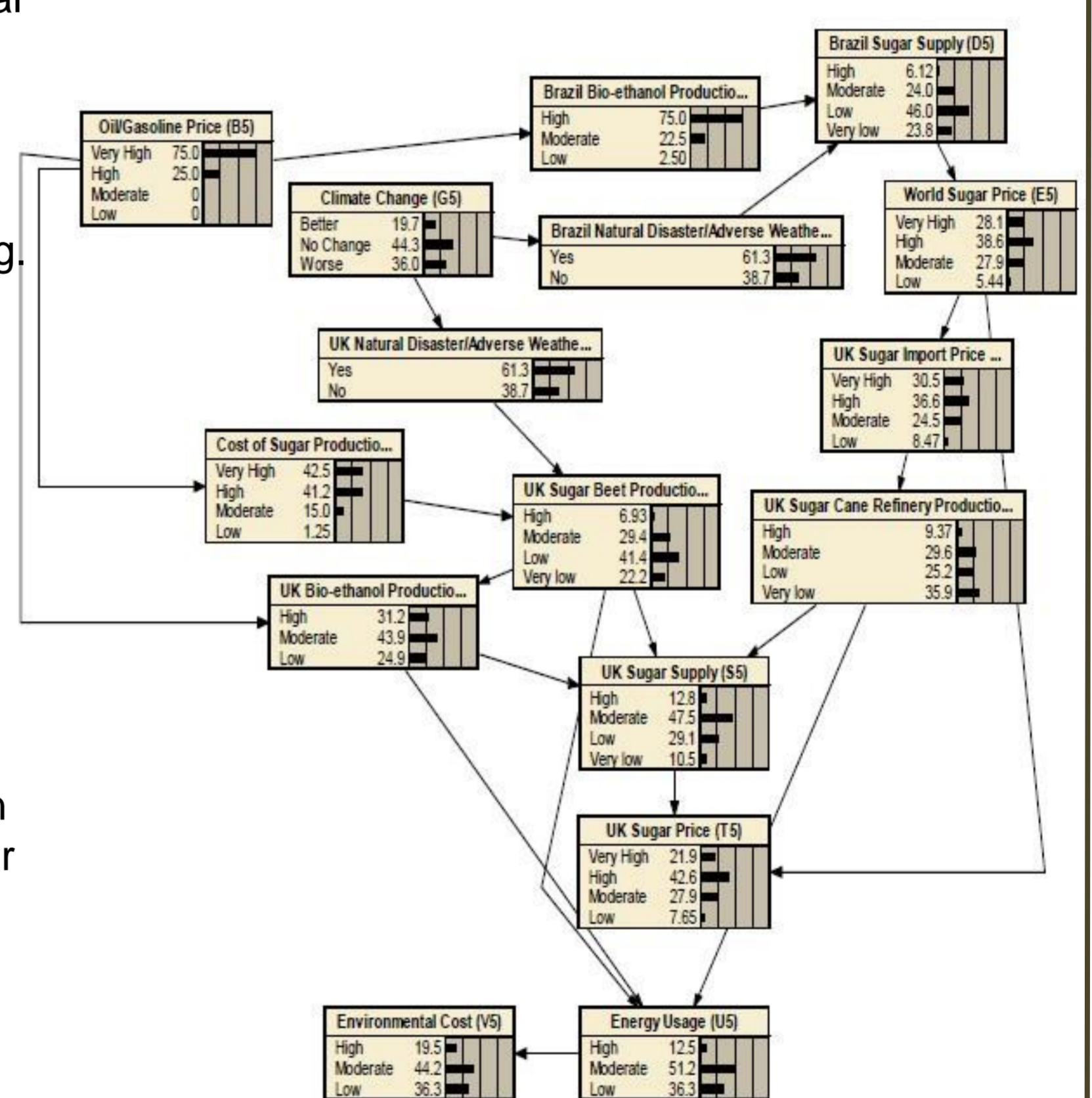


Fig 2: Bayesian network showing the medium term (5 years) effect of a sharp rise in oil price.

After the expert opinion was added, 'What if..?' questions can be asked. This Bayesian network shows how the UK sugar supply and UK sugar price is likely to be affected in the medium term if there was a sharp rise in oil prices.

Jim Smith and Martine Barons are finding out when the probabilistic judgments of different panels of experts can be coherently drawn together and measures for the lack of coherence when full coherence is not possible¹.

References:
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