

Towards UK Decision Support for Food Security

Martine J. Barons

University of Warwick

Martine.Barons@warwick.ac.uk

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- 2 Who are the users?
 - Multi-attribute utility
 - Health
 - Education
 - Social cohesion
 - Probabilistic supply chains
- 3 Constitution and definition of the panels
- 4 Future research

Towards a DSS for UK food security

- EPSRC grant 3 years
- PI Jim Q Smith
- CIs Liz Dowler and Rosemary Collier
- Named visiting researchers Ann Nicholson & Eva Riccomagno
- Building on the theory Jim presented
- Working with end-users Warwickshire County Council Jonathan Horsfield, Andy Davis & colleagues

Food security is...

Definition

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life

FAO (1996). Rome declaration on world food security. Technical report, Food and Agriculture Organisation of the United Nations.

'Sufficient' means the right amount (John Ingram)

'At all times' requires a sustainable solution, not a stop-gap

'Nutritious' quality: not all about calories (Caireen Roberts).

Food security is...

A matter of human rights...

Ensuring access to food for life is one of the defining roles of governments

UK Food Security Assessment: Our approach DEFRA 2009.

International Covenant on Economic, Social and Cultural Rights (Article 11) :human right to grow or buy adequate food.

UK problem seen in rising food bank use.

The report of the All-Party Parliamentary Inquiry into Hunger in the United Kingdom Dec. 2014

Food banks are a humanitarian response; restoration of self-sufficiency is the solution we seek.

Complex

The food system is a complex adaptive system: non-linear interdependencies mean that the effects of interventions are not fully predictable and some may be unforeseeable.

The food system is tied closely to two other complex adaptive systems, the energy and water systems, known as the food-energy-water nexus.

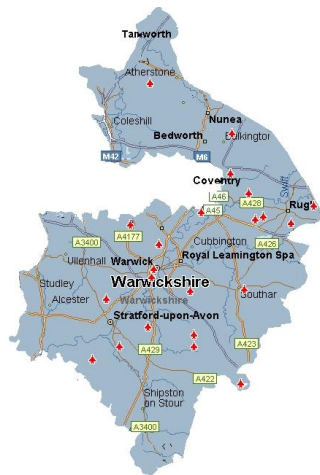
Complex interdependencies between food, health, employment, family composition, location and infrastructure, etc. mean policy decision support is essential.

Who are the users?

Potentially

- Local government, e.g. Warwickshire County Council (WCC)
- Central government
- European government

Warwickshire County Council



Midlands of England; Population 548,729; Area 1,975 km^2

Measurement of food poverty

No agreed measure of household food poverty or food insecurity in UK at present (Rachel Loopstra, Caireen Roberts).

Little data on UK household-level food insecurity.

Holmes B (2008) The influence of food security and other social and environmental factors on diet in the National Low Income Diet and Nutrition Survey. *Proc Nutr Soc.*;

Pilgrim, A., M. Barker, A. Jackson, G. Ntani, S. Crozier, H. Inskip, K. Godfrey, C. Cooper, R. S, and S. S. Group. (2012). Does living in a food insecure household impact on the diets and body composition of young children? Findings from the Southampton women's survey. *J Epidemiol Community Health.*

Some data on UK food bank use.

Measurement of food poverty

Proxy measures developed by DEFRA :

- Index of fruit and vegetable prices relative to all food
- Food prices in real terms
- Household access to food stores

DEFRA 2009 UK food security assessment: detailed analysis

But as Nicole Darmon reminded us, lower prices for fruit and vegetables does not always increase consumption as much as we might expect.

Policy

Development of policy at national level.

Delivery and development of policy at local level.

Multi-attribute utility

Elicited most important attributes for WCC utility: Health; Educational attainment; Social unrest.

Data: Surveillance of children & vulnerable groups through health and educational public services.

Use as surrogate for food security.

Consequences

Consequences of food insecurity: Dowler, E., S. Turner, B. Dobson, and CPAG (2001). *Poverty Bites: Food, Health and Poor Families*. Poverty publication. Child Poverty Action Group, Great Britain.

Food, Health and Poor Families. Poverty publication. Child Poverty Action Group, Great Britain.

- Women in mildly- and moderately- or severely-food insecure households had a typically 'less healthy' diet than women in food-secure households indicated by their lower or higher (as appropriate) consumption of particular foods. The relationship was less clear for men and children. Holmes B (2008) The influence of food security and other social and environmental factors on diet in the National Low Income Diet and Nutrition Survey. *Proc Nutr Soc*.
- BMJ letter on rise of food poverty in UK states in 2013 (with graph) that number of malnutrition-related admissions to hospital has doubled since 2008/9. Taylor-Robinson, D., E. Rougeaux, D. Harrison, M. Whitehead, B. Barr, and A. Pearce (2013).
- Foetal development problems when a pregnant mother is food insecure; children in food insecure households are more likely to be hospitalised and suffer poor health RTI (2014) Current and prospective scope of hunger and food security in America: A review of current research. Technical report, RTI International.

How do we measure this?

- It is reported in the press that UK hospital admissions for malnutrition are rising.
- Hospital Episode Statistics (HES) is a data warehouse containing details of all admissions, outpatient appointments and A&E attendances at NHS hospitals in England.
- Use number of admissions with a primary or secondary diagnosis of malnutrition to monitor rates of malnutrition.

Educational attainment

Impact indicator 7: Attainment gap at age 11 between free school meal pupils and all other pupils Year: 2013 - 2014 (revised) Coverage: England, state-funded schools (including academies and CTCs)

	2014		2013	
	Number of eligible pupils	Percentage of pupils achieving level 4 or above in reading, writing & mathematics	Number of eligible pupils	Percentage of pupils achieving level 4 or above in reading, writing & mathematics
Pupils eligible for free school meals	95,761	63.6	97,973	59.9
All other pupils	457,525	81.6	435,830	78.7
Attainment gap		18.1		18.8

Table: Source (National Pupil Database)

- Food insecure Kindergarten-age children have lower test scores in reading and maths by third grade; at school-age they suffer more mental health problems, lower cognitive development and impaired peer interactions as well as lower grades RTI (2014). Current and prospective scope of hunger and food security in America: A review of current research. Technical report, RTI International

How do we measure this?

- Educational attainment is routinely measured in UK children attending state schools via the SATS (Standard Assessment Tests) and other assessments.
- By far the majority of UK children are educated in state schools and thus the educational assessments carried out there provide a useful proxy to monitor to educational progress and attainment of the nation's child population at various stages and show whether it is stable, improving or deteriorating.
- Department for Education schools performance tables

- Food riots have been recorded in a large number of countries in 2008 and 2011 The Food Crises and Political Instability in North Africa and the Middle East Marco Lagi, Karla Z. Bertrand and Yaneer Bar-Yam New England Complex Systems Institute 238 Main St., Suite 319, Cambridge, MA 02142, USA (Dated: September 28, 2011)
- In the UK, a riot is defined by the Public Order Act 1986 as where 12 or more persons who are present together use or threaten unlawful violence for a common purpose and the conduct of them (taken together) is such as would cause a person of reasonable firmness present at the scene to fear for his personal safety, each of the persons using unlawful violence for the common purpose is guilty of riot.
- UK food riots could occur: in August 2011, thousands of people rioted in several London boroughs and in cities and towns across England. The resulting chaos generated looting, arson, and mass deployment of police; five people died.

How do we measure this?

Riots

Police always attend, so easy to record.

Crime records: Crime in England and Wales Statistical Bulletin, ONS.

The cost: policing plus the ongoing costs of community re-building.

Gross, M. Why do people riot? *Curr. Biol.* 21, 673676 (2011).

Riots Communities and Victims Panel. After the riots: final report of the Riots Communities and Victims panel. URL <http://riotspanel.independent.gov.uk/>

Toby P. Davies, Hannah M. Fry, Alan G. Wilson & Steven R. Bishop (2013) A mathematical model of the London riots and their policing *SCIENTIFIC REPORTS* 3 : 1303 DOI: 10.1038/srep01303

- Let (X_1, X_2, \dots, X_n) be discrete random variables
- if A , B and C are disjoint subsets of X_1, X_2, \dots, X_n , a conditional independence statement has the form *A is independent of B given C*
- in symbols $A \perp\!\!\!\perp B \mid C$

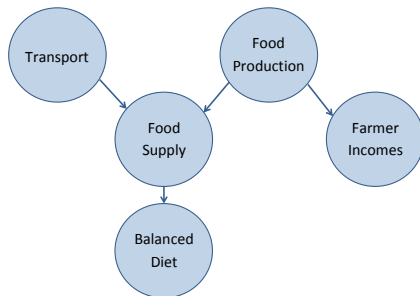


Figure: In this illustrative example, Balanced Diet depends on Food Supply. Food Supply depends on Food Production, which also dictates Farmer Incomes. Food Supply is also dependent on the ability to transport the food from the production site to where it is needed. Food Production and Transport are called the parents of Food supply. The sequence Transport - Food Supply - Balanced Diet is a serial connection since there is a causal connection and if Food Supply is known, then there is sufficient information about Transport that Balanced Diet adds no further information. The

Bayesian Networks: definition

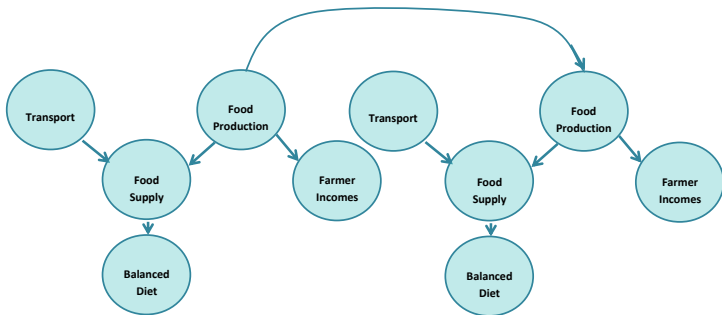
A Bayesian Network on the set of measurements (X_1, X_2, \dots, X_n) is

- a set of $(n - 1)$ conditional independence statements
- together with a Directed Acyclic Graph \mathcal{G}
- The set of vertices $V(\mathcal{G})$ of \mathcal{G} is (X_1, X_2, \dots, X_n)
- The indices i on the vertices are ordered
- The parent set \mathcal{Q} is a set of vertices whose indices lie in a proper subset $Q_i \subseteq \{1, 2, \dots, i - 1\}$, possibly empty
- The remainder set $R_i \subseteq \{\{1, 2, \dots, i - 1\} \setminus Q_i\}$
- directed edge for X_i to X_j is in $E(\mathcal{G})$ iff $i \in Q_j, 1 \leq i, j \leq n$

- A Bayesian Network is a simple and convenient way of representing a factorisation of a joint probability density function of a vector of random variables $\mathbf{X} = (X_1, X_2, \dots, X_n)$.
- Bayes' theorem says that the joint density function can be factorised as a product $f(\mathbf{x}) = \prod_{i=1}^n f_i(x_i | x_1, x_2, \dots, x_{i-1})$ where $f_i(x_i | x_1, \dots, x_{i-1})$ denotes the conditional density of x_i given its predecessors.
- When all the components of (X) are independent we have $f(\mathbf{x}) = \prod_{i=1}^n f_i(x_i)$

Dynamic Bayesian Networks

If we believe that the value of a random variable influences its own value at a future time, the DAG structure is lost. We represent this by producing a BN for each time slice and adding links between the variable at time t and time $t+1$. In this illustrative example, food production this season is influenced by food production last season

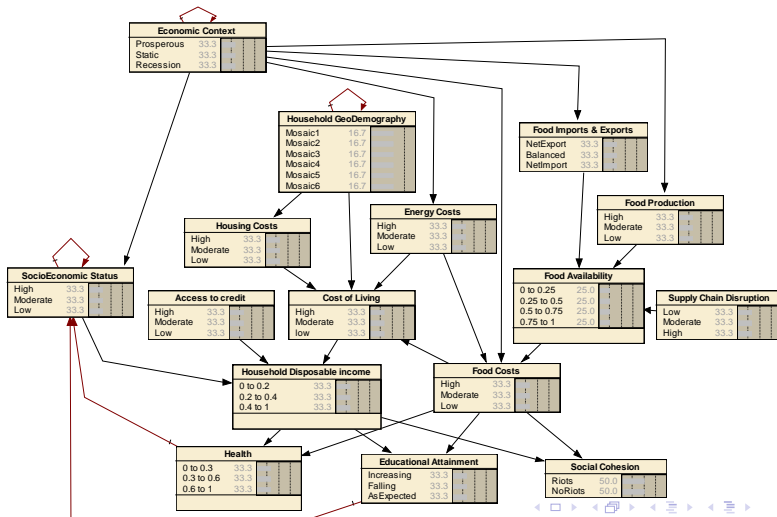


DBNs for Decision Support

- Graphical representation accessible to domain experts
- faithful representation of known interdependencies
- Captures uncertainty rigorously
- Can update beliefs in event of new evidence
- captures Decision-makers priorities through expected utility maximisation
- Can be interrogated
- Integrating decision support system draws together expert panels

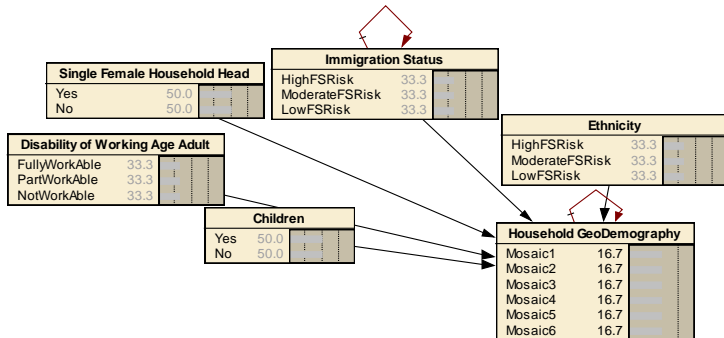
Food Poverty

Using available literature, produced a plausible representation of the system. Since this is an integrating decision support system, there are other models underlying the nodes seen here.



Food Poverty

Household demography is a combination of many factors; those known to be linked to household food security are here



Conditional probabilities

We need to be able to define a conditional probability for each of the combinations of levels of each variable

Node: HouseholdDemography

Chance % Probability

Apply OK

Reset Close

Single Female Household Head	Children	Immigration	Status	Ethnicity	Household Demography	Mosaic1	Mosaic2	Mosaic3	Mosaic4	Mosaic5	Mosaic6
Yes	Yes	HighFSRrisk	HighFSRrisk	HighFSRrisk	Mosaic1						
Yes	Yes	HighFSRrisk	HighFSRrisk	HighFSRrisk	Mosaic2						
Yes	Yes	HighFSRrisk	HighFSRrisk	HighFSRrisk	Mosaic3						
Yes	Yes	HighFSRrisk	HighFSRrisk	HighFSRrisk	Mosaic4						
Yes	Yes	HighFSRrisk	HighFSRrisk	HighFSRrisk	Mosaic5						
Yes	Yes	HighFSRrisk	HighFSRrisk	HighFSRrisk	Mosaic6						
Yes	Yes	HighFSRrisk	ModerateFSRrisk	ModerateFSRrisk	Mosaic1						
Yes	Yes	HighFSRrisk	ModerateFSRrisk	ModerateFSRrisk	Mosaic2						
Yes	Yes	HighFSRrisk	ModerateFSRrisk	ModerateFSRrisk	Mosaic3						
Yes	Yes	HighFSRrisk	ModerateFSRrisk	ModerateFSRrisk	Mosaic4						
Yes	Yes	HighFSRrisk	ModerateFSRrisk	ModerateFSRrisk	Mosaic5						
Yes	Yes	HighFSRrisk	ModerateFSRrisk	ModerateFSRrisk	Mosaic6						
Yes	Yes	HighFSRrisk	LowFSRrisk	LowFSRrisk	Mosaic1						
Yes	Yes	HighFSRrisk	LowFSRrisk	LowFSRrisk	Mosaic2						
Yes	Yes	HighFSRrisk	LowFSRrisk	LowFSRrisk	Mosaic3						
Yes	Yes	HighFSRrisk	LowFSRrisk	LowFSRrisk	Mosaic4						
Yes	Yes	HighFSRrisk	LowFSRrisk	LowFSRrisk	Mosaic5						
Yes	Yes	HighFSRrisk	LowFSRrisk	LowFSRrisk	Mosaic6						
Yes	Yes	ModerateFSRrisk	HighFSRrisk	HighFSRrisk	Mosaic1						
Yes	Yes	ModerateFSRrisk	HighFSRrisk	HighFSRrisk	Mosaic2						
Yes	Yes	ModerateFSRrisk	HighFSRrisk	HighFSRrisk	Mosaic3						
Yes	Yes	ModerateFSRrisk	HighFSRrisk	HighFSRrisk	Mosaic4						
Yes	Yes	ModerateFSRrisk	HighFSRrisk	HighFSRrisk	Mosaic5						
Yes	Yes	ModerateFSRrisk	HighFSRrisk	HighFSRrisk	Mosaic6						
Yes	Yes	ModerateFSRrisk	ModerateFSRrisk	ModerateFSRrisk	Mosaic1						
Yes	Yes	ModerateFSRrisk	ModerateFSRrisk	ModerateFSRrisk	Mosaic2						
Yes	Yes	ModerateFSRrisk	ModerateFSRrisk	ModerateFSRrisk	Mosaic3						
Yes	Yes	ModerateFSRrisk	ModerateFSRrisk	ModerateFSRrisk	Mosaic4						
Yes	Yes	ModerateFSRrisk	ModerateFSRrisk	ModerateFSRrisk	Mosaic5						
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Yes	Yes	ModerateFSRrisk	LowFSRrisk	LowFSRrisk	Mosaic4						
Yes	Yes	ModerateFSRrisk	LowFSRrisk	LowFSRrisk	Mosaic5						
Yes	Yes	ModerateFSRrisk	LowFSRrisk	LowFSRrisk	Mosaic6						

Variable	Levels	%age with food insecurity
National average		14.5
Household composition		
HH with children		20
Single female head of household	More prevalent than single male or married couples	?
Grandchild	Grandparents more insecure, grandchildren more secure	?
Socio-economic status		
Low income from paid employment and other sources	\geq 185% FPL	7
	\leq 100% FPL	41
Job loss or underemployment		?
Educational attainment	Less than high school	42.4
	High school degree 29.6	
	some College	24.5
	Bachelors or higher	8.1
Disability		
	Prevents workforce participation	33.5
	Could work with appropriate accommodations	24.8
Ethnicity	African American, American Indian Hispanic	?
Immigration status	estimated twice as high as non-immigrant	?
health status	Bi-directional - causes and caused by food insecurity	?
Geography		
	More than 0.5 miles from grocery store and no vehicle, 5.4% pop.	
	Low-income area more than 1 mile from grocery store, 4.1% pop.	
Housing costs		
	\geq 30% income	?
	\$100 greater than median leads to	
	21 % greater odds of food insecurity	?

Table: USA Food Insecurity Variables, percentage with food insecurity. Other factors include non-standard work arrangements e.g. multiple part-time jobs can often lead to unstable income and food insecurity. Individuals' financial management skills. Exposure to violence through mental health. Social capital increases coping skills

Quality of Life in Warwickshire 2013-14

Mosaic UK is Experian's system for geodemographic segmentation classification of UK households derived from consumer household and individual data collated from a number of governmental and commercial sources.

How do food security risk factors map to Mosaiscs?

How is UK different from USA? (Caireen Roberts)

Percentage of households in Mosaic Groups	North Warwickshire	Nuneaton & Bedworth	Rugby	Stratford-on-Avon	Warwick	Warwickshire
Total Households, All Groups	26,866	51,021	43,376	54,304	60,172	235,739
A Residents of isolated rural communities	6.6%	0.2%	3.7%	13.1%	1.7%	4.9%
B Residents of small and mid-sized towns with strong local roots	16.8%	6.6%	11.4%	16.6%	5.8%	10.8%
C Wealthy people living in the most sought after neighbourhoods	0.4%	0.1%	1.0%	4.4%	7.7%	3.2%
D Successful professionals living in suburban or semi-rural homes	13.9%	8.1%	13.5%	25.8%	14.1%	15.4%
E Middle income families living in moderate suburban semis	12.9%	14.2%	12.7%	5.9%	13.6%	11.7%
F Couples with young children in comfortable modern housing	3.5%	6.6%	10.8%	11.1%	11.0%	9.2%
G Young, well-educated city dwellers	0.7%	0.3%	0.8%	0.8%	16.0%	4.6%
H Couples and young singles in small modern starter homes	3.4%	5.3%	8.8%	3.1%	4.7%	5.1%
I Lower income workers in urban terraces in often diverse areas	1.7%	11.3%	8.0%	0.1%	0.7%	4.3%
J Owner occupiers in older-style housing in ex-industrial areas	14.9%	16.3%	8.0%	3.9%	5.0%	8.9%
K Residents with sufficient incomes in right-to-buy social houses	13.2%	12.7%	5.2%	4.0%	5.9%	7.6%
L Active elderly people living in pleasant retirement locations	1.6%	2.8%	4.8%	5.8%	5.3%	4.3%
M Elderly people reliant on state support	7.3%	6.3%	6.0%	4.3%	4.4%	5.4%
N Young people renting flats in high density social housing	0.7%	2.7%	2.2%	0.3%	1.7%	1.6%
O Families in low-rise social housing with high levels of benefit need	2.4%	6.3%	3.1%	0.6%	2.5%	3.0%

Source: Experian, Warwickshire Observatory, 2012

Calculation of consumer prices index

Measure of purchase, not consumption (Liz Dowler); takes no account of differing eating of low income families (Nicole Darmon, Caireen Roberts, Liz Dowler)

Basket

The food part of the CPI basket of goods is divided into : Bread and Cereals; Meat; Fish; Milk, Cheese and Eggs; Oils and Fats; Fruit; Vegetables; Sugar, Jam Syrups, Chocolate and Confectionery; Coffee, Tea and Cocoa; Mineral Waters, Soft Drinks and Juices.



Calculation of consumer prices index

- Need a probabilistic model of supply for each food category
- Sugar category DBN well developed
- Ann Nicholson's exchange student worked on Fish DBN
- Warwick student working on meat DBN - building on supply network from Angela Druckman's event
- Keen to explore more suitable, probabilistic modelling

The World Sugar Market

UK perspective on the world sugar market

World sugar

- Brazil is the world price-setter for cane sugar.
- sugar can be used for biofuel - two markets.

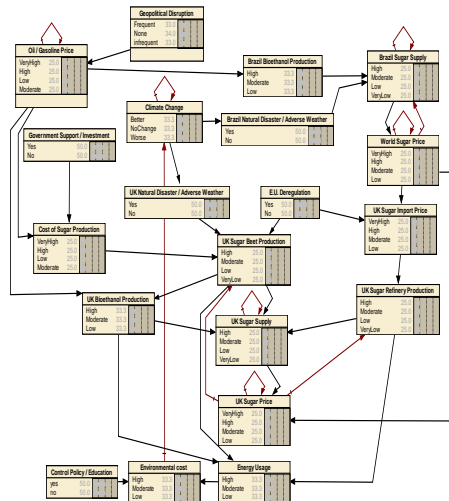
UK sugar

- UK produces sugar beet.
- UK imports cane sugar.

Software

- Netica software (Norsys Software Corp)
- *Dynamic* Bayesian network.

Naïve model of Sugar Supply

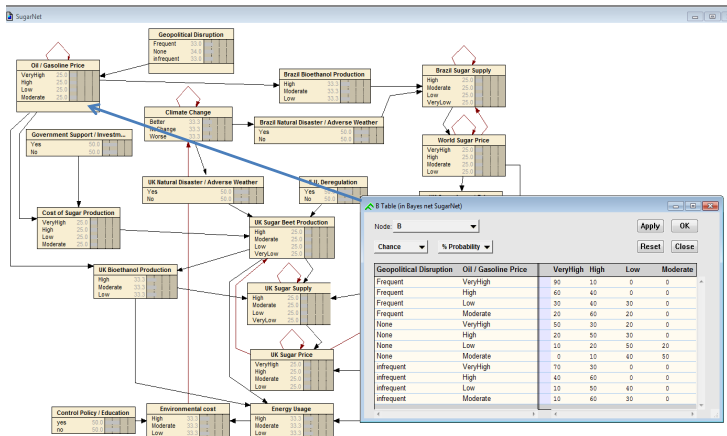


- Variables identified from research literature.
- List refined with domain experts.
- Conditional probabilities by domain experts
- Dynamic Bayesian Networks for decision support and sugar food security, Martine J. Barons, Xiaoyan Zhong and James Q. Smith, Applied Artificial Intelligence. CRiSM report 14-18

Working with a local expert

Conditional probability tables elicited from Warwick Food GRP member, Dr Ben Richardson, expert in Brazil sugar market.

Note: Red loops indicate an influence from the variable to itself at a future time point



What-if analysis

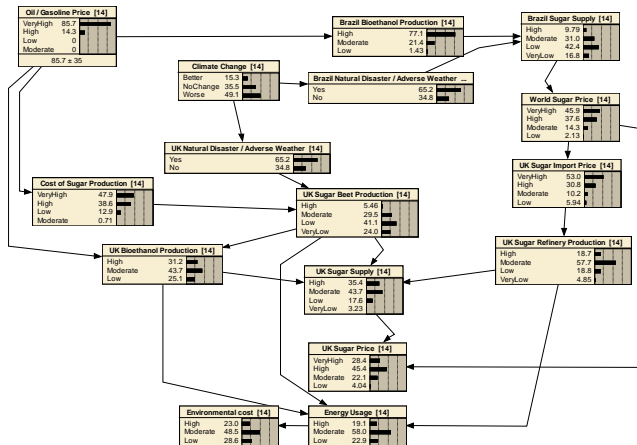
- Any event or combination of events can be examined.
- Set probability of event to 100% to examine its effects.
- Dynamic Bayesian Network - so unfold in time.

Example

- Geopolitical disruption leading to very high oil prices.
- Examine effect on UK sugar price.
- Estimate proportion of UK households in food poverty before and after.

Geopolitical disruption and very high oil price

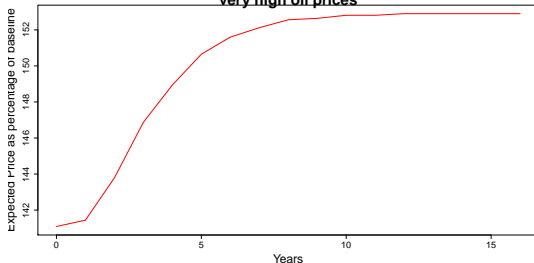
15-year effect



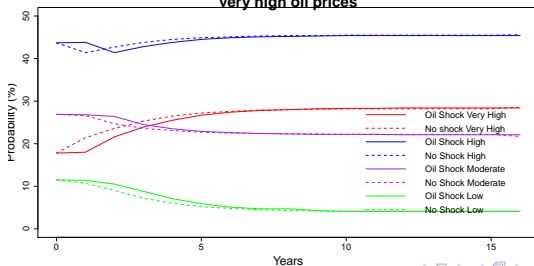
- High oil price persists.
- Increased probability of very high world sugar price, high UK sugar supply & high UK sugar price.

Effect on UK sugar price over time

Expected UK sugar price following a geopolitical disruption and very high oil prices



Probability for UK sugar prices following a geopolitical disruption and very high oil prices



Assumptions

Under the scenario of Geopolitical disruption leading to very high oil price

- Assuming the levels of price increases produced by the model
- Using the consumer prices index

Results

- Sugar and its derivatives contribute 10% to the cost of the food element
- UK households spending more than 20% of disposable income (income after housing costs) rose from 10% to 20% following the event

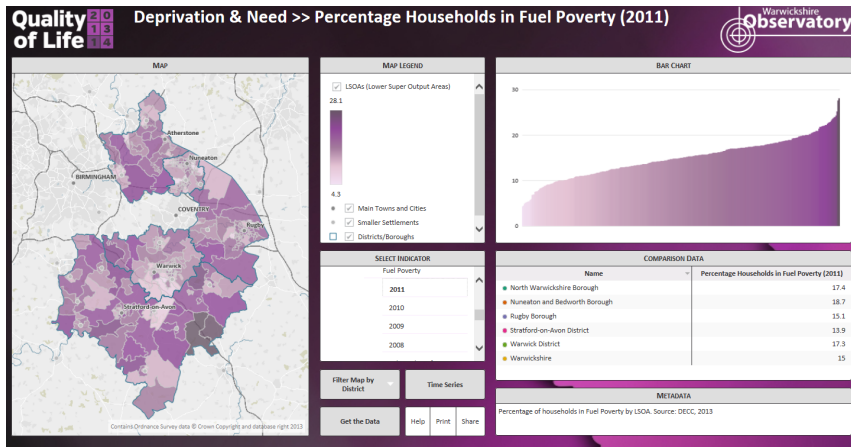
For county Council food security

- Largely paper-based.
- Displays *current* situation/past situations presented to Government/Local Government through graphs & maps.
- But *no annotated predictions* of impact on poor of future events.
- Or *impact of central government changes* in legislation or evaluations of *effectiveness of different implementations* of changes.

Plan Use their standard GUI with our probabilistic technologies to better support decision-making.

Current data visualisation

The type of data visualisation used at present:



http://maps.warwickshire.gov.uk/iareports/qol2013/deprivation_and_need/

Constitution and definition of the panels

Returning to the IDSS, panels required on

- Health
- Education
- Social cohesion
- economy
- household demography / mosaics
- cost of living
- household disposable income
- household access to finance

Each would receive background information from the same sources, e.g. relevant weather information

UK data sources

Variable	Data source	measurement
Health	Hospital Episode Statistics	Admissions with malnutrition & food-related excess mortality
Education	DfE school performance tables	SATs results and GCSE results relative to expected
Social cohesion	ONS	Crime in England and Wales Statistical Bulletin
Household disposable income	ONS	Quintiles median
Food availability	DEFRA	Food statistics pocketbook
Socioeconomic status	ONS	SES in standard reduction to 4 categories inc unemployed
Tax & SS	ONS	Change in household income due to tax or benefit.
Gross Income	ONS	Income quintiles / tertiles
Employment	ONS	UK Labour Market monthly statistical bulletin (from surveys)
Cost of living	ONS	CPI
Housing costs	ONS	CPI
Energy costs	ONS	CPI
Food Costs	ONS	CPI (inc. Basket of food)
Household demography	ONS	UK Families and households, annual statistical bulletin (from
Children	ONS	UK Families and households, annual statistical bulletin (from
Disability (Adult)	ONS	Key Statistics and Quick Statistics for local authorities in the
Single female head	ONS	UK Families and households, annual statistical bulletin (from
Immigration status	ONS	Key Statistics and Quick Statistics for local authorities in the
Ethnicity	ONS	Key Statistics and Quick Statistics for local authorities in the
Tenure of home	ONS	Key Statistics and Quick Statistics for local authorities in the
Geography	DEFRA	Statistical Digest of Rural England
Geography	ONS	Rural and urban areas: comparing lives using rural/urban clas
Food balance of trade	DEFRA	Food statistics pocketbook 2014 page 10 food chain
Supply chain disruption	DEFRA	report FO0108 Resilience of the food supply to port disruption
Food production	DEFRA	Farming statistics Provisional crop areas, yields and livestock
Access to credit	Bank of England	Trends in Lending
Access to credit	Bank of England	Credit union annual statistics
Access to credit	Bank of England	Money and Credit statistical release: Part two: Lending to inc
Economic indicators	ONS	Key Figures included Prices, Inflation and Productivity, Labour National Accounts Economic Activity, Health, Population and

Future work

- The theory for the generic technique has been developed and is being **written up**. Coherent Inference for Integrated Decision Support Systems *Jim Q. Smith, Martine J. Barons & Manuele Leonelli*. In preparation
- Applying any generic technique to a specific application always brings new challenges; UK IDSS in preparation *Martine J. Barons & James Q. Smith 2015*
Dynamic Bayesian Networks for UK food security decision support (in preparation)
- Map food security to UK Mosaics
- Determine which ethnic groups are more vulnerable to food insecurity (and why?)
- Uncertainty handling, building on Manuele's work *Manuele Leonelli, James Q. Smith (2013)* Using graphical models and multi-attribute utility theory for probabilistic uncertainty handling in large systems, with application to the nuclear emergency management, ICDEW, pp.181-192, 2013 IEEE
- Extend to EU / global

J.Q.Smith@warwick.ac.uk

Martine.Barons@warwick.ac.uk

go.warwick.ac.uk/MJBarons



FOOD

THE UNIVERSITY OF
WARWICK

EPSRC
Engineering and Physical Sciences
Research Council

Warwick
Statistics