




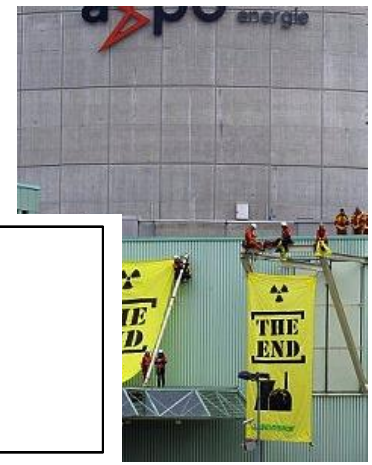
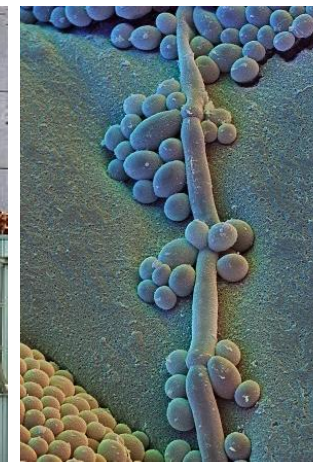

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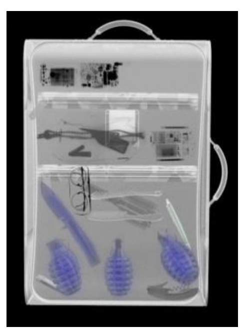
Mapping conditional scenarios for knowledge structuring in tail dependence elicitation: A case study on innovation and risk in the UK higher education sector

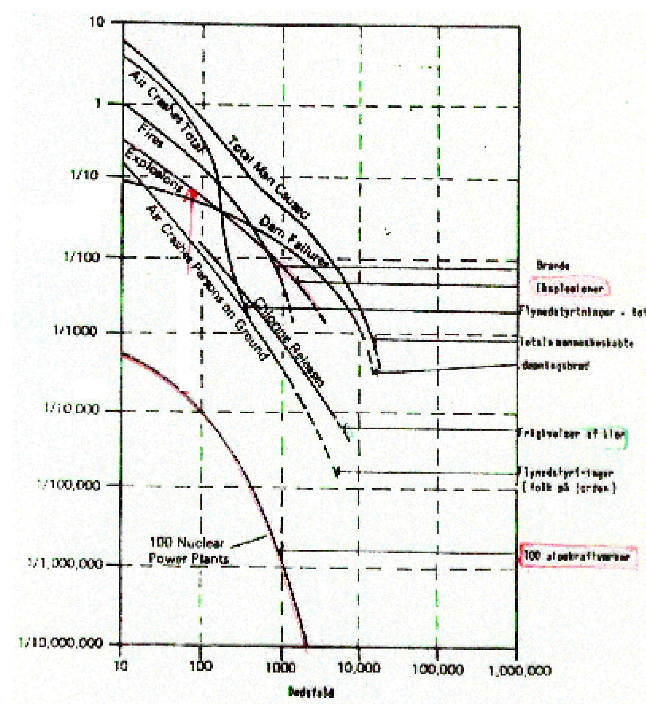
Christoph Werner | University of Strathclyde, UK | COST Conference, Espoo | 25th -27th April 2017

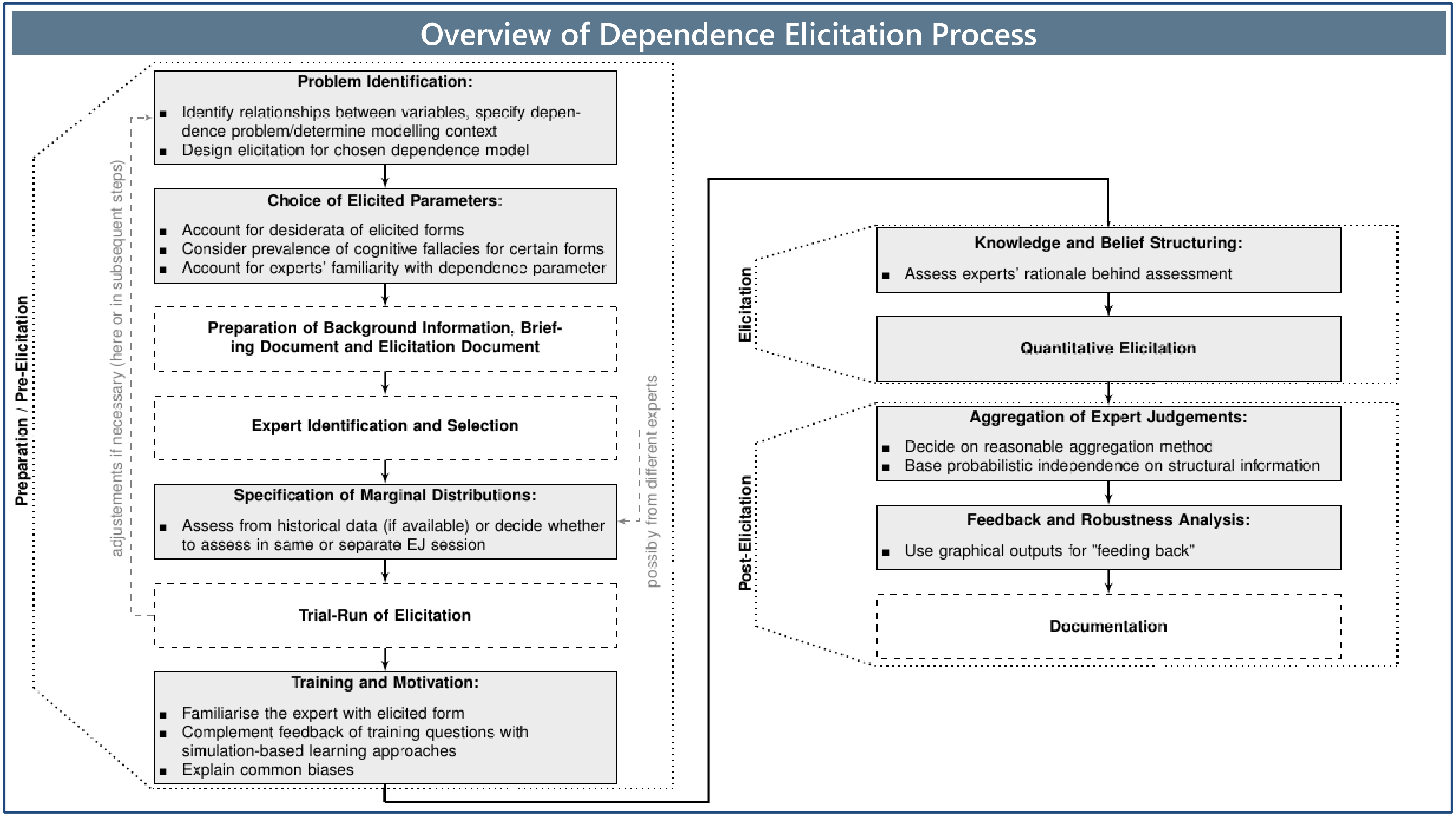
Need for formal elicitation processes

Why should we use formal elicitation processes?

- The need for a structured and formal elicitation process has been recognised since the earliest approaches of Probabilistic Risk Analysis (PRA):
  - Expert judgement was used only in a semi-formal way in one of the first full-scale PRAs, the original Reactor Safety Study by the US Nuclear Regulatory Commission (USNRC, 1975)
  - A more scientific and transparent elicitation process were developed for the subsequent studies, known as NUREG 1150 (USNRC, 1991; 1987; Keeney and Von Winterfeldt, 1991)
- Another formal elicitation process was proposed by the Stanford Research Institute (SRI).



Structured process for eliciting dependence



Main cognitive fallacies for dependence elicitation

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Overview of Biases for Eliciting Dependence

Table 1 Main biases and heuristics for dependence elicitation

	Name	Reference(s)[a]	Description	Originates with	Suggested Remedies
conditional	Confusion of the inverse	Meehl and Rosen (1955), Eddy (1982), Dawes (1988), Hastie and Dawes (2001)	Experts confuse conditional probabilities of P(X|Y) with its inverse P(Y|X)	representativeness heuristic, causal interpretation, "non-natural" base-rates	elicit frequency formats (if possible) (O'Hagan et al. 2006, Meder and Gigerenzer 2014), structure rationale/relationships, include graphical aids (see Fountain and Gunby (2011))
	Causality heuristic	Ajzen (1977), Tversky and Kahneman (1980)	Experts overestimate P(X|Y) when perceiving causal relationship, i.e. Y *causing* X	causal interpretation, base-rate neglect	avoid single, focal scenarios as experts' rationale, evoke alternative scenarios, use experts with different backgrounds (Wright and Goodwin 2009)
	Insufficiently regressive prediction	Kahneman and Tversky (1973)	Experts *translate* one scale to the other, not adjusting for imperfect association	representativeness heuristic, predictive interpretation	specify reference class with central tendency and variability → assess individual case → adjust/calibrate (O'Hagan et al. 2006)
	Bayesian likelihood bias	Edwards (1965), DuCharme (1970)	Experts are more conservative than Bayes' Theorem implies	representativeness heuristic, base-rate neglect	decompose into assessing priors (odds) and likelihoods (ratios) (Montibeller and Von Winterfeldt 2015)
conjunction	Confusion of joint and conditional probabilities	Einhorn and Hogarth (1986)	Experts confuse joint and conditional probabilities	causal/temporal interpretation	address semantic misunderstandings in training, structure rationale/scenarios/ functional relationships
	Conjunction fallacy	Ajzen (1977), Tversky and Kahneman (1980)	Experts overestimate probabilities when perceiving causal relationship	causal interpretation, base-rate neglect	demonstrate probability logic (Montibeller and Von Winterfeldt 2015)
concordance	Cell A strategy	Smedslund (1963), Allan (1980), Kao and Wasserman (1993)	Experts overvalue joint presence of variables (in bivariate assessment)	predictive interpretation	clarify underlying assumptions, such as rarity assumption
general	Illusory correlation	Chapman and Chapman (1969), Eder et al. (2011)	Experts base assessment on false (pre-existing) belief about relationships	availability bias, causal interpretation	as for availability: provide probability training, counter-examples, relevant statistics (if available) (Montibeller and Von Winterfeldt 2015)

[a] only main and/or original references listed

Illustrative case-study: Innovation and risk in the UK Higher Education (HE) sector

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Brief Overview of UK HE sector

- While general management of the higher education (HE) sector in the United Kingdom has been studied and is well-understood, an aspect that has been neglected in this regard is the management and assessment of risk.
- Considering risks in HE is of key importance as today the sector faces a more complex environment to operate in, for instance:
    - global movement of staff and students together with increased exposure to and reliance on overseas markets
    - variable tuition fees, which increase competition and change students' expectations
    - large investments in infrastructures to facilitate institutional expansion
    - loss of market share due to new technologies
    - And some more general uncertainties affection HE are e.g.: political realities together with national security concerns, such as changing visa requirements, government policies influencing the cost of studies, the alignment and accreditation of degrees and the future impact of e-learning offerings
- A consequence is that higher education institutions need to be able to offer new courses that are in line with the demands of employers and hence manage a variety of courses profitably and effectively within a university department's portfolio.

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Motivation and contribution of case-study

- For decision makers in HE, probabilistic modelling of uncertainties can offer insights into the risks involved with their actions. A common challenge is however that relevant historical data are lacking, in particular for dependence relationships.
- Accounting for and modelling dependence is nevertheless of key importance in such a complex business environment such as HE.
- In this case study, we use expert judgement for quantifying dependence between tuition fee income in 2020/21 for the *MSc Business Analysis and Consulting* and the *MSc Data Science.*
- First, we elicit the marginal distribution of both courses' incomes and then the dependence between them.
- A scenario mapping method is introduced and used with the aim of, supporting experts in making sense of their underlying knowledge and beliefs, and mitigating some common heuristics and biases that might occur when assessing dependence.

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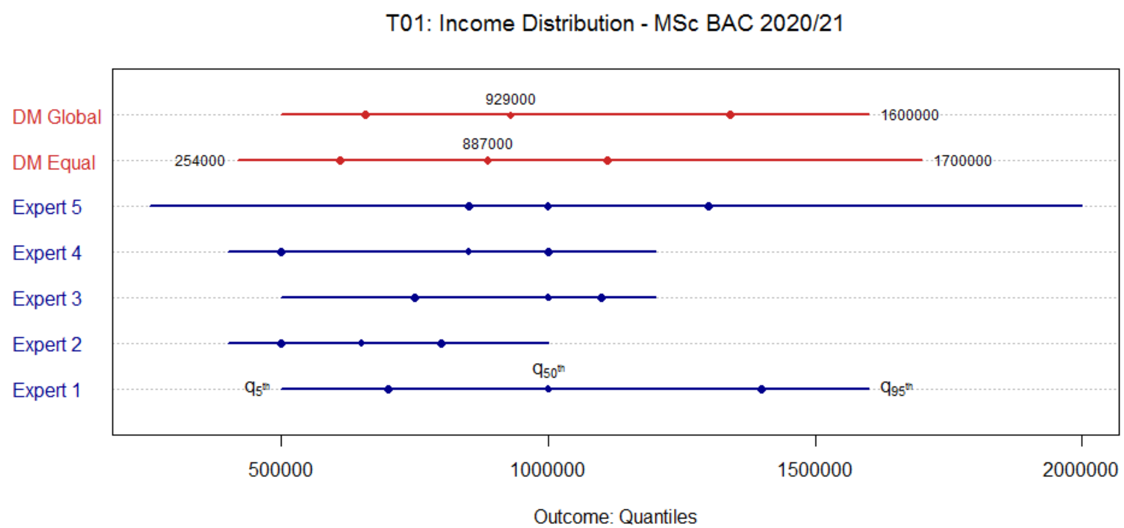
Elicitation of Marginal Distributions (1/2)

T01: *For the academic year 2020/2021, i.e. in 4 years from now, what will be the generated income from the MSc Business Analysis and Consulting?*



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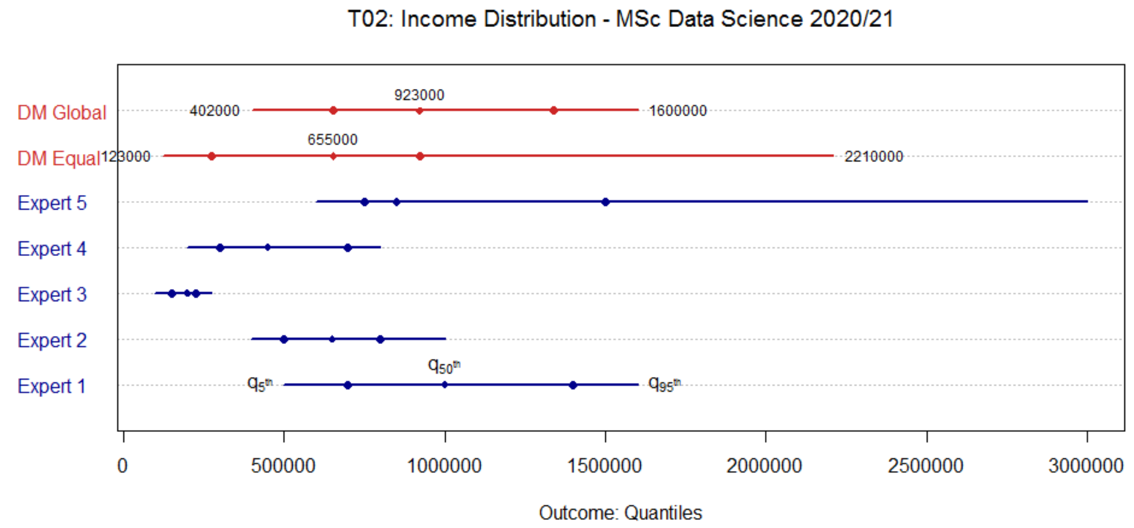
Elicitation of Marginal Distributions (2/2)

T02: *For the academic year 2020/2021, i.e. in 4 years from now, what is the generated income form the MSc Data Science (reminder: this course start from next year onwards)?*



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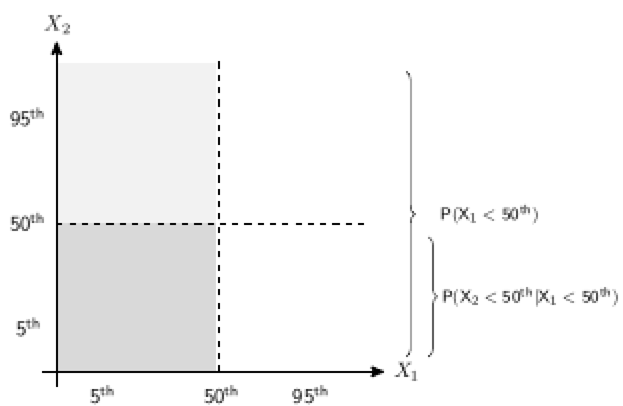
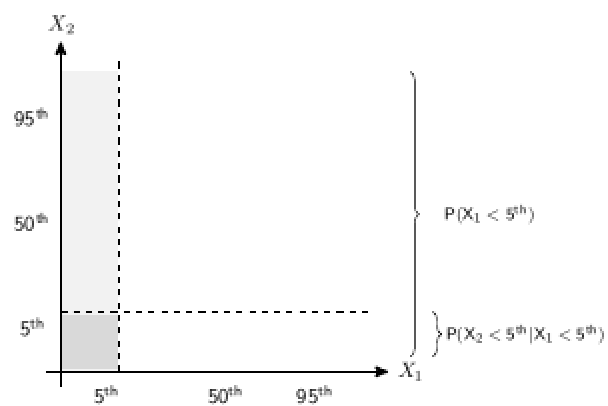
Elicitation of Dependence

After having specified the marginal distributions for our variables of interest, the next step is to assess their dependence. The elicitation questions for this are in the form of conditional probabilities:

1) Given that the generated income of the MSc BAC is below its $median$, i.e. £929,000 in the academic year 2020/21 what is the probability that the MSc Data Science is also below its $median$, i.e £923,000? $P(DS < 50^{th}|BAC < 50^{th})$?

2) Given that the generated income of the MSc BAC is below its $5th\ quantile$, i.e. £417,000 in the academic year 2020/21 what is the probability that the MSc Data Science is also below its $5th\ quantile$, i.e £402,000? $P(DS < 5^{th}|BAC < 5^{th})$?





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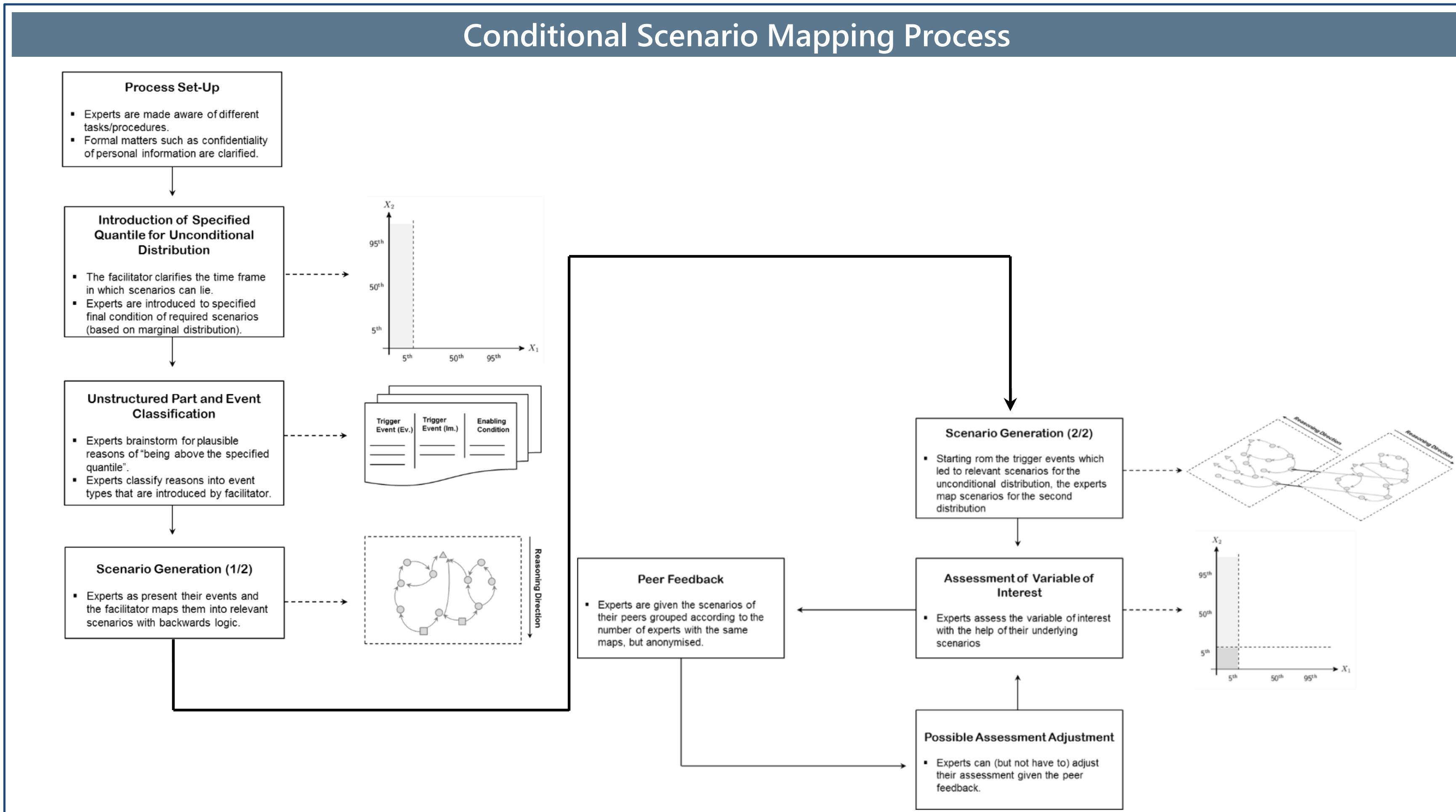

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Scenario Definition (1/2)

$$\omega_i = (x_0, x_1, \dots, x_k, x'_0, x_1, \dots, x_k \in \mathcal{A}_u)$$

- ω_i: one possible outcome from the entire sample space
- x_0: current state of world
- x_k: state of world in k time steps
- x'_0: specified current state of the world
- $x_k \in \mathcal{A}_u$: State of the world in k time steps with specified aspect (condition) at u^{th} quantile

- "hypothetical sequences of events constructed as causal chains of argumentation for the purpose of focussing attention on alternative future" (Eden and Ackerman, 1999)
- decomposed into: triggering events, intermediate conditions and specified condition

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Scenario Definition (2/2)

- ***Trigger Events (Immediate)*** : A *trigger event* is a plausible initiator of a scenario which is contained in the current state of the world and which may or may not be (fully) observable. Sometimes it might be possible to add words like "start", "outbreak", "attack", "eruption", "shock" etc. if necessary for clarification; e.g. *disease outbreak*, *terrorist attack*, *volcanic eruption, oil price shock*. If we identify observable trigger events, it should be possible to neglect any events that led to the trigger event as we condition on them anyways. However, if we identify trigger events that are only partly observable, then we need to further include past events which led to the trigger event for ensuring a richer set of scenarios.

- ***Trigger Events (Evolving)*** : Similar to *immediate* trigger events, an *evolving* counter-part exists. These events differ as they describe a longer development which can be seen as an initial cause. It should be possible to insert in a sensible manner words like "development"; e.g. *development of (long lasting) rain showers.*

- **Enabling Conditions:** Complementary to both types of trigger events, the experts should also identify enabling conditions. In a temporal order these follow from the trigger events and they relate to evolving trends in a system. Therefore, they should include terms such as "higher"/"lower" (or similar), e.g. lower economic growth, higher risk of infection, higher migration.

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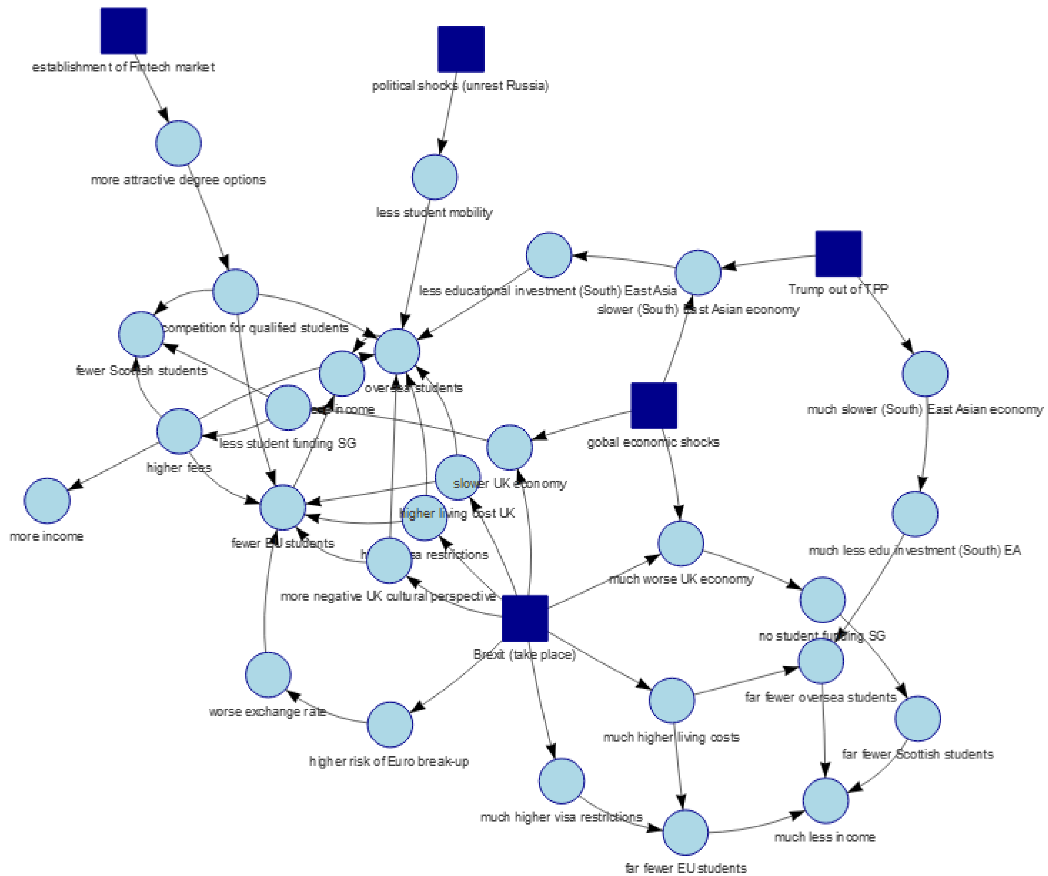
Expert B: Unconditional distribution, i.e. MSc BAC $\leq 50^{th}$ quantile



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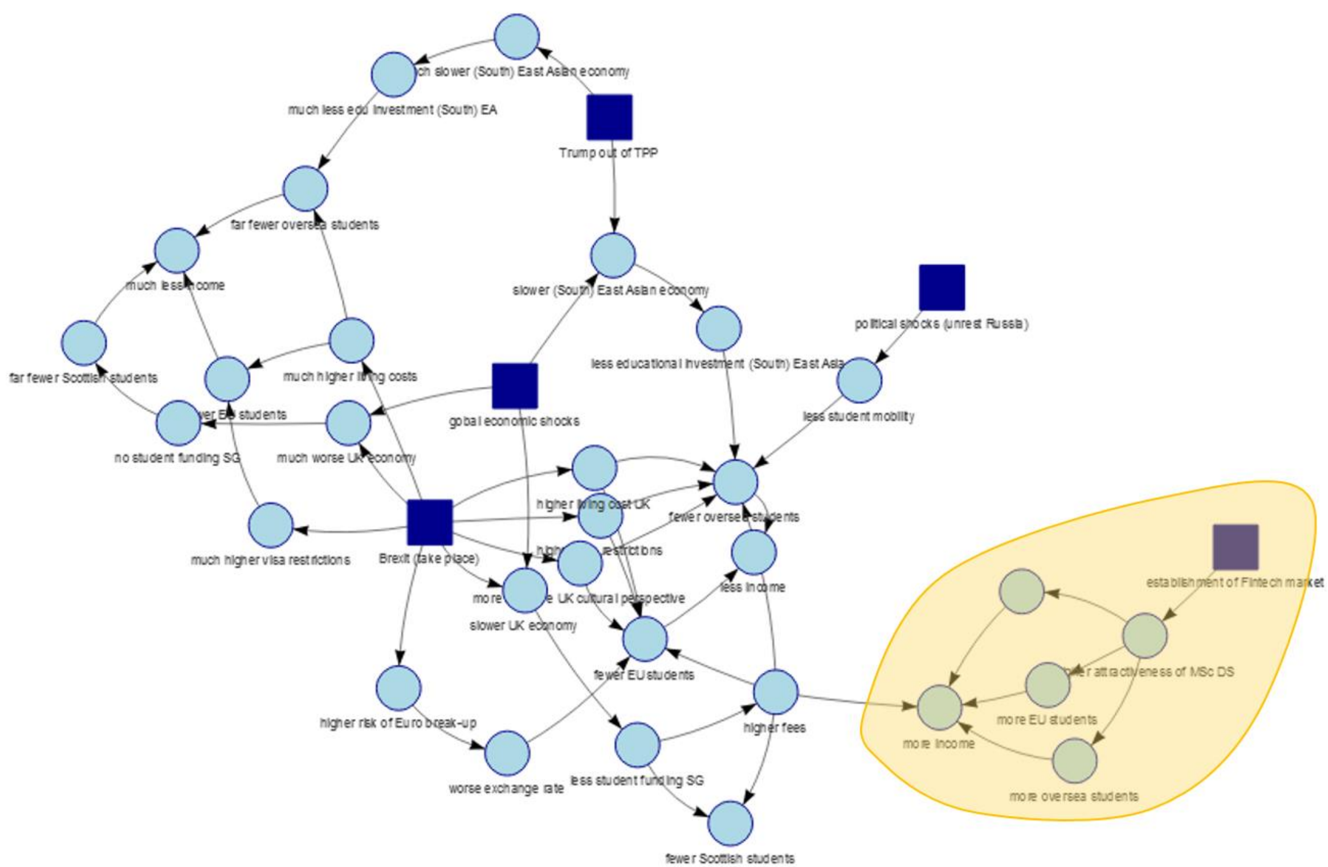
Expert B: Conditional distribution, MSc DS $< 50^{th}$ | MSc BAC $< 50^{th}$



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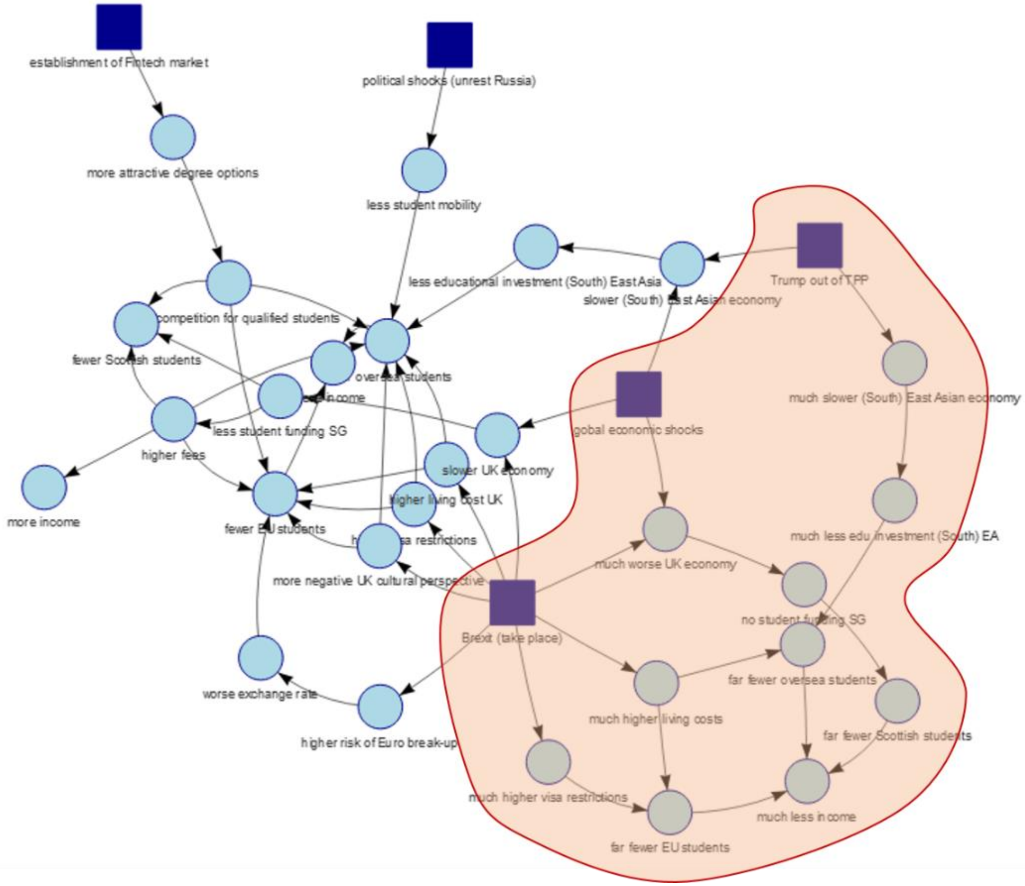
Expert B: Unconditional distribution, i.e. MSc BAC $\leq 5^{th}$ quantile



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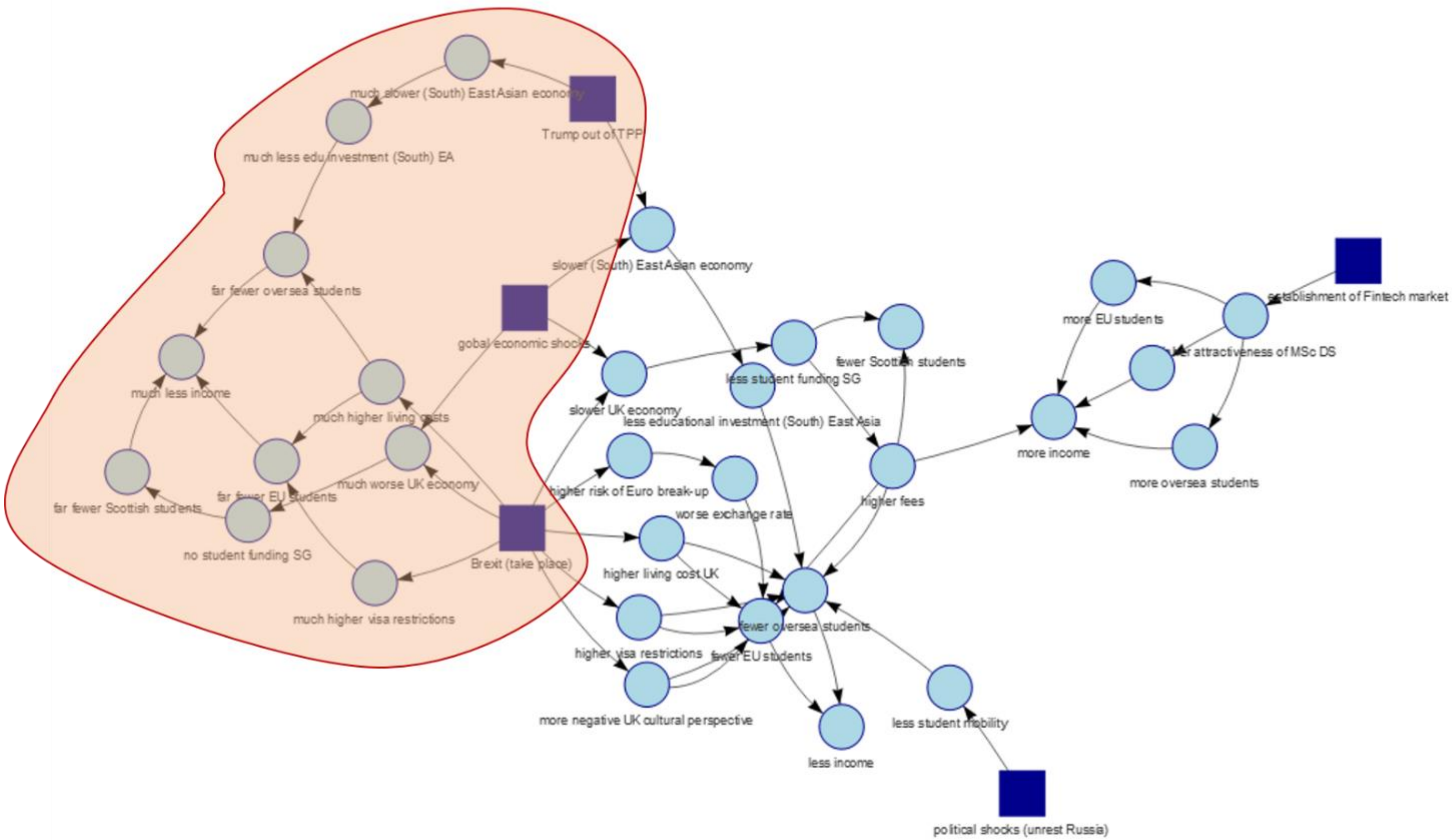
Expert B: Conditional distribution, MSc DS $< 5^{th}$ | MSc BAC $< 5^{th}$



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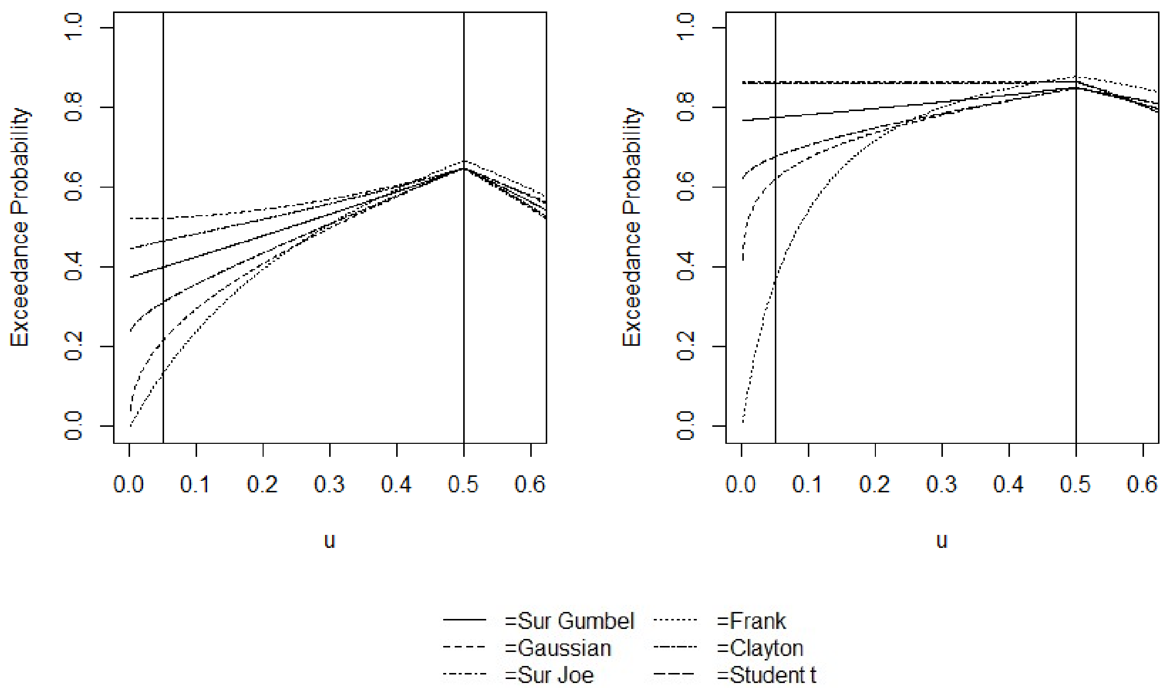
Common independent and lower tail dependent parametric copulas (rc=0.3 and 0.7)



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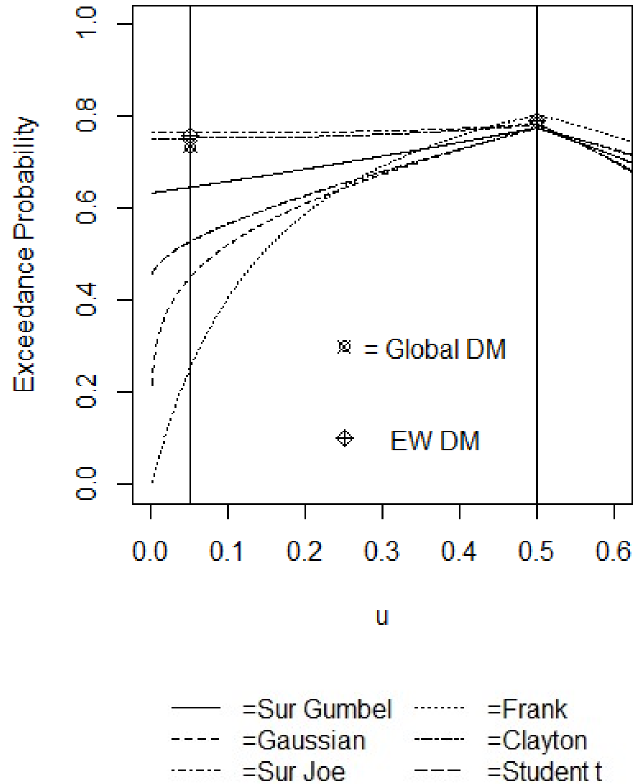
Fitting aggregated result to parametric copula

	50th quantile	*5th quantile*
Expert 1	0.8	0.7
Expert 2	0.7	0.9
Expert 3	0.8	0.8
Expert 4	0.8	0.9
Expert 5	0.85	0.5
DM Global	0.787	0.729
DM EW	0.79	0.76



Thank you for your attention.