Quantifying Uncertainties Using Expert Assessments in a Dynamic New Product Development Environment

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Outline

- ❑ **Problem description: its importance and need for expert elicitation**
- ❑ **New development for combining expert intuition with data: technical details**
- ❑ **Implementation notes /process change at Dow AgroSciences**
- ❑ **Benefits**
- ❑ **Broader implications for practice**

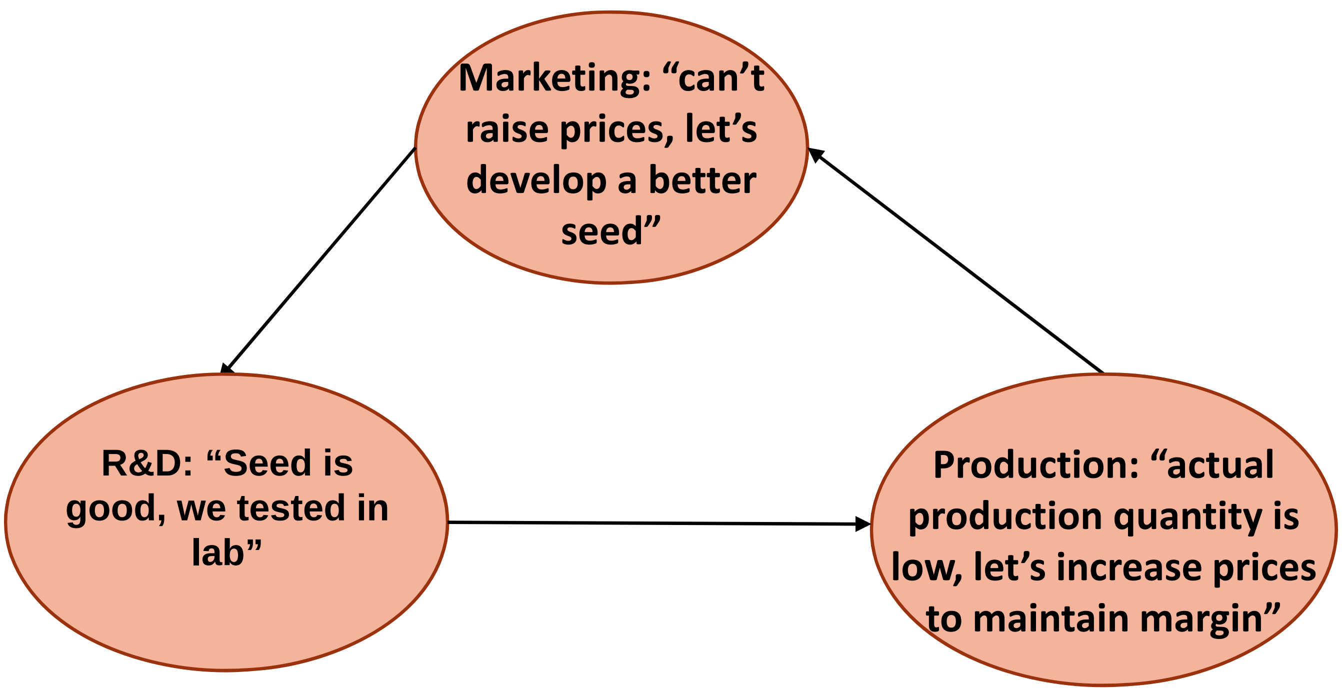
Need for Expert-Input to Estimate Distributions

Agribusiness Domain: Perhaps the earliest use of expert judgment

- ❑ **Dow: about 100-125 parent seeds →** ~22500 combinations
- ❑ **R&D funnels it down to 400**
- ❑ **Expert input to**
  - ❑ Estimate the production uncertainty of all.
  - ❑ Shrink the assortment down to 200
  - ❑ Invest upwards of $200-400 million annually.
  - ❑ **No relevant data is available.**

Critical Issues in the absence of systematic judgments

1. Tension between R&D, Production, and Marketing

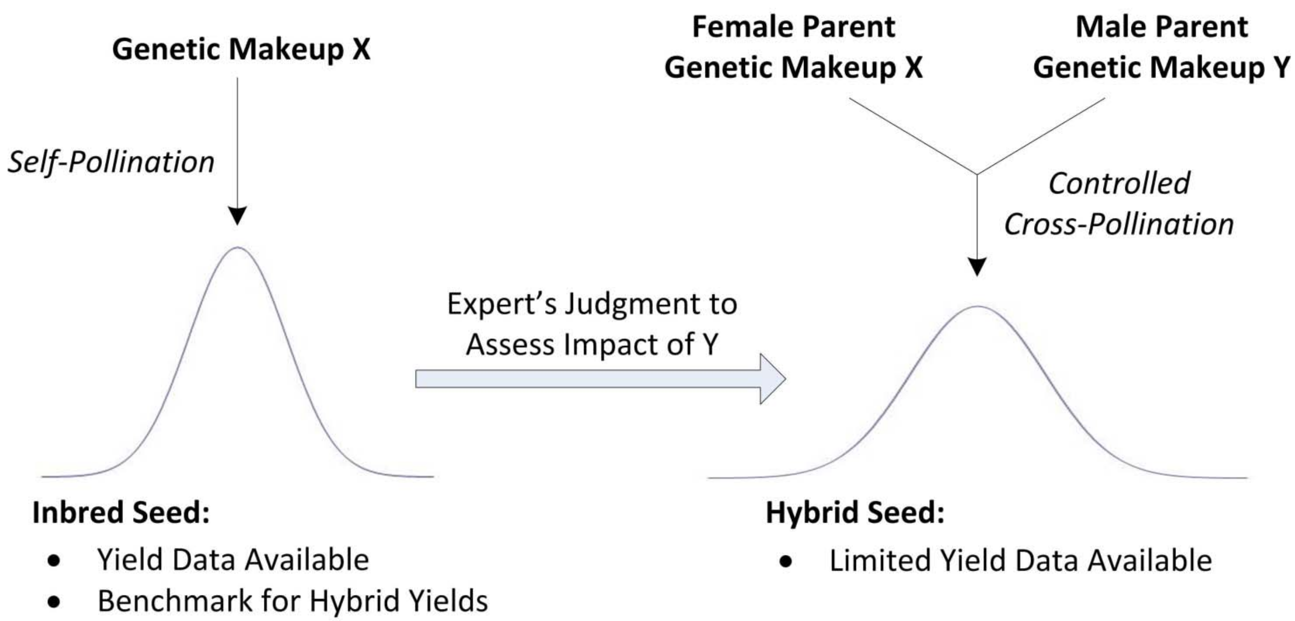


Critical Issues in the absence of systematic judgments

2. How much to produce? Which seeds to select?

- Use too much land, and end up with a surplus
- Use too little land, and end up with shortage (permanent loss of customers)
- The key is to have the mean and spread of uncertain **yield**!
  - Yield = bags of seed obtained per acre
  - No prior data to test to estimate the **yield distribution**

Expert’s task

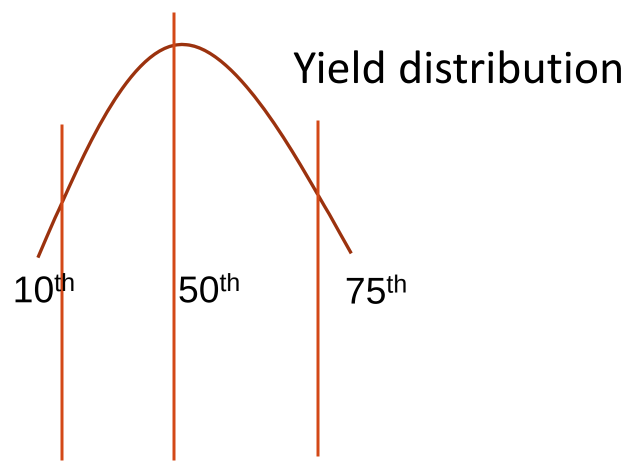


Mental Model:

- ❑ Take the female parent’s inbred distribution
- ❑ Modify it based on the male parent’s pollinating power and biological interactions

Our Focus …

Estimate complete probability distributions using expert input for quantiles



Our Approach: Weights for Quantile Estimates

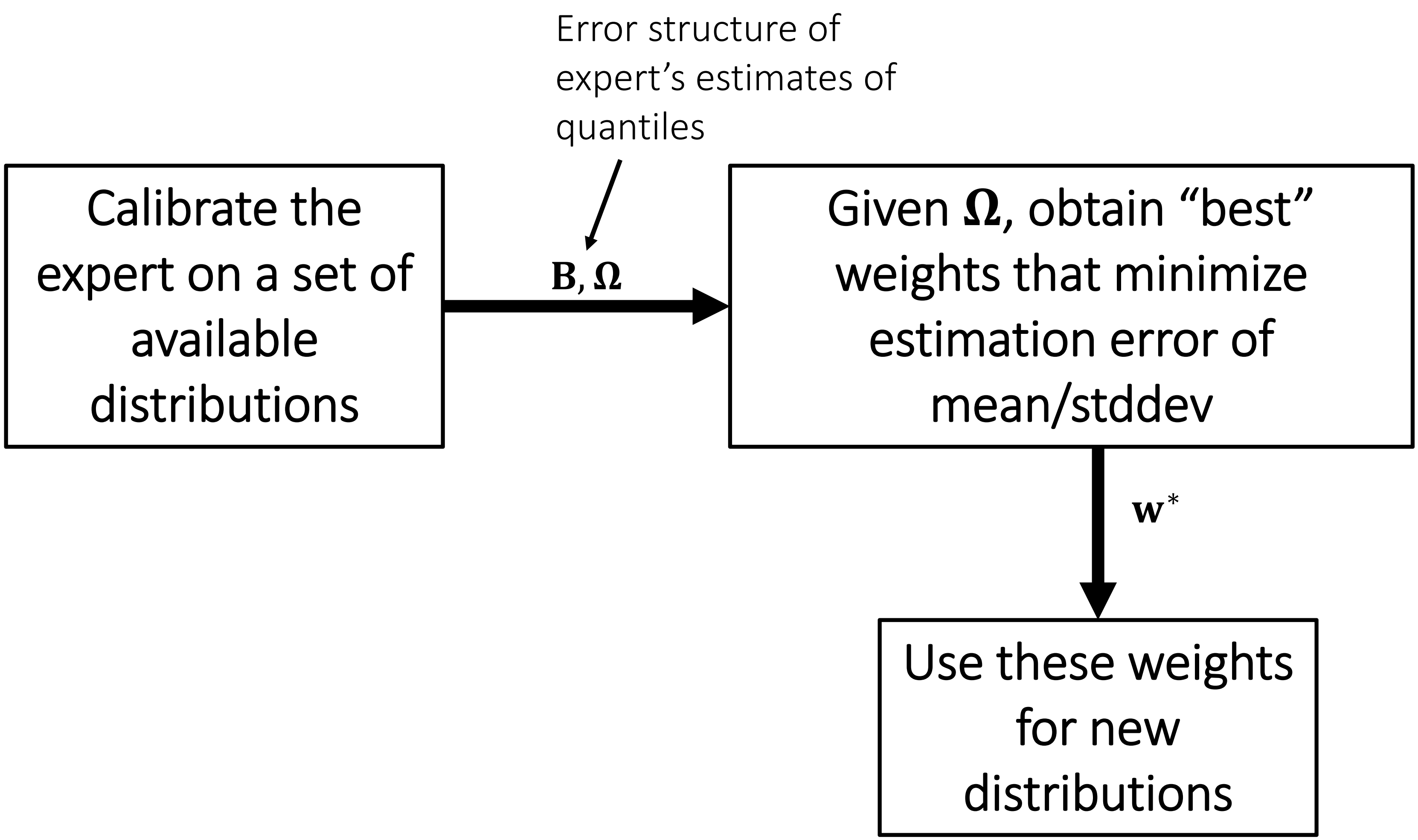
Obtain quantile estimates: $\widehat{x_1}, \widehat{x_2}, \ldots$ and attach weights.

$$\text{Estimated Mean: } \hat{\mu} = \sum w_{i\mu}\, \widehat{x_i}$$

$$\text{Estimated Stdev: } \hat{\sigma} = \sum w_{i\sigma}\, \widehat{x_i}$$

Existing Literature	Our Focus
Assume there is no judgmental error in $\widehat{x_i}$	Acknowledge experts' estimates have errors.
Elicit the median and two/four symmetric quantiles.	Elicit any set of quantiles: 10^{th}, 50^{th}, 75^{th}
Obtain point estimates of the mean/stdev	Obtain the uncertainty in the estimates

Steps of Our Generalized Approach



Useful Properties with Practical Appeal

A fundamental feature: Variance of Estimate:

$$Var[\hat{\mu}] = W_\mu^{*T} \Omega W_\mu^*$$

Prop 1. Expertise can be quantified in terms of equivalent random sample.

$$N_\mu = \frac{\sigma^2}{[1,\kappa_1](\mathbf{Z}^{\mathrm{T}}\Omega^{-1}\mathbf{Z})^{-1}[1,\kappa_1]^{\mathrm{T}}}$$

$$N_\sigma \approx \frac{\sigma^2\left(\frac{\sum_{j=0}^{4}(-\kappa_1)^j\kappa_{4-j}}{(\kappa_2-\kappa_1^2)^2} - \frac{\left(\sum_{j=0}^{2}(-\kappa_1)^j\kappa_{2-j}\right)^2}{(\kappa_2-\kappa_1^2)^2}\right)}{4[0,\sqrt{\kappa_2-\kappa_1^2}](\mathbf{Z}^{\mathrm{T}}\Omega^{-1}\mathbf{Z})^{-1}[0,\sqrt{\kappa_2-\kappa_1^2}]^{\mathrm{T}}}$$

E.g. expert 1 is equal to 20 data points and expert 2 is equal to 10 data points.

Useful Properties with Practical Appeal

A fundamental feature: Variance of Estimate:

$$Var[\hat{\mu}] = {W_\mu^*}^T \Omega W_\mu^*$$

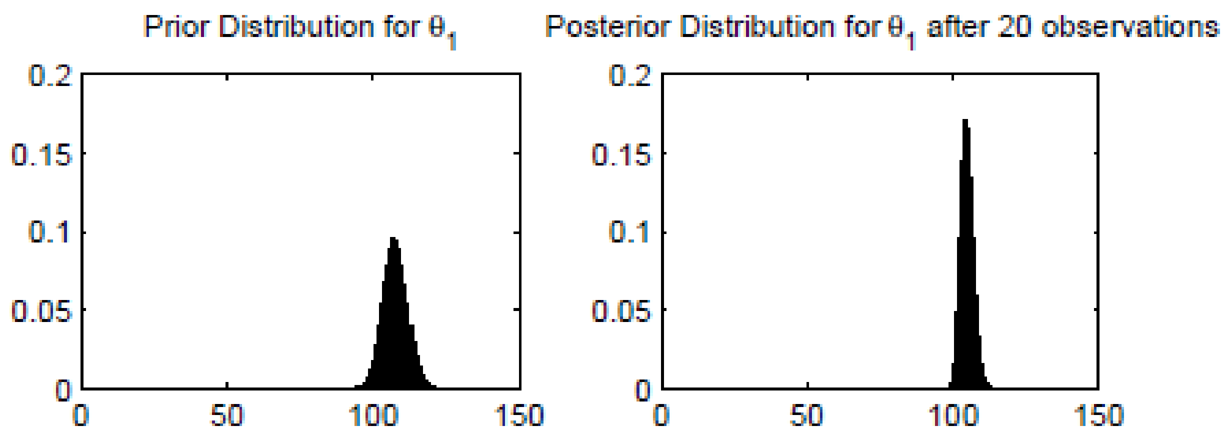
Prop 2. Combine assessments from multiple judgments

- ❑ Multiple assessments of mean/stdev
- ❑ Each assessment has a point estimate and noise
- ❑ We can then use classical signal theory to combine these estimates!

Useful Properties with Practical Appeal

Prop 3. Bayesian updating to use data when it is available

- Copula based development for updating parameter values
  - Expert provides the prior, data provides the likelihood



Implementation: Changes in Decision Making Process

Earlier	Now
Expert gave a mean yield value, and it was used to make investment decisions assuming yield is deterministic.	**Expert's inputs are used to deduce the mean and standard deviation, which are fed to stochastic optimization models.**
Use of "fudge factors" to adjust for yield risk.	**Yield risk is acknowledged by the stochastic optimization model.**
Perceived subjectivity in decisions.	**Decisions have become more objective.**

Benefits from Using the Approach

- Monetary benefits
    - $800 million revenue, a large chunk in cost
    - $15-17 million in additional profit annually
- Non monetary benefits
    - Importance of cultivating experts at the firm
    - Investment in training and quantifying expertise

Questions?