Agribusiness Analysis and Forecasting
Scenarios & Sensitivity Analysis

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Using a Simulation Model

Assume we have a working simulation model.

Model has the following parts.

- Input section where the user enters all input values that are management control variables
- Area where parameters are organized
- Stochastic variables
- Equations to calculate intermediate variables.
- Equations to calculate final output variables.

We are ready to run scenarios on control variables and make recommendations.
What are Scenarios?

- One key reason to build simulation models is to test the impacts of alternative management or policy options.

- Each alternative management or policy option is a scenario.

- Care must be taken to insure that all values, including the risk, in the model are identical from one scenario to the next.

- If we use different risk (underlying standard uniform draws) across scenarios then the results are not comparable.

- Distributions of final output variables should reflect changes in management variables and nothing else.
Simulating Scenarios with Simetar

- Simetar includes functions to simulate multiple scenarios.
- The functions guarantee that the random variables have the same underlying standard uniform values from across scenarios.
- User must provide values for all variables that define the alternative scenarios using

$$= \text{SCENARIO}(alt1, alt2, alt3, \ldots, altN)$$

- The model can have as many scenarios as needed.
Specifying the Number of Scenarios

Simetar simulation engine controls:
- Number of scenarios.
- Sensitivity analysis.
- Sensitivity elasticities.
Flow Chart for Scenario Analysis

Generate All Random Values

Use the same random **USDs** for all random variables, so there is the same risk for all M scenarios

Scenario loop $S = 1, M$

Change management variables ($X$) from one scenario to the next

Iteration loop $I_T = 1, N$

simulate all equations

$\tilde{Y} = f(X) + \tilde{e}$

Save KOV ($\tilde{Y}$s)

Next iteration

Next scenario
Example of a Scenario Table

Example of 5 Scenarios for the risk and variable costs:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Mean</td>
<td>12,000</td>
<td>=SCENARIO(D6:H6)</td>
<td>12,000</td>
<td>13,000</td>
<td>15,000</td>
<td>17,000</td>
<td>18,000</td>
</tr>
<tr>
<td></td>
<td>Std Dev</td>
<td>1,200</td>
<td>=SCENARIO(D7:H7)</td>
<td>1200</td>
<td>2400</td>
<td>3000</td>
<td>4000</td>
<td>5000</td>
</tr>
<tr>
<td></td>
<td>Stochastic Price</td>
<td>13,167</td>
<td>=NORM(B6,B7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td>Min</td>
<td>25</td>
<td>=SCENARIO(D11:H11)</td>
<td>25</td>
<td>25</td>
<td>20</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>30</td>
<td>=SCENARIO(D12:H12)</td>
<td>30</td>
<td>30</td>
<td>25</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>45</td>
<td>=SCENARIO(D13:H13)</td>
<td>45</td>
<td>45</td>
<td>40</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>Stochastic Price</td>
<td>35</td>
<td>=GRKS(B11,B12,B13)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed Costs</td>
<td>25,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable Cost/Unit</td>
<td>25</td>
<td>=SCENARIO(D18:H18)</td>
<td>25</td>
<td>25</td>
<td>20</td>
<td>20</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Total Receipts</td>
<td>456,443</td>
<td>=B8*B14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC</td>
<td>25,000</td>
<td>=B16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VC</td>
<td>329,174</td>
<td>=B18*B8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profit</td>
<td>102,269</td>
<td>=B20-B21-B22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results of the Scenario Analysis

Scenarios are numbered in SimData for ease of graphing and comparison of statistics.
Sensitivity analysis used to determine how sensitive the output variables are to changes in one parameter or variable at a time. For example:

- Does net return change a little or a lot when you change variable X by 10%?
- Does NPV change greatly if the assumed fixed cost changes by 10%?

Simulates the model 7 times changing the “change” variable for each simulation.

Like scenario analysis, Simetar has a sensitivity option that insures the same random values used for each run.
Sensitivity Analysis

- Specify as many KOVs as you want.
- Specify only ONE sensitivity variable.
- Simulate the model and 7 sensitivities are run.
Demonstrate Sensitivity Simulation

Change the Price per unit by these percentages:
- + or – 5%
- + or – 10%
- + or – 15%

Simulates the model 7 times:
- The initial value specified in the change cell.
- Two runs for + and – 5% for the control variable.
- Two runs for + and – 10% for the control variable.
- Two runs for + and – 15% for the control variable.
Sensitivity Results

- Test the sensitivity of price received for the product on Net Cash Income.
- Note that we get 7 sets of results in SimData; base plus six.
- Labels indicate the % difference from the initial value of the change variable.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Simetar Simulation Results for 500 iterations.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Variable</td>
<td>ModellB50</td>
<td>ModellB50</td>
<td>ModellB50</td>
<td>ModellB50</td>
<td>ModellB50</td>
<td>ModellB50</td>
</tr>
<tr>
<td>3</td>
<td>Mean</td>
<td>4,359,704</td>
<td>1,641,859</td>
<td>7,077,549</td>
<td>735,911</td>
<td>7,983,497</td>
<td>(170,037)</td>
</tr>
<tr>
<td>4</td>
<td>StDev</td>
<td>4,818,880</td>
<td>3,499,541</td>
<td>6,256,265</td>
<td>3,112,439</td>
<td>6,748,779</td>
<td>2,770,766</td>
</tr>
<tr>
<td>5</td>
<td>CV</td>
<td>111</td>
<td>213</td>
<td>88</td>
<td>423</td>
<td>85</td>
<td>(1,630)</td>
</tr>
<tr>
<td>6</td>
<td>Min</td>
<td>(6,805,331)</td>
<td>(7,530,597)</td>
<td>(6,161,688)</td>
<td>(7,772,352)</td>
<td>(6,077,965)</td>
<td>(8,014,107)</td>
</tr>
<tr>
<td>7</td>
<td>Max</td>
<td>16,213,694</td>
<td>10,758,714</td>
<td>21,668,673</td>
<td>8,940,388</td>
<td>23,486,999</td>
<td>7,122,062</td>
</tr>
<tr>
<td>8</td>
<td>Iteration</td>
<td>NCI</td>
<td>85.00% SA on N</td>
<td>115.00% SA on N</td>
<td>80.00% SA on N</td>
<td>120.00% SA on N</td>
<td>175.00% SA on N</td>
</tr>
</tbody>
</table>

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Display Sensitivity Results in a Chart

Fan Graph for 7 Categories

- NCI
- 85.00% SA on Model!B11
- 115.00% SA on Model!B11
- 80.00% SA on Model!B11
- 120.00% SA on Model!B11
- 75.00% SA on Model!B11
- 125.00% SA on Model!B11

Legend:
- Mean
- 5th Percentile
- 25th Percentile
- 75th Percentile
- 95th Percentile
Sensitivity Elasticities (SE)

- Sensitivity of one output variable with respect to multiple values in the model can be estimated and displayed in terms of elasticities, calculated as:

\[ SE_j = \frac{\% \Delta \text{output variable}}{\% \Delta \text{value}_j} \]

- Calculate SE’s for an output variable wrt. the change \( var_j \) for each iteration, then calculate the mean and standard deviation of the SE.

- \( SE \)'s can be calculated for small changes in parameters or control variables, say, 1%
### Interlude: Value types

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal</td>
<td>Just names, IDs</td>
</tr>
<tr>
<td>Ordinal</td>
<td>Have / represent rank order (e.g. fully agree, mostly agree, somewhat agree)</td>
</tr>
<tr>
<td>Interval</td>
<td>Has a fixed size of interval between data points. (E.g. degrees Centigrade)</td>
</tr>
<tr>
<td>Ratio</td>
<td>Has a true zero point (e.g. mass, length, degrees Kelvin)</td>
</tr>
</tbody>
</table>

- [http://www.psy.gla.ac.uk/~steve/best/ordinal.html](http://www.psy.gla.ac.uk/~steve/best/ordinal.html)
### Interlude: Value Types

<table>
<thead>
<tr>
<th>Incremental progress</th>
<th>Measure property</th>
<th>Mathematical operators</th>
<th>Advanced operations</th>
<th>Central tendency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal</td>
<td>Classification, membership</td>
<td>=, ≠</td>
<td>Grouping</td>
<td>Mode</td>
</tr>
<tr>
<td>Ordinal</td>
<td>Comparison, level</td>
<td>&gt;, &lt;</td>
<td>Sorting</td>
<td>Median</td>
</tr>
<tr>
<td>Interval</td>
<td>Difference, affinity</td>
<td>+, −</td>
<td>Yardstick</td>
<td>Mean, Deviation</td>
</tr>
<tr>
<td>Ratio</td>
<td>Magnitude, amount</td>
<td>×, /</td>
<td>Ratio</td>
<td>Geometric mean, Coefficient of variation</td>
</tr>
</tbody>
</table>
Be careful what types of values you specify for calculating elasticities.

**Percentage change is a ratio/division operation.** This should be a valid operation for the type of value you are considering.

These operations should be reserved for *ratio* values, and are not valid for *interval* values.

For example, the idea of percentage change in profit does not make sense, given that profit may be negative. Profit is an interval value, not a ratio value.

Simetar will **silently** calculate non-sensical sensitivity elasticities if you apply this feature to non-ratio values.
Activating Sensitivity Elasticities

- Turn on the SE option by clicking on the Estimate Sensitivity Elasticities tab.
- Specify the Single KOV in List of Output Variables.
- Specify change variables in the List of Sensitivity Test Variables.
Once a model can simulate multiple scenarios, the question becomes “which is the best scenario?”

How to answer this question is a key issue in microeconomics.

There are many different methods, with varying degrees of complexity and theoretical attractiveness.

We will present and evaluate several methods.
Simulation results can be presented many different ways to help the decision makers (DM) make the best decision for themselves.

- Tables of summary statistics
- Probabilities for different values for output variables
- PDFs and CDFs.
- StopLight charts.
- Fan graphs.
- Others

Purpose here is to present some helpful methods for ranking risky alternatives to facilitate decision making.
Decision makers rank risky alternatives based on their utility for income and the risk aversion reflected in their utility function.

Several of the ranking procedures ignore utility, but they are easy to use.

The more complex procedures incorporate utility but can be complicated to use.
Easy to Use Ranking Procedures

- **Mean only** – Pick scenario with the highest mean – **ignores all risk**

- **Minimize Risk** – Pick the scenario with lowest Std Dev – this ranking strategy **ignores the level of returns** (mean and relative risk)

  ![Diagram](image)

  Blue Dist has the smaller Std Dev!

- **Mean Variance** – Always select the scenario in lower right quadrant often difficult to read and often results in tied rankings, does not work well for non-normal distributions.
  - In the diagram below A is preferred to C; E is preferred to B
  - Indifferent between A and E

![Diagram](image)
Easy to Use Ranking Procedures

- **Worst case** – Bases decisions on scenario with highest minimum, but it was observed with less than a 1% chance. Worst case had a 1 out of 500 chance of being observed — has merit in that it avoids catastrophic losses, but ignores the level of returns and ignores upside risk.

- **Best case** – Looks at only one iteration, the best, which has < 1% chance. Best case had a 1 out of 500 chance of being observed — ignores the overall risk and downside potential risk.
Easy to Use Ranking Procedures

Relative risk - Coefficient of Variation (CV), pick the scenario that has lowest CV. Easy to use, considers risk relative to the expected value, but ignores the decision maker’s risk aversion and is only valid for ratio values (so, for example, not valid for profit)

\[ CV = \frac{Std.\ Dev}{Mean} \times 100 \]

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
<th>Option 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>5948.63</td>
<td>4894.94</td>
<td>3277.08</td>
<td>1642.44</td>
<td>-92.55</td>
</tr>
<tr>
<td>StDev</td>
<td>13012.63</td>
<td>14130.17</td>
<td>13615.85</td>
<td>13697.44</td>
<td>14419.89</td>
</tr>
<tr>
<td>CV</td>
<td>218.75</td>
<td>288.67</td>
<td>415.49</td>
<td>833.97</td>
<td>-15579.92</td>
</tr>
<tr>
<td>Min</td>
<td>-33653.55</td>
<td>-38159.43</td>
<td>-38331.16</td>
<td>-40112.24</td>
<td>-43798.94</td>
</tr>
<tr>
<td>Max</td>
<td>39572.48</td>
<td>41537.27</td>
<td>38627.14</td>
<td>37145.60</td>
<td>37376.81</td>
</tr>
</tbody>
</table>
Stoplight Chart – Calculate and report the probability of achieving a preferred target and probability of failing to achieve a minimum target, i.e., the StopLight chart. This method is easy to use and easy to present to decision makers who do not understand risk.
Easy Ranking Procedures

Rank Scenarios Based on Complete Distribution - Graph the distributions as CDFs and compare the relative risk of the returns for each distribution at alternative levels of return. Pick the distribution with the highest return at each risk level or pick the distribution with the lowest risk for each level of returns, i.e., the distribution furthest to the right.

![Comparison of 5 CDF Series](image-url)