Corn Ethanol Plant Investment and Divestment Decisions
A Real Options Approach

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3. Determine which framework best explains the investment and divestment decisions that actually occurred.

2. Compare these constructed trigger margins to determine if the real options framework must satisfy the two following conditions:

   \[
   V_{k0}(\theta_k) = V_{k1}(\theta_k) - S
   \]

   \[
   V_{k0}'(\theta_k) = V_{k1}'(\theta_k),
   \]

   where \( V_{k0} \) is the value of being in regime \( k_0 \), \( V_{k1} \) is the value of being in regime \( k_1 \), \( \theta_k \) is the gross margin, and \( S \) is the switching cost, and the prime symbols indicate first derivatives.

   This first condition has an intuitive meaning that the value of switching to regime \( k_1 \) must be equal to value of being in regime \( k_0 \) less any switching costs.

   Suppose \( k_0 \) is entry and \( k_1 \) is wait. Then, the real options framework allows for the value of waiting to be positive, while the NPV framework assumes it is zero.

   The Geometric Brownian motion process (GBM) is specified as:

   \[
   d\theta = \alpha d\tau + \sigma \theta d\zeta,
   \]

   where \( \alpha \) is the drift parameter and \( \sigma \) is the volatility parameter.

   The mean-reverting process (OUP) used is specified as:

   \[
   d\theta = \eta (\bar{\theta} - \theta) dt + \sigma d\zeta,
   \]

   where \( \eta \) is the mean-reversion parameter and \( \bar{\theta} \) is the normal value to which the gross margins revert.

   These stochastic process parameters are estimated using publicly available ethanol and corn price data.

**Methods**

- The key contribution of the real option framework is that it takes into account the “real option” of waiting when evaluating an investment opportunity. The NPV framework assumes this value is zero.

- The trigger margin switching from regime \( k_0 \) to regime \( k_1 \) under the real options framework must satisfy the two following conditions:

   \[
   V_{k0}(\theta_k) = V_{k1}(\theta_k) - S
   \]

   \[
   V_{k0}'(\theta_k) = V_{k1}'(\theta_k),
   \]

   where \( V_{k0} \) is the value of being in regime \( k_0 \), \( V_{k1} \) is the value of being in regime \( k_1 \), \( \theta_k \) is the gross margin, and \( S \) is the switching cost, and the prime symbols indicate first derivatives.

**Results**

**Table 1. Trigger margins by plant size ($/liter)**

<table>
<thead>
<tr>
<th>Plant Size</th>
<th>Trigger Margin</th>
<th>GBM (SLT)</th>
<th>GBM (Current)</th>
<th>OUP</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>Entry</td>
<td>48.4</td>
<td>33.5</td>
<td>15.2</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Reactivate</td>
<td>21.7</td>
<td>18.7</td>
<td>10.1</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Mothball</td>
<td>5.1</td>
<td>3.6</td>
<td>5.9</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Exit</td>
<td>4.7</td>
<td>0.7</td>
<td>3.8</td>
<td>12.0</td>
</tr>
<tr>
<td>Medium</td>
<td>Entry</td>
<td>36.7</td>
<td>25.9</td>
<td>12.0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Reactivate</td>
<td>17.3</td>
<td>15.2</td>
<td>8.4</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Mothball</td>
<td>4.4</td>
<td>3.2</td>
<td>1.6</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Exit</td>
<td>3.6</td>
<td>0.5</td>
<td>3.1</td>
<td>9.7</td>
</tr>
<tr>
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<td>34.1</td>
<td>24.5</td>
<td>11.6</td>
<td>-</td>
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<tr>
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<td>16.9</td>
<td>15.0</td>
<td>6.5</td>
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<tr>
<td></td>
<td>Mothball</td>
<td>4.6</td>
<td>3.5</td>
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</tr>
<tr>
<td></td>
<td>Exit</td>
<td>3.4</td>
<td>0.5</td>
<td>3.1</td>
<td>9.6</td>
</tr>
</tbody>
</table>

**Conclusions**

- The value of waiting drastically changes the trigger margins.

- Making different assumptions about the future behavior of the gross margin drastically changes the results.

- It appears that the trigger margins using the real options framework best approximate the behavior of ethanol plant investors.

- The choice of evaluation framework may not have played an important role in the boom-and-bust period of the mid-2000s.