As the study of agricultural business becomes more and more prevalent, it is becoming increasingly important that new tools and timely concepts are delivered to students in a rigorous way. The presentation of this material can be content focused (e.g., theoretical) or process focused (e.g., implementing strategy). Through various teaching techniques, such as case studies, both forms of teaching can be used simultaneously. The new theories on real options are becoming increasingly important and are poised as the first challenger to conventional net present value (NPV) analysis of investments. As its popularity increases and solutions for solving real options problems emerge, real options will become a field of study unto itself and business students will have to be adept in its intricacies. The purpose of this article is to provide an introduction to real options as a strategic management tool by first reviewing the state of the art, and then applying it to Nicholas Kalaitzandonakes’ popular case study “Mycogen: Building a Seed Company for the Twenty-First Century.”

Introduction

Perhaps the most innovative model of corporate finance in recent years is in the valuation of real options and flexibility. A real option is an option on real assets rather than financial assets and is often tied to managerial flexibility.
under conditions of risk. Flexibility refers to management’s ability to make choices. When evaluating an investment in research and development (R&D), for example, management has the option to postpone the investment until a later date without any obligation to undertake the project. This “real option” has value and is often referred to as an option to wait. In another project, conventional NPV analysis might result in a negative NPV. Going ahead with the project may give rise to opportunities that will not otherwise occur; forgoing the project means giving up the option to grow the business. A mistake has been made since conventional NPV analysis has failed to take into consideration the value of growth options, even if the growth opportunities are uncertain. The notion behind real options is based on three factors; flexibility, irreversibility, and uncertainty. Irreversibility refers to the making of fixed investments in capital which are unrecoverable at the original cost, flexibility refers to the right that managers have to postpone making an irreversible decision until markets or other cash-generating economic activity improves, and it is uncertainty which causes irreversibility to be a problem and for flexibility to have value. While the idea behind real options is almost 20 years old, it has only been recently that modern options pricing tools have been used to value flexibility. In terms of the theoretical justification of valuing flexibility as an option most of this work can be credited to Pindyck (1988, 1991), Dixit, and Dixit and Pindyck. Their insight flowed from an observation that decisions on capital projects had options-like qualities. If the net present value of an investment was negative or did not support a corporate hurdle rate, managers need not discard the project in its entirety. In fact, the manager has the option to make an investment at a later date without any obligation to do so if it is not value increasing.

Proponents of the real options model to investment analysis argue that the NPV rule does not adequately capture the multitude of contingencies that arise from investment. It is true that the NPV criteria can be adjusted to market risk or simulated across a number of scenarios, but they do not provide a means for managers to mitigate contingent risks in terms of the downside, nor do they allow managers to take advantage of uncertainty in terms of the upside. As Pindyck and Dixit argued, the ability of a manager to postpone making the investment can increase value, even if the project has a negative NPV in the first place.

More recently academics, managers, and consultants have extended this basic notion of real options to parallel the Black–Scholes model, if not figuratively then at least metaphorically. These include Amran and Kulatilaka, Copeland and Keenan, Leslie and Michaels, and others who have applied real options theory in practice. What is important about this work is the number of options that have been uncovered. Table 1 summarizes a number of the real option categories available to managers. These options can be used to identify different strategic actions and can provide discipline to the process of making investments under conditions of risk. Indeed, the real options framework is one that ties traditional investment, strategy, and risk management into a single paradigm.

Recognizing that there are a multitude of real options available to managers is important to understanding and implementing risky investment in agriculture. How significant real options are is not fully understood, but it has been shown that the more uncertain a new venture is, the greater the value that flexibility will be. Emerging technologies based in science are perhaps the most
### Table 1. Summary and definitions of real options

<table>
<thead>
<tr>
<th>Option Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting-to-invest or timing options</td>
<td>The waiting-to-invest option is available prior to any capital expansion. Because of uncertainties in future cash flows, the manager may want to postpone the investment until uncertainty is resolved towards a reasonable end. This option gives the investor the right but not the obligation to make an investment at a future date. If the investment is made immediately, the option is exercised below its true value and the manager faces all of the uncertainties that give rise to the real option value. Even in a competitive market, the waiting-to-invest option can still increase value over the invest-immediately option.</td>
</tr>
<tr>
<td>Growth options</td>
<td>A growth option arises from making an investment which provides payoffs in uncertain markets that would not have ordinarily occurred. Growth options arise from some action, most likely the exercise of a timing option. Consequently when evaluating a timing option, the value of the option may well be the sum of the growth options that become available when the option is exercised.</td>
</tr>
<tr>
<td>Flexibility options</td>
<td>Flexibility arises from uncertainties about multiple markets, products, and even human resources. Under conditions of risk, it is often necessary to move or reallocate resources from one product or market to another. In some instances, the flexibility option will have such a high value that when added to the costs of multiple plants (which exceed the costs of a single plant), the multiple plant alternative becomes more favorable. The value of the option increases with uncertainty. The recognition of a flexibility option is at odds with conventional measures of economies of scale and size. It is somewhat related to the concept of economies of scope except that risk minimization rather than cost minimization is the objective.</td>
</tr>
<tr>
<td>Exit options</td>
<td>Exit options can include a graceful departure from an industry or an abandonment from a project. In some instances, for example, a rigid regulatory environment, firms develop technologies that may or may not be approved by the regulatory authority. How a firm manages this has value. On the one hand, the firm can proceed as if the new technology would meet regulatory approval with certainty, or it can establish a contingency plan to deal with the possibility. Assuming certainty does not create value, but the existence of a contingency plan does have value and this is often sufficiently high to continue with investment.</td>
</tr>
</tbody>
</table>
Table 1. Continued

<table>
<thead>
<tr>
<th>Option Type</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Note that the payoff to an exit or abandonment option is measured in terms of positive cash flow as a growth option might be measured, but rather in minimizing the negative cash flow associated with a particular event.</td>
<td></td>
</tr>
<tr>
<td>Learning options</td>
<td>Learning options arise from making a small number of investments to test the value of a much larger investment. Learning options will be higher for new products and early stage innovations than for mature products because less is known about the new markets. The solution to this problem is to create options through incremental staging of new products or technologies. For example, an early stage investment in market research might indicate poor acceptance of a new product, thereby saving millions of dollars in advertising, or it might indicate that the market is much larger than originally thought. In either case, the learning option has value (probably) in excess of costs, either in preventing large losses or indicating higher profit potential. Note also that the learning option can also give rise to either a growth option if the small investment in market research indicates profitability or an exit option if the learning option indicates poor market conditions.</td>
</tr>
<tr>
<td>Hybrid options</td>
<td>As indicated above, real options should not be considered as mutually exclusive measures of uncertainty. In fact any project may have several different types of options available to it at any given moment in time. Each option when valued alone leads to an individual decision or strategy, which may or may not give rise to further options. It is the contemporaneous and consecutive evaluations of real options that gives rise to strategic risk management, which increases firm value.</td>
</tr>
<tr>
<td>Compound or platform options</td>
<td>A compound option arises when the exercise of one option gives rise to one or more seen or unforeseen options. For example, R&amp;D involves a significant expenditure, and R&amp;D in itself does not create cash flow. What R&amp;D does is to provide the learning option, which in turn provides more learning options and growth options.</td>
</tr>
<tr>
<td>Rainbow options</td>
<td>A rainbow option arises when an investment faces several sources of uncertainty simultaneously. These uncertainties may conflict with each other, creating options that are to some degree mutually exclusive.</td>
</tr>
</tbody>
</table>
capital intensive and uncertain of all investments within the agricultural sector. Research and development requires investment capital, all of which is sunk and irreversible many years before a consumable product is ready. Regulatory approval, trademarks, and distribution then follow this with various degrees of uncertainty. The evidence to date is that using a real options paradigm can save firms from making large sunk-cost investments while simultaneously increasing firm value. As Copeland and Keenan suggest, recognizing real options can help managers assess the profitability of new projects and can provide flexibility in deciding whether and when to proceed with new and later phases of projects, especially when they are close to break-even or not currently profitable.

The primary purpose of this article is to provide an introduction into real options. Rather than relating previous literature to the problem, this article will take advantage of the published case study on Mycogen (Kalaitzandonakes). The original intent of the Mycogen case was to provide students of agribusiness with a problem-solving exercise in the area of strategic investments. However, upon closer scrutiny, this case provides an exceptional retrospective on the use of flexibility and real options by Mycogen, while allowing for a real options analysis of the decision required of the chief executive officer.

**Background to the Real Options Model of Capital Investment**

The decision to make an investment is like a call option because it provides the owner with a right but not an obligation to make the investment now or in the future. Under the NPV rule, the manager will invest if the present value of cash flows from the investment exceeds the present value cost of the investment. The NPV rule is simple and the decision whether to proceed with the investment or not is straightforward. For the most part, NPV assumes that cash flows are nonstochastic and by tradition the discount rate is adjusted to compensate for any increases or decreases in risk from the main risk profile of the company. The usual practice is to set a hurdle rate that is in excess of the firm’s weighted average cost of capital or to adjust the return on equity according to the capital asset pricing model. This procedure has worked well for simple projects or investments that have fairly predictable cash-flow streams, but is inadequate when risk is immeasurable, sizeable, or uncertain.

Courtney, Kirkland, and Viguerie provide an interesting categorization of uncertainties faced in strategic decision making. They argue that under uncertain conditions, conventional analysis of strategic decision making can be “downright dangerous.” The four categories of risk described by Courtney et al. are as follows.

1. A clear-enough future: In this category, a single forecast is precise enough to determine the correct strategy. Traditional tools such as forecasting and NPV calculations are sufficient to provide reasonably accurate calculations. Purchasing a piece of machinery which is fully engineered for specs and planning a strategy to take market share from a competitor are examples of this low-grade class of uncertainty.
2. Alternate futures: In this case, a few discrete outcomes that define the future are known, with some variables known with varying degrees of risk. In most instances, probability distributions are sufficient for making strategic decisions, but they are more involved than a simple NPV. Monte Carlo simulations on an NPV model, real options valuation, and game theoretic approaches to management would allow management to move forward with some confidence, but the actual outcome cannot be predicted. Management of production capacity by a firm and estimating inventory requirements across a supply chain are examples of this category of uncertainty.

3. A range of futures: With this category, only a range of possible outcomes are known. No natural scenarios such as those found in category 1 are evident. The quantitative requirements for decision making are complex and could involve a number of real options, latent demand research, technology forecasting, and/or scenario planning. A firm entering new markets or developing new technologies would fall in this category.

4. True ambiguity: With this category, there is no basis for forecasting the future. Providing a new consumer product or technology with no possible measurement of acceptance or regulatory environment would be an example of this kind of uncertainty. In short, the strategic decision must be made with zero information. Analogies and case studies of previous attempts to introduce unknown technologies might help in the strategic decision; otherwise a range of solutions might be found from building nonlinear models of consumer behavior and so on.

As qualitative as these categories sound, they reveal a great deal about the complexities of strategic decision making under conditions of risk and uncertainty. What is important about the categories in the context of this note and the Mycogen case study is that in only one category would the NPV rule actually have sufficient information to provide a reasonably accurate decision rule. (Courtney et al., consultants at McKinsey and Company, state that in their experience 50% of all risks lie in category 1, with most of the remainder being in categories 2 or 3. Category 4 risk is rare, but they suggest that with it being the most ambiguous, managers often make a guess, apply category 1 rules, and simply ignore the residual uncertainty.)

The problem with the NPV rule is laid out simply in figure 1, which displays a prediction success matrix for a capital investment. The diagonal elements in figure 1 result in net increases (actually nonnegative) to shareholder value while the off-diagonal elements show either an opportunity loss or a direct loss to shareholder value. Successful decisions using the NPV rule would most likely occur with category 1 risks, while the off-diagonal outcomes would more likely be associated with higher category risk. In some instances, successful application of higher category risk occurs. But this would be due to either luck or a subjective “gut” feeling. In either case, it would not be the NPV rule that determined the outcome.

Within this environment a focus on flexibility in investments evolved. The intention is to reduce Type I and II errors while ensuring those strategic decisions about successful investments are not superfluous. For category 2 or higher risks, it is argued that the strategists can take advantage of uncertainty to increase
Figure 1. The predictions–success table for NPV investments

<table>
<thead>
<tr>
<th>Prediction Success Table for NPV-Based Investments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accept project based on NPV</strong></td>
</tr>
<tr>
<td><strong>Project Succeeds</strong></td>
</tr>
<tr>
<td><strong>Project fails</strong></td>
</tr>
</tbody>
</table>

value by examining the implicit options embedded in the investment. These options arise from strategic decisions to postpone, modify, or increment the investment as a response to uncertainty.

Figure 2 illustrates how options emerge from flexibility. The mapping of alternatives is done using a decision-tree structure. The sources of uncertainty are displayed under development, marketing, sales, and price. The (conditional) probabilities for each payoff at the terminal node are obtained by multiplying the (marginal) probabilities associated with each branch. In figure 1, there are 16 different states of nature describing project uncertainty. The classical decision rule in finance is to accept the project if the expected NPV, $E[NPV]$, is positive and reject otherwise. In a real options framework, some flexibility is added to the rule. For example, if the result is a positive $E[NPV]$, management has the right
Figure 2. Decision framework for real options valuation

but not the obligation to pursue the project. Likewise if the E[NPV] is negative, management has the right but not the obligation to reject the investment.

What is this flexibility worth? Suppose that management has the opportunity to delay the investment for a period of time (e.g., 1 year or 5 years) and by doing so, a number of uncertainties can be resolved so that the E[NPV] increases. This is depicted in the lower branches of figure 2. Note that nothing has changed in this simple framework except that postponement has resulted in revised probabilities. The value of the option in this case will be the maximum of the E[NPV] of the lower branches less the E[NPV] of the upper branches or zero (e.g. E[max{0, NPV₁ - NPV₀}]). Hence the decision has an imbedded real (call) option with a strike or exercise price equal to the net present value of the original investment decision (i.e., NPV₀).
Figure 3. Real option profile

The nonlinear payoff structure of the real option is presented in figure 3. The line \( i, i' \) represents the payoff possibilities for delaying the investment. At point \( a \), the values of postponing the investment and making the investment immediately are equal. The horizontal axis is the value of the project and the vertical axis represents the value of the payoff and the value of the option. The nonlinear payoff structure is equal to \( \text{abi} \) with a strike or exercise price of \( \text{E[NPV]} \) at point \( a \). The reason for a nonlinear payoff structure is that waiting will only have a value if the expected value of waiting exceeds the expected value of not waiting. If this is true, then postponing the investment means that the option to wait is being exercised. If it is false then postponing the investment is not expected to increase value; the option to wait will be killed and the project will be undertaken currently.

The curved line in figure 3 represents the actual value of the option in current dollars. The value of the option will be zero when the project value is zero. However, the option always has value to the right of the \$0 intersection. Even if the payoff structure is negative (e.g., between points \( a \) and \( i \)) there is always a positive probability that postponing will have value. At point \( b \), the option value is equal to the payoff line. Point \( b \) represents the maximum current value of the option. (This point represents the value matching and smooth pasting conditions discussed by Dixit and Pindyck.) To consider payoffs to the right of point \( b \) is speculative, so the option has little interpretation beyond point \( b \).

A Real Options Valuation Using the NPV Rule

Figure 4 provides a simple example of how options emerge. Suppose that an investment had a 10% chance of receiving \$5m in present value dollars, but because of uncertainties (in science, regulation, markets, etc.) there is a 90% chance that the investment value will be \(-\$1m\). The expected NPV of investing immediately is therefore \( 0.9 \times (-1.0) + 0.10 \times (5.0) = -0.40 \) and would be rejected under the NPV rule. Suppose that management has the opportunity
Figure 4. Real options example

A Real Options Example Using the Black–Scholes Formula

In the science and technology sectors, a common strategy for growth is to acquire science, scientists, and markets from other companies. Strategic investments however create a dilemma. If expertise is to be purchased, what is that expertise worth?

Suppose that the decision is to invest in a company that is developing new technology. The technology company is interested in purchasing the company but does not want to underwrite all of the risks; product development may be stalled by scientific limitations, marketing may be stalled by regulatory bodies, or the acquiring company may lose interest in the market over time. The acquiring company can buy the new technology company today or wait to see how products and markets develop. If they invest now they might lose the investment but if they wait they may have to pay a multiple of its current value if it is successful.

Suppose that the target firm is currently valued at $3m. The acquirer can offer to buy the company now, or it can enter into a flexibility contract that gives it the exclusive right to purchase the company for $5m in 2 years. Because it is a right and not an obligation, the option can be allowed to expire if the value of the firm is less than $5m in 2 years, or it can buy the company for $5m if the value of the company equals or exceeds this value. In terms of real option valuation, the NPV of the investment is $3m, the strike price is $5m, the time to expiration is
2 years, and the discount rate is market prevailing. Assume that existing market instruments can span the risk of the company and that risk can be measured by the stock price volatility of the target firm or a proxy measure of uncertainty from another company with similar risks. Suppose that the volatility of the stock price returns is 40% per year, which is probably midpoint for biotechnology companies.

With these assumptions it is possible to put a price on the value of waiting using the Black–Scholes option pricing formula for a call option. The relationship between the classical pricing of options on financial assets and the pricing of options on real assets using the Black–Scholes option pricing formula is presented in table 2, as is the Black–Scholes formula. Using the notation and formula in table 2 consider two scenarios. In scenario 1, \( S = \$3m \), \( X = \$3m \), \( t = 2 \) years, \( \delta = 0 \), \( r = .06 \), and \( \sigma = .40 \), and the value of the real option is in excess of \$579,718.93. Therefore if the firm was acquired for \$3m the acquirer will receive the NPV value plus a growth option of \$579,718. In reality the target firm's investment bankers will probably recognize the growth option and so the acquisition price will range somewhere between \$3m and \$3.579m. In other words, the growth option becomes part of the transacted value.

In the second scenario the acquiring firm does not want to underwrite all of the risks. It can buy a right to the target firm’s assets in the future without having to purchase the firm immediately. Suppose that rather than spending the money to purchase the target today, management decided to pay for the right to purchase the company in 2 years for \$5m. In this case set \( X = \$5m \) and the option value is \$176,838.82. That is, management would be willing to pay, and the target would be willing to consider, \$176,838.82 for the right without the obligation to buy the company in 2 years. If the company’s value exceeds \$5m, then the scientific discovery was likely successful and the growth option was worth its value. However, if the science is unsuccessful, the value of the firm would be less than \$5m and the option would expire worthless. Even though the acquiring firm may have to pay \$5m for the target firm in the future, its loss is limited to the real option premium. By paying less for the company now it is actually increasing its exposure to risk, since unsuccessful trials could result in significant and irreversible losses.

The value of the real option is synonymous with the value of the flexibility it provides. The above example illustrates how real options can be used to avoid losses. While the option focused on the option to wait or postpone an investment, there are a number of other options available to managers. These are summarized in table 1 and will be discussed in practical and qualitative detail below. However, it is important to keep in mind that each option on each project will be quite unique and will require substantial effort to define, set up, and resolve. For example Perdue et al. recite a real options valuation of 13 embryonic research projects at Westinghouse that required 1 month in lapsed time and 2 months of human time to evaluate.

**Mycogen Case Review**

Kalaitzandonakes’ case study on Mycogen is centered on the May 1997 problem faced by Jerry Caulder, Chairman and CEO of Mycogen, on what
Table 2. Investment opportunity as a call option

<table>
<thead>
<tr>
<th>Investment Variable</th>
<th>Black–Scholes Option Symbol</th>
<th>Call Option Variable</th>
<th>Direction of Option Value as Variable Changes</th>
<th>Economic Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present value of investment opportunity</td>
<td>S</td>
<td>Stock price</td>
<td>increase</td>
<td>As PV of cash flow increases, the NPV of the project increases, holding $X$ constant. The option increases value as this intrinsic value increases. As the call value increases, there is greater flexibility to postpone the decision to invest now, but with a greater chance of a future payoff. But suppose that $S &lt; X$ so that $NPV &lt; 0$. The option will still have value if $\sigma &gt; 0$ since there is the chance that $NPV &gt; 0$ at some future date. The greater the call option value the greater will be the ultimate value of the investment.</td>
</tr>
<tr>
<td>Initial investment</td>
<td>X</td>
<td>Strike price</td>
<td>decrease</td>
<td>For reasons similar to those above. As $X$ increases, the NPV decreases. As NPV decreases, the call value decreases, as does the value of the investment.</td>
</tr>
<tr>
<td>Length of time to defer decision</td>
<td>$t$</td>
<td>Time to expiration</td>
<td>increase</td>
<td>In a real option world, the smooth pasting condition is triggered by the value of the option relative to the value of the investment. It is not time dependent per se. However, the longer it takes for the decision to invest, the greater the value is because uncertainty is resolved with time. On the other hand, time is implicit in the calculation of the NPV. The life of the option, all other things being equal, cannot exceed the life of the investment.</td>
</tr>
</tbody>
</table>
Table 2. Continued

<table>
<thead>
<tr>
<th>Investment Variable</th>
<th>Black–Scholes Option Symbol</th>
<th>Call Option Variable</th>
<th>Direction of Option Value as Variable Changes</th>
<th>Economic Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dividend rate δ</td>
<td>Dividend yield or convenience yield</td>
<td>decrease</td>
<td>The real option value can be impacted by how rapidly a resource is depleted for nonrenewable resources or the costs of storage. The convenience yield in Pindyck’s model is the difference between yield on the real asset and the CAPM return. For commodities, the convenience yield would be the return above storage. As convenience yield increases, the value of the option decreases. This provides some indications of directions of strategy. If, for example, δ represents waste, then the value of adopting technologies to reduce waste can increase the real option. In agricultural land values, δ might represent the rate at which top soil is eroded. The real option value of land will increase as a result.</td>
<td></td>
</tr>
<tr>
<td>Time value of money r</td>
<td>Risk-free rate of return</td>
<td>decrease</td>
<td>The value of the real option and the value of the investment will increase as the discount rate or hurdle rate is increased. This is due to the fact that the present value of the option at exercise decreases as the opportunity costs of postponement increase.</td>
<td></td>
</tr>
<tr>
<td>Riskiness of investment σ</td>
<td>Standard deviation of stock returns</td>
<td>increase</td>
<td>Real options exist because of uncertainty. Like financial options, if there is no risk, there is no option value or need for options. The real option is a contingent claim, which means that its value is derived from positive value only. This is the upside semivariance that is so often ignored in conventional analysis. Downside risk is</td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Continued

<table>
<thead>
<tr>
<th>Investment Variable</th>
<th>Black–Scholes Option Symbol</th>
<th>Call Option Variable</th>
<th>Direction of Option Value as Variable Changes</th>
<th>Economic Significance</th>
</tr>
</thead>
</table>

limited because the option value converges to zero as the probabilities associated with out-of-the-money outcomes (dynamically) increase relative to probabilities associated with in-the-money outcomes. Uncertainty in an options framework has value because it provides opportunities to increase value while truncating outcomes that diminish value. If risk is exogenous, e.g., commodities market volatility, then the higher the volatility, the higher the value of the call. Interestingly this suggests that the owner of a real option might actually take actions to increase risk in order to increase the value of the option, especially if the option is traded. An example of this occurs with the increased risks and opportunities that arise from increased competition. A patent holder of a genetically modified organism may want to publicize the technology in the hopes that competition will extend the use of the technology.

Black–Scholes Model: \( C = Se^{-\delta t}(N(d_1) - Xe^{-rt}N(d_2)) \) where \( d_1 = \frac{\ln(S/X) + (r - \delta + \sigma^2/2)t}{\sigma \sqrt{t}} \), and \( d_2 = d_1 - \sigma \sqrt{t} \) and \( N( ) \) is the cumulative normal probability distribution evaluated at \( d_1 \) or \( d_2 \).

direction the company should take. The essential question was how Mycogen, a biotechnology and seed company, could reach an appropriate size to withstand competition and capture profits from a rich technology base built up over the previous 14 years. The options facing Mycogen in 1996 were to

- grow through mergers and acquisitions, buying highly contested assets at high prices;
• continue the past approach of networking and access strategic assets through alliances; or
• focus on internal growth where competition and new technology could shut the window of opportunity for profiting from current technology assets.

As of 1996, the strategic assets owned by Mycogen included intellectual property rights, a wide variety of germplasm, and a distribution system. Historically Mycogen had acquired these assets through its own research and development, strategic alliances, and through mergers and acquisitions. Along the way, the public shares of Mycogen had not responded to many of the actions that it took to grow the company over the past 14 years.

Mycogen started out as a company that discovered and developed Bt genes, which had pesticidal action against insects. Mycogen owned both the genes and the patents. Ultimately it made sense for Mycogen to move into the seed business either by licensing its gene technology or by forward integrating and eventually merging with Agrigenetics, a biotechnology and seed company, and through it, streamline operations under a single brand name of Mycogen Seed®. Using Mycogen’s intellectual property rights and technology as currency, it built its seed company through a network of partnerships including:

• Ciba Seeds (cross licensing agreement);
• Delta and Pine Land’s corn and sorghum (acquisition of germplasm plus distribution);
• Cargill (distribution agreement plus access to tropical germplasm);
• Pioneer Agreement (10 year product development agreement. Bt gene supplied for Pioneer’s expertise in plant transformation and product development. Mycogen genes to be placed into certain crops’ germplasm);
• Dow Elanco Agreement … Mycogen acquired United Agriseed from Dow Elanco (added sales, germplasm, production expertise, modern factories). Dow Elanco acquired 46% of Mycogen. Mycogen now had a technology partner in the agrochemical industry;
• Morgan Seed (acquisition in Argentina);
• Verneuil (merger in France).

The details of these and other strategies that built Mycogen to its current strength are found in the original case.

Strategic Risk Management

The problems to be solved in the Mycogen case study are found on page 462 of the original article. There are several approaches to evaluating these choices including looking at strengths, weaknesses, opportunities, and threats or by examining the competitive environment. However, this type of analysis can subjugate the best solution by failing to recognize that the issue facing Mycogen is not so much asset acquisition and competition as it is risk and uncertainty. It is simple to intimate that Mycogen has a strength in biotechnology and distribution, a weakness in penetrating overseas markets, an opportunity to invest or partner with new technology firms, and is threatened by larger pharmaceutical firms and the falling of the pillars which used to separate biology from chemistry. Indeed, these are all part of the larger issues of uncertainty. If they were not,
then weaknesses and threats would be converted into opportunities which in turn would be converted into strength. Such is not the case.

A real options framework provides a range of choices based upon uncertain outcomes. There are two significant contributions that the Mycogen case offers to better understand real options. First the strategic course that Mycogen had taken provides an interesting retrospective on the types of options available to it and the types of options that it exercised. Second, as Mr. Caulder decides the next strategic step, the student has the opportunity to identify the uncertainties and then forward think through the number and types of options that result from this uncertainty.

Before continuing, it is useful at this point to explain how Mycogen as a case study in real options will be used in a graduate course on financing agriculture in the electronic MBA in Agriculture program at the University of Guelph. Note that the analysis is qualitative and it is not expected that the options would actually be priced. The original case study does not provide enough information to do this. The questions attached to the original case study are revised as follows.

Using a real options framework:

1. Consider Mycogen’s strategy prior to May of 1997. Describe the various uncertainties that Mycogen faced, the types of options open to it, and the types of options it exercised.
2. It is now May of 1997. Should Mycogen grow through mergers and acquisitions (M&A), strategic alliances, or grow internally?

A Real Options Solution to Mycogen

In this section a candidate solution to the Mycogen case is provided using the qualitative aspects of a real options framework. The usual case study disclaimer applies in that this does not necessarily represent either a correct or incorrect analysis of the facts and other readers of the Mycogen case study could (and probably would) have different interpretations.

Consider Mycogen’s strategy prior to May of 1997. Describe the various uncertainties that Mycogen faced, the types of options open to it, and the types of options it exercised.

To answer this question the students would need to summarize the strategic acquisitions made by Mycogen prior to 1997. Although there are many ways in which the strategies and uncertainties could be identified, the most useful would probably be to identify strategy in terms of functionality. A solution is provided in table 3.

First of all, it is important to identify the nature of the uncertainties facing Mycogen. In the early stages of its growth, there was uncertainty about the directions of technological advances and the regulatory environment, as many of the germplasms developed had not been invented before. In addition there were concerns over patent infringement outside of the United States. Mycogen could make irreversible investments in R&D but certain techniques required were not yet invented and these roadblocks could ultimately kill development. Even if the roadblocks were overcome, there was, in the early 1980s, an untested regulatory
### Table 3. A retrospective examination of Mycogen’s options

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Activity</th>
<th>Uncertainty</th>
<th>Real Option Type</th>
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</table>
| Cross licensing | • Ciba seeds  
• Cargill  
• Pioneer | • Drawn out litigation over intellectual property rights  
• Competition | • Flexibility option in a “free to operate” environment  
• Growth options as merging technologies compounded value added and led to more and different types of uncertainty and opportunities. |
| Distribution agreements | • Delta and Pineland  
• Cargill  
• Dow Elanco  
• Morgan Seed  
• Verneuil | • Access to markets  
• Competition  
• International reach | • Growth options: Had Mycogen attempted to compete directly in these markets, it would be competing against significant corporations with deep pockets. By establishing distribution agreements it created valuable growth options to enter new markets quickly. |
| Germplasm | • Agrigenetics  
• Delta and Pine Land  
• Dow Elanco | • R&D: as a genetics company, this is where Mycogen’s expertise lay. However the R&D investment in discovering and developing new germplasms and genes involved a significant and irreversible investment. | • Flexibility options: by adding to its existing line of germplasm Mycogen accumulated an inventory which could be used or abandoned as markets and technologies developed.  
• Learning options: By blending its expertise with smaller companies such as Agrigenetics, Mycogen also accumulated new knowledge and new techniques. These could be levered into value at a future date.  
• Growth options: With the increased inventory of germplasm, Mycogen increased its scientific reach for new products and opportunities. |
Table 3. Continued

<table>
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</tr>
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<tbody>
<tr>
<td>Seed</td>
<td>• Agrigenetics</td>
<td>R&amp;D: Mycogen started out as a genetics company with R&amp;D at the cellular level rather than the seed or plant level. To enter this market, Mycogen would have had to acquire expertise from within, which would be costly and, because of the knowledge base, uncertain.</td>
<td>• Learning options: By acquiring or partnering with seed companies, Mycogen could lever its expertise at the cellular level with its partners’ expertise at the seed or plant level. Not only would this reduce the time to develop and market new products, but it would allow Mycogen, as a business unit, to focus on its own core competencies.</td>
</tr>
<tr>
<td></td>
<td>• Ciba Seeds</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>• Pioneer</td>
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<tr>
<td>Agrochemical Dow Elanco</td>
<td>• R&amp;D: like the uncertainties in germplasm and seed, Mycogen needed to gain access to the agrochemical industry. The longer it waited, the more uncertain the competitive environment would be. This would be costly if the biologists needed to learn the chemistry.</td>
<td>• Learning option: Value is created because these contracts provide an option to accumulate knowledge that would not easily be obtained otherwise. • Growth option: The learning option, particularly related to how genetic material can be used to replace chemicals, provided a growth opportunity which would not otherwise occur.</td>
<td></td>
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Moreover the various uncertainties facing Mycogen were not in isolation of each other. The environment was such that rainbow options (see table 1) were required to balance simultaneous risk. However, as the rainbow options were identified, new opportunities arose. That is, the growth of Mycogen was driven by a series of compound options with the exercise of one option leading to new and different options.
Table 3. Continued

<table>
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<tr>
<td>Production and operations</td>
<td>Agrigenetics</td>
<td>Fixed plant and distribution result in significant irreversible costs. The</td>
<td>Operating options: If a partnering agreement provided high quality physical plant</td>
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<tr>
<td></td>
<td>Cargill</td>
<td>routine building of infrastructure adds to risk, especially if the infrastructure is in highly</td>
<td>and distribution at a lower cost than would otherwise exist, then the option would</td>
</tr>
<tr>
<td></td>
<td>Dow Elanco</td>
<td>contested market areas or brand new markets.</td>
<td>have some value. If the nature of the various agreements regarding physical plant</td>
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<td></td>
<td>Morgan Seed</td>
<td></td>
<td>and distribution had exit clauses, then there is also enhanced value created by a flexibility option, which would also include an exit option or the option to abandon.</td>
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<td>Vernuile</td>
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As indicated in table 3, it appears that the most valuable options to Mycogen had been the learning options and the growth options. This is not unusual for high technology companies. The learning option provided Mycogen with the right to accumulate knowledge (for a fixed payment in cash, stock, or other). The growth options emerged from the learning options and provided Mycogen with the right but not the obligation to enter a new market and/or develop new products. But Mycogen, through its accumulation of germplasms, other genetic material, and associated intellectual property rights, also held a number of flexibility options. At any moment in time and as market conditions warranted, Mycogen had the right but not the obligation to either add a new product, abandon an old product, or both.

It is now May of 1997. Should Mycogen grow through M&A, strategic alliances, or grow internally?

Before answering this question it is important to note that this combines the first three questions on page 458 of the original text. In a real options framework, it would be imprudent to examine each alternative without considering the others. Furthermore, as of May 1997, Mycogen faced the same uncertainty regardless of what decision was made. The key to the real options analysis is to exploit the relationship between uncertainty, costs, and cash flow to create the real option or portfolio of real options with the greatest value.

Keeping in mind that uncertainty creates value because it creates options and flexibility, the strategist might start out by ranking the three key assets in
Table 4. Some of the real options available to Mycogen

<table>
<thead>
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<th>Category</th>
<th>Options</th>
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| Waiting-to-invest or timing options | - Pharmaceuticals looking to compete in GMO market  
- Overlapping technologies between biotech and chemical/pharmaceutical  
- Patent disputes                                                                 |
| Growth options            | - Development of seed to  
- resist pests and disease  
- protect against herbicides  
- improve composition through modified oil, protein or starch  
- Global expansion of GMO market                                                                 |
| Flexibility options       | - Large investment in R&D provided base to use technology across a number of crops  
- Acquisitions targeting biotechnology, germplasm, and distribution systems  
- Patent disputes and freedom to operate                                                                 |
| Exit/abandonment options  | - Licensing arrangements with an exit clause  
- Staged investments in which the option to invest has value only if the previous stage had a positive outcome.                                                                 |
| Learning                  | - Large investment in R&D provided in-house expertise that could continually improve knowledge and techniques                                                                 |
| Operating                 | - Leasing facilities on a short-run basis  
- Subcontracting detail work                                                                 |

terms of uncertainty and then matching this uncertainty against incremental and expected cash flow. Following the four categories of strategic risk as defined by Courtney et al., R&D into germplasm would create the most uncertainty because the uncertainty is compounded. The first degree of uncertainty relates to the success or failure of R&D. This creates a learning option and if this learning option has value (i.e., valuable information was garnered), this might then give rise to a growth opportunity in terms of new products and markets.

Second would be the intellectual property rights. These assets are uncertain because they generally have a fixed life and can become obsolete as new technology is discovered or more competitors enter the market and make similar intellectual discoveries. However, while alive, they provide a significant growth option by protecting the company against competition, at least in the short run. The inventory of rights also provides a flexibility option because Mycogen has the option to activate an old technology to which it has the rights or to abandon an existing technology to which it has the rights. Note that even the remote possibility that a previously discarded technology could be resurrected gives it a real option value.

The third asset is in distribution. These assets are probably quite close to category 1 risks but there is still irreversibility if money was invested in a new distribution system for a highly contested market or an unknown market. In this case Mycogen probably has a learning option which would allow it to step into the market by subcontracting fixed capacity, transport, and delivery, or forming
strategic alliances. As the uncertainty becomes resolved, Mycogen can then step into the distribution investment with increasing levels of investment.

Depending on how much weight management places on risk versus return, the greater value, in theory at least, would be to leverage the risk of the most risky assets. Since learning options followed by growth options have worked for Mycogen in the past, they would possibly work in the future. This still leaves the three alternatives to be analyzed, M&A, strategic alliance, or internal growth. Each alternative has potential but in a real options world, the strategy with the most flexibility will likely have the largest value. If merger or acquisition possibilities arise, the strike price would equal the cost of the investment on a fully diluted basis. The underlying real asset would be described by the cash flows generated from the investment, and the volatility would be measured by the daily change in stock price of the company to be acquired or some spanning proxy. If a strategic alliance is considered, the real option value would be described by a strike price equal to the present value cost to Mycogen, and the underlying cash flow would be equal to the financial contribution of the partnering company (if any) plus the incremental cash flows to Mycogen resulting from the alliance. In the third instance, where internally generated funds are used for R&D, Mycogen must weigh its present value cost against the present value of cash flows. The underlying volatility would be measured by the implied volatility in Mycogen shares. If all companies are in the same line of business, then underlying systematic risks should be the same anyway, but if Mycogen were to venture into new territory, a different sort of risk ought to describe the numbers.

In a qualitative sense, it is important for students to understand that real options theory is about risk and flexibility. To further the discussion it might be useful to present or have presented a figure such as figure 2. It is unlikely that students will be able to actually calculate the real option values, but by viewing strategy in terms of payoffs to uncertainty, the traditional view of strategy will be challenged.

Discussion and Conclusions

Modern corporate finance and options theory has blended through the framework of real options. Real options arise from contingent payoff structures on real assets. The real options paradigm is important because it bundles into one model the essence of finance, risk, and strategy. Not only can real options be used to value managerial flexibility but it also provides a new way of thinking about strategy. Across the agricultural sector, new technologies and businesses are giving rise to new uncertainties and opportunities. The largest growth industry is clearly in the life sciences, where biotechnology and genetically modified organisms are changing the landscape of agriculture and food.

The economics and valuation tools associated with real options are in their infancy, but real options models will continually develop, and with ever-increasing importance will become commonplace in our business teachings. This article provided an introduction to the qualitative aspects of real options and uses the Mycogen case study written by Nicholas Kalaitzandonakes to illustrate the relationship between real options and real strategy. Through analyzing this
case, it becomes evident that Mycogen built itself by understanding the nature of uncertainty in its domain and took actions to minimize the downside risk. While it is unlikely that management at Mycogen was openly thinking about real options models as they built the company, a retrospective summary indicates that it did indeed create and exercise real options through its growth phase. As Mycogen attempts to determine its next step, it will find that entangled in the uncertainties that it faces there are a host of options that can create opportunities.

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References