EVALUATION OF INVESTMENT IN AGRICULTURAL TECHNOLOGY

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Abstract

Agricultural producers are continually faced with decisions regarding the adoption of new technologies. This paper reviews the applied decision tools available for use in assessing technology adoption decisions with emphasis on livestock production decisions. Decisions and decision tools are categorized by relative scale, perceived risk and degree of reversibility. The tools required to assess decisions increase in sophistication and information requirements as the investment's scale, risk and reversibility decrease. Tools discussed include partial budgeting, enterprise budgeting, whole farm budgeting, cashflow budgeting, capital budgeting, and real option pricing models. How investment in technology can increase value by increasing future options to producers is also discussed.

Introduction

Investment in agricultural technology can be expensive. New livestock production facilities can require investment of millions of dollars. New harvest equipment can run into the hundreds of thousands of dollars. Genetic testing of breeding stock can be equal or even exceed a year's average return on a per head basis. Further, the returns from adopting new technology are usually uncertain. For example, will buyers pay for genetic information? What if a producer discovers through testing that his stock does not have genetics desired by the market? While theoretical-based tools are available to analyze even the most complex decision problems, the information requirements or training needed to utilize these tools are often too onerous to be practical for most real world decisions. Here, I discuss the practical shortcomings of theory-based decision analysis and review several applied alternatives. While these applied decision tools require numerous simplifications, they have lower informational requirements and are accessible to most real-world decision makers. These tools are discussed in relation to three criteria: relative scale of the decision, perceived riskiness of the decision and the degree of reversibility of the decision.

Theory versus Practice of Decision Making

Economic theory of investment under uncertainty utilizes the expected utility hypothesis (von Neumann and Morgenstern 1949). Under this framework, investors allocated limited funds between competing investment alternatives in order to maximize their individual expected utilities. In a multi-period model, expected utilities over time are discounted and summed. There are several well-known criticisms of this framework (see, *e.g.*, Fishburn 1981). Despite the economists' "rational man" assumption of economic behavior, there are several well-known inconsistencies (or paradoxes) with the expected utility hypothesis (see, e.g., Hirshleifer and Riley). Perhaps most relevant criticism in the context of this paper is the difficulty in obtaining subject joint probability distributions that characterize the randomness of returns from competing investment alternatives. If investments are mutually exclusive (e.g., technology *A* versus technology *B*), the difficulty is only somewhat mitigated as the joint distributions of returns associated with each new technologies and existing enterprises must still be determined.

To further mitigate the difficulties in applying the expected utility framework, assumptions regarding the utility function and independence of investments are often imposed. For example, by assuming constant absolute risk aversion and independence of return distributions, the model simplifies to analyzing the expected utility associated with one investment at a time while ignoring other on-going investments. This assumption is maintained for many *applied* decision frameworks. With this simplification, only the distributions of returns from the technologies being considered must be determined. While greatly simplifying the analysis, elicitation of subjective probability distributions is a non-trivial and potentially impossible task. It requires the decision maker to subjectively determine all possible outcomes from an investment and the relative likelihood of each outcome. For unproven technologies, asking a producer to assess the potential outcomes and likelihoods may result in highly unrealistic probability distributions. This is due to the presence of ambiguity, rather than risk[1]. While alternative decision models have been developed when ambiguity is present (Fox and Tversky 1995), these models are even more difficult to apply to practical decision making.

To illustrate some of the difficulties associated with probability distribution elicitation, consider a seed stock producer decision to adopt marker-assisted selection for tenderness. At the time of this writing, there are no large-scale marketing channels that reward tenderness. While it is not certain when or if market channels will develop to reward tender carcasses, it does seem likely that eventually packers or other market channels will pay premiums on carcasses that meet some tenderness criteria. However, when that will happen and what the level of premiums will be are both uncertain. In order to use the formal decision analysis method, a producer would need to subjectively assess 1) the probability that premiums will be paid for tenderness for all future marketing dates, 2) the probability distribution for returns paid for premiums in all future time periods, 3) the probability distribution for premiums paid to seed stock producers with verified markers for tenderness for all future time periods, and 4) the distribution of tenderness markers in his herd for all future time periods. The difficulty associated with these assessments means that formal decision analysis is not useful in most real world applications.

Given the difficulty in employing formal decision analysis for practical decision making, a wide variety of managerial tools have been developed for use by agricultural producers. Some are "back-of-the-envelop" calculations; others would likely require the assistance of an economist trained in their use. To help aid in the choice of decision tools, I suggest three criteria for aiding the determination of the tools required. These three criteria are relative scale of the

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[1] To illustrate risk and ambiguity, consider an urn containing 50 black balls and 50 red balls. Most people would correctly conclude that the odds of drawing a black ball is 50%. This scenario can be described as risky or uncertain. Now, consider an urn with a total of 100 black and red balls. What is the probability of drawing a black ball now? Subjective probability assessment may fail miserably to reflect reality. A "naïve" distribution of 50% black and 50% red balls might be significantly in error. If the person filling the urn put in 100 black balls, the naïve believe is highly inaccurate. This second scenario demonstrates ambiguity.

investment, perceived riskiness of the investment and the degree of reversibility of the investment.

First is the relative scale of the investment. Relative scale might be in terms of percent of business being changed or in terms of dollars invested. For example, consider a US soybean producer considering changing 160 acres to a new variety. For a 2000-acre farm, this is probably a fairly minor change. In contrast, a 10-acre change for an African subsistence farmer might be a large percent of the farm's acres.

Second is perceived risk. In the previous US farm example, a 160-acre change to a new variety is most likely a low-risk decision. Producers routinely make these decisions, seed companies and land grant universities routinely publish varietal trial results, and markets likely exist for the new variety. So, this decision has a low-level of perceived risk. While for the African subsistence farmer, a 10-acre change might have very significant consequences. Get the decision wrong and his family could suffer malnutrition and lose their farm and home. So, the decision might have a high-level of perceived risk.

Third is the degree of reversibility. Some decisions can be "un-done" at a low cost and in a short-time period. In the soybean example, the US producer can switch back to the old variety in the next growing season, a low-cost and short-time reversal. An example of a potential high-cost and long-time reversal is the decision to change hide color in a breeding herd. Individually and collectively, many US producers have selected for black-hided cattle in response to premiums associated with Certified Angus Beef (CAB). While a rational response to economic conditions, it would be costly and take several years to "undo" this decision. Few producers have the financial ability to sell off existing breeding animals and replace them in a short-time period, say one or two years. Perhaps most US producers would take eight to ten years or more to either replace their existing breeding herd by buying new bulls and breeding in the desired hide color or buying replacement females over several years.[2]

Reversibility is essentially an option. It gives the producer the option to revert to previous production practices and has real economic value. Economists call these types of options "real options" as opposed to financial options (*e.g.*, futures options), also called financial derivatives. However, determining the value of an option is difficult—especially for non-traded options. Financial options, such as puts and calls, are traded on exchanges and their market values readily observed. Real options are not traded in markets. Real option pricing models are mathematically complicated and, similar to decision analysis, are information intensive. Few people, other than a subset of economists, are trained in modeling real options. Given the complexity of modeling the value of real options, real option price models are not used by agricultural producers. Their usefulness is discussed later in the context of how investment in technology can increase options and, therefore, add value.

Applied Decision Tools

Given the practical difficulties of employing formal decision analysis, Extension specialists and farmers utilize several less formal decision making tools or aids. Only under the

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[2] This is not a criticism of black-hided cattle or the decision to select for black hides but to demonstrate the difficulty/costs associated with reversing or "undoing" some decisions.

most severe assumptions are these tools compatible with the expected utility hypothesis. However, the reduced informational requirements and lack of sophistication can be viewed strengths in the practice of decision making. A number of these tools are discussed below. Most are variants of budgeting. Budgeting is used to test a production, marketing and/or investment plan on paper before real world implementation. These tools are used to identify bottlenecks to profitability, compare the profitability of alternative plans, and assess cashflow difficulties.

Partial Budgeting

The simplest form of applied decision tools is partial budgeting. This tool is useful when considering small-scale, low-risk and highly-reversible decisions. In a previous example, a 2000-acre US soybean producer was considering switching 160 acres to a new soybean variety. A partial budget is an appropriate tool for analyzing this decision.

With a partial budget, only changes in revenues and expenses are included. In the soybean example, rent would not change with the adoption of a new variety. So, rent is not included as an item on the budget. Table 1 provides a suggested format for a partial budget. In the table, the left column lists the "cons," reduced revenues and additional costs, from proposed change and the right column lists the "pros," additional revenue and reduced costs, from the adoption. The columns as summed with the left column summing to ***A*** and the right column summing to ***B***. If ***B-A*** > 0, then the change appears to be advisable. Given the simplicity of the method, there are other factors that might need to be considered. For example, are there impacts on labor or machinery constraints? Is convenience improved or reduced? Is the family's lifestyle affected? Before implementing a change, a producer should assess these potential factors, even if the partial budget suggests that the change would be beneficial.

Table 1. Partial budget format[*]

Reduced revenues Additional expenses	Additional revenues Reduced expenses
Reduced revenues + Additional expenses = ***A***	Additional expenses + Reduces expenses = ***B***

[*]Adapted from Kay, Duffy and Edwards (2008).

Partial budgeting has been used to analyze a wide range of beef production. Examples include preconditioning of calves (Dhuyvetter et al. 2005), testing for disease in feeder cattle (Larson et al. 2005), and estrus synchronization in beef heifers (Gaines et al. 1993).

Enterprise Budgeting

Similar to partial budgeting, enterprise budgeting is used to compare competing enterprises. An enterprise budget projects all revenues, variable expenses, and fixed (overhead) expenses that can be allocated to a given enterprise. Decisions cDonsidered may be less reversible, larger in scale and somewhat more risky. For example, consider switching acres to a new crop. There may be more than a few minor changes in revenues and expenses. The producer may need to purchase new equipment, incurring additional ownership expenses. This also reduces the degree of reversibility as the disposal of the additional equipment may require time. And, risk exposure may increase as the producer may not be as familiar with the production, handling, storage and marketing of the new crop.

While risk is not formally incorporated into enterprise budgeting, *ad hoc* methods are frequently employed. Producers can analyze "what if" type questions. For example, what if yield is 25% below expectation? What if price falls by 15%? By assessing a wide range of yield, price and expense scenarios, producers can develop a sense of the range of possible returns from alternative levels of competing enterprises.

Enterprise budgets are available for most crops, fruits, nuts, berries, and livestock. Many can be found at the website for the Digital Center for Risk Management Education, University of Minnesota (UM DCRME 2010).

Whole Farm Budgeting

Whole farm budgeting builds on enterprise budgeting. Enterprise budgets are aggregated, and unallocated expenses are subtracted from aggregate returns. With the focus on the whole farm, even larger scale decisions can be analyzed. These include, for example, the implications of discontinuing an entire enterprise or investment/disinvestment in facilities. Impacts on the farm's bottom line are the focus of whole farm budgeting. While larger scale, higher-risk and less reversible decisions might be analyzed with this method, it is only slightly more illuminating than enterprise budgeting. Risk is again considered using *ad hoc* measures, and the degree of reversibility is not formally considered.

Cashflow Budgeting

The budgeting tools discussed up to this point are focused on profitability and the economic advisability of investments. In contrast, cashflow budgeting is focused solely on cash. This tool is used to project time periods where cash is short or in excess of current cash demands. It is particularly useful in assessing the feasibility of an investment rather than the advisability.

An annual cashflow budget is typically developed using month to month sources and used of cash. Importantly, *all* projected sources and uses of cash are included. Unlike budgets focused on profitability, cash items such as projected capital asset purchases and sales, principal payments, planned new borrowings, withdrawals for family living expense and contributed capital from off-farm income are considered in a cashflow budget. Also unlike most other budgeting tools, non-cash expenses, *e.g.*, depreciation, are not considered.

Even if one of the profit-focused budgeting tools suggests that an investment will be profitable, it may not be self-liquidating. That is, the additional income generated may not be sufficient to cover debt service on the investment. For example, land investments often do not self-liquidate, *i.e.*, cashflow. But, the land investment might still be economically advisable, *i.e.*, profitable. Cashflow budgeting is useful in determining if additional sources of cash are needed to make an investment feasible. So, cashflow budgeting is recommended for all investments, even if they appear to be profitable.

Capital Budgeting

Capital budgeting is concerned with investments that are long-lived. That is, revenues and expenses are incurred over multiple years. There are several tools that are used for capital budgeting. Three of the most commonly used tools are payback period, net present value (NPV), and internal rate of return (IRR) (Barry et al. 2000). The payback period calculates the number years required for the sum of annual net returns to equal the investment cost. This method ranks investments that quickly self-liquidate as most advisable. However, it ignores the potential differences in productive lives of alternative investments and the time value of money.

The net present value method discounts future cashflows and sums them up. If the NPV is positive, an investment is projected to be profitable. When comparing mutually exclusive investments (e.g., investment *A* vs. investment *B*), the investment with the highest NPV is chosen. The NPV method is consistent with an objective of maximizing expected profits and is recommended by economists.

The IRR method is similar to the NPV method, except that the discount rate is solved for rather than assumed. With the IRR method, the discount rate needed to make an investment's net present value equal zero is calculated. The investments are ranked then using IRR, with a higher IRR preferred. In most cases, the IRR will rank investments the same as NPV, but there are cases where the IRR method will generate incorrect rankings (Barry et al. 2000).

Since NPV is consistent with a profit maximizing, it is used for investment analysis. Net present values can be mathematically converted to annuities. An annuity is computed as the constant annual dollar amount that has the NPV as an investment. Using an annuity equivalent, it is possible to project the optimal timing of some investments. Perrin (1972) developed investment decision rules that utilize annuity equivalents. The rules are used to decide when to replace an existing investment (called the defender) with a new investment (called the challenger). Returns for the defender are projected several years into the future. In the year when the projected annuity equivalent return for the challenger exceeds the projected returns for the defender, the investment should be made.

Capital budgeting techniques do not explicitly consider risk and irreversibility. Again, *ad hoc* approaches to risk analysis are often used. However, capital budgeting methods allow for more analysis of sophisticated investment decisions by considering the optimal timing of investments.

Real Options

As discussed above, real options are options related to future actions. Reversibility is a real option and has value to decision makers. Budgeting tools do not adequately account for the degree of reversibility of alternative investments. Real option pricing models explicitly model the value of real options, including reversibility (Dixit and Pindyck 1994). Using real options modeling, the optimal timing of investments can be found. However, this richness is not costless. These models are mathematically sophisticated and require more information than budgeting tools. Most challenging is assessing the variability of returns from investment over time. As was discussed in the introduction, probability elicitation is challenging. Few producers will be able to use real option modeling to evaluate investment in new technology, and few—if any—software tools are available to aid producers. Producers might be able to get assistance at a land grant university.

Technology and real options

There are cases where a budgeting tool does not project profitability from an investment, but the investment might still be advisable. New technology can create flexibility in future activities. In other words, new technology can create real options. Deterministic budgeting tools (partial budgeting, enterprise budgeting, whole farm budgeting, cashflow budgeting, and capital budgeting) do not adequately account for the value of these options.

To illustrate, return to the example of a seed stock producer considering the use of tenderness marker-assisted selection. Since there are currently no large-scale markets for beef with verified tenderness genetics, simple budget tools would suggest that this is not a profitable investment. However, given there is some probability that markets will provide incentives to producers of tender beef, a real option can be created by using marker-assisted selection. If the seed stock producer begins using this selection tool, he will be in a position to market seed stock with desired genetics if and when the channels develop to reward tenderness. This is flexibility can have value.

Note, however, there is risk associated with this strategy. The markets might not be created during the farmer's productive time horizon. Lower-cost methods producing tender beef might be found, perhaps as simple as feed additives or post-slaughter treatment. Or worse, the US market for beef might collapse due to some unforeseen circumstance. So, the producer might invest in a technology that does not eventually result in improved profitability.

The tools required to analyze this type of investment are real option pricing models and stochastic programming models. Both are likely more sophisticated than can be readily developed and used on farm or in an Extension context. The proof of this can be found in the lack of research literature utilizing these approaches. A few applied economics studies (Lusk 2007, DeVuyst et al 2007; Mitchell et al. 2009) have used analyzed the value of alternative markers in fed cattle. However, at the time of this writing, no economic studies have analyzed the investment in marker-assisted selection.

Resources available to producers

Most land grant universities provide enterprise budgets for a wide range of crops, livestock, fruits, nuts and vegetables. And, many of those budgets are available on the internet. For example, Oklahoma State University has enterprise budgets available on line (OSU Ag Econ 2010). The University of Minnesota maintains a farm management budget database (U of M DCRME 2010) with budgets from several states. Also, some land grant universities have the ability to work with producers to generate budgets for specialized investments. Again using OSU as an example, the Food and Agricultural Products Center (OSU FAPC 2010) provides services to individuals and companies considering investment in agricultural-related technology and businesses. Producers can contact their local Cooperative Extension Service office to find similar resources available in their home state.

Conclusion

Decision making in the real world is complex, suggesting that complex decision models are appropriate. However, the information requirements of most complex decision models render them useless in an applied context. So, producers and Extension specialists rely on several readily available low-information requirement budgeting tools. Partial budgets, enterprise budgets, whole-farm budgets, cashflow budgets and capital budgeting tools are most often used to assess investment in new technology at the farm level. The cost of using these tools is a lack of ability to formal assess risk and the degree of reversibility associated with alternative investments. More sophisticated tools, including real option pricing models, do consider risk and reversibility but are not accessible to most agricultural producers.

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