Transition to Organic Cropping Systems under Risk

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Abstract

We analyze the risks, returns and optimal adoption strategies for a representative Minnesota farm switching from conventional to organic cropping systems. The EPIC simulation model was calibrated based on the yields observed in a farming systems field study. A farm-level simulation model was constructed using the EPIC simulated crop yields and historical prices. Results were compared for an expected utility maximizing farm under a range of risk aversion levels, with and without management learning curves and biological transition effects. A dynamic programming model was then constructed to evaluate the joint effects of machinery replacement decisions, learning curves, and biological transition effects on optimal adoption strategies. Results show that producers will find it optimal to transition to organic systems as rapidly as possible, even with significant learning curves and machinery adjustment costs.

Keywords: organic, cropping systems, risk, adoption, dynamic programming.

Introduction

Adoption of organic cropping practices has been rapidly increasing. Certified organic cropland acreage increased by 111% from 1992-1997, and by another 71% from 1997-2003 (USDA-ERS, 2005). However, the transition period from conventional cropping systems to organic cropping systems often represents a barrier to adoption. During the organic certification process, producers generally cannot earn organic price premiums on their production. In addition, producers go through a learning process which may lead to reduced income as farmers learn new production techniques, and is often compounded by a biological transition effect in which yields may temporarily be decreased due to increased weed pressures or nutrient deficiencies as new crop rotations are becoming established (Dabbert and Madden, 1986). Finally, producers may also need to acquire different machinery during the transition process. These changes all occur in a stochastic environment that affects both the prices and yields a producer receives. While others have analyzed the economic performance of organic cropping systems (see Welsh, 1999 for a review), only some have included risk (Mahoney, et al., 2004) or transition effects (Hanson, Lichtenberg and Peters, 1997; Dabbert and Madden, 1986), but none have included both risk and transition effects. This paper extends this work by specifically looking at risk during the transition to organic systems.

In the following sections we analyze the risks, returns and optimum adoption strategies for a representative Minnesota farm switching from conventional to organic cropping systems. First, we will describe the yield and enterprise budget estimation process. The cost and yield information will then be used in a stochastic simulation model to compare the risks and returns of the alternative systems. Finally, a dynamic optimization model will be used to evaluate optimum adoption strategies.

Yield and Cost Data

A farming systems field study was initiated in 2002 at the Swan Lake Research Farm near Morris, Minnesota to evaluate the economic and environmental performance of alternative cropping systems. The farming systems study includes a wide range of cropping system treatments including two types of systems: conventional and organic (CNV and ORG), two tillage treatments: conventional and strip tillage (CT and ST), two crop rotations: corn-soybean and corn-soybean-spring wheat/alfalfa-alfalfa (2YR and 4YR), and two levels of fertility management: fertilizer or manure applied at recommended rates, and no fertilizer or manure applications. Data from a subset of the cropping systems treatments are used as the basis for this analysis. Only the treatments receiving fertilizer or manure are included. The baseline system for this analysis is the conventional system with conventional tillage and a corn-soybean rotation (CNV CT 2YR). This system reflects the most commonly used practices in the region. The organic alternatives include the four organic treatments from the study that receive manure applications (ORG CT 2YR, ORG CT 4YR, ORG ST 2YR, and ORG ST 4YR).

Enterprise budgets were constructed using the USDA-Natural Resources Conservation Service Cost and Returns Estimator (CARE) based on the operations and inputs used in the field study from 2002-2005. Equipment prices and costs were based on information from Lazarus and Selley (2005). Equipment ownership costs were calculated outside CARE following American Agricultural Economics Association (1998) standards and using a farm size of 600 acres.

Yield data from the field study could be used with the cost estimates to identify the system that provided the highest net returns during the first four years of the study. However, the results represent only one realization of stochastic weather events, and only identify the optimum transition process given that realization. In order to evaluate the performance of alternative transition strategies under varying weather conditions, the crop management treatments from the field study were used with the EPIC simulation model (Sharpley and Williams, 1990) to simulate crop yields under different weather realizations. One of the biggest factors affecting crop yields in organic cropping systems is weed competition. EPIC is capable of modeling the growth of multiple crops. This feature was used to simulate the effects of weed pressure on organic yields and weed densities were adjusted to calibrate the model to simulate yields to within five percent of the averages observed over the 2002-2005 period. As the primary focus of this study was to model transition strategies under varying weather conditions, 20 series' of daily weather realizations were generated and used to simulate 20-year sequences of crop yields. The result was 400 yield observations for each crop with each cropping system treatment. Yields were also simulated using historical daily weather observations. The yields simulated from historical weather observations were used in estimating farm-level correlations between yields and prices for the risk analysis.

Conventional crop prices for the analysis were the marketing year average prices for Minnesota (USDA-NASS, 2006) for 1991-2005. Organic crop prices were price estimates from Streff and Dobbs (2004) for 1995-2003. Organic price information for organic alfalfa hay was not available as premium markets for organic hay are just emerging. For this analysis, organic hay prices were assumed to be equal to conventional prices.

Stochastic Simulation

The stochastic model compares the distributions of the present value of net returns for each treatment over a 20-year planning horizon:

$$(1)\ PV(\pi_i) = \sum_{t=1}^{20} \frac{1}{(1+r)^t} \pi_{it},$$

where $\pi_{it} = P_{it} Y_{it} - C_{it}$ is the per acre net return for cropping system i in year t, P_{it} is stochastic crop price, Y_{it} is stochastic crop yield, C_{it} is production cost, and r is the discount rate. A discount rate of six percent is used for this analysis. Note: To simplify the notation the subscript i is used as a general cropping systems indicator. In the most disaggregated case, i represents each crop phase of each cropping system, so for our example 14 cropping systems-crop phase combinations. However, i can also be used to represent rotation averages, five cropping systems in our example. We analyze both cases. The stochastic crop price and yield distributions were constructed as multivariate empirical distributions following the procedures outlined by Richardson, Klose, and Gray (2000) using the Simetar (Richardson, Schumann, and Feldman, 2006) spreadsheet add-in. Ordinary least squares (OLS) regression of prices and yields on trend was used to identify the non-random component of prices and yields. Where trend variables were not statistically significant, simple means of the data were used. Trend was not significant for any of the price variables, but was significant for 8 of the 14 yield variables. A 21 × 21 intra-temporal correlation matrix for the yield and price variables (14 yields and 7 prices) was estimated using the simulated yields based on daily weather observations and the annual price data for 1995-2003. An inter-temporal correlation matrix was estimated for each yield variable using the simulated yields generated with the 20 random weather seeds. Inter-temporal correlation matrices for prices were estimated using the 1991-2005 conventional price data and the 1995-2003 organic price data. The longer price series for conventional prices was used to improve the estimates. This was not an option for the organic price data since a longer price series was not available. Inter-temporal correlation coefficients were estimated out to a lag of 4 years, however, if a t-test showed the correlation at a particular lag to be non-significant, that coefficient and all higher lag coefficients were set to zero. For all of the yield and price variables, no variable had a significant correlation beyond a lag of two years.

The stochastic simulation used 500 draws from the MVE price and yield distribution. Risk comparisons among the cropping system alternatives were conducted using stochastic efficiency with respect to a function (SERF) and using a negative exponential utility function (Hardaker et al., 2004). For the organic cropping systems, organic price premiums were only earned in years 3-20. In calculating price for both organic and conventional systems, government loan deficiency payments (LDPs) were included. LDPs were calculated as the difference between the conventional crop price realization and the local county loan rate using the 2005 loan rates for Stevens County, Minnesota. No other government payments were included in this analysis.

Stochastic simulation was used under five different scenarios: 1) Baseline case with no biological or learning effect, and no adjustment to machinery ownership costs (BASE), 2) No biological or learning effect, but including a changes in machinery costs

(MACH), 3) Including a short-term biological or learning effect and machinery ownership cost changes (SLEARN), 4) Including a permanent biological or learning effect and machinery ownership cost changes (PLEARN), and 5) including short-term biological or learning effect and machinery ownership cost changes and a 50% reduction in organic price premiums (HALFP).

The machinery cost changes were modeled using the whole-farm estimates of changes in machinery ownership costs for each cropping system. This does not consider any cash-flow or credit constraints that might occur. This also does not account for any transition timing decisions that might occur due to machinery replacement decision involving wear-out of existing equipment. It was thought this would likely be a small factor since switching to organic production would involve acquiring additional equipment rather than replacing existing equipment.

For the SLEARN scenario, learning curves during the adoption process were modeled based on the results of the field experiment. Declining yield trends were observed during the first four years of the field study for corn under each of the organic cropping systems, and for soybeans under the ORG ST 4YR system. These declining yield trends were primarily due to increases in weed pressure over that period. For crops that showed declining yields during the first four years of the field study, this trend was calculated as a percentage of the four-year average yield for that treatment. The trend factor was then used to adjust the mean yields during the first four years of the simulation. However, in years 5-20, it was assumed that mean yields would recover to the four-year average yield. This assumption reflects the idea that biological shifts and management experience will allow the producer to better deal with weed pressures, reducing yield losses. This is a conservative estimate of yield potential under organic management, since mean yields for each of the organic treatments are still assumed to be below yields for the conventional systems in the long-run. While it has been observed that organic systems can produce crop yields greater than or equal to conventional systems (Delate and Cambardella, 2004), a Minnesota study comparable to this one showed reductions in organic crop yields in the long-term compared to conventional systems (Porter et al., 2003).

For the PLEARN scenario the same decline in yields was used as in SLEARN; however, it was assumed this decline was permanent and mean yields in years 5-20 would stay at year-four levels. This is a pessimistic assumption that biological shifts and management experience will only prevent further yield decreases, but will not help to regain yield losses experienced in years 1-4.

The HALFP scenario was included to investigate the sensitivity of results to maintaining current organic price premiums into the future. Risk analysis for a long-term Minnesota cropping systems study (Mahoney et al., 2004) showed that organic premiums at 50% of current estimated premiums were sufficient for an organic cropping system to dominate conventional cropping systems.

Dynamic Model

A simple dynamic optimization model was constructed to evaluate optimum adoption strategies when the entry point into a cropping system can have a significant impact on future returns. This model included only an “all or nothing” adoption decision to focus on the rotation entry point decision. It is recognized that this model ignores the possibility of a gradual transition, where the farm-level learning effects might be reduced by experience gained on a portion of the farm; however, the gradual transition model greatly increases model size and complexity, and is left for future research. The general model was formulated as:

$$(2)\quad \max_{x_{ijt}} E(\pi) = \sum_{t=1}^{8}\left(\frac{1}{(1+r)^{t}}\right)E\left[\sum_{i=1}^{5}\sum_{j=1}^{3}\pi_{ijt}x_{ijt}\right]$$

where x_{ijt} is the adoption decision variable for cropping system i in period t and j is used to track time of adoption for calculating organic price premiums and learning effects. For the "all or nothing" adoption model, x_{ijt} was restricted to be either 0 or 1, with $\sum_{i=1}^{n} x_{ijt} = 1$. Appropriate dynamic linkages were used to link adoption decisions in one period to "time since adoption" in subsequent periods. Since the entry point into a rotation is an important factor in this model, the starting crop mix under the conventional system drives the model solution. Two extreme cases were considered for this analysis, with the initial crop mix assumed to be either 100% corn or 100% soybeans. The transition timing decision then weighs the advantages of continuing the conventional rotation an additional year to get to a more favorable entry point into the organic system versus the delay in potential economic benefits from immediate transition to the organic system. The dynamic model was run for the BASE, PLEARN, and HALFP scenarios. An additional run was also conducted for a modified version of the PLEARN scenario restricting the organic cropping system alternatives to the ORG CT 4YR treatment only. The two-year organic rotations in this study all include cover crops as a third crop in the rotation. Although there are some certifiers that have allowed this system to be certified, there is some controversy whether this meets the criteria for organic certification. Restricting the organic cropping system alternatives to the four-year treatment only models the situation that would occur if the two-year treatments could not be certified.

Stochastic Simulation Results

Looking at rotation average net returns, the stochastic simulation results for the BASE scenario show the ORG CT 2YR treatment dominates all other cropping systems for absolute risk aversion coefficients ranging from 0 to 0.2 (Figure 1). For a 20-year planning horizon, the CNV CT 2YR system is dominated by three of the four organic systems, indicating strong economic incentives for producers to adopt these organic systems over the conventional system in the absence of machinery adjustment and learning effects. Results for the MACH scenario and SLEARN scenario showed the same ranking of treatments indicating that the organic systems perform well relative to the conventional system even when machinery adjustment costs and learning effects are included.

Under the PLEARN scenario, the CNV CT 2YR system would be preferred to the ORG ST 2YR for all producers with an absolute risk aversion greater than 0.0006 (Figure 2); however, the ORG CT 2YR and ORG CT 4YR systems still dominate the conventional system for all risk averse producers. These results are dependent on organic price premiums; however, even if organic price premiums were reduced by 50 percent, the ORG CT 2YR system would still dominate the CNV CT 2YR system (Figure 3). The CNV CT 2YR system and the ORG CT 4YR systems show little difference in certainty equivalents for small risk aversion levels. The conventional system dominates ORG CT 4YR for risk aversion coefficients between 0.005 and 0.035, while the ORG CT 4YR system dominates the conventional system for risk aversion coefficients above or below this range.

The SERF results are robust over a range of planning horizons. The certainty equivalent premium for the ORG CT 2YR system compared to the CNV CT 2YR system is generally positive for planning horizons down to four years (Figure 4). At four years, the risk neutral case still shows an advantage for the organic system, while risk averse producers would prefer the conventional system.

Entry point into the rotation has a substantial effect on risks and returns for each system. SERF results for different rotation entry points under the SLEARN scenario are shown in Figure 5. Transitioning from the CNV CT 2YR system to either the ORG CT 2YR system or the ORG CT 4YR system, there are two entry points into each system. If the last conventional crop is corn, then the entry point into both of the organic systems is soybean (S). If the last conventional crop is soybean, then the entry point into ORG CT 2YR is corn (C), and the entry point into ORG CT 4YR is wheat (W). For the risk neutral case, there was an $87 difference in net present value of net returns depending on entry point into the ORG CT 2YR rotation, and a $229 difference in net present value of net returns depending on entry point into the ORG CT 4YR rotation. The differences in certainty equivalents between rotation entry points tended to increase with increasing risk aversion. The dynamic model was designed to determine if this difference in returns affects optimum transition timing decisions.

Dynamic Model Results

The optimum transition strategy for each of the scenarios is listed in Table 1. For the BASE scenario and the PLEARN scenario, the economic benefits of an immediate transition to the organic system outweighed any additional benefits to waiting until the best entry point into the rotation. In the HALFP scenario, the net returns for the ORG CT 2YR system are much closer to the net returns for the CNV CT 2YR system, so the benefits to converting to the organic system are not as great. If the starting crop mix is 100% corn, then the benefits to transition are enough for a risk neutral producer to see a net benefit over an 8-year planning horizon. However, if the starting crop mix is 100% soybean, the benefits are not as great due to the entry point into the rotation, and the transition does not pay over that horizon. With a longer planning horizon, it is likely the optimum transition strategy would be to wait one year, and then transition to the ORG CT 2YR system.

When the PLEARN scenario is restricted to include ORG CT 4YR as the only organic cropping system option, the optimum strategy does include timing the transition to the best rotation entry point. When the starting crop is corn, the optimum strategy is to wait one year and then transition to the organic system. However, when the starting crop is soybean, the optimum strategy is an immediate transition. This strategy is directly tied to the importance of price premiums in the organic system. When the starting conventional crop is corn, the first certified organic crop (the third organic crop) would be alfalfa which does not earn a price premium. By waiting one year, the rotation would be timed so the first certified organic crop would be corn, which does earn an organic price premium.

Conclusion

Although there are several potential barriers to adoption of organic farming systems during the transition from conventional cropping systems, organic price premiums provide a strong incentive for producers to overcome these obstacles. In this paper we analyzed the risks and returns for a representative Minnesota farm transitioning from conventional farming practices to organic farming. Stochastic simulation results showed that, even with significant learning curves and biological transition effects that may reduce yields during the transition period, with increases in equipment costs, and with a three-year transition period during which organic practices are used but organic price premiums are not earned, a risk averse farmer would find several organic production alternatives preferable to the conventional system. A simple dynamic adoption model showed that an expected profit maximizing farmer would generally find it optimal to adopt the organic system as rapidly as possible rather than timing the transition to the best entry point into the new system. Since the amount of grain produced organically in the U.S. is still relatively small, organic price premiums could rapidly be eroded if many producers adopted organic systems. However, our analysis showed that organic systems would still be economically viable alternatives to conventional systems with a 50% reduction in organic price premiums.

It is recognized that the dynamic model used in this analysis did not include some factors that may be important to the optimum adoption decision. The model will be expanded in future research to include the possibility of transitioning parts of the farm into organic production over time. The model will also be expanded to include more detailed information on relevant constraints (e.g. labor, cash-flow) that producer may face during the transition.

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Table 1. Dynamic model optimum adoption strategies

Scenario	Optimum Strategy - Initial Crop 100% Corn	Optimum Strategy - Initial Crop 100% Soybean
BASE	Immediately transition to ORG CT 2YR	Immediately transition to ORG CT 2YR
PLEARN	Immediately transition to ORG CT 2YR	Immediately transition to ORG CT 2YR
HALFP	Immediately transition to ORG CT 2YR	Do not transition
PLEARN 4YR ORG only	Wait 1 year, then transition to ORG CT 4YR	Immediate transition to ORG CT 2YR

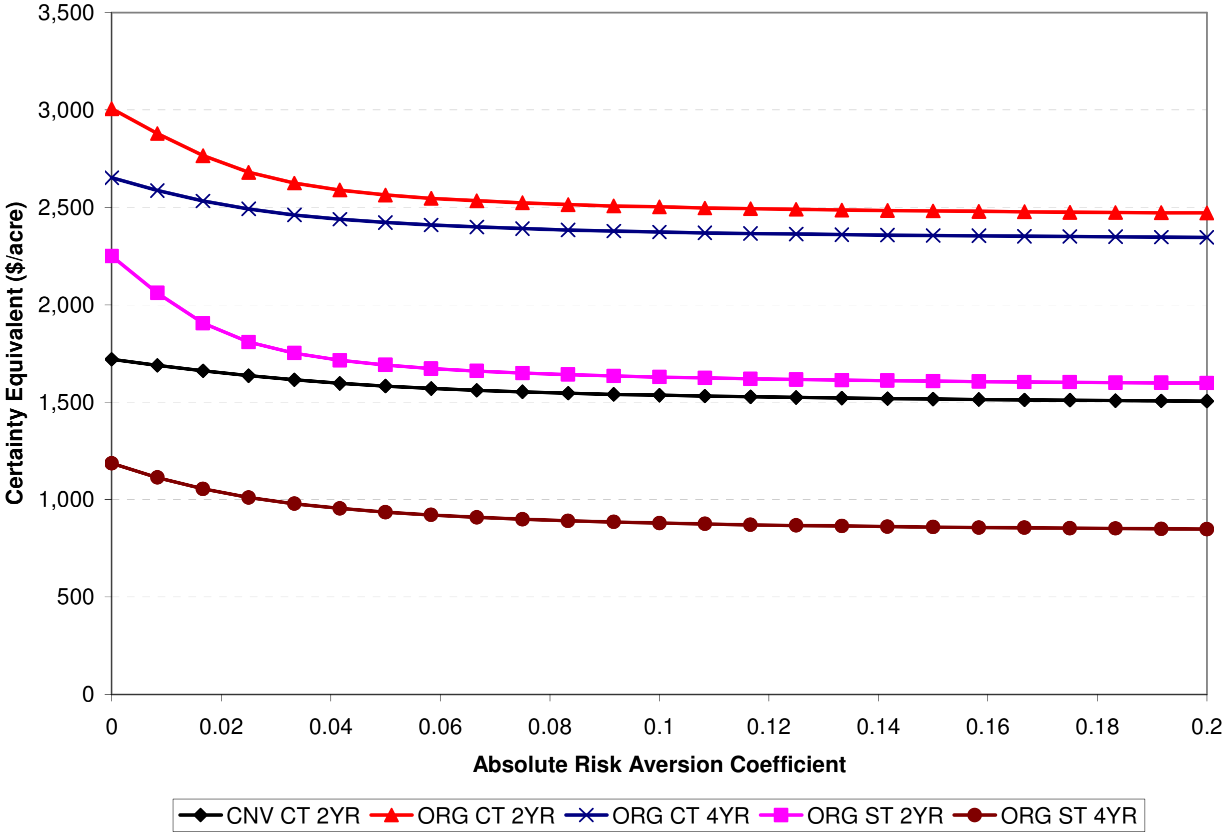

Figure 1. BASE scenario stochastic efficiency with respect to a function under negative exponential utility

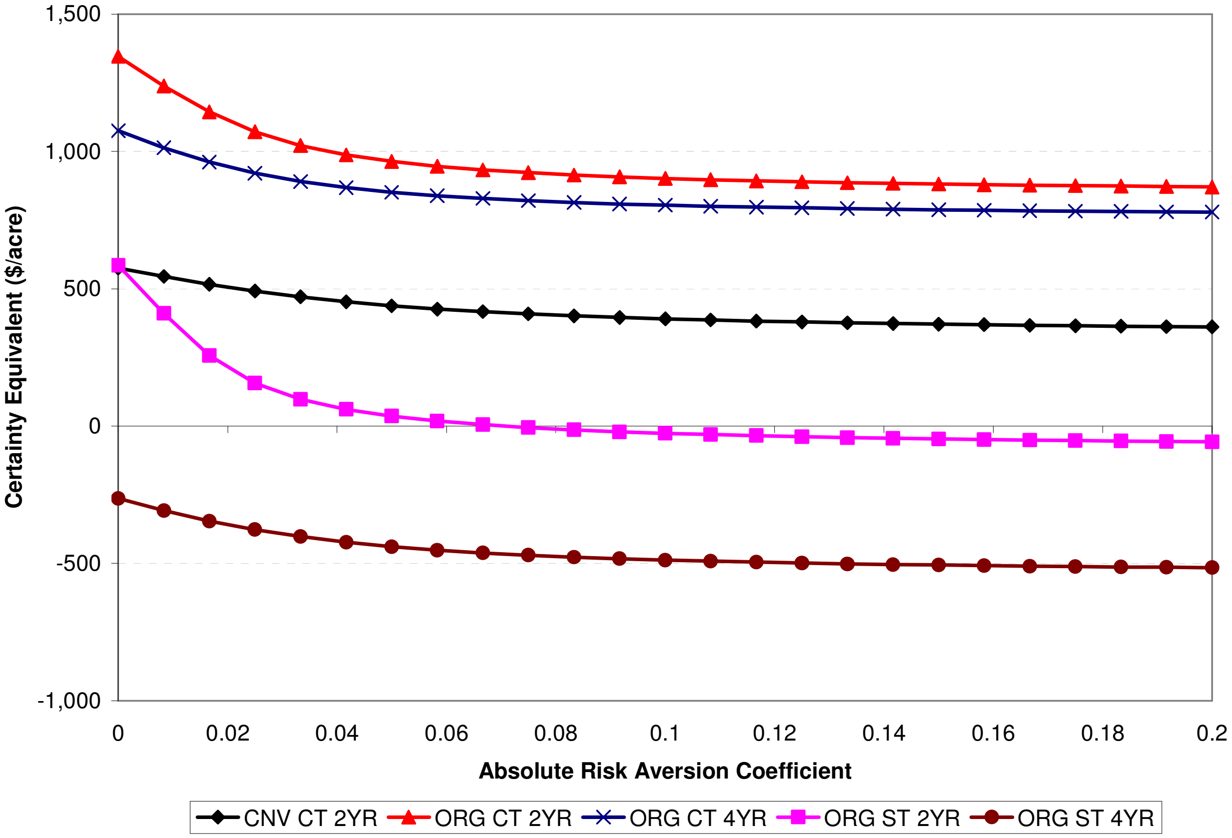

Figure 2. PLEARN scenario stochastic efficiency with respect to a function under negative exponential utility

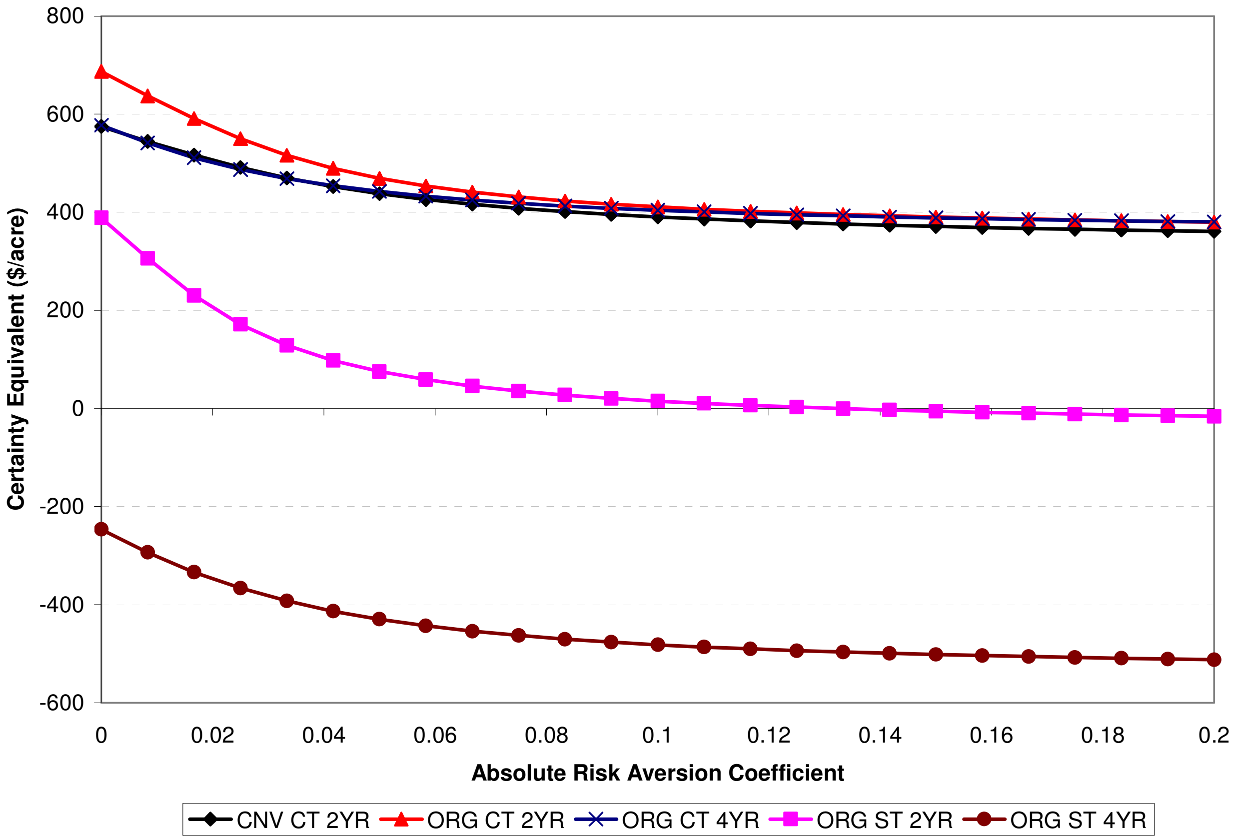

Figure 3. HALFP scenario stochastic efficiency with respect to a function under negative exponential utility

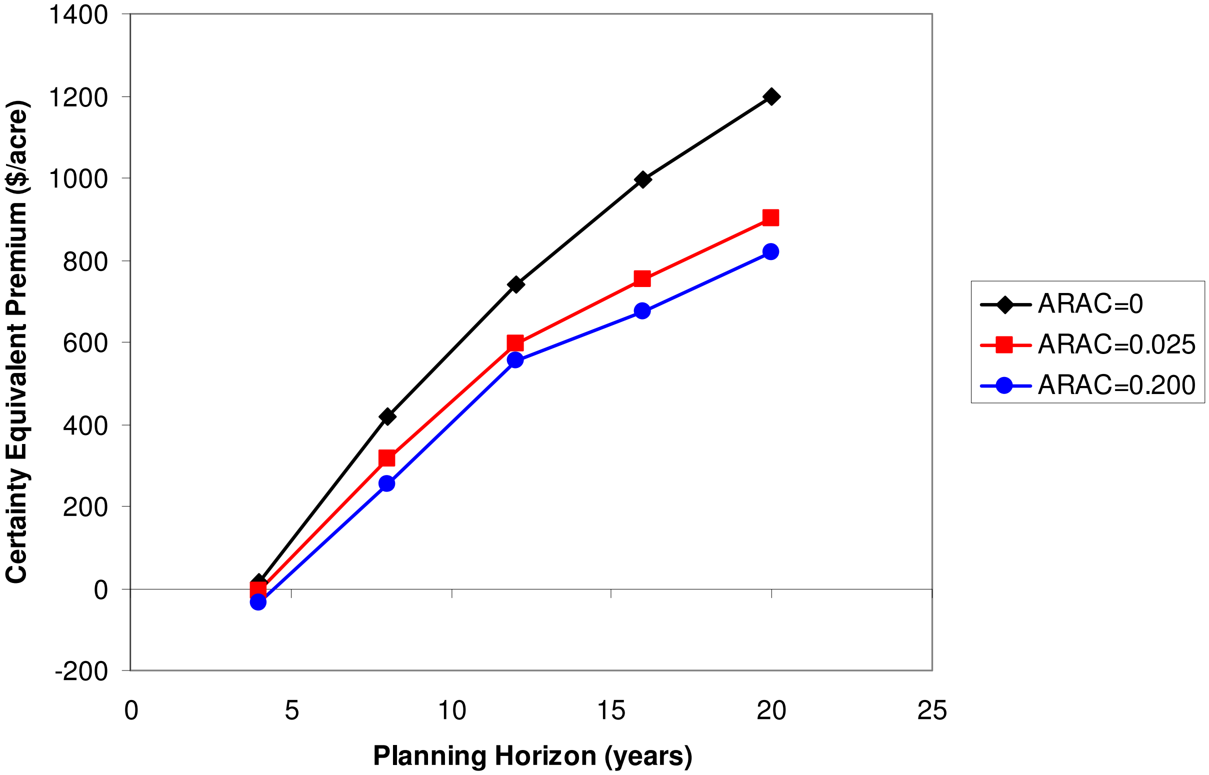

Figure 4. Certainty equivalent premium for ORG CT 2YR over CNV CT 2YR as a function of planning horizon length for absolute risk aversion coefficients 0, 0.025, and 0.200 under the SLEARN scenario

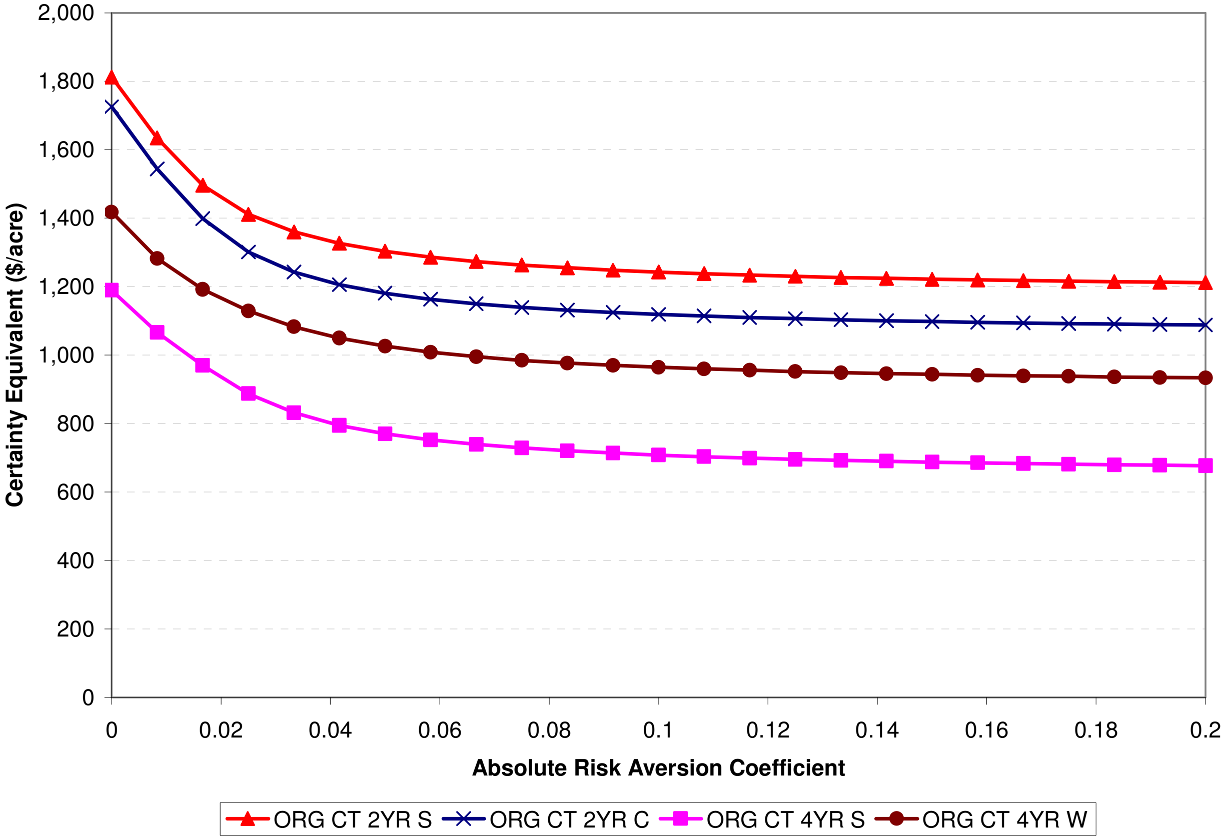

Figure 5. Rotation entry point effects on stochastic efficiency, SLEARN scenario