AN OPERATIONAL APPROACH FOR EVALUATING INVESTMENT RISK: AN APPLICATION TO THE NO-TILL TRANSITION

School of Economic Sciences

Working Paper 2005-1

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January 3, 2005

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The USDA-STEEP project at Washington State University provided financial support.

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Abstract:

Roy's safety-first rule is used to provide measures popular with farmers of short and long term business risk associated with various no-till transition strategies over an investment horizon. The short run rule provided more sensitivity to inter-year financial risk than other commonly used criteria. Results revealed that speed of adoption influenced the probability of successful transition more than did the sequence of drill acquisition methods. Higher equity and larger farms had a greater chance of transition success. Slow acreage expansion with a custom or rental drill reduces risk until a no-till yield penalty is eliminated.

Keywords: Investment risk, Monte Carlo simulation, no-till, rent-purchase, risk, safety-first, technology adoption, transition strategy

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Despite considerable methodological progress in the past (Buschena and Zilberman), there has been concern that standard risk analytical methods including expected utility/stochastic dominance have not been practical for agricultural extension use (Just and Rausser; Selley and Wilson; Anderson and Mapp). Castle cited a need to fill a "communication gap" between farm managers and risk analysts. A survey by Selley and Wilson indicate that many producers want to know specific strategies and probabilities of success or failure. Safety-first rules, which explicitly consider probability of experiencing an unfavorable outcome, have been recognized as a viable alternative (Hardaker, Huirne and Anderson; Dillon and Anderson; Buschena and Zilberman).

Among the three variants of the safety-first rule (Katoka; Telser; Roy), Roy's rule which minimizes the probability of falling below a critical level of net cash flow is the simplest. Telser's and Katoka's rules require potentially challenging elicitation of safety constraints and do not report performance as a simple probability of adverse outcome. Selley and Wilson reported that "expected frequencies/probabilities," as in Roy's rule, ranked number one in a survey of 229 extension and research faculty as their preferred tools in risk education programs. Among the risk education tools evaluated in the survey, expected utility and stochastic dominance ranked much lower in communicating risk information to farmers and ranchers. Indeed, even faculty with predominantly research appointments reported probabilities as their favored communication tool in outreach work.

Risky decisions regarding large infrequent investments in land and machinery have the greatest impacts on firm survival, but critics have argued that standard risk analytical techniques are most deficient in this multi-year setting (Just; Kingwell, Pannell and Robinson). In the past, whole-farm multi-year cash flow simulations have been used to illustrate the effects of investment risk; however, these studies often relied on expected or stochastic ending net present value (NPV) or ending net worth as the objective function (Held and Helmers; Richardson and Condra; Lien). These criteria exclude farmers who may be averse to fluctuations in cash flow within the investment period.

In this study of a risky multi year transition to no-till farming in eastern Washington, annual net cash flow is a key performance variable. Failure to meet annual cash requirements (including family living and debt payments) during any year or sequence of years of the transition could precipitate forced refinancing, erosion of equity or even bankruptcy. Many early adopters of no-till in the study region subsequently abandoned the practice in part due to difficulties in managing the large investment costs of acquiring a no-till drill. Others indicated that fear of investment risk was a major barrier to no-till adoption (Juergens et al.). However, surveys showed that no-till can boost profits in this region if the transition to no-till is navigated successfully (Camara, Young, and Hinman).

The objective of this study is to rank several no-till transition strategies for farmers who follow short term and long term safety-first decision criteria. These rankings are compared to those for a risk neutral criterion. Recent Monte Carlo simulation techniques are used to model the sequence of net cash flows for different transition strategies and farm types. A better understanding of the economic viability of different no-till transition strategies could hopefully accelerate adoption of no-till where it is suitable, and thereby reduce the economic and environmental losses from soil erosion. The illustration of multi-year risk criteria which are sensitive to sequence of cash flows as well as terminal investment performance may be useful in other risky investment applications.

Model and Assumptions

The Simetar farm simulation program (Richardson; Richardson, Klose and Gray) will be used to describe stochastic returns of eastern Washington wheat-barley-pea farms of different sizes and equity structures for different no-till transition strategies. The diversified wheat-barley-pea rotation has proven successful for no-till in this annual cropping region as it inhibits diseases and weeds (F. Young et al.). The farm's annual net after tax cash flow will be stochastically simulated for 500 "draws" from risky weather and prices for each of the years of a six-year transition to no-till farming. The risk modeling exercise for each of 104 farm type-strategy combinations yields 3000 (500 draws x 6 years) simulated annual net cash flows. This generates a total of 312,000 annual economic farm cash flow performances. To reflect the "learning curve" for no-till in the region, expected yields will be assumed to suffer a 10% penalty relative to conventional tillage in year one which linearly disappears by year six**.** Prior to imposition of the penalty no-till mean yields were standardized to the conventional mean, but variances retained their empirical patterns.

Recent farm simulation models have focused on incorporating inter and intra-temporal correlations of yield and prices (Richardson, Klose and Gray; Ramirez and Somarriba). Following Richardson, Klose and Gray, the intra-temporal correlation matrix for X_{it} to X_{jt} will be derived as:

(1)
$$\rho = \begin{bmatrix} \rho\left(e_{it,}\ e_{it}\right) & \rho\left(e_{it,}\ e_{jt}\right) \\ 0 & \rho\left(e_{jt,}\ e_{jt}\right) \end{bmatrix}$$

where $e_{it,}$ are the residual from each random variable (prices and yields) X_i and each year '*t*'.

Inter-temporal correlation matrix for variable X_{it} to $X_{\mathrm{it-1}}$ will be derived as (Richardson, Klose and Gray):

$$\rho' = \begin{bmatrix} 1 & \rho\left(e_{\mathrm{it}}, e_{\mathrm{it-1}}\right) & 0 \\ & 1 & \rho\left(e_{\mathrm{jt}}, e_{\mathrm{jt-1}}\right) \\ & & 1 \\ & & \end{bmatrix} \qquad (2)$$

Stochastic yield ($\tilde{Y}$) and prices ($\tilde{P}$) are generated from a multivariate empirical distribution. Assuming the data are distributed empirically avoids enforcing specific distributions and permits incorporating observed correlations (Richardson, Klose and Gray). The procedure utilizes the inverse transformation method of imposing these inter and intra-temporal correlation matrices to standard normal deviates (Law and Kelton). The resulting distributions will reflect skewness and other non-normal patterns in the empirical data.

Farm budgets will be prepared, using stochastic yield and prices, to generate net cash flows (*S)* for each year *t* of the six-year no-till transition of 104 farm type-strategy combinations (4 farm types by 26 transition strategies) as follows:

$$(S_t) = \tilde{P} * \tilde{Y} - E - \tilde{L} + \tilde{G} - \tilde{T} - F \qquad (3)$$

Where, E = Cash expenses for crop production, land and machinery payments, property taxes, insurance and overhead. Crop production expenses will be allowed to inflate by 3% per annum.

$\tilde{L}$ = Landlord’s crop share on rented land set at one-third for grain and one-fourth for peas less proportionate contribution for crop insurance and fertilizers.

$\tilde{G}$ = Net government payments received which are the sum of direct, loan program, and counter cyclical payments of the 2002 farm bill, as eligible, less the landlord’s proportionate share of government payments.

$\tilde{T}$ = Income tax paid by the farmer as a function of annual before tax income.

F = Family living withdrawals of \$17,118 to \$32,073 per year which are positively correlated with farm size and equity and inflate by 3% per year.

Cash flow surpluses or deficits from previous years are permitted to adjust net cash flow in current year. Within the transition period, the farmer receives 6% interest on any cash reserve and pays 8% loan interest to finance a cash deficit.

Four types of modeled farms include a large size of 3000 acres and a small size of 800 acres combined with a high (low) equity levels of 80% (20%). Equity percent corresponds with fully paid owned acreage. The remainder is assumed rented. Twenty six no-till transition strategies represent 13 drill acquisition sequences from purchasing, renting and/or custom hiring a drill over the six-year transition period combined with two (immediate and gradual) speeds of no-till adoption over the farm acreage. With immediate adoption, the farmer no-tills 100% of the acreage from year 1 to year 6. With gradual adoption the farmer no-tills 5% of acreage in the first year and adds 5% each year until the sixth year when 30% of farm acreage is no-tilled. The farmer is assumed to pay \$53,750 for the no-till drill with a required 30% down payment and the balance amortized over the next five years at 8% interest. Rental and custom hire rates are set at \$12 and \$20 per acre, respectively.

The probability of no-till transition failure (TF), consistent with Roy's safety first rule, is derived as:

(3) $$\Pr(TF) = \frac{\sum Z_{\bullet}}{M}$$

Where $Z_{\bullet}$ are the elements of an $Mx1$ vector **Z**, for each farm type-strategy combination (26 x 4 = 104) and M = 500. $Z_{\bullet}$ gets 1 if transition failed (depending on definition), 0 otherwise.

A short run "transition failure" will be defined as two consecutive years of negative cash flow. This definition means the farmer fails to meet production expenses, debt payments, and family living from current year's crop revenues, reserves, and government payments for two years in a row. In agriculture, variable incomes are expected so most growers are considered unlikely to "give up on no-till" after just one year's cash flow shortfall. But growers with a moderate degree of risk aversion are assumed to be unwilling or unable to see the investment through its complete six-year course if a cash flow shortfall occurs over two consecutive years. In the short run, transition failure for any draw *m* (out of *M* draws) of a farm type-strategy combination (out of 104) will be computed as:

(4) $$Z_{\bullet} = 1 \text{ if } [(S_{m1} < 0) \text{ } and \text{ } (S_{m2} < 0)], and/or, ..., and/or[(S_{mt-1} < 0) \text{ } and \text{ } (S_{mt} < 0)]$$

$$0 \text{ otherwise.}$$

For each farm type-strategy combination, there will be different matrix of net cash flow (**S**) with M =500 rows and t =6 columns as shown below:

(5) $$\mathbf{S} = \begin{vmatrix} S_{11} & S_{12} & .... & S_{1t-2} & S_{1t-1} & S_{1t} \\ S_{21} & S_{22} & .... & S_{2t-2} & S_{2t-1} & S_{2t} \\ .. & .. & .. & .. & .. & .. \\ S_{M1} & S_{M2} & .... & S_{Mt-2} & S_{Mt-1} & S_{Mt} \end{vmatrix}$$

In contrast, "transition failure" in a long run sense is defined as experiencing a negative present value of net cash flow (PVNCF) over the six-year transition period. This criterion may appeal to farmers who have comparatively strong financial situation and/or are willing to endure the full six years to assess the probability that PVNCF is positive. For each draw *m* for a farm type-strategy combination, the "transition failure" in long run sense is calculated as:

(6) $$Z_{\bullet} = 1 \text{ if } \left[\left\{ \frac{S_{m1}}{(1+r)^1} + \frac{S_{m2}}{(1+r)^2} + ... + \frac{S_{mt}}{(1+r)^t} \right\} < 0 \right]$$

$$0 \text{ otherwise.}$$

S_{mt} is the net cashflow for the m^{th} draw, r is the discount rate, and t is the transition year.

Data

Historic crop price patterns were used to project multivariate price distributions for wheat, barley and peas. Trends in average crop prices over the transition period were based on localized national forecasts (Michell and Black). However, due to absence of national forecast mechanisms, pea prices were forecasted linearly from historical Washington state prices (WASS). Price variability on peas was generated from historical marketing year average price in the state. Crop enterprise expenses were based on a survey of no-till farms in the region (Camara, Young, and Hinman).

Multivariate yield distributions for conventional and no-till wheat, barley, and peas was based on annual yields of these crops in a 9-year eastern Palouse field experiment (Boerboom et al.; Hall; Young, Kwon, and Young). The experiment utilized large plots that permitted use of typical-size machinery and cultural practices. Table 1 shows nine-year mean yields of conventional tillage winter wheat (86.08 bu/ac), spring barley (83.57 bu/ac) and spring peas (16.89 cwt/ac). The yields are similar to those on well managed farms in the region (Young, F. et al.). Use of site rather than regional average data should better reflect farm-level yield variability (Debrah and Hall). Winter wheat yields were slightly negatively skewed. Spring barley and spring peas were positively skewed. The coefficient of variation (CV) showed that conventional crop yields were more variable than the no-till yields (Table 1). Conventional tilled spring pea had the highest CV (39.10%), followed by conventional tilled spring barley (35.11%), and conventional tilled winter wheat (28.38%). Although CV's of prices were less than those for yields; wheat price CV was 17.47%, barley was 13.76% and pea was 14.15%.

The price and yield correlation matrix (Table 1) shows that all variables except spring pea price were intra-temporally correlated with one or more variables at 5% level of significance. Not surprisingly, significant and high correlation was observed between no-till and conventional tilled spring pea yield (0.97), spring barley yield (0.97) and winter wheat yield (0.92). Winter wheat and spring barley yield showed high correlation under conventional tillage (0.92) than under no-till (0.70). The correlation between conventional winter wheat and no-till spring barley yields was 0.85. The correlation between conventional spring barley and no-till winter wheat was

0.82. Prices were not significantly correlated with own yields, but wheat price had high and significant correlation with barley price (0.80).

The inter-temporal correlation matrix (Table 1) shows moderately high and negative correlation for spring pea no-till (-0.52) and conventional till (-0.62) yields. Spring barley yields were positively correlated (0.38). Among prices, spring barley had comparatively higher inter-temporal correlation (0.38) compared to spring peas (-0.25) or winter wheat (-0.04).

Results

Table 2 shows the probability of transition failure for four farm types across 26 transition strategies employing a short term "two consecutive years of negative net cash flow" criterion. The 26 no-till transition strategies represent all combinations between two speeds of no-till acreage adoption and thirteen sequences in which a no-till drill is acquired via custom hiring, renting, and/or purchasing. The strategies are defined in the footnote accompanying Table 2.

For a given farm type, risk of short run transition failure is higher for immediate adoption compared to gradual adoption. For example, for a large farm with 80% owned land, the probability of transition failure ranged from 0.09-0.11 under gradual adoption. But, it ranged from 0.18-0.33 under immediate adoption. The higher transition risk of immediate adoption is attributable to the initial 10% yield penalty for no-till. As shown in Table 1, no-till actually had slightly lower yield variance than conventional tillage in the 9-year data set, but this advantage was offset by the yield penalty in early years.

As expected, the low equity farm exhibits higher risk of short run transition failure for a given size. For example, the mean probability of failure for the large farm with 20% owned land ranged from 0.42 to 0.68 across speeds of adoption, while that for the large farm with 80% owned land ranged from 0.10 to 0.25. This difference is attributed to additional outlay for land rental payments for the low equity farm.

As shown in Table 2, speed of no-till adoption over farm acreage tends to dominate acquisition sequence in terms of short run transition risk. For a large farm, choice of transition strategy is more important under immediate adoption than gradual adoption. For example, the large farm showed higher mean probability of transition failure (0.25-0.68) across equity levels and transition strategies for immediate adoption compared to gradual adoption (0.10-0.42). For the small farm, choice of transition strategy is also relatively more risky under immediate adoption. Again, the initial yield penalty with no-till increases the risk of immediate adoption.

Table 3 is similar in format to Table 2. However, a longer term measure of risk is used, namely a negative PVNCF over the entire six-year transition period. As expected, risk of failure was higher for immediate adoption compared to gradual adoption for a given farm type. For example, the large farm with 80% owned land experienced probability of failure ranging from 0.02-0.14 over strategies with a mean of 0.07 for immediate adoption compared to a range of 0-0.01 and mean of 0.01 under gradual adoption. Similar patterns, but higher risk levels, prevail for low equity large farms and for small farms.

As expected, the results in Tables 2 and 3 reveal that the long term PVNCF criterion shows lower risk of failure for most transition strategies. For example, the large farm with 80% owned land under immediate adoption showed a long run probability of transition failure of 0.02-0.14 over strategies compared to 0.18-0.33 for the short run probabilities. The small farm with 80% rented land under immediate adoption was an exception. In general, negative PVNCF implies more patience over time for a sequence of negative annual cash flows than the two-consecutive-year criterion. But in the small equity farm, some exceptionally large negative cash flows, not always in sequence, accounts for the high risk under the negative PVNCF criterion.

Both decision criteria produced generally consistent results in identifying minimum or maximum risk strategies (Tables 2 and 3). Interestingly, immediate purchase of a drill was less risky than custom hiring or renting for large farms immediately placing 100% acreage under no-till. The reason is that economies of size made purchasing cheaper than custom or rental. In contrast, renting a no-till drill for the entire transition period was less risky than custom hiring or buying for all small farms and for large farms under gradual adoption. Custom hiring for the entire transition period was the most risky for large farms under immediate adoption, but for small farms some combinations of custom hire and purchase were the most risky transition strategies. These results follow from the fact that custom hire and renting expenses increase linearly with acreage whereas the fixed costs associated with a purchased drill decrease with acreage. Custom hiring incurs cash outflows for labor, but no cash cost is incurred for operator's labor for rental or purchased drills.

Table 4 shows mean present value of net cash flow (over 500 simulations) for twenty six transition strategies for four farm types. Not surprisingly given initial yield penalties, gradual adoption shows higher PVNCF than immediate adoption. For example, in the case of the large farm with 80% owned land, gradual adoption returned mean annual net cash flow ranging from \$457,800 to \$488,400 where as immediate adoption returned only \$197,300 to \$314,500.

Figure 1 plots the tradeoff between probability of transition failure against mean PVNCF for pure purchase, rent and custom hire transition strategies for a large high equity farm. Not surprisingly, probability of transition failure declines directly with mean PVNCF under both decision criteria. The slope of the curve in Figure 1 is downward in contrast to most annual risk/ return tradeoff curves. In annual tradeoff curves for financial investments or farm plans, higher expected returns generally require bearing additional risk (Hardaker, Huirne, and Anderson; Robison and Barry). However, for the multi-year analysis, both probability of failure and final PVNCF are dependent upon the performance of the series of the annual cash flows. This business cash flow perspective will generally lead to a negative correlation between mean PVNCF and probability of failure. “Risk dominant” strategies occur at the lower right of Figure 1. Gradual (G) no-till adoption dominates in Figure 1 for this problem. In contrast, immediate adoption strategies are less profitable and display higher probability of failure. For the large high equity farm in Figure 1 with gradual adoption, six-year drill rental (GR-6) and custom hire (GC-6) are risk-return dominant among the “pure” acquisition strategies displayed. Also, as explained earlier, the probability of transition failure is smaller under the long term PVNCF criterion than the under the short term criterion.

Discussion and Conclusions

This study proposed two cash flow based performance criteria related to investment risk that are likely to be of interest to farmers. Both measures use Roy’s safety-first criterion which minimizes the probability of net cash flow falling below a critical level. The first or short run measure may appeal to farmers who are averse to certain sequences of annual cash flows within the investment horizon. A longer run measure evaluates the probability of experiencing a negative PVNCF over the six-year transition period. Based on the responses of surveyed extension and research economists, these probability-based measures supply the type of information that farmers and ranchers understand and desire (Selley and Wilson).

The proposed short run risk decision criterion provides potential advantages over expected utility and stochastic dominance criteria in that it permits aversion to the sequence of outcomes within the investment period, rather than only to terminal summary measures such as present value or equity as in past studies (Held and Helmers; Richardson and Condra; Lien). Despite the use of ending farm equity as the sole risky farm performance measure in a stochastic dominance analysis, Lien acknowledged the importance of sequential outcomes in the investment period by noting that “a couple of bad years in production and an unexpected rise in interest rates can send the business bankrupt” (p. 399). Mossin, and Spence and Zeckhauser have also pointed out that expected utility models encounter theoretical inconsistency in dynamic problems because the timing of uncertainty resolution within the period may lead to violations of the independence axiom of expected utility.

Several generalizations and recommendations for managing (and surviving) the no-till transitions emerge from the simulation results. Regardless of farm type, speed of adoption has a larger effect on navigating the no-till transition successfully than does the drill acquisition method. This implies that if a farmer is still learning to make no-till work, it is wise to go slow in acreage expansion. Low equity farmers have the lowest probability of successfully navigating the no-till transition while financing a drill. Farmers renting a high proportion of their cropland may want to wait until they can pay cash for a (possibly lower cost) no-till drill. Custom and rental drill acquisition in early years of the transition is recommended for small farmers, especially if they are expanding no-till acreage gradually.

Farmer's choice of decision criteria will also depend on the financial position of the farm. High equity farms may be more likely to have the risk tolerance to maximize long run PVNCF. However, short tem and long term criteria converged in the selection of transition strategies for many situations.

Earlier survey results from small samples of farmers in the region who were in the no-till transition, or had completed it, support the sequential nature of the transition process (Juergens et al.; Camara, Young and Hinman). Most transition farmers, who generally had medium or large farms, custom hired or rented a drill in years 1-3, but many had purchased a drill by years 4 and 5. Personal adoption histories varied considerably indicating that adoption plans must be strategically tailored to the particular farm business situation as in this study.

This study was intended to provide practical decision criteria for risky investments. Farmers and other businessmen will benefit from practical models for managing investment risk.

Decisions on large long term investments will often have the greatest bearing on firm survival. Of course, the results of this particular no-till transition study are influenced by the assumptions of the example farm situation. Application of the methods to other technologies or to other geographical areas would require suitable modification to the setting.

References

Anderson, K.B., and H.P. Mapp. “Risk Management Programs in Extension”. *Journal of Agricultural and Resource Economics* 21(1996)31-38.

Boerboom, C.M., F.L. Young, T. Kwon, and T. Feldick. *IPM Research Project for Inland Pacific Northwest Wheat Production*. Washington State University, Agric. Res. Ctr. Bulletin. XB1029, 1993.

Buschena, D.E. and D. Zilberman. “What Do We Know About Decision Making Under Risk and Where Do We Go From Here?” *Journal of Agricultural and Resource Economics* 19(1994):425-445.

Camara O.M., D.L. Young, and H.R. Hinman. *Economic Case Studies of Eastern Washington No-till Farmers Growing Wheat, Barley, Lentils and Peas in the 19-22 Inch Precipitation Zone*. Washington State University, Pullman, Farm Business Management Report EB1886, 1999.

Castle, E.N. “On the Communication Gap in Agricultural Economics.” *American Journal of Agricultural Economics* 75(1993):84-91.

Debrah, S., Hall, H.H., “Data Aggregation and Farm Risk Analysis.” *Agricultural Systems* 31 (1989):239-245.

Dillon, J.L. and J.R. Anderson. *The Analysis of Response in Crop and Livestock Production*. 3rd Edition, New York: Pergamon press, 1990.

Hall, M. J. “Economics of Weed Management and Farming Systems in the Palouse Region.” M.A. thesis, Washington State Univ., Pullman, 1995.

Hardaker, J.B., R.B.M. Huirne, and J.R Anderson. *Coping With Risk in Agriculture*., New York: Cab International, 1997.

Held L.J. and G.A. Helmers. “Growth and Survival in Wheat Farming: the Impact of Land Expansion and Borrowing Restraints.” *Western Journal of Agricultural Economics* 6(December 1981):207-216.

Juergens, L., D. Young, D. Roe and H. Wang. “Preliminary Farmer Survey Results on the Economics of the Transition to No-till.” In J. Burns and R. Veseth (Editors) 2001 *Field Day Proceedings: Highlights of Research Progress*. Tech. Report 01-04, 112-114. Dept. Crop and Soil Sciences, Wash. State U., Pullman, 2001.

Just, R.E. “Risk Research in Agricultural Economics: Opportunities and Challenges for the Next Twenty-Five Years.” *Agricultural Systems* 75(2003):123-159.

Just, R.E. and G.C. Rausser. “An Assessment of the Agricultural Profession.” *American Journal of Agricultural Economics* 71(1989):177-190.

Katoka, S. “A Stochastic Programming Model.” *Econometrica* 31(1963):181-96.

Kingwell, R.S., D.J. Pannell and S.D. Robinson. “ Tactical Responses to Seasonal Conditions in Whole Farm Planning in Western Australia.” *Agricultural Economics* 8(1993):211-216.

Law, A.M. and W.D. Kelton. *Simulation Modeling and Analysis*. Second edition. New York: Mc Graw Hill Book Co., 1991.

Lien, G. “Assisting whole-farm decision-making through stochastic budgeting.” *Agricultural Systems* 76(2003) 399-413.

Michell, D.O. and J.R. Black. “Incorporating Aggregate Forecasts into Farm Firm Decision Models.” In *Modeling Farm Decision for Policy Analysis*. Eds. K.H. Baum and L. P. Schertz. Westview Special Studies in Agriculture Science and Policy, 1983.

Mossin, J. “A Note on Uncertainty and Preferences in a Temporal Context.” *American Economic Review* 59(1969):172-174.

Ramirez, O.A. and E. Somarriba. “Risk Returns of Diversified Cropping Systems Under Nonnormal, Cross-, and Autocorrelated Commodity Price Structures.” *Journal of Agricultural and Resource Economics* 25(December, 2000):653-668.

Richardson, J.W. *Simulation for Applied Risk Management With an Introduction to The Software Package Simetar©*: *Simulation for Excel to Analyze Risk*. Department of Agricultural Economics, Texas A&M University, 2001.

Richardson, J.W. and G.D. Condra. “Farm Size Evaluation in the El Paso Valley: A Survival/Success Approach.” *American Journal of Agricultural Economics* 63(1981):430-437.

Richardson, J.W., S.L. Klose, and A.W. Gray. “An Applied Procedure for Estimating and Simulating Multivariate Empirical Probability Distributions in Farm Level Risk Assessment and Policy Analysis”. *Journal of Agriculture and Applied Economics* 32(2000):299-315.

Robison, L.J., and P.J. Barry. *The Competitive Firm’s Response to Risk*. New York: Macmillan Publishing Company, 1987.

Roy, A.D. “Safety First and The Holding of Assets.” *Econometrica* 20(1952):431-439.

Selley, R.A. and P.N. Wilson. “Risk Research and Public Outreach: A Tale of Two Cultures?” *Journal of Agricultural and Resource Economics* 22(1997):222-232.

Spence, M. and R. Zeckhauser. “The Effect of the Timing of Consumption Decisions and the Resolution of Lotteries on the Choice of Lotteries.” *Econometrica* 40(1972):401-403.

Telser, L. “Safety First and Hedging.” *Review of Economic Studies* 23(1955):1-6.

WASS (Washington Agricultural Statistics Service). *Washington Agricultural Statistics*. Olympia, 1986-94.

Young, D.L., T. Kwon, and F.L. Young. “Profit and Risk for Integrated Conservation Farming Systems in the Palouse”. *Journal of Soil and Water Conservation* 49(1994):601-606.

Young, F.L., A.G. Ogg, Jr., R.I. Papendick, D.C. Thill, and J.R. Alldredge. “Tillage and Weed Management Affects Winter Wheat Yield in an Integrated Pest Management System.” *Agronomy Journal* 86(January-February 1994):147-154.

Table 1. Intra/Inter-Temporal Correlations and Summary Statistics of Experiment Yields and Prices of Winter Wheat, Spring Barley and Spring Pea in Whitman County, WA, 1986-1994

	Intra-temporal Correlation of Yield and Prices								
	NWW	NSB	NSP	CWW	CSB	CSP	PWW	PSB	PSP
NWW	1	0.70*	0.07	0.92*	0.82*	0.23	-0.35	-0.19	-0.09
NSB		1	0.18	0.85*	0.97*	0.26	-0.43	-0.45	-0.13
NSP			1	0.01	0.11	0.97*	0.03	-0.10	0.41
CWW				1	0.92*	0.14	-0.60	-0.44	-0.06
CSB					1	0.21	-0.45	-0.45	-0.22
CSP						1	0.03	-0.04	0.40
PWW							1	0.80*	-0.32
PSB								1	0.01
PSP									1
Inter temporal [a]	-0.20	0.38	-0.52	0.00	0.38	-0.62	-0.04	0.38	-0.25
Mean [b]	86.08	83.57	16.89	86.08	83.57	16.89	3.39	2.15	9.02
CV	25.72	35.08	36.77	28.38	35.11	39.10	17.47	13.76	14.15
Min	52.82	35.95	7.63	49.07	42.52	7.69	2.51	1.63	7.60
Median	87.06	79.43	15.58	90.3	75.52	15.91	3.45	2.24	9.00
Max	113.0	138.3	25.3	127.8	138.7	27.3	4.1	2.5	12.1

[a] One-year correlations.

[b] Mean restricted to the level of conventional tillage.

* is significant at 5% level (t-critical = 2.36).

Note: WW is winter wheat (bu), SB is spring barley (bu) and SP is spring pea (cwt). Yield in per acre and prices in $/unit. First letter N signifies no-till, C signifies conventional tillage and P signifies price.

Sources: Yield data: Boerboom et al. and Hall; Price data: Washington Agricultural Statistics, 1986-94.

Table 2. Probability of Two Consecutive Years of Negative Cash Flows Within a Six-Year Transition for Four Farm Types and Twenty Six No-till Transition Strategies

Sequences	Large Farm 80% Own Land		Large Farm 20% Own Land		Small Farm 80% Own Land		Small Farm 20% Own Land	
	Imm	Grad	Imm	Grad	Imm	Grad	Imm	Grad
P-6	0.18	0.10	0.57	0.44	0.48	0.35	0.89	0.76
R-1	0.19	0.10	0.59	0.44	0.53	0.38	0.91	0.76
R-2	0.21	0.11	0.63	0.42	0.51	0.32	0.91	0.77
R-3	0.23	0.10	0.66	0.42	0.50	0.31	0.91	0.74
R-4	0.24	0.10	0.69	0.42	0.49	0.29	0.89	0.74
R-5	0.26	0.09	0.70	0.41	0.46	0.23	0.88	0.63
R-6	0.26	0.09	0.71	0.40	0.44	0.19	0.86	0.58
C-1	0.20	0.10	0.60	0.45	0.54	0.38	0.92	0.76
C-2	0.24	0.11	0.67	0.42	0.54	0.32	0.92	0.77
C-3	0.28	0.10	0.71	0.42	0.54	0.32	0.93	0.74
C-4	0.30	0.10	0.76	0.43	0.54	0.29	0.92	0.74
C-5	0.32	0.09	0.78	0.42	0.52	0.24	0.91	0.64
C-6	0.33	0.09	0.79	0.41	0.51	0.20	0.90	0.59
Mean	0.25	0.10	0.68	0.42	0.51	0.29	0.90	0.71
CV	19.10	6.52	10.36	3.27	6.27	21.10	2.07	9.85

Note: Grad = Gradual speed of adoption (5%,10%,15%,20%,25%,30% of crop area no-tilled from 1-6 years) and Imm = Immediate adoption (100% in all 6 years). x-i are the drill acquisition sequences where x denotes option (P = purchase, R = rent and C = custom hire) and i denotes the number of years the option was used within a six year period. Remaining 6-i years the drill was purchased. 80% and 20% refer to percentage of land owned rather than rented.

Table 3. Probability of Negative Present Value of Six-Year Net Cash Flows for Four Farm Types and Twenty Six No-till Transition Strategies

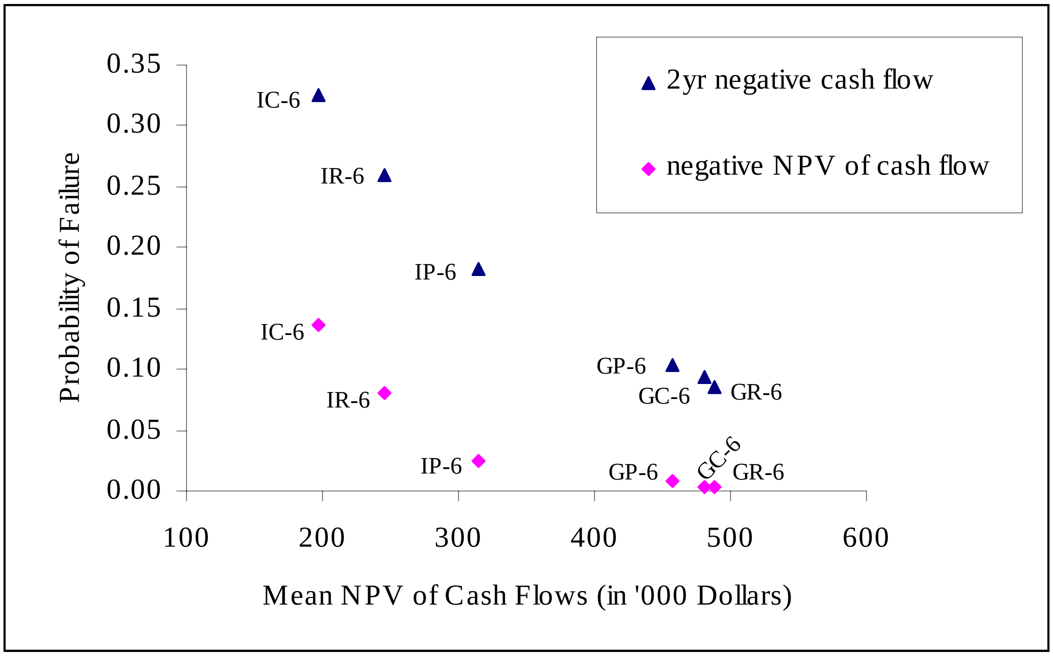
Sequences	Large farm 80% own land		Large farm 20% own land		Small farm 80% own land		Small farm 20% own land	
	Imm	Grad	Imm	Grad	Imm	Grad	Imm	Grad
P-6	0.02	0.01	0.48	0.24	0.28	0.10	0.91	0.65
R-1	0.03	0.01	0.53	0.21	0.34	0.11	0.94	0.66
R-2	0.04	0.01	0.59	0.21	0.33	0.08	0.94	0.62
R-3	0.04	0.01	0.62	0.20	0.31	0.05	0.93	0.58
R-4	0.06	0.00	0.65	0.19	0.29	0.04	0.92	0.52
R-5	0.07	0.00	0.67	0.18	0.27	0.03	0.91	0.46
R-6	0.08	0.00	0.68	0.17	0.22	0.02	0.87	0.37
C-1	0.04	0.01	0.57	0.21	0.38	0.11	0.96	0.66
C-2	0.05	0.01	0.63	0.21	0.37	0.08	0.96	0.62
C-3	0.08	0.01	0.68	0.20	0.38	0.06	0.96	0.59
C-4	0.10	0.01	0.72	0.20	0.37	0.04	0.96	0.53
C-5	0.11	0.01	0.77	0.19	0.36	0.04	0.95	0.47
C-6	0.14	0.00	0.78	0.18	0.32	0.02	0.93	0.38
Mean	0.07	0.01	0.64	0.20	0.33	0.06	0.93	0.55
CV	50.51	21.64	13.69	8.54	15.17	53.20	2.75	18.65

Note: Grad = Gradual speed of adoption (5%,10%,15%,20%,25%,30% of crop area no-tilled from 1-6 years) and Imm = Immediate adoption (100% in all 6 years). x-i are the drill acquisition sequences where x denotes option (P = purchase, R = rent and C = custom hire) and i denotes the number of years the option was used within a six year period. Remaining 6-i years the drill was purchased. 80% and 20% refer to percentage of land owned rather than rented.

Table 4. Mean Present Value of After Tax Net Cash Flows ('00$) across Twenty Six No-till Transition Strategies for Four Farm Types

Sequences	Large farm 80% own land		Large farm 20% own land		Small farm 80% own land		Small farm 20% own land	
	Imm	Grad	Imm	Grad	Imm	Grad	Imm	Grad
P-6	3145	4578	23	1248	307	755	-594	-220
R-1	3016	4679	-133	1348	213	736	-703	-249
R-2	2867	4725	-298	1405	233	811	-679	-164
R-3	2735	4767	-444	1453	258	886	-651	-81
R-4	2620	4802	-575	1491	288	959	-620	-2
R-5	2519	4831	-692	1522	323	1033	-583	77
R-6	2454	4884	-767	1581	394	1140	-507	192
C-1	2917	4674	-245	1343	183	734	-734	-251
C-2	2677	4712	-512	1391	176	807	-740	-168
C-3	2462	4743	-753	1426	176	878	-740	-90
C-4	2270	4764	-971	1449	182	947	-733	-15
C-5	2098	4776	-1167	1461	196	1016	-719	59
C-6	1973	4812	-1311	1499	249	1117	-663	167

Note: Grad = Gradual speed of adoption (5%,10%,15%,20%,25%,30% of crop area no-tilled from 1-6 years) and Imm = Immediate adoption (100% in all 6 years). x-i are the drill acquisition sequences where x denotes option (P = purchase, R = rent and C = custom hire) and i denotes the number of years the option was used within a six year period. Remaining 6-i years the drill was purchased. 80% and 20% refer to percentage of land owned rather than rented. 80% and 20% refer to percentage of land owned rather than rented.



Note: I = immediate adoption and G = gradual adoption; P = purchase, R= rent, and C= custom hire options; 6 means the option is used for all six years in the transition period. For example: IC-6 means farmer used custom hired drill on all land for the entire period.

Figure 1. Trade-off Between Probability of Transition Failure and Mean Present Value of Net Cash Flow for Six Pure Transition Strategies Under Two Decision Criteria for A Large Farm With 80% Owned Land