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An operational Approach for Evaluating Investment Risk: An Application to the No-till Transition

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Abstract. This study analyses short and long term safety first business risk associated with twenty six no-till transition strategies across four types of farms in eastern Washington. Risk of transition failure generated from risk averse criteria are also contrasted with a risk neutral criterion. Results revealed (1) that speeds of adoption have a larger effect than drill acquisition sequences in successful transition, (2) high equity farm have higher chance of success, and (3) slow acreage expansion with a custom or rental drill is preferred until 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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Introduction

The Pacific Region, including the Pacific Northwest (PNW), seriously lags the rest of the country in adoption of no-till farming. Furthermore, many early adopters of no-till subsequently abandoned the practice in part due to difficulties in managing the large investment costs and attendant financial risks of acquiring a no-till drill. Farmers indicate that fear of investment risk from purchasing an expensive no-till drill is a major barrier to no-till adoption (Juergens et al.). Recent studies of PNW no-till farmers have shown wide variation in their economic success depending on how the financial transition to no-till was managed. However, previous research shows that no-till can boost profits in this region once the transition to no-till has been navigated (Camara, Young, and Hinman).

A no-till drill is a major capital investment for most farmers. For a successful navigation through the no-till transition, farmers must carefully consider several alternative transition strategies. Transition strategies include choosing among combinations of speeds of adoption over the farm acreage and drill acquisition sequences involving custom hire, rent and purchase. The farm-wide net cash flow will also vary with farm size, equity position, government payment policies, taxes and tenancy arrangements.

Despite considerable methodological progress in the past (Buschena and Zilberman), there has been concern that standard risk analytical methods for short and long run decisions have not been practical for agricultural extension use (Just and Rausser; Castle; Shelley and Wilson; Anderson and Mapp). A survey by Shelly and Wilson indicate that many producers want to know specific strategies and the odds of success. Safety-first rule 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).

In this study of a risky no-till transition period extending over several years, annual cash inflows over cash outflows(net cash flow) is a key performance variable. Failure to meet annual cash requirements (including family living and debt payments) during any year of the transition process could precipitate forced refinancing, erosion of equity or even bankruptcy. The focus on business survival and the need for measurable parameters responds to the needs of farmers and extension (Shelley and Wilson; Anderson and Mapp). This approach also supports use of the safety first criteria. Among the three variants of the safety first rule (Katoka; Telser; Roy), variants of Roy's rule that minimizes the probability of the farm falling below a critical level of net cash flow is adopted in this study.

In the past, whole-farm (Robb, Smith, and Ellis) and multi-year (Patrick; Foster and Rausser) cash flow simulations have been used to illustrate the effects of risk on annual management decisions. For example, Weersink et al. compared simulated cash flows across tillage methods using stochastic dominance. Held and Helmer, Patrick, and Richardson and Condra also examined the effects on long run land investment decisions of a risky environment. However, past studies generally did not examine the risk of financial failure among alternative multi-year technology transition strategies.

Past studies often relied on expected long term net present value (NPV) and/or ending net worth (Held and Helmer; Walker and Helmer; Richardson and Condra) as the objective function. This long run approach excludes farmers who may be averse to fluctuations in cash flow within the investment period.

This study makes use of recent Monte Carlo simulation to incorporate intra and inter-temporal correlation from historical price and yields data. This study evaluates investment risk for a multi product firm for the multi period no-till drill investment problem. Different drill acquisition modes, in different sequences, are combined with variable speeds of adoption of no-till over the entire farm. In addition, this study contrasts short term and long term safety first decision criteria with a risk neutral decision criterion.

The objective of this study is to evaluate the economic success of several no-till investment transition strategies using risk averse and risk neutral decision criteria for different types of farms. 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.

Multiyear stochastic cash flow simulation: 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 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.

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:

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

wheare $e_{\mathrm{it},}$ are the residual from each random variable 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):

$$(2)\quad \rho_{i(t,t-1)} = \begin{bmatrix} 1 & \rho\left(e_{\mathrm{it},}\, e_{\mathrm{it-1}}\right) & 0 \\ & 1 & \rho\left(e_{\mathrm{jt},}\, e_{\mathrm{jt-1}}\right) \\ & & 1 \end{bmatrix}$$

Stochastic yield ($\widetilde{Y}$) and prices ($\widetilde{P}$) will be generated from an empirical distribution of correlated uniform deviates obtained by imposing these inter and intra temporal correlation matrices to standard normal deviates. Farm budgets will be prepared, using stochastic yield and prices, to generate net cash flows for each year of the six-year no-till transition of 104 farm type-strategy combinations (4 farm types by 26 transition strategies) as follows:

(3) Net cash flow (S_t) = $\widetilde{P} * \widetilde{Y}$ - E - $\widetilde{L}$ + $\widetilde{G}$ - $\widetilde{T}$ –F

Where,

E = 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.

$\widetilde{L}$ = Land lord's crop share set at one-third for grain and one-fourth for peas less proportionate contribution for crop insurance and fertilizers.

$\widetilde{G}$ = 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.

$\widetilde{T}$ = 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.

Four types of modeled farms include a large farm of 3000 acres and a small farm of 800 acres. Each size level is combined with a high (low) equity level with 80% (20%) owned acreage and renting the remainder. Owned land is assumed paid for. 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-tills100% 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. Following local practices, the farmer pays \$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. Within the transition period, the farmer receives 6% interest on any cash reserve and pays 8% loan interest to finance a cash deficit.

The probability of no-till transition failure will be derived following Roy's safety first decision rule:

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

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.

In a short run sense "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:

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

0 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:

$$(5) \quad S_{mt} = \begin{vmatrix} S_{11} & S_{12} & .... & S_{1t-2} & S_{1t-1} & S_{1t} \\ S_{21} & S_{22} & .... & S_{2t-2} & S_{2t-1} & S_{2t} \\ .. & .. & .. & .. & .. & .. \\ S_{m1} & S_{m2} & .... & S_{mt-2} & S_{mt-1} & S_{mt} \end{vmatrix}$$

where, m is the index for number of "draws" in simulation and t is the transition years.

In contrast, "transition failure" in a long run sense is defined as experiencing a negative net present value (NPV) of cash flows 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 NPV of net cash flow is positive. For each draw m for a farm type-strategy combination, the "transition failure" in long run sense is calculated as:

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

0 otherwise.

S_{mt} is given in equation (5), r is the discount rate, and t is the transition years.

Data

Historic crop price patterns were used to project future price fluctuations 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 price data (WASS). Price variability on peas was generated from historical marketing year average price in the state.

Yield risk with conventional and no-till wheat, barley, and peas was based on annual yield fluctuations of these crops in a long term eastern Palouse field experiment (Young, Kwon, and Young). This experiment provided nine years of yield data under both conservation and conventional tillage. Table 1 shows nine-year mean yields of winter wheat (86.08 bu/ac), spring barley (83.57 bu/ac) and spring peas (16.89 cwt/ac). 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 spring barley price (0.80).

The inter-temporal correlation matrix (Table 1) shows moderately high and negative correlation for spring pea no-till (-.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 (-.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 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 transition failure is higher for immediate adoption compared to gradual adoption. For example, for a large farm with 80% owned land, probability of transition failure ranged from 0.09-0.11 with a mean of 0.10 (over 500 simulation draws) under gradual adoption. But, it ranged from 0.18-0.33 with a mean of 0.25 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, but this advantage was offset by the yield penalty in early years.

As expected, the low equity farm exhibits higher risk of failure compared to the high equity farm 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 cash outflow for 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 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). Also, for the small farm choice of transition strategy is 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 NPV of farm cash flow 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 showed probability of failure ranging from .02-0.14 over strategies with a mean of 0.07 for immediate adoption compared to a range of 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 NPV 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 NPV implies more patience over time for (potentially minor) negative 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 NPV criterion.

Both decision criteria produced generally consistent results in identifying minimum or maximum risk strategies (Tables 2 and 3). Interestingly, immediate purchasing 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 make sense because 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 for operator's labor occurs for rental or purchased drills.

Table 4 shows mean NPV of net cash flow (over 500 simulation draws) for twenty six transition strategies for four farm types. Not surprisingly given initial yield penalties, gradual adoption shows higher NPV of net cash flows 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.

As expected, mean NPV of net cash flow was higher for the high than for the low equity farm (Table 4). The low equity farm incurs greater cash outflow in the form of land rent, where as the high equity farm is assumed to own outright 80% of his land.

The NPV results in Table 4 provide further insight into optimal transition strategies. Large farms with either equity level who purchase drills (P-6) should adopt no-till immediately, earning mean NPVs of net cash flow of \$314,500 or \$2,300 (depending on equity level). However, gradual adopters would be better off renting the drill for the entire transition period (R-6) earning mean NPVs of net cash flow of \$488,400 and \$158,100 for the high and low equity large farm, respectively. The high equity small farm with gradual adoption would be best off renting for the entire transition period earning \$114,000. The low equity small farm electing immediate adoption failed to generate positive mean NPV of cash flow for all acquisition options. Under the optimal gradual adoption, renting for the entire transition period maximized the mean NPV of net cash flow for both high and low equity farms.

Figure 1 plots the tradeoff between probability of transition failure against mean NPV 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 NPV under both decision criteria. The pattern in Figure 1 is the opposite of most annual risk and return tradeoff curves. In annual curves relating to 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 NPV 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 NPV and probability of failure. "Risk dominant" strategies occur at the lower right of the curve. 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 example, in Figure 1, 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 NPV criterion.

Discussion and Conclusions

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. Not surprisingly, higher equity farmers, without the drain of rental payments, showed a higher chance of no-till transition success. If large farmers have the cash or financing, early purchase of a no-till drill has a reasonable chance of success; however, gradual or moderate acreage expansion is still recommended until any yield penalty is eliminated. Low equity farmers have the lowest probability of successfully navigating the no-till transition while financing a drill. Small low equity farmers are at greatest risk. 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 (Juergens et al.). 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. Of course, farmers who are willing or able to wait longer periods for no-till to produce a positive cash flow will be less likely to give up on the practice.

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 NPV. However, short tem and long term criteria converged in the selection of transition strategies for many situations. We believe it is important to use alternative readily understood cash flow based risk measures in many farm and business situations.

Earlier survey results from small samples of farmers in the region who were in the no-till transition, or had completed it, enrich these modeling results in several ways (Juergens et al., Camara, Young and Hinman). Responses by experienced no-tillers went beyond simply determining the pace of no-till adoption and drill acquisition method. No-till farmers emphasized that tight fisted machinery cost management was a key to success (Camara, Young and Hinman). Perseverence was also a common attribute. Although the speed of conversion to no-till varied, none of the surveyed transition no-till farmers "backtracked" in no-till acreage over five years (Juergens et al.). 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. In contrast to the financing assumed in this study, most stated they had paid cash for their no-till drills. Some stated that they had overcome the no-till yield penalty in less than the six years assumed in this study. Personal adoption histories varied considerably indicating that adoption plans must be strategically tailored to the particular farm business situation. Furthermore, many farmers combined no-till with other new practices such as continuous spring cropping. New no-tillers sought out information aggressively from extension, industry, and neighbors who were using no-till.

This study was intended to provide a practical investment risk analysis where multiple input acquisition options can be put through alternative sequences and alternative speeds of application. This research is intended to help extension and industry staff better communicate to farmers about investment risk. Of course, the results are influenced by the assumptions of the example farm situation. Application of the methods to other technologies or to other geographical areas would require adequate modification to the setting.

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Table 1. Inter, Intra-temporal correlations and summary statistics of yields and prices of winter wheat, spring barley and spring pea in Whitman County, WA, 1986-1994

	Inter [a] temporal	Intra-temporal correlation of yield and prices								
		NWW	NSB	NSP	CWW	CSB	CSP	PWW	PSB	PSP
NWW	-0.20	1	0.70*	0.07	0.92*	0.82*	0.23	-0.35	-0.19	-0.09
NSB	0.38		1	0.18	0.85*	0.97*	0.26	-0.43	-0.45	-0.13
NSP	-0.52			1	0.01	0.11	0.97*	0.03	-0.10	0.41
CWW	0.00				1	0.92*	0.14	-0.60	-0.44	-0.06
CSB	0.38					1	0.21	-0.45	-0.45	-0.22
CSP	-0.62						1	0.03	-0.04	0.40
PWW	-0.04							1	0.80*	-0.32
PSB	0.38								1	0.01
PSP	-0.25									1
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		113.05	138.35	25.34	127.87	138.75	27.38	4.19	2.58	12.10

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. [a] one year correlations. [b] Mean restricted to the level of conventional tillage. * is significant at 5% level (t-critical = 2.36).

Sources:

Yield data: Young et al. 1994;

Price data: WASS, 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

	Large Farm 80% Own Land		Large Farm 20% Own Land		Small Farm 80% Own Land		Small Farm 20% Own Land	
Sequences	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 Net Present Value of Six-Year Cash Flows for Four Farm Types and Twenty Six No-till Transition Strategies

	Large farm 80% own land		Large farm 20% own land		Small farm 80% own land		Small farm 20% own land	
Sequences	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

	Large farm 80% own land		Large farm 20% own land		Small farm 80% own land		Small farm 20% own land	
Sequences	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.

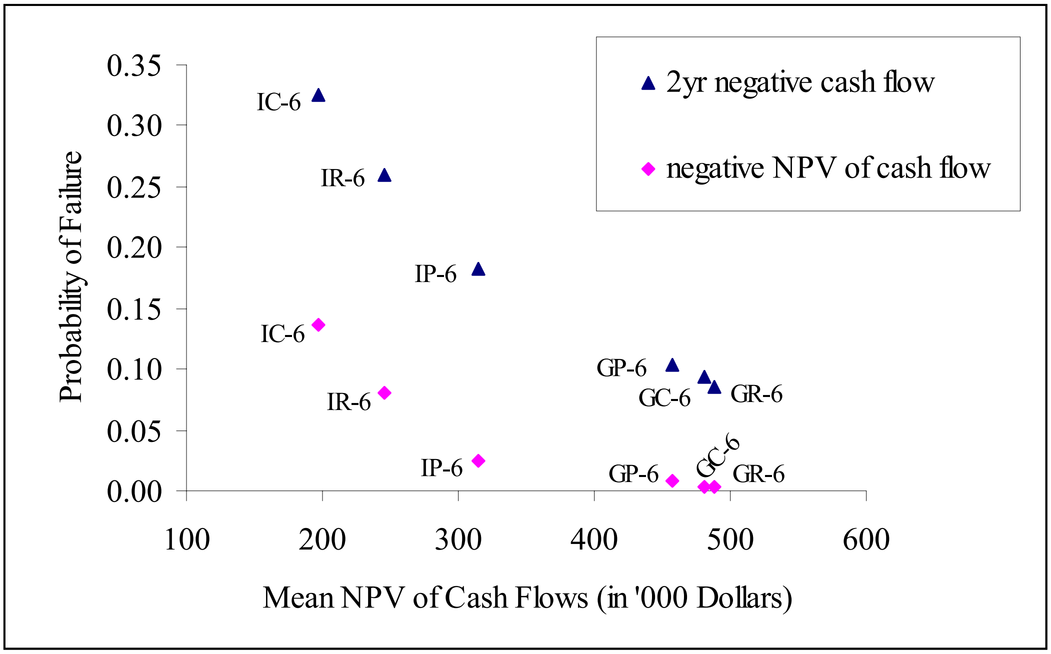

Figure 1. Trade-off between probability of transition failure and mean NPV of cash flows for six pure transition strategies under two decision criteria for a large farm with 80% owned land.

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.