Journal of Agricultural and Resource Economics 36(1):139–159

Machinery-Sharing Contractual Issues and Impacts on Cash Flows of Agribusinesses

Jared L. Wolfley, James W. Mjelde, Danny A. Klinefelter, and Victoria Salin

Contractual arrangements for joint machinery ownership between independent agribusinesses are explored. A two-farm economic simulation model of locations in Texas, Colorado, and Montana is developed to provide insight associated with sharing combines. Important variables include combine size (efficiency), yield losses resulting from untimely access to equipment, the penalty structure for untimely delivery, and cost-sharing and depreciation deductions claimed between producers. Combine sharing is risk-reducing in most cases. The gains to both parties are lowest when harvesting periods overlap. While the value of sharing is positive under many scenarios, benefits from sharing are small relative to total farm revenue.

Key Words: combines, machinery sharing, risk, simulation

Introduction

Agribusinesses constantly seek ways to reduce costs and improve machinery management to maintain profitability and decrease risk. Unfortunately, most reductions to machinery costs lead to concurrent decreases in net returns. Purchasing a lower quality machine, for example, may reduce initial costs, but additional repairs negatively affect productivity, costs, and consequently net returns. Initial costs are higher if a higher quality machine is purchased, but fewer repairs and increased productivity may offset cost increases. For most agribusinesses, machinery costs represent a large portion of total capital outlays. Machinery costs are typically the largest annual, non-land expense that agricultural producers face, accounting for up to 41% of annual farm production costs (Schwalbe, 2006; Foreman, 2006; Ali, 2002).

In an effort to improve farm profitability, reduce costs, and manage risk, producers in the United States are beginning to adopt unique managed lease and machinery ownership programs (Artz, Colson, and Ginder, 2010; Schwalbe, 2006; MH Equipment, 2007; Caterpillar Financial Services, 2007). One such management option is machinery sharing—the use of machinery by two or more farms—which may benefit farms because of production seasonality and the infrequent use of some machines. Sharing may reduce capital investments in machinery and potentially allow farms access to higher quality, larger capacity, or additional machines. Physical productivity may also increase as a result of production timeliness when newer, more efficient equipment is used. Farms sharing machines, however, may face decreased production

---

Jared L. Wolfley is a market analyst with AgriNorthwest, Kennewick, Washington. James W. Mjelde is professor, Danny A. Klinefelter is professor and extension economist, and Victoria Salin is associate professor, all in the Department of Agricultural Economics, Texas A&M University. Financial support from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration Grant No. NA17RJ1227 is gratefully acknowledged. The authors thank the editor and anonymous reviewers for their helpful comments. We are also grateful to *JARE* editorial assistant Amy Johnson and technical editor Judy Harrison for their valuable input.

Review coordinated by Myles J. Watts.

if the shared machines are not available when needed. Further, shared machinery may deteriorate faster because of increased use.

A whole-farm simulation model of combine sharing between two farms is developed to gain insights into contractual issues. The specific objective is to examine how different contractual arrangements will affect the net present value of after-tax cash flows for each of the two farms considering whether to share combines. Impacts associated with the contractual issues of combine size, percentage of shared costs paid by each farm, percentage of shared depreciation claimed by each farm, with whom to share, and the penalty structure for late combine delivery are presented.

Little to no research has been conducted on how machinery-sharing contractual issues affect a firm's bottom line.[1] Drawing on a range of previous research on farm machinery, this study begins to fill in the gaps in the machinery-sharing literature. To our knowledge, this is the first comprehensive study of the potential effects of machinery sharing on two U.S. producers.

Literature Review

Research on machinery sharing is limited. Studies examining machinery sharing have either been in the context of farm cooperatives (de Toro and Hansson, 2004; Musabelliu and Skreli, 1997) or agricultural production (Olszweski, 1997; Werschnitzky, 1972). Through modernization and equipment sharing, Olszweski concludes farm managers in the Ostroeka and Suwaki provinces of northeast Poland are able to reduce capital expenditures by 39% to 78%. De Toro and Hansson examine a Swedish machinery cooperative taking into account labor, specific machinery, timeliness costs, and weather variability. Their simulation model suggests machinery sharing contributes to a 15% decrease in total costs and a 50% reduction in investment requirements. Results from both studies apply to farms in one region; sharing machinery between farms in different regions with different weather-determined harvesting windows was not examined.

Musabelliu and Skreli (1997) report that scattered parcels of land from state farm break-ups in Albania have led farmers to examine cooperative machinery use. Werschnitzky (1972) uses previously developed empirical investigations to describe the economic and social aims of interfarm cooperation for machinery sharing. Upon examining six cases of machinery sharing in the Midwest, Artz, Colson, and Ginder (2010) conclude that access to reliable labor is also a motivation for participating in a machine-sharing arrangement.

General Simulation Model

To address the problem of sharing combines, a discrete, stochastic, multi-year simulation model, which calculates net present value of expected after-tax cash flows [E(NPV)] is developed. The problem facing two producers considering the purchase of new combines is depicted in figure 1. Producers must decide whether to buy and use the combines independently, or jointly buy the combines and share in their use. For each individual, the decision rule is specified as:

---

[1] We do not consider options other than sharing and buying, such as leasing and custom operations.

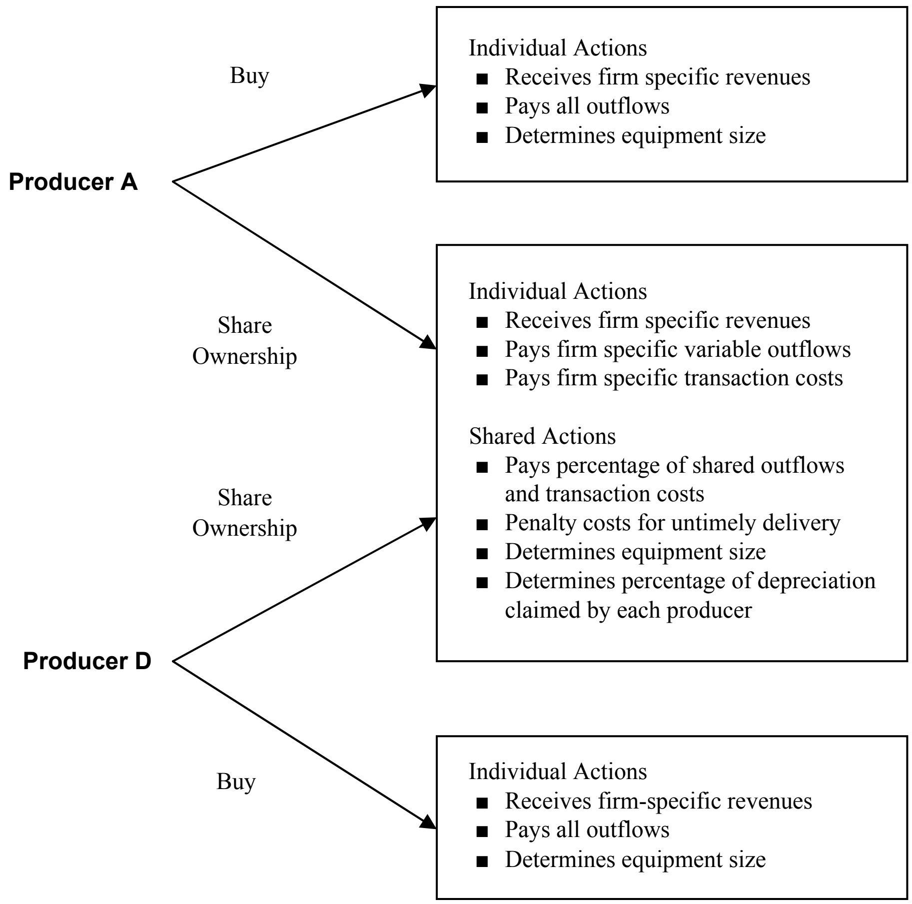

Figure 1. Machinery-sharing decision problem for two economic agents

(1)
$$V_S^i - V_B^i \begin{cases} < 0 & \text{Buy Independently,} \\ > 0 & \text{Share Ownership,} \end{cases}$$

where V_j^i represents E(NPV) for producer i, subscript S denotes shared ownership (sharing), and subscript B denotes independent purchase (buying). With two producers, four outcomes are possible: both are better off buying, one is better off buying and the other sharing and vice versa, and both are better off sharing. Only the last outcome results in combine sharing.

Buy Independently

In figure 1, the independent purchase branches are the standard machinery purchase/capital investment problems that have been previously investigated (Barry and Robison, 2001). Obviously, the decision to purchase independently involves no contractual issues between producers. A producer's E(NPV) for independent purchase, which is similar to other previous whole-farm models, is expressed as:

$$(2) \qquad V_B^i(I\,|\,\cdot) = \sum_{w=1}^{1,000} \frac{1}{1,000}\left[\sum_{t=1}^{5}\left\{Rev_t^i(I\,|\,\cdot) - Cost_t^i(\cdot) - P_t^i(I\,|\,\cdot) - m_t^i(I\,|\,\cdot) - Tax_t^i(I\,|\,\cdot)\right\}\frac{1}{(1+r)^t}\right],$$

where

i and B	are as previously defined;
I	represents combine size and efficiency characteristics;
w and t	are indexes for the simulation, where w indexes the simulation iteration and t the year within each simulation iteration [there are 1,000 iterations, with each iteration simulating five years, equal probability being assigned to each of the 1,000 iterations and five years in calculating the E(NPV)];
$Rev_t^i(I\,|\,\cdot)$	is revenue generated in year t;
$Cost_t^i(I\,|\,\cdot)$	is firm-specific cash outflows, excluding those cash outflows associated with purchasing and using the combines;
$P_t^i(I\,|\,\cdot)$	represents relevant yearly purchasing cash outflows associated with the combine purchase (principal payment, interest, and/or salvage value—specific values vary by year);
$m_t^i(I\,|\,\cdot)$	is maintenance costs associated with the combines;
$Tax_t^i(I\,|\,\cdot)$	includes self-employment and federal income taxes;
r	is the discount rate; and
$(\cdot)$	represents all other factors that affect cash flows, such as acreage, input prices, debt load, etc.

A whole-farm model is necessary for this decision problem because of the potential importance and implications of the U.S. tax code, with its deductions and varying tax rates, on combine sharing. Tax deductions may change based on sharing, which may alter one's marginal tax rate. Accordingly, total revenues and variable and fixed costs are included and not limited to the revenues and costs directly associated with machinery sharing.

Combine Sharing

A producer considering combine sharing must decide with whom to share, as well as address contractual issues such as: (*a*) combine size (efficiency); (*b*) how the combine ownership costs (principal repayment, interest, taxes, housing, and insurance) are split; (*c*) how depreciation is split; and (*d*) a penalty function in the event the combines are not delivered as stated in the contract. It is assumed that once agreed upon, these contractual issues remain constant throughout the life of the contract.

The model is a modified version of equation (2). For two producers, A and D, assume producer A uses the combines first. Modifications include changes in revenues and changes to account for shared ownership and operating cash outflows associated with the combines. The producers' E(NPV)s are written as:

(3) $V_S^A(I\,|\,\cdot) =$

$$\sum_{w=1}^{1,000} \frac{1}{1,000}\left[\sum_{t=1}^{5}\begin{Bmatrix} Rev_t^A(I\,|\,\cdot) - Cost_t^A(\cdot) - \alpha P_t^A(I\,|\,\cdot) \\ -\, m_t^A(I\,|\,\cdot) - Pen_t^A(I\,|\,\cdot) - Tax_t^A(\beta, I\,|\,\cdot) \end{Bmatrix}\frac{1}{(1+r)^t}\right]\frac{1}{1,000}$$

and

(4) $V_S^D(I\,|\,\cdot) =$

$$\sum_{w=1}^{1,000} \frac{1}{1,000}\left[\sum_{t=1}^{5}\begin{Bmatrix} Rev_t^D(I\,|\,\cdot) - Cost_t^D(\cdot) - (1-\alpha) P_t^D(I\,|\,\cdot) \\ -\, m_t^D(I\,|\,\cdot) - Pen_t^D(I\,|\,\cdot) - Tax_t^D[(1-\beta), I\,|\,\cdot] \end{Bmatrix}\frac{1}{(1+r)^t}\right]\frac{1}{1,000},$$

s.t.: $0 \le \alpha \le 1, \quad 0 \le \beta \le 1,$

where $Rev_t^i(I\,|\,\cdot)$, $Cost_t^i(I\,|\,\cdot)$, $P_t^i(I\,|\,\cdot)$, $m_t^i(I\,|\,\cdot)$, Tax_t^i, and S are as previously defined. The values for $P_t^i(I\,|\,\cdot)$ and $m_t^i(I\,|\,\cdot)$ differ from independent purchase because of the additional combine usage due to sharing. When sharing combines, cash outflows associated with the combines are allocated according to α, the percentage of shared outflows paid by producer A. Depreciation can also be shared in various percentages; β represents the percentage of depreciation claimed by producer A. Shared cash outflows associated with purchasing a combine include down payment, interest, principal, salvage value, and yearly transportation costs incurred when moving the combines between farms. $Pen_t^i(I\,|\,\cdot)$ is a penalty for untimely combine delivery paid by producer A to producer D. It is assumed α and β lie in the relevant range of 0 to 1.

Geographical Location of Producers (With Whom to Share)

Transaction costs and combine availability are two main concerns when determining with whom to share the combine. Overlap in optimal harvesting windows is a major determinant whether the combine will be delivered on time by producer A to producer D. On-time delivery by producer A is necessary to avoid penalty payments. The harvesting window is the time from when the crop is ready to be harvested until harvesting is completed. Generally, the further the distance between two producers, the less overlap in harvesting windows and the smaller the expected penalty. Increases in distances, however, lead to increased transaction and transportation costs of delivery.

Combine Size

Costs and benefits differ as combine sizes vary. Size and efficiency of the combines are closely related. The larger the combine, generally the less time is necessary to complete harvest. Hence, larger combines may increase returns and decrease expected penalties. Shared cash outflows, which include purchase price, maintenance, and transportation costs, along with firm-specific outflows, increase for larger combines relative to smaller combines, but there are tradeoffs. Generally each producer's returns and cash outflows differ with respect to combine size.

Percentage of Shared Cash Outflows

It is clear from equation (3) that producer A can increase cash flows if the sharing parameter (α) equals 0, ceteris paribus, consequently paying none of the shared cash outflows. This circumstance occurs because many of these specific outflows are tax deductible, effectively decreasing taxes paid. The increase in deductions is less than the cost outflow. Similarly, producer D's expected cash flows are larger if $\alpha = 1$, where producer A pays all the shared cash outflow and producer D pays none. Given these two outcomes, there is room for negotiation between the producers.

Percentage of Depreciation Claimed

It is possible to set up the combine-sharing arrangement such that depreciation is shared unequally. Generally, as long as taxable income is positive, a producer will want to claim more depreciation. The percentage of debt-free land and machinery determines yearly interest expenses, which may impact the effect of depreciation sharing. A producer who owns his/her machinery and land debt-free will have smaller tax deductions relative to a producer who has a high debt load. Thus, a producer with fewer deductions may be willing to pay more of the deductible shared cash outflows in exchange for additional depreciation deductions.

Penalty Function

Overlap in harvesting windows between the two farms is a major determinant of the penalty payment. If there is no overlap in harvesting windows, producer A will always complete harvesting before producer D needs the combine. No penalty payment is necessary in this case. Two producers whose harvest windows never overlap will usually be separated by a large distance, leading to high transaction and transportation costs. A more realistic scenario is one of overlapping windows. The amount of overlap—which is a function of locations, weather conditions, and production practices—is one factor determining the penalty paid by a producer.

Many penalty functions can be devised to enable machinery-sharing arrangements that satisfy both parties. Several reasonable versions of the penalty function are analyzed. One extreme would be producer A compensating producer D for all yield losses associated with untimely delivery. Such compensation is possible if producer A knows how untimely delivery affects the net returns of both producers (full information). Producer A delays delivery and completes harvest if his/her increases in net returns are larger than any decreases in producer D's net returns. Keeping the combines to complete harvest increases producer A's net returns. Delaying delivery, however, will decrease producer D's returns if his/her crop is ready to harvest. If producer D's returns are not affected by untimely delivery, then no penalty is paid. Likewise, if producer A's harvest is completed on time, the combines will be delivered by the specified contractual date and no penalty paid. Under this full-information scenario, producer A is taking on the entire risk associated with untimely delivery. The other extreme penalty function is when producer A never pays a penalty for untimely delivery. In essence, producer D is taking on all the risk. This penalty function is easy to implement, but not likely in the real world. As such, penalty function arrangements can be used to transfer the risk of not being able to deliver machinery between the producers.

A multitude of penalty functions lie in between the full-information and no-penalty functions. One such function is a lump-sum penalty. In this case, the penalty function would be a function of combine size. Larger combines (requiring fewer days to complete harvest) would be associated with smaller lump sums. Once combine size is determined, this penalty function is easy to implement, but very inflexible. No incentives are provided to producer A to deliver the combine once the delivery date has been missed. The selection of this penalty function reduces information requirements.

Model Specifics—Baseline

A discrete, stochastic, multi-year simulation model that calculates E(NPV) is developed based on equations (1)–(4). The model is capable of simulating combine sharing between any two of four farm locations: Dumas, Texas; Pampa, Texas; Akron, Colorado; and Big Sandy, Montana. These four locations allow for different overlap in harvesting windows. Each farm uses a wheat-fallow rotation on 10,000 acres; therefore, 5,000 acres are in production each year. All farms are the same size to eliminate size-of-farm impacts. Each producer is considering purchasing two combines either independently (a total of four combines at two per farm) or sharing in the purchase of two combines to be used jointly (total of two combines).

The baseline assumes 75% of the land and nonshared machinery are owned debt-free. In addition, each farm includes a debt-free homestead consisting of five acres where a house and buildings reside. Costs and returns normally included in a single farm simulation model are present, but because of sharing combines, two farms are simultaneously simulated including machine-sharing specific issues.

As in any investment analysis, the discount rate used may affect the investment decision. To isolate contract-sharing issues, the discount rate used reflects the market price of borrowed funds. The same discount rate is applied to both producers. Sensitivity analysis on the discount shows that inferences of combine sharing did not change, although modest changes in the E(NPV) occurred for nominal after-tax discount rates between 3% and 9%. Results using a 6% discount rate are presented.

It is assumed that the farms engaging in sharing have formed a limited liability company which encompasses only the shared combines. Given this assumption, depreciation and other costs associated with sharing the combines can be transferred between the farms. The model is simulated using Simetar© (Richardson, Schumann, and Feldman, 2006). Each iteration represents five crop years.

Revenues

When the producer buys the combines independently, revenues consist of market returns and government payments. If wheat is harvested, market revenues are based on stochastic prices and yields. Under the independent purchase scenario, if the producer decides to harvest, harvest continues until completion. If the producer does not harvest, revenues are crop insurance payments, which are determined from purchasing a crop insurance price guarantee of $3.00 per bushel and yield coverage of 85% of the mean wheat yields. All 5,000 planted acres are insured. For each year, a randomly generated price for each farm is drawn from an empirical distribution of correlated state wheat prices (Wolfley, 2008). Yields are assumed to be independent of each other and of price. These are reasonable assumptions given: (*a*) the estimated correlations between the simulated yields are small except between the Texas farms, (*b*) the distance between some of the farms' locations is substantial, and (*c*) the effect of an individual farm's yield on state-level prices would be small.

The loan deficiency payment program of the 2002 Farm Bill guaranteed farmers a target price of $3.92 per bushel of wheat for 2004–2007. Wheat farmers are allowed to achieve this price using a combination of direct payments, loans, and countercyclical payments. In the model, farmers are guaranteed the target price of $3.92 per bushel of harvested wheat through an end-of-year direct payment. If the price is greater than the target price, then no government payments are received. All planted acreage is assumed to be eligible for the direct payment.

When combines are shared, revenues are calculated similarly to the independent purchase scenario, with one major modification. The contract allows the first producer a set number of days from crop maturity to harvest his/her crop. At the end of this predetermined number of days, if the first producer has not completed harvest, he or she must decide whether to continue and finish harvest, thereby incurring a penalty payment to the second producer. Alternatively, the first producer can avoid the penalty by delivering the combine on time, leaving some acres unharvested. Market returns are adjusted for both producers depending on the decision made. If the first producer decides to deliver on time, the first producer's market returns are reduced by the number of acres not harvested. On the other hand, if the first producer decides to complete harvest, both producers' market returns are reduced based on yield loss calculations.

Yields

DSSATv4 (Hoogenboom et al., 2004), a crop growth model, is used to generate consistent wheat yields between the farms. Daily weather data were obtained from the U.S. Department of Commerce (2008) and Weather Underground (2008). The soil type with the highest prevalence rate within each county is selected. Representative soil characteristics from Natural Resources Conservation Service online county soil surveys for each of the locations are used (U.S. Department of Agriculture, 2007). For Moore County (Dumas location), Sherm silty clay loam is the predominant soil type. Pullman clay loam, a silty clay loam, is the predominant soil type in Gray County (Pampa). Weld silt loam is the predominant soil type in Washington County (Akron). In Chouteau County (Big Sandy), Telstad-Joplin loam is the predominant soil type. The dominant class of wheat grown in each region is modeled. U.S. winter wheat is the dominant cultivar used in the Texas and Colorado locations, while spring wheat is the cultivar planted in Montana.

Simulated yields for 1956–2006 are verified against county historical yields (U.S. Department of Agriculture, 2007) using a Bartlett-adjusted test (Abdulsalam, Pittroff, and Dahm, 2008). One observation from the 51 simulated years is randomly drawn with replacement for each of the five years per iteration. Akron's simulated mean yield of 36 bushels per acre is the largest of the four farms, followed by Dumas at 27.7 bushels per acre and Pampa at 24.6 bushels per acre. Big Sandy has the smallest mean yield at 20.4 bushels per acre. Akron also has the largest variance at 12.2 bushels per acre, followed by Big Sandy at 8.7, Dumas at 7.7, and Pampa at 4.8 bushels per acre.

Harvesting Window Calculations

DSSATv4 provides a maturity date, but not a beginning harvesting date. After maturity, wheat requires a dry-down period whereby the moisture content is lowered to a level safe for storage, a period of usually two to three weeks (Monson et al., 2007). Using this information, the harvesting window for each farm is assumed to begin 17 days following the simulated maturity date and continue until the first producer either finishes harvesting or delivers the combines. The second farm begins harvest at the maximum of the simulated maturity date plus 17 days, or at the first farm's ending harvest date plus travel time.

In addition to travel time, one day is assumed necessary for loading, unloading, and preparing the combines for harvest. [2] Travel time between farm locations is a function of the distance and speed of travel. It is assumed travel averages 50 miles per hour (including time for fuel, food, and rest stops) for 10 hours per day.[3]

The end of the harvesting window for the second farm occurs when the last acre is harvested. If producer A does not harvest and collects crop insurance payments, there is timely delivery to the second farm and harvesting begins 17 days after the crop maturity date.

Yield Reductions Related to Untimely Harvesting

Because yield data are verified to county-level data, it is assumed simulated wheat yields already account for yield loss from the date of maturity until the end of harvest in a normal year. This period includes the 17-day dry-down period plus 25 consecutive harvesting days. Given combine size and acreage, 25 workable days are necessary to complete harvest. Delays in harvesting because of weather and/or untimely combine delivery, however, are not included in the simulated yields. In the model, delays in harvesting result in a 0.5% yield loss per acre for each additional day beyond the first 25 harvesting days, following results reported in Bolland (1984). Based on previous studies (Whitson et al., 1981; Dillon, Mjelde, and McCarl, 1989; Rotz and Harrigan, 2005; Dyer and Baier, 1979; Rounsevell, 1993), a day is deemed suitable for harvesting if daily precipitation is less than or equal to 0.1 inches. Daily rainfall during the harvest period is given by rainfall in the year that is randomly selected to provide yields.

It is assumed the contract guarantees the first farmer 25 consecutive days from the harvesting window start date plus travel time to deliver the machinery without penalty. Because the 25 contracted harvest days may not all be workable field days, the first farmer faces a decision 25 days after the harvesting window start date. If his/her harvest has not been completed, the farmer's decision is to either stop harvesting to ensure timely delivery or to complete harvesting, and therefore delay delivery.

Penalty Payment

The full-information scenario discussed above is assumed throughout the results, except in the "Alternative Penalty Structures" section, in which results from the full-information, no-penalty, and lump-sum structures are compared. Under the full-information structure, the penalty paid by producer A to producer D is the yield loss associated with late combine delivery (L_t^D) multiplied by the price producer D receives (p_t^D) in year *t*. The decision rule used by producer A in deciding either to continue harvesting or to deliver the combines is written as:

(5) $$DEC_t^A = p_t^A K_t^A - HC_t^A - p_t^D L_t^D,$$

where p_t^A is the price received by producer A (maximum of market or target price), K_t^A is the total wheat left to be harvested, and HC_t^A represents producer A's variable harvesting costs for the acreage remaining to be harvested. If DEC_t^A is greater than zero, producer A completes

[2] Total travel was calculated as the amount of time necessary to travel (rounded to the next highest day), plus an additional day for preparation. Total travel times are as follows: Dumas to Pampa = 1 day, Dumas to Akron = 2 days, Dumas to Big Sandy = 3 days, Pampa to Akron = 2 days, Pampa to Big Sandy = 4 days, and Akron to Big Sandy = 3 days.

[3] One-way travel costs are calculated as $2.30/mile, the trucking rate per loaded mile times distance between farms. Distances between farms are: Pampa to Dumas = 69 miles, Pampa to Akron = 456 miles, Pampa to Big Sandy = 1,252 miles, and Akron to Big Sandy = 872 miles.

harvesting and delays delivery, whereas if DEC_t^A is less than zero, producer A delivers the combines. Penalty payments are taxable income for producer D and tax deductible for producer A.

Firm-Specific Cash Outflows

All ownership and operating cash outflows not directly associated with purchasing and using combines are considered firm-specific cash outflows. Fixed cash outflows include payments for land, real estate taxes, housing, and insurance. It is assumed that the producer refinanced the loan amount for both land and firm-specific machinery at the beginning of the five simulated years. The amount of debt-free land and firm-specific machinery may have an impact on the decision to share purchase or buy the combines independently. The base model assumes 75% of the land and equipment is owned debt-free. Sensitivity analysis on this percentage is presented in the results section. Variable costs include seed, fertilizer, herbicide, crop insurance, operating interest, machinery interest, repairs, labor, and fuel and lube. Production costs for each location are consistent with input levels used in the crop yield simulations.

To avoid complicating issues, the machinery complement for each farm is assumed to be the same. The Machinery Cost Analysis software program (Smathers, Patterson, and Shroeder, 2002) is used to develop operating and ownership costs for the assumed machinery complement. The cost analysis program requires yearly machinery usage estimates, which were obtained from engineering equations (American Society of Agricultural and Biological Engineers, 2006a, b). Other firm-specific outflows are determined using information provided by Outlaw et al. (2007) and state cost projections (Texas AgriLife Extension, 2007; University of Idaho, 2003; Colorado State University Cooperative Extension, 2006). Total firm-specific cash outflows and depreciation for the first year are lowest for Akron at $93.16 per acre, followed by Big Sandy at $97.47 per acre, Pampa at $102.31 per acre, and Dumas at $102.58 per acre. Variation in nonshared variable outflows between farm locations is attributed to differences in fertilizer and operating interest costs. Average annual inflation rates for taxes, wages, variable and fixed costs, fuel, operating interest, savings, consumer price index, land value, and machinery are included. Rates are determined from the average percentage change in values from the Food and Agricultural Policy Research Institute (2006, 2008) and the U.S. Department of Agriculture (2008).

Combine Cash Outflows

Combine ownership cash outflows include principal repayment, interest, taxes, housing, and insurance. Each producer bears all costs when combines are not shared. When the combines are shared, the total of the two farms' purchasing, financing, and deprecation outflows are lower because two instead of four combines are purchased. An individual combine, however, depreciates faster when shared because of increased use. Based on discussions with the sales manager for John Deere, the salvage values of combines that are shared are assumed to be 37.5% of the nonsharing combine salvage value (Stewart, 2008). Depreciation for tax purposes is determined using straight-line depreciation net of salvage value. Purchase price is $240,000 per combine with a salvage value of $83,388 after five years for combines that are not shared. It is assumed the combines are sold at their salvage value at the end of the five years.

When the combines are shared, combine operating costs—which include labor, repair and maintenance, and fuel and lube—are assessed to the producer operating the machinery. It is assumed that both producers perform necessary maintenance. Operating (operating loan interest, repairs, labor, fuel, and lube) and transportation costs are higher in the shared case because of the additional use. The same percentage of shared machinery costs is applied to both ownership and operating outflows when the combines are shared.

Federal Taxes

Both self-employment (Social Security plus Medicare taxes) and income taxes are included. Social Security tax is the minimum of 12.4% of either the first $102,000 of taxable income or 92.35% of all taxable income. Medicare tax is 2.9% of all taxable income (*RIA Federal Tax Handbook*, 2008). Taxable income is revenue generated from wheat sales, government payments, crop insurance payments, and penalty payments (positive for farm 2 and negative for farm 1) minus cash operating expenses and depreciation.

Federal income taxes are calculated by applying 2007 Schedule Y-1 to adjusted gross income, which is taxable income minus one-half of self-employment taxes, any business carry-over loss from the previous year, standard deductions ($10,900, married and filing jointly), and personal exemptions ($14,000—husband, wife, and two children). To reduce taxation impacts from differences in state laws, state income taxes are assumed to be zero. This assumption has no effect on the Texas farms because Texas does not have a state income tax. However, there is some effect on the Montana and Colorado farms because both of these states have state income taxes.

Combine Size

Two combine sizes are compared for the Pampa/Akron combination. The larger combine, which was described in the baseline scenario, is based on recommendations from equipment dealers. The smaller combine takes 10 additional days to complete harvest, resulting in an additional yield loss of 5% on the portion of the acreage requiring the additional time compared to the larger combine. With the smaller combines, operating and repair costs also increase because of the additional harvest time.

Results

Results presented are the differences between the E(NPV) of sharing and nonsharing scenarios [equation (1)]. Changes in risk are examined by differences in standard deviations of the cash flows. In the following discussion, producer A is listed first and producer D second. Five combinations of two farms sharing machinery are considered: 1) Pampa and Pampa, 2) Pampa and Dumas, 3) Pampa and Akron, 4) Pampa and Big Sandy, and 5) Akron and Big Sandy. The combinations are chosen to demonstrate how sharing decisions are affected by harvesting windows that completely or almost completely overlap (combinations 1 and 2), partially overlap (combinations 3 and 5), and have very little overlap (combination 4).

Combine Size—Full-Information Penalty Structure

Results for a 50:50 outflow and depreciation sharing percentages are as follows for the Pampa/Akron combination (see figure 2). In considering whether to share in the purchase of the larger

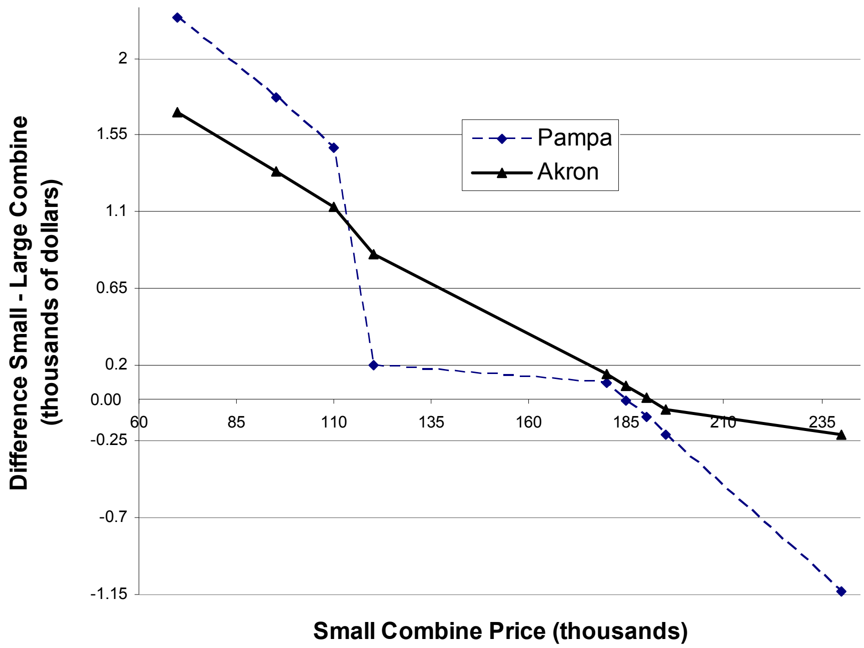

Figure 2. Differences in net present value of expected after-tax cash flows for the Pampa/Akron combination associated with buying a small combine independently or sharing in the purchase of a large combine assuming a 50:50 outflow and depreciation sharing (positive differences indicate the small combine is preferred)

combines or purchase smaller combines independently, the Pampa farm prefers to share when the price of the smaller combine is approximately $185,000 or more (recall, the larger combine costs $240,000). Akron prefers sharing over buying for the smaller combine at prices of $190,000 or higher. Risk is reduced by combine sharing for both Akron and Pampa.

This example clearly shows that the use of machinery sharing to obtain larger combines is a viable option producers may want to consider. To control for combine size effects, the remainder of the discussion uses the larger combines for both sharing and independent purchase.

Full-Information Penalty Structure—Variable Percentage of Outflows Paid

As expected, when producer A bears 100% of shared outflows, differences in E(NPV) between sharing and independent purchase (henceforth referred to as the gains from sharing) are negative for producer A and positive for producer D in each farm combination (table 1). Producer A will not share if he/she bears all shared costs and risk. Obviously, producer D is willing to share combines when paying none of the shared outflows and assuming none of the risk.

Besides the 100% payment scenarios, the only other scenario where producer A does not benefit from sharing is when Akron pays 75% of the outflows in the Akron and Big Sandy combination. Akron has a negative gain from sharing because of the higher average price Big Sandy receives (almost 37 cents larger on average than Akron's price). Given that Akron must compensate Big Sandy for yield losses beyond the contractual date at the price Big Sandy receives, untimely machinery delivery is costly to Akron.

Table 1. Differences in Expected Values and Standard Deviations of NPV of Expected After-Tax Cash Flows for the Base Penalty Payment for Each Farm Combination Assuming Different Percentages of Shared Outflows Paid (in $100,000s), Depreciation Shared 50%/50%

	Combination [1]		Combination [2]		Combination [3]		Combination [4]		Combination [5]	
Description	Pampa	Pampa	Pampa	Dumas	Pampa	Akron	Pampa	Big Sandy	Akron	Big Sandy
Producer A Pays 100%										
Mean	−1.285	2.993	−1.292	2.948	−1.284	4.047	−1.406	4.558	−1.444	3.954
(Std. Dev.)	(−0.035)	−0.418	(−0.038)	(−0.451)	(−0.032)	(−0.066)	(−0.019)	(−0.330)	(−0.052)	(−0.386)
2-Farm Sum [a]	1.707		1.656		2.763		3.152		2.510 †	
Producer A Pays 75%										
Mean	***0.324***	***1.426***	***0.316***	***1.483***	***0.341***	***2.714***	***0.259***	***3.120***	−0.070	2.510
(Std. Dev.)	(−0.099)	(−0.356)	(−0.102)	(−0.388)	(−0.098)	(−0.068)	(−0.088)	(−0.281)	(−0.060)	(−0.334)
2-Farm Sum	1.750 †‡		1.799 ‡		3.055		3.379		2.440	
Producer A Pays 50%										
Mean	1.980	−0.168	1.899	−0.007	***1.941***	***1.377***	***1.897***	***1.665***	***1.298***	***1.047***
(Std. Dev.)	(−0.174)	(−0.304)	(−0.176)	(−0.317)	(−0.175)	(−0.068)	(−0.167)	(−0.221)	(−0.064)	(−0.271)
2-Farm Sum	1.740		1.892		3.318		3.562		2.345 ‡	
Producer A Pays 25%										
Mean	3.458	−1.779	3.448	−1.522	***3.506***	***0.036***	***3.497***	***0.190***	2.661	−0.438
(Std. Dev.)	(−0.254)	(−0.265)	(−0.256)	(−0.244)	(−0.256)	(−0.066)	(−0.252)	(−0.151)	(−0.065)	(−0.201)
2-Farm Sum	1.679		1.926 †		3.541 ‡		3.687 ‡		2.223	
Producer A Pays 0%										
Mean	4.972	−3.401	4.961	−3.060	5.033	−1.310	5.058	−1.306	4.020	−1.944
(Std. Dev.)	(−0.329)	(−0.236)	(−0.331)	(−0.174)	(−0.332)	(−0.060)	(−0.331)	(−0.077)	(−0.063)	(−0.129)
2-Farm Sum	1.571		1.901		3.722 †		3.751 †		2.076	

Notes: † denotes the largest two-farm sum, whereas ‡ denotes the largest two-farm sum given both farms benefit—i.e., both differences are positive. Values in bold/italics indicate scenarios where positive gains are experienced for both farms.

[a] Two-farm sum is the sum of the differences in expected values for the two farms.

Producer D gains from sharing when producer A pays 75% or more of the shared outflows. When shared costs are split evenly or when producer D pays a larger percentage of the outflows, the overlap in harvesting window helps determine if the gains to sharing are positive or negative for each producer. Similar to producer A, if producer D pays 100% of the outflows, its changes in E(NPV) are always negative. When the harvesting windows highly overlap—as they do for Pampa/Pampa (100% overlap) and Pampa/Dumas—even at base 50% sharing of outflows, producer D is harmed by sharing. The losses resulting from sharing combines occur because producer A is not required to compensate for yield loss before the end of the 25 harvest days specified in the contract; producer D suffers up to 25 days of uncompensated yield loss. When the harvest windows only partially overlap, as in the Pampa/Akron combination, producer D can generally pay up to 75% of the costs and still gain from sharing. An exception is the Akron/Big Sandy farm combination, in which Big Sandy has a negative difference when it pays 75% of the shared outflows.

Differences in standard deviations of E(NPV) for all farms in each farm combination are negative, indicating that machinery sharing may be risk-reducing. Reduction in this risk measure is caused by shared machinery outflows being spread over two farms instead of only one farm, even though outflows per machine are higher. As the percentage of shared outflows paid for a farm is reduced, risk decreases for all farms in every combination except Akron in the Pampa/Akron and Akron/Big Sandy combinations.

Alternative Penalty Structures

As noted earlier, two alternative penalty structures are no penalty and lump sum. Under the no-penalty structure, producer D bears all the risk. This is just the opposite of the full-information structure. In the no-penalty case, producer A does not pay a penalty for untimely delivery. As expected, producer A is always better off and producer D is worse off relative to the full-information penalty. As the harvesting window overlap decreases, there is less yield loss from untimely delivery and the penalty becomes less important to combine sharing. Changes in standard deviations reveal that risk is generally reduced by sharing.

A third penalty structure is a lump-sum payment of $2,500 from producer A to producer D whenever the contracted machinery delivery date is not met. This penalty amount is approximately equal to the average penalty payment under the full-information penalty structure. Risk is shared by both producers under this structure. When the risk of untimely delivery is shared between farms, results and inferences are similar to those of the base penalty contract. To illustrate the effect of the penalty payments, consider the Pampa/Pampa combination. In the base case, producer A completed harvest of all acres 84% of the time, whereas producer A completed harvest 92% of the time under the lump-sum case. Harvesting is not completed in 3% of the simulated years in both scenarios because crop insurance payments are larger than the value of the wheat crop.

Alternative Depreciation Sharing

To examine potential depreciation and debt-level tradeoffs, the Pampa/Akron combination is considered. For both farms, the higher the percentage of depreciation deducted at the base debt-free percentage (75%), the larger the gains from sharing. The higher the percentage of depreciation deducted, the lower the federal income tax liability; therefore, E(NPV) increases. At all percentages of shared depreciation, differences in E(NPV) are positive for both farms when the percentage of shared outflows paid by Pampa is either 50% or 75%. However, risk is reduced for both farms at all percentages of shared depreciation only when Pampa pays 50% or less of the shared outflows.

Gains from sharing for varying percentages of shared depreciation and shared outflows for the Pampa/Akron combination are given in table 2 for different debt levels. When the percentage of shared machinery depreciation claimed increases for either farm, gains from sharing increase at all percentages of shared outflows. Similarly, when the percentage of debt-free land and nonshared machinery decreases, gains generally increase at all percentages of shared costs and percentages of depreciation. Depreciation becomes more valuable as the percentage of debt-free land and machinery increases because of larger taxable income. Alternatively, when the debt-free percentage is small, there are larger tax deductions, and the depreciation deduction is not always used.

To further illustrate the effects of depreciation sharing, consider the following examples. Let Akron be 0% debt-free and Pampa pay 100% of the shared outflows (table 2, panel A). Gains from sharing for Akron are $492,000 (panel A, column 2, row 1) and $408,000 (panel A, last column, row 1) when Pampa deducts 0% and 100%, respectively, of the shared depreciation. When Akron is 100% debt-free and Pampa pays 100% of the shared outflows (table 2, panel B), however, gains from sharing are $458,300 (panel B, column 2, row 1) and $336,400 (panel B, last column, row 1) when Pampa deducts 0% and 100% of the shared depreciation. The difference in the gains for Akron when it is 100% debt-free is $121,900

Table 2. Differences in Expected Values and Standard Deviations of NPV of Expected After-Tax Cash Flows for Different Percentages of Shared Depreciation and Debt-Free Land and Non-Shared Machinery for the Pampa and Akron Combination Assuming Different Percentages of Shared Outflows Paid (in $100,000s)

PANEL A: Pampa 100% Debt-Free / Akron 0% Debt-Free

	Pampa	Akron	Pampa	Akron	Pampa	Akron
% Debt-Free	100%	0%	100%	0%	100%	0%
% Shared Depreciation Claimed by Pampa	0%		50%		100%	
Pampa Pays 100%						
Mean	−1.616	4.920	−1.307	4.524	−1.086	4.080
(Std. Deviation)	(−0.161)	(−0.202)	(−0.034)	(−0.337)	(0.097)	(−0.456)
Pampa Pays 75%						
Mean	−0.130	3.480	0.212	3.099	0.472	2.675
(Std. Deviation)	(−0.232)	(−0.142)	(−0.115)	(−0.283)	(0.017)	(−0.409)
Pampa Pays 50%						
Mean	1.327	2.023	1.697	1.660	1.993	1.252
(Std. Deviation)	(−0.288)	(−0.075)	(−0.182)	(−0.222)	(−0.054)	(−0.356)
Pampa Pays 25%						
Mean	2.759	0.547	3.157	0.204	3.486	−0.186
(Std. Deviation)	(−0.328)	(−0.005)	(−0.234)	(−0.159)	(−0.114)	(−0.299)
Pampa Pays 0%						
Mean	4.175	−0.944	4.601	−1.267	4.959	−1.639
(Std. Deviation)	(−0.356)	(0.064)	(−0.274)	(−0.093)	(−0.164)	(−0.241)

PANEL B: Pampa 0% Debt-Free / Akron 100% Debt-Free

	Pampa	Akron	Pampa	Akron	Pampa	Akron
% Debt-Free	0%	100%	0%	100%	0%	100%
% Shared Depreciation Claimed by Pampa	0%		50%		100%	
Pampa Pays 100%						
Mean	−1.285	4.583	−1.265	3.976	−1.251	3.364
(Std. Deviation)	(−0.046)	(−0.007)	(−0.017)	(−0.030)	(0.004)	(−0.051)
Pampa Pays 75%						
Mean	0.402	3.254	0.426	2.652	0.442	2.044
(Std. Deviation)	(−0.059)	(−0.011)	(−0.027)	(−0.036)	(−0.002)	(−0.058)
Pampa Pays 50%						
Mean	2.087	1.923	2.114	1.327	2.134	0.723
(Std. Deviation)	(−0.074)	(−0.014)	(−0.038)	(−0.041)	(−0.010)	(−0.065)
Pampa Pays 25%						
Mean	3.771	0.591	3.801	0.002	3.825	−0.602
(Std. Deviation)	(−0.091)	(−0.017)	(−0.052)	(−0.047)	(−0.020)	(−0.071)
Pampa Pays 0%						
Mean	5.451	−0.744	5.486	−1.328	5.512	−1.928
(Std. Deviation)	(−0.111)	(−0.018)	(−0.068)	(−0.050)	(−0.033)	(−0.075)

($458,300 − $336,400), which is larger than if Akron is 0% debt-free, $84,000 ($492,00 − $408,000). Differences in changes in E(NPV) for both farms at all percentages of shared outflows are larger when the percentage of debt-free land and nonshared machinery increases. Clearly, there is an interaction between depreciation and the debt-free percentage that impacts E(NPV). Similarly, differences of gains in E(NPV) decrease as the percentage of shared outflows paid increases, whereas the differences in gains increase as the percentage of shared depreciation increases. As indicated by these two inferences, there are tradeoffs between the percentages of shared outflows paid and shared depreciation claimed when considering different levels of debt-free land and nonshared machinery. In contrast to the scenarios in the previous sections, risk is not always reduced for both farms when considering different depreciation sharing amounts. In three cases, Pampa has increased risk from sharing machinery, while risk is reduced in all cases for Akron.

Total yearly shared machinery ownership outflows ($117,067 including principal and interest) are higher than the tax-deductible depreciation ($83,492) from shared machinery. As the percentage of debt-free land and nonshared machinery increases, depreciation may become more valuable because the operation lacks other tax deductions. These dollar amounts suggest the potential tradeoff between ownership outflows and depreciation is such that the percentage of outflows paid must be less than the percentage of depreciation claimed. To illustrate the potential tradeoff, let Akron pay 55% of the shared outflows and deduct 75% of the shared machinery depreciation. In this case, gains from sharing are larger for both farms ($215,093 for Pampa and $138,323 for Akron) than under the situation of equal sharing of outflows and depreciation ($194,111 for Pampa and $137,658 for Akron). Results show that Akron is willing to pay 5% more of the shared costs for an additional 25% of the deduction amount.

Harvesting Windows

Previous results suggest the less overlap in harvesting windows, the more both farms may benefit from machinery sharing, even with higher transportation costs. To isolate harvesting window effects, two farms with identical prices, yields, and costs are simulated at two different levels of harvesting window overlap (complete and little overlap). The Pampa/Pampa combination is examined using complete overlap and little overlap. The little overlap scenario is generated by assigning the Big Sandy farm's harvesting windows to the second Pampa farm. As expected, when there is little overlap in harvesting windows, gains from sharing are larger at all percentages of shared outflows than when harvesting windows highly overlap (table 3). Gains are larger because of a decrease in yield losses from untimely combine delivery. The yield benefits outweigh increases in transportation costs, confirming the previous inference that gains from sharing are larger when harvesting windows have little overlap.

Potential Outcomes

Obvious inferences from the previous discussions and the best options for each farm are to share machinery, bear none of the risk, claim all the depreciation, pay none of the shared outflows, and minimize harvesting window overlap. These inferences indicate there is room for contract negotiation. Unfortunately, given the nature of the problem, changing a contract variable generally hurts one producer and helps the other. As such, no specific optimal outcome can be generated, but insights can be gained.

Table 3. Differences in Expected Values and Standard Deviations of NPV of Expected After-Tax Cash Flows for the Base Penalty Payment for the Pampa/Pampa Combination Assuming Different Percentages of Shared Outflows Paid and Different Harvesting Windows (in $100,000s)

	Harvesting Window Overlap			
	Complete Overlap		Little Overlap	
Description	Pampa	Pampa	Pampa	Pampa
Producer A Pays 100%				
Mean	−1.266	2.993	−1.187	5.037
(Std. Deviation)	(−0.037)	(−0.418)	(−0.036)	(−0.252)
Producer A Pays 75%				
Mean	0.338	1.426	0.419	3.569
(Std. Deviation)	(−0.101)	(−0.356)	(−0.101)	(−0.206)
Producer A Pays 50%				
Mean	1.917	−0.168	2.008	2.079
(Std. Deviation)	(−0.175)	(−0.304)	(−0.177)	(−0.163)
Producer A Pays 25%				
Mean	3.463	−1.779	3.547	0.574
(Std. Deviation)	(−0.255)	(−0.265)	(−0.257)	(−0.126)
Producer A Pays 0%				
Mean	4.972	−3.401	5.058	−0.944
(Std. Deviation)	(−0.329)	(−0.236)	(−0.331)	(−0.095)

Using the Pampa farm as an example, results reported in table 1 indicate the Pampa producer would be better off sharing with either Akron or Big Sandy producers than to share closer to home with another Pampa producer or a Dumas producer. Both the Akron and Big Sandy producers are better off sharing with the Pampa producer than with each other, although the gain for the Akron producer is less than for the Big Sandy producer. Room for negotiation on the percentage of outflow sharing is large, ranging between 25% and 75% for sharing with either Akron or Big Sandy. Common sense and results in table 1, however, suggest the percentage of outflow sharing would end up near 50%. For example, in the case of Pampa/Big Sandy with Pampa paying 75% of the shared outflows, the gain for Pampa is $25,900, whereas Big Sandy gains $312,000. Although both gain, it is highly unlikely Pampa would settle for the 75% outflow sharing percentage when there is full compensation to Big Sandy for yield losses. Similarly, the same argument would hold for Big Sandy paying 75% of the shared outflows.

Two-farm E(NPV) defined as the sum of the gains from sharing for the two farms gives society's outcome (table 1). Two-farm E(NPV) is positive for all percentages of shared outflows and farm combinations regardless of the penalty structure. As the overlap in harvest windows decreases, two-farm E(NPV) increases, with the largest two-farm welfare being associated with the Pampa/Big Sandy combination. Among the penalties examined, the differences in two-farm E(NPV) are small. The range of differences in two-farm E(NPV) is small because producer A is compensating for producer D's yield loss associated with waiting when using a penalty or gaining additional net revenue from completing harvest when there is no penalty. Differences in two-farm E(NPV) are explained by yield losses occurring beyond the contracted delivery date and the inclusion of taxes. The assumed penalty function results in an almost zero sum transfer.

In table 1, a superscript dagger (†) indicates the maximum two-farm E(NPV). Even though these values provide the largest two-farm welfare, individual farms are not always better off from sharing than buying the combines (the Pampa/Pampa combination is the exception, with both farms being better off at the two-farm maximum). Society's optimal differs from what will most likely occur if two producers decide to share. At society's optimal, sharing will generally not occur unless the winner provides additional compensation to the other producer.

Discussion

Inferences from the various scenarios help to explain why machinery sharing is observed and increasing in importance but not widely practiced in today's farming operations. There are increases in E(NPV) and reductions of risk when farmers share machinery. One reason machinery sharing is not widely practiced is because gains from machinery sharing are small in comparison to annual farm revenue. Consider the Pampa/Akron combination in the base penalty case where producer A pays 25% of the shared costs (table 1). In this combination, Pampa gains $350,600 over a five-year period, or approximately $70,000 per year. Akron gains only $3,600, or approximately $700 per year. Either gain is only a fraction of E(NPV) and the farm's net worth. A second reason for the limited practice of machinery sharing may be attributed to additional transaction costs, such as finding a farmer to share machinery, resolving trust issues, and determining actual contractual parameters. Such market and non-market psychological transaction costs are not modeled.

Taking all the results together, there is room for negotiation when determining the machinery size, percentage of shared outflows paid, penalty structures associated with untimely machinery delivery, with whom to share (harvest window overlap), and depreciation claimed by each farm. A potential reasonable arrangement to reduce transaction costs and facilitate machinery sharing is for two identical size farms to equally share outflows associated with machinery sharing. The "best" contractual arrangement for any two given farms may not occur where the outflows are shared equally. This becomes very apparent in the Pampa/Pampa farm combination where harvesting completely overlaps. For sharing to occur, producer A must pay a larger portion of the costs to compensate producer D for any harvest delays.

An inference from the results is that in situations which include the sharing of resources, the "best" arrangement will be influenced by the organization of the businesses. Of particular importance are potential tax consequences. For example, as noted by a reviewer, one of the principles commonly used in share-renting farmland is that total returns should be shared in the same proportion as resources contributed. Further work is warranted to determine if the principle is appropriate when considering tax implications involved in the sharing of depreciable assets. The implications of taxes on contractual issues represent an area of fruitful future investigation.

As expected, when a farm deducts a larger percentage of depreciation, ceteris paribus, machinery sharing becomes more profitable because less federal income taxes are paid. Depreciation becomes more valuable when a farm has smaller tax deductions. Farms with larger taxable incomes may benefit more than farms with lower taxable incomes from using a larger percentage of tax-deductible depreciation. Alternatively, when the debt-free percentage is small, there are larger tax deductions associated with interest expenses. When large tax deductions are available, depreciation may not always be used even when considering carry-over losses. For farm managers considering machinery sharing, the percentages of debt-free land and nonshared machinery, shared outflows, depreciation, and tax consequences are important factors to consider when negotiating machinery-sharing contracts.

The penalty structures examined here shift the risk of delaying harvest between farms. As expected, each farm prefers to shift the risk to the other farm. Accordingly, harvesting windows and specified penalty contractual arrangements will help determine if machinery sharing is a viable management tool. Options available to minimize harvesting time conflicts are: (*a*) enter into contracts with geographically separate producers (consider variables such as climate and elevation, along with actual distance) to minimize harvesting overlap; (*b*) increase machinery size (efficiency); and (*c*) consider sharing with a producer who grows a different crop. There appears to be more room for negotiation when harvesting windows only partially overlap. Reduced overall costs and increased efficiency by sharing larger machinery, which effectively reduce producers' expected harvesting windows, are shown to increase E(NPV).

Several other issues may make machinery sharing more feasible. Sensitivity analysis not reported here suggests that as production costs increase, machinery sharing may be more valuable to both producers. Only one depreciation schedule was examined in this study. Different schedules will impact the timing of cash flows and thus the feasibility of machinery sharing. One example may be fully depreciating the machinery to a zero salvage value and including depreciation recapture in the last year.

Thinking beyond this study, several inferences on potential effects of machinery sharing can be made and other future research suggested. Because the percentages of debt-free land and nonshared machinery, in combination with depreciation percentage claimed, have important tax implications, other forms of financial structure may change the inferences. The full-information penalty function is highly information dependent, relying on information on yield loss and prices received for both producers. Further, it was assumed both producers performed necessary maintenance. A more likely scenario is that of asymmetric information where the actions of one producer affect the other. A moral hazard problem, for example, may arise when one producer agrees to perform maintenance on the machinery as stated in the contract, but only performs the maintenance shortly before delivery rather than according to manufacturers' recommendations. This and other asymmetric information issues should be studied in the machinery-sharing context. There is also a need to consider machinery sharing between producers who grow different crops. The type or form of machinery that can be shared may differ. Corn and wheat producers, for example, may share a combine, but each would have to buy the header particular to their crop.

Manufacturers and dealers may also need to adjust their product mix. If, by sharing machines, producers buy larger machines than they would without sharing, manufacturers and dealers may need to shift their product mix toward larger, more efficient machines to accommodate any increase in demand. Further, the equipment sector may want to offer specialized services as a strategy to profit from this emerging trend. Studies examining the potential impact of machinery sharing on equipment manufacturers and dealers, as well as the effects of increased competition on custom operators, are warranted.

[*Received December 2009; final revision received January 2011.*]

References

Abdulsalam, F., W. Pittroff, and P. F. Dahm. "Testing for Calibration Accuracy, Measuring Device Equivalency, or Simulation Model Validity in the Presence of Measurement Error." Work. pap., Dept. of Quant. Methods and Information Systems, Kuwait University, Kuwait, 2008.

Ali, M. B. "Characteristics and Production Costs of U.S. Wheat Farms." Statis. Bull. No. 974-5, USDA, Washington, DC, 2002. Online. Available at http://ers.usda.gov/publications/sb974-5/sb974-5.pdf. [Accessed November 2009.]

American Society of Agricultural and Biological Engineers. "Agricultural Machinery Management." ASAE Pap. No. EP496.3 FEB2006, pp. 385–390. St. Joseph, MO: ASABE, 2006a.

———. "Agricultural Machinery Management Data." ASAE Pap. No. D497.5 FEB2006, pp. 391–398. St. Joseph, MO: ASABE, 2006b.

Artz, G., G. Colson, and R. Ginder. "A Return of the Threshing Ring? A Case Study of Machinery and Labor-Sharing in Midwestern Farms." *J. Agr. and Appl. Econ.* 42,4(2010):805–819.

Barry, P. J., and L. J. Robison. "Agricultural Finance: Credit, Credit Constraints, and Consequences." In *Handbook of Agricultural Economics*, Vol. 1A, eds., B. L. Gardner and G. C. Rausser, pp. 513–571. Amsterdam: Elsevier, 2001.

Bolland, M. D. A. "Grain Losses Due to Delayed Harvesting of Barley and Wheat." *Austral. J. Experimental Agr. and Animal Husbandry* 24,126(1984):391–395.

Caterpillar Financial Services. "Caterpillar Financial Services: Home." 2007. Online. Available at http://finance.cat.com/cda/layout?M=103161&x=7. [Accessed April 2007.]

Colorado State University, Cooperative Extension. "2006 Estimated Production Costs and Returns—Dryland Winter Wheat in Northeastern Colorado Conventional-Till Wheat-Fallow Rotation." 2006. Online. Available at http://www.coopext.colostate.edu/ABM/nedrywht06.pdf. [Accessed October 2007.]

de Toro, A., and P. A. Hansson. "Machinery Co-operatives: A Case Study in Sweden." *Biosystems Engineering* 87,1(2004):13–25.

Dillon, C. R., J. W. Mjelde, and B. A. McCarl. "Biophysical Simulation in Support of Crop Production Decisions: A Case Study in the Blacklands Region of Texas." *S. J. Agr. Econ.* 21,1(1989):73–86.

Dyer, J. A., and W. Baier. "Weather-Based Estimation of Field Workdays in Fall." *Can. Agr. Engineering* 21,2(1979):119–122.

Food and Agricultural Policy Research Institute. "Representative Farms Economic Outlook for December 2006 FAPRI/AFPC Baseline." Agricultural and Food Policy Center, Texas A&M University System, 2006. Online Available at http://www.afpc.tamu.edu/pubs/0/459/WP%2006-4%20to%20WEB.pdf. [Accessed May 2008.]

———."Representative Farms Economic Outlook for January 2006 FAPRI/AFPC Baseline." Agricultural and Food Policy Center, Texas A&M University System, 2008. Online. Available at http://www.afpc.tamu.edu/pubs/0/511/Jan%20Baseline%20to%20Web.pdf. [Accessed May 2008.]

Foreman, L. "Characteristics and Production Costs of U.S. Corn Farms 2001." Econ. Info. Bull. No. 7. USDA/ERS, Washington, DC, 2006. Online. Available at http://ageconsearch.umn.edu/bitstream/7205/2/ei060007.pdf. [Accessed November 2009.]

Hoogenboom, G., J. W. Jones, P. W. Wilkens, C. H. Porter, W. D. Batchelor, L. A. Hunt, K. J. Boote, U. Singh, O. Uryasev, W. T. Bowen, A. J. Gijsman, A. du Toit, J. W. White, and G. Y. Tsuji. "DSSATv4, Decision Support System for Agrotechnology Transfer," Version 4.0. University of Hawaii, Honolulu, 2004. Online. Available at http://www.icasa.net/dssat/. [Accessed March 2008.]

MH Equipment Co. "MH Equipment Company: The Fastest Growing Material Handling Company in America." St. Louis, MO, 2007. Online. Available at http://www.mhequipment.com/. [Accessed April 2007.]

Monson, J. P., V. O. Sadras, P. A. Abbate, and O. P. Caviglia. "Modeling Management Strategies for Wheat-Soybean Double Crops in the South-Eastern Pampas." *Field Crops Res.* 101,1(2007):44–52.

Musabelliu, B., and D. Skreli. "An Associative and Cooperative Alternative for Agriculture." *Options Mediterraneennes*. Serie B, Etudes et Recherches, 1997. [English translation of abstract available from Texas A&M University Library.]

Olszweski, T. "Possibilities of Reducing Mechanization Costs on Agricultural Holdings." *Zemes Ukio Inzinerija, Mokslo Darbai* 29,1(1997):123–130. [English translation of abstract available from Texas A&M University Library.]

Outlaw, J. L., J. W. Richardson, G. M. Knapek, J. M. Raulston, B. K. Herbst, R. J. Fumasi, D. P. Anderson, S. L. Klose, and P. Zimmel. "Representative Farms Economic Outlook for the January 2007 FAPRI/AFPC Baseline WP-2007-1." Agricultural and Food Policy Center, Texas A&M University, 2007. Online. Available at http://www.afpc.tamu.edu/pubs/0/466/WP%2007-1%20-%20for%20web.pdf. [Accessed June 2007.]

RIA Federal Tax Handbook. New York: Thomson/Reuters, 2008.

Richardson, J. W., K. D. Schumann, and P. A. Feldman. "Risk Analysis Management Modeling." Simetar©, Version 2006, Dept. of Agr. Econ., Texas A&M University, 2006.

Rotz, C. A., and T. M. Harrigan. "Predicting Suitable Days for Field Machinery Operations in a Whole-Farm Simulation." *Appl. Engineering in Agr.* 21,4(2005):563–571.

Rounsevell, M. D. A. "A Review of Soil Workability Models and Their Limitations in Temperate Regions." *Soil Use and Mgmt*. 1,9(1993):15–20.

Schwalbe, R. K. "Machinery Link—Reshaping the Farm Equipment Landscape." *AgriMarketing* 44,3(2006): 72–75.

Smathers, R., P. E. Patterson, and B. Shroeder. "Machine Cost Analysis (MachCost)," Version 1.3. Dept. of Agr. Econ. and Rural Sociol., University of Idaho, 2002. Online. Available at http://ww.ag.uidaho.edu/aers/r_software.htm. [Accessed February 2008.]

Stewart, D. Manager of Agricultural National Sales for John Deere Co., Moline, IL. Personal communication with authors, 13 May 2008.

Texas AgriLife Extension. "2007 Texas Crop and Livestock Budgets." Dept. of Agr. Econ., Texas A&M University, 2007. Online. Available at http://agecoext.tamu.edu/fileadmin/user_ upload/Documents/Budgets/District/1and2/2007/rwfwmtw.pdf. [Accessed October 2007.]

University of Idaho. "2003 Southeastern Idaho Crop Costs and Returns Estimate, Hard White Spring Wheat: High Rainfall Dryland." Pub. No. ID EBB4-HWSD2-03, 2003. Online. Available at http://www.ag uidaho.edu/aers/crop_EB_03.htm. [Accessed June 2007.]

U.S. Department of Agriculture, National Agricultural Statistics Service. "Quick Stats—Texas Data—Crops." USDA/NASS, 2007. Online. Available at http://www.nass.usda.gov/QuickStats/CreateFederalAll.jsp. [Accessed December 2007.]

———. "Agricultural Prices." USDA/NASS, April 2008. Online. Available at http://usda.mannlib.cornell.edu/usda/ current/AgriPric/AgriPric-04-30-2008.pdf. [Accessed May 2008.]

U.S. Department of Commerce, National Climatic Data Center. Daily weather data, 2008. Online. Available at http://www.ncdc.noaa.gov/oa/ncdc.html. [Accessed January 2008.]

Weather Underground. Daily weather data, 2008. Online. Available at http://www.wunderground.com/. [Accessed September 2007.]

Werschnitzky, U. "Inter-Farm Co-operation: Results of Investigations-Synopses." Landwirtschaft-angewandte Wissenschaft. Bonn, German Federation ref. Secondary Journal Source: *Informationsdienstartei* (AGLBO), 1972. [English translation of abstract available from Texas A&M University Library.]

Whitson, R. E., R. D. Kay, W. A. Le Pori, and M. E. Rister. "Machinery and Crop Selection with Weather Risk." *Transactions Amer. Society Agr. Engineering* 24,2(1981):288–295.

Wolfley, J. L. "Machinery Sharing by Agribusiness Firms: Methodology, Application, and Simulation." Unpub. Ph.D. diss., Dept. of Agr. Econ., Texas A&M University, 2008.