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Advanced breakeven analysis of agricultural enterprise budgets

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ABSTRACT

Advanced conceptual techniques for breakeven analysis of agricultural enterprise budgets are developed and applied. Breakeven points of a single agricultural enterprise, breakeven points between enterprises, and elasticities of breakeven points between enterprises are defined and mathematically derived. Breakeven equations were reduced to computational formulas for several budget components: output price, yield, input price, input requirement, variable cost, fixed cost, and total cost. Application of the advanced breakeven techniques provide evidence that both rice and wheat production seem especially desirable for the Arkansas Delta region in light of a fluctuating economic environment.

INTRODUCTION

Breakeven analysis for agricultural decision-making has been proposed and discussed (Kay, 1986; Schmisseur and Landis, 1985; Forster and Erven, 1981; Herbst, 1976; Barnard and Nix, 1979; Giles and Stansfield, 1980). Enterprise budgeting enables farm managers to conduct breakeven analysis, estimate production costs, and select between competing production alternatives. The more common breakeven yield and price relationships

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have been expanded to include acreage or usage levels for machinery management (Herbst, 1976; Forster and Erven, 1981; Barnard and Nix, 1979), returns above purchase and feed costs for livestock management (Herbst, 1976), breakeven output price and yield analysis between agricultural enterprises (Casey, 1977; Herbst, 1976) and breakeven output price elasticities between agricultural enterprises (Dillon and Casey, 1990). While these serve as worthwhile decision-making tools, development of advanced breakeven analytical procedures has been suggested (Giles and Stansfield, 1980; Forster and Erven, 1981). Even with recent computerization (e.g. Levins and Rego, 1990) and linkages to economic theory (Bradford and Debertin, 1985), methodological development in breakeven analysis seems lacking.

While farmers are concerned with profits, decision-making includes considerations of risk, farm survival, and attaining certain output levels. Sensitivity analysis of profits should be considered as important as estimating profits. Relative profitability between competing enterprises under a dynamic environment becomes an important concern beyond the scope of profit per acre and the minimal breakeven yield and output price.

The objective of this study is to develop advanced breakeven techniques within and between agricultural enterprises. The need for such advancement in analytical breakeven methodology is evidenced by a request for such research (Giles and Stansfield, 1980; Kay, 1986; Dillon and Casey, 1990; Forester and Erven, 1981) in light of an intricate decision-making environment filled with interactions and complexities. Consequently, a plethora of breakeven factors remain to be developed. Input price, input requirement, variable cost, fixed costs, and total cost breakeven analysis of a single enterprise as well as between competing enterprises is not addressed in the literature. The ability of breakeven elasticities to expand beyond static analysis into dynamic sensitivity analysis more reflective of the agricultural producer's environment has only been developed for output price relationships (Dillon and Casey, 1990). In addition to providing a source summarizing the breakeven output price (single enterprise, enterprise, elasticities) and yields (single enterprise, between enterprise), this paper will develop the above mentioned breakeven relationships, to extend the currently available breakeven techniques to include the remaining budge components.

An empirical application of the analytical procedures is conducted on four major crops in the Arkansas Delta: rice, irrigated soybeans, dryland soybeans, and dryland wheat. The analysis is based upon a point on a production function as representative of an enterprise budget, permitting breakeven point calculation as opposed to a multidimensional function. Such an approach has appeal as a farm management planning device.

METHODOLOGICAL DEVELOPMENT OF THE BREAKEVEN ANALYSIS EQUATIONS

Methodological development is conducted in three areas: breakeven points for a single enterprise, breakeven points between enterprises, and the elasticity of breakeven points between enterprises. Examples of potential use are given when applicable.

Breakeven points for a single agricultural enterprise

There are several determining factors of single enterprise profitability. Breakeven equations can be derived for all conceivable budget components: output price, output yield, input price, input requirements, variable cost, fixed cost, and total cost (Table 1). These breakeven points are

TABLE 1

Breakeven analysis equations for a single enterprise

Single enterprise breakeven point for [a]	Equation
Output price	$P = \dfrac{\text{VC}_i + \text{FC}_i + \pi_i}{Y_i}$
Yield	$Y = \dfrac{\text{VC}_i + \text{FC}_i + \pi_i}{P_i}$
Variable cost	$\text{VC} = P_i Y_i - \text{FC}_i - \pi_i$
Fixed cost	$\text{FC} = P_i Y_i - \text{VC}_i - \pi_i$
Total cost	$\text{TC} = P_i Y_i - \pi_i$
Input price	$R = \dfrac{P_i Y_i - \text{VC}'_i - \text{FC}_i - \pi_i}{X_i}$
Input requirement	$X = \dfrac{P_i Y_i - \text{VC}'_i - \text{FC}_i - \pi_i}{R_i}$

where P_i output price of commodity i, Y_i yield of output i, R_i input price for input X for the production of commodity i, X_i the level of input X required for the production of commodity i, VC_i variable costs for production of commodity i, FC_i fixed costs for production of commodity i, VC'_i variable costs for production of commodity i exclusive of costs for input X, and $\text{TC} = \text{VC}_i + \text{FC}\ i$.

[a] Breakeven equations are calculated by arithmetic manipulation of the profit equation $P_i Y_i - \text{VC}_i - \text{FC}_i = \pi_i$, and solving for the item of interest. Analysis for net returns above variable costs involves setting fixed costs to zero. Breakeven considerations to just cover costs can be investigated by setting profits (π_i) to zero; alternatively, breakeven analysis of obtaining specified profit levels can be conducted.

derived by solving a single enterprise profit equation for the desired component. These breakeven concepts can include analysis for net returns above total or variable costs equivalent to either zero or a non-zero amount. Sensitivity analysis of profits for a single agricultural enterprise can therefore be conducted with respect to any element of the enterprise budget: minimum levels of output price or yield as well as maximum levels of variable costs, fixed costs, total costs, input price, or input utilization.

Breakeven output price can be used as a simple risk management tool to evaluate the impacts of marketing decisions under price variability. Maximum potential yield losses due to detrimental weather can be investigated with breakeven yield analysis. Breakeven analysis is also useful from the input side. In light of growing concerns regarding petroleum prices, the utilization of breakeven input (diesel) price analysis can be conducted. Input requirement breakeven analysis can be used to study the economic impacts of the need for additional irrigation during an unseasonable draught to avoid yield loss. Also, the importance of accurate data can be investigated. For instance, if profits are stable relative to alterations in urea requirements, little concern would arise if urea usage was somewhat underestimated. Breakeven variable cost analysis can provide insight into relative efficiencies of resource allocation. The importance of overhead cost allocation to an enterprise can be evaluated through the breakeven fixed cost technique. While certain input prices may rise, input substitution can alleviate rising costs of production to some degree embodied in breakeven total cost analysis.

Breakeven points between agricultural enterprises

While the above concepts allow detailed evaluation for a given enterprise, decisionmaking needs span across enterprises. Study of interactive effects of changes on relative profitability between production alternatives is possible with breakeven analysis between agricultural enterprises since most enterprise budgets are non-joint in inputs. The production technology exhibits interdependencies only in the sense of competing for scarce resource endowments (Chambers, 1988).

Between enterprise breakeven analysis simply involves equating two separate agricultural enterprise budget net return functions and solving for the item of interest. The breakeven price for output '*i*' between enterprise '*i*' and enterprise '*j*' would thereby be the necessary price of output '*i*' which would achieve a net return for enterprise '*i*' equivalent to the net return for enterprise 'j'. Consequently, a common input price breakeven point is:

$$P_iY_i - \text{VC}_i' - R_iX_i - \text{FC}_i = P_jY_j - \text{VC}_j' - R_jX_j - \text{FC}_j$$

$$P_iY_i - \text{VC}_i' - R_iX_i - \text{FC}_i = \text{NR}_j' - R_jX_j$$

$$P_iY_i - \text{VC}_i' - \text{FC}_i - \text{NR}_j' = R_i(X_i - X_j) \qquad \text{since} \quad R_i = R_j$$

$$\frac{P_iY_i - \text{VC}_i' \ \text{FC}_i - \text{NR}_j'}{X_i - X_j} = R_i$$

Similar results can be derived for items such as those conducted for single enterprise breakeven analysis (Appendix, Table A1). However, input analysis between agricultural enterprises differs from single enterprises input analysis. Common input price's effects on the net returns of both enterprises complicates calculations somewhat.

The minimum output price or yield required for a given commodity to be competitive with an alternative enterprise can be calculated (e.g. the required soybean yield or price necessary for dryland soybean production to possess net returns equivalent to irrigated soybean production). The responsiveness of relative profitability under technological change can be analyzed (via breakeven input requirements) as well as the relative competitiveness under fluctuating input prices. The margin of error for inefficiencies or data estimation can be investigated by breakeven variable cost, breakeven fixed cost, and breakeven total cost between enterprises.

Comparable net returns for breakeven analysis between enterprises should be used: both using above total or variable costs levels. Limitations of these techniques include exclusion of government program considerations and incomplete modeling of substitution effects. Nonetheless, breakeven variable and total cost can indirectly account for some substitution effect unlike breakeven input prices or input requirements.

ELASTICITY OF BREAKEVEN POINTS BETWEEN AGRICULTURAL ENTERPRISES

Elasticities for all breakeven points between enterprises can be derived (Appendix, Table A2). While breakeven elasticity between output price 'i' to output price 'j' has been proposed for studying relative marketing risk between enterprises (Dillon and Casey, 1990), the usefulness for the various breakeven elasticities likewise transcend to studying responsiveness of relative profitability between enterprises in a dynamic, multi-factor decision-making environment. Each of these breakeven elasticity concepts can be interpreted as the necessary percentage change in the first component for enterprise 'i' that must accompany a 1% change in the second component given for enterprise 'j' to maintain equivalent net returns between the two production alternatives. For instance, the breakeven elasticity of soybean price to wheat price is the percentage change in the soybean price that must accompany a 1% change in wheat price to retain relative profitability. This thereby allows dynamic sensitivity analysis for comparisons between enterprises under which two components of the economic decision-making environment are concurrently changing. As opposed to traditional static analysis, cross-effects can be considered moving towards a general rather than partial equilibrium framework. Results are obtained by calculation of the relevant derivative and subsequent multiplication by the appropriate ratio. Derivatives are based upon the breakeven point equation between agricultural enterprises for the budget components in question. For example, breakeven elasticity of price i to yield j is:

$$\frac{\partial\left(\mathrm{VC}_i + \mathrm{FC}_i + P_j Y_j - \mathrm{VC}_j - \mathrm{FC}_j\right) Y_i^{-1}}{\partial P_j} \frac{P_j}{P_i} = \frac{Y_j}{Y_i} \frac{P_j}{P_i}$$

Several patterns between the various breakeven elasticity equations can be seen. The breakeven elasticity equations for output price to alternative factors is computationally identical to its counterpart breakeven elasticity of yield to the same factor which is therefore excluded in Table A2 in the interest of brevity.

The breakeven equations between variable cost, fixed cost, and total cost for the first enterprise to factors of the second enterprise are identical. The breakeven elasticity for cross effects of cost components is given by the inverse ratio of the cost components. For example, the breakeven elasticity of variable cost 'i' to total cost 'j' is given by the ratio of total cost 'j' to variable cost 'i'.

Similar results are found for breakeven elasticities of input prices or input requirements. A notable difference is the inclusion of the expenditures (e.g., $R_j X_j$, or input price multiplied by input usage) for the input under consideration for cross-effects involving an uncommon input price, a common input requirement, or an uncommon input requirement. However, the calculation of equations involving a common input price gives rise to the inclusion of a component which considers the difference of input expenditures between the two agricultural enterprises (e.g., $R_j X_i - R_j X_j$ or the input price multiplied by the difference in input usage levels). An input requirement alteration in one enterprise does not affect the budget for a different enterprise, even if a common input; the computational formulas for input requirements and uncommon input prices are therefore identical.

Similarities can be noted for common groupings of breakeven elasticity equations. For instance, all breakeven elasticity equations for output price or yield to some factor possess the inclusion of the gross returns for the first enterprise in the denominator of the computational formula. Similarities also can be noted for the elasticities to the second budget component being considered (e.g. the elasticity of a given factor to the second enterprise's variable cost includes the variable cost of the second enterprise as a numerator).

Some notable exceptions to straightforward calculations of breakeven elasticities occur when considering common input components. The breakeven elasticity of a common input price to the second enterprise's input requirement associated with that price demonstrates an especially involved term with a quadratic effect and the difference of net returns exclusive of the costs of that input. However, the breakeven elasticity of a common input requirement to that input price for the second enterprise is simply the difference in net returns divided by the costs associated with the input for the first enterprise.

RESULTS AND ANALYSIS OF AN EMPIRICAL APPLICATION

With the advanced breakeven equations now developed, attention can be focused upon empirical application to the four major crops of the Arkansas Delta based upon enterprise budget estimates from the University of Arkansas Cooperative Extension Service (Table 2). Net returns specified in Table 2 do not include charges for land, operator labor, crop insurance, real estate taxes, management, and risk bearing. Results and analysis are presented for each of the categories developed: breakeven points for single enterprises, breakeven points between enterprises, and breakeven elasticities between enterprises. Results focus upon calculations for output price, yield, variable cost, fixed cost, total cost, petroleum price, and urea requirements for net returns above total cost.

In light of growing concerns, the impact of petroleum price variations is computed but is difficult to investigate because a composite number is given for fuel, oil, and lubricants in agricultural operations. Requirements and prices for these individual factors of production are not disaggregated within budget data. Analysis of petroleum based factors of production is therefore conducted on a cost-wise basis. Thus, the price of petroleum is standardized at $1.00 per unit, where a unit of petroleum is some combination of fuel, oil, and lubricants. The petroleum cost given for the four enterprises thereby represents the input requirements for each crop. This procedure illustrates the adaptability of the advanced breakeven concepts to unique research situations.

TABLE 2

Summary 1989 statistics and 1990 estimated budget components for Arkansas rice, irrigated soybeans, dryland soybeans, and wheat

	Rice	Irrigated soybean	Dryland soybean	Wheat
Harvested ha (1000's)	2816	2818	5086	2964
Yield/ha (kg)	2652	1950	1479	2958
Value of productiion ($1000's)	453264	190031	259249	195360
Output price ($/kg)	0.1749	0.2113	0.2113	0.1396
Yield (kg/ha)	5848.41	2688.92	1680.58	3025.04
Variable costs ($ha)	625.28	303.98	223.88	168.38
Fixed costs ($/ha)	178.41	168.73	104.56	69.63
Total costs ($/ha)	803.69	472.71	328.44	238.01
Net returns above variable cost [a] ($/ha)	397.60	264.12	131.18	253.99
Net returns above total cost [a] ($/ha)	219.19	95.39	26.63	184.36
Petroleum costs ($/ha)	70.37	47.75	23.44	12.45
Urea requirement (kg)	268.89	NA	NA	224.08
Urea price ($/kg)	0.1543	NA	NA	0.1543
Urea costs ($/ha)	41.50	NA	NA	34.58

Source: Arkansas Agricultural Statistical Service and Cooperative Extension Service.

[a] Net returns above variable costs and above total costs do not reflect charges for land, operator labor, crop insurance, real estate taxes, or management.

Breakeven estimates are displayed in Table 3. Given each crop's positive net returns, each breakeven budget component considered can move in an unfavorable direction (e.g., lower output prices or higher input prices) and still allow for a non-negative net returns above total costs. The percentage allowable deviations in the budgeted items are also given. For instance, the output price for rice can drop by about 21% from the budgeted estimate of $0.1749 to the level of $0.1374 and still retain non-negative net returns above total cost. Analyses indicate that wheat would perform relatively more favorable in a risky, highly variable environment. While the net returns above total cost demonstrate that wheat is a less profitable crop than rice, it displays a greater ability to withstand relative fluctuations in four of the factors considered. Rice was more favorable than both irrigated and dryland soybeans. In turn, irrigated soybean performs more favorably than dryland soybeans.

Wheat production is the best suited for withstanding increases in petroleum prices but all crops can withstand an increase of more than 100% before net returns above total cost are negative. Rice production can absorb a greater absolute urea requirement before suffering a negative net

TABLE 3

Single enterprise breakeven analysis results

Breakeven point for	Rice	Irrigated soybean	Dryland soybean	Wheat
Output price ($/kg)	0.1374	0.1758	0.1954	0.0787
	(−21.43)	(−16.79)	(−7.50)	(−43.65)
Yield (kg/ha)	4595.18	2237.42	1554.55	1704.64
	(−21.43)	(−16.79)	(−7.50)	(−43.65)
Variable costs ($/ha)	844.47	399.37	250.51	352.74
	(35.05)	(31.38)	(11.89)	(109.49)
Fixed costs ($/ha)	397.60	264.12	131.18	253.99
	(122.86)	(56.54)	(25.47)	(264.77)
Total costs ($/ha)	1022.88	(568.10)	(355.06)	422.37
	(27.27)	(20.18)	(8.11)	(77.46)
Petroleum price ($/unit)	4.11	3.00	2.14	15.81
	(311.48)	(199.79)	(113.59)	(1480.95)
Urea requirement (kg/ha)	1689.22	NA	NA	1418.73
	(528.21)	NA	NA	(533.14)

Numbers in parentheses give the percentage change from the level budgeted for the factor above it (e.g., breakeven rice price is 21.43% below the budget price estimate of $0.1749 per kg).

return above total cost than can wheat production. As a nitrogen fixing crop, soybeans do not require urea and therefore calculation of breakeven points for urea requirements are not applicable to soybean production. While these results provide indications of profitability and riskiness, other factors need to be reflected for decision-making purposes (e.g. whole farm profits, crop rotation patterns, cash flow, and government program restrictions).

Breakeven points for comparisons between agricultural enterprises are provided in Table 4. Again the crops display flexibility to alterations in the economic environment. However, breakeven fixed costs for dryland soybeans are actually negative for comparisons to rice and wheat production, highlighting that net returns for rice and wheat are greater than those for dryland soybeans by an amount more than fixed costs for dryland soybeans. The dryland soybean farmer would have to be paid the breakeven amount ($88 for rice and $53 for wheat) and have no fixed costs ($105) to possess equivalent net returns to these other enterprises. Negative breakeven petroleum prices also indicate a necessity of a payment for the utilization of an input in order to obtain equivalent net returns between enterprises,

TABLE 4

Cross enterprise breakeven analysis results

Cross breakeven point for	Output price ($/kg)	Yield (kg/ha)	Variable costs ($/ha)	Fixed costs ($/ha)	Total costs ($/ha)	Petroleum price ($/unit)	Urea requirement (kg/ha)
Rice to							
SOY-IRR	0.1537	5140.59	749.08	302.20	927.49	6.47	1071.09
SOY-DRY	0.1420	4747.42	817.84	370.97	996.25	5.10	1516.68
wheat	0.1689	5649.28	660.11	213.24	838.52	1.60	718.65
Irrigated soybeans to							
rice	0.2573	3274.87	180.19	44.93	348.91	6.47	NA
SOY-DRY	0.1857	2363.45	372.75	237.49	541.47	3.83	NA
wheat	0.2444	3110.03	215.01	79.76	383.74	−1.52	NA
Dryland soybeans to							
rice	0.3259	2592.01	31.32	−88.01	135.87	5.10	NA
SOY-IRR	0.2522	2006.05	155.12	35.79	259.67	3.83	NA
wheat	0.3051	2427.16	66.15	−53.18	170.70	−13.35	NA
Wheat to							
rice	0.1511	3274.47	133.55	34.80	203.18	1.60	267.29
SOY-IRR	0.1102	2387.83	257.35	158.60	326.98	−1.52	800.59
SOY-DRY	0.0875	1895.34	326.11	227.36	395.74	−13.35	1246.19

SOY-IRR refers to irrigated soybeans and SOY-DRY refers to dryland soybeans.

reflecting lower petroleum usage and greater net returns above total costs of wheat relative to soybeans.

Cross-breakeven point analysis for rice to other crops indicates its relative economic desirability more so to soybeans than wheat. In all cases, output price and yield could decrease from the current budgeted levels or a considerable absolute increase in cost can be sustained by rice and maintain an equivalent net returns above total costs. Additionally, petroleum price or urea requirements can increase quite significantly in relation to the other crops and still allow rice production to be conducted profitably.

Breakeven analysis for soybeans generally indicates more flexibility for irrigated soybeans relative to rice and wheat than for dryland production to rice and wheat. All crops did possess some degree of allowable alterations in various budget components in the single enterprise analysis (Table 3); however, this is not the case for the relative comparisons between agricultural enterprises. Wheat generally performs well relative to soybean production and is extremely attractive regarding petroleum price analysis in reference to all crops considered although rice still possesses greater profits until petroleum products rise in price by more than 60%.

The cross enterprise breakeven elasticity results are presented in Table 5. Given the favorable performance of rice and wheat in the above

TABLE 5

Cross enterprise breakeven elasticity analysis results

Breakeven elasticity for — Factor *i* to Factor *j*	Rice *i*			Wheat *i*		
	Irrigated soybean *j*	Dryland soybean *j*	Wheat *j*	Rice *j*	Irrigated soybean *j*	Dryland soybean *j*
Output price to:						
output price	0.5554	0.3471	0.4129	2.4218	1.3450	0.8406
total costs	−0.4621	−0.3211	−0.2327	−1.9028	−1.1192	−0.7776
petroleum price	0.0221	0.0459	0.0566	−0.1371	−0.0836	−0.0260
urea requirement	NA	NA	−0.0338	−0.0982	NA	NA
Total costs to:						
output price	−0.7069	−0.4418	−0.5255	−4.2976	−2.3869	−1.4918
total costs	0.5882	0.4087	0.2961	3.3767	1.9861	1.3799
petroleum price	−0.0282	−0.0584	−0.0721	0.2434	0.1483	0.0462
urea requirement	NA	NA	0.0430	0.1743	NA	NA
Petroleum price to:						
output price	−25.1092	−7.5658	−7.2921	17.6597	16.0952	32.3034
total costs [a]	18.7828	6.4989	3.8942	−12.6606	−12.0399	−27.7483
petroleum price	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
urea requirement	NA	NA	0.5970	−0.7164	NA	NA
Urea requirement to:						
output price	−13.6905	−8.5565	−10.1786	−29.5800	−16.4286	−10.2679
total costs	11.3917	7.9149	5.7357	23.2414	13.6700	9.4979
petroleum price	−0.5452	−1.1310	−1.3958	1.6750	1.0207	0.3179
urea requirement	NA	NA	0.8333	1.2000	NA	NA

Output price is in \$ per kg, total costs are in \$ per ha, petroleum price is in \$ per unit, and urea requirement is in kg/ha. Elasticities are in percentage change in factor *i* to a 1% change in factor *j* for enterprise *i* and *j* to maintain current net returns.

[a] Exclusive of petroleum costs.

analyses, breakeven elasticity results focus on these two alternatives in reference to the others. To avoid excessive presentation of information, breakeven elasticities are calculated for cross effects of four factors: output price, total cost, petroleum price, and urea requirements.

The results for output price elasticities to output price indicate the desirability of the production of rice under an increasing price market. Since all output price comparisons for rice are inelastic, as prices for other commodities increase by 1% the price of rice can increase by less than 1% in order to maintain relative profitability. Wheat prices perform less favorably to rice and irrigated soybeans in light of an increasing price market but favorably to dryland soybeans. Rice performs relatively more favorably than wheat with regard to fluctuations in output price and total cost. However, wheat production is relatively more desirable regarding alterations in petroleum prices and urea requirements. Irrigated soybeans performs relatively well in comparison to dryland soybeans and wheat under rice production analysis.

SUMMARY AND CONCLUSIONS

Development of advanced breakeven analysis techniques is conducted, extending current literature. The advanced breakeven analytical equations include (1) output price, (2) yield, (3) common and uncommon input price, (4) common and uncommon input requirement, (5) variable costs, (6) fixed costs, and (7) total costs for breakeven levels for a single enterprise, breakeven levels between enterprises, and breakeven elasticities between enterprises. The advanced techniques developed demonstrate adaptability and potential usefulness. Empirical application of the new techniques demonstrate rice and wheat production as especially desirable for the Arkansas Delta region in terms of overall profitability in light of a fluctuating economic environment. Rice is able to withstand a significant rise in costs or urea requirements. Wheat is extremely tolerant to fluctuations in the price of petroleum. However, factors such as government programs, crop rotations, cash flow, and alternative goals and objectives of the farm manager should be duly considered. All four crops analyzed (rice, irrigated soybeans, dryland soybeans, and wheat) showed an ability to withstand some degree of fluctuation while maintaining non-negative returns above total costs.

Future research should include the derivation of breakeven concepts analyzing the cross effects of intermediate inputs, fixed inputs, and multiple outputs. Further expansions of research could focus on double crop alternatives as well as output loss (e.g. calving percentage, death loss, and heifer replacement rates).

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APPENDIX: Table A1

Breakeven point analysis among enterprises

Between enterprise breakeven point for [a]	Equation
Output price	$P = \dfrac{VC_i + FC_i + NR_j}{Y_i}$
Yield	$Y = \dfrac{VC_i + FC_i + NR_j}{P_i}$
Variable cost	$VC = P_iY_i - FC_i - NR_j$
Fixed cost	$FC = P_iY_i - VC_i - NR_j$
Total cost	$TC = P_iY_i - NR_j$
Common input price	$R = \dfrac{P_iY_i - VC'_i - FC_i - NR'_j}{X_i - X_j}$
Uncommon input price	$R = \dfrac{P_iY_i - VC'_i - FC_i - NR_j}{X_i}$
Common or Uncommon input requirement	$X = \dfrac{P_iY_i - VC'_i - FC_i - NR_j}{R_i}$

where P_i output price of commodity i, Y_i yield of output i, R_i input price for input X for the production of commodity i, X_i the level of input X required for the production of commodity i, VC_i variable costs for production of commodity i, FC_i fixed costs for production of commodity i, VC'_i variable costs for production of commodity i exclusive of costs for input X, and $TC = VC_i + FC_i$; $NR_j = P_jY_j - VC_j - FC_j$; and $NR'_j = P_iY_j - VC_j - FC_j$.

[a] Breakeven equations are derived by equating the profit functions of two alternative production enterprises i and j; solving for the item of interest. Analysis for net returns above variable costs is permitted by setting fixed costs for enterprise i to zero and using net returns above variable costs for j (NR_j). Otherwise, net returns above total costs are used for enterprise j (NR_j). NR_j is therefore net returns for enterprise j above variable or above total costs as appropriate.

APPENDIX: Table A2

Breakeven elasticity analysis among enterprises

Between enterprises breakeven elasticity for [a]	Equation
Output price – Yield i to Output price – Yield j	$\varepsilon_{P_iP_j}=\frac{\partial P_i}{\partial P_j}\frac{P_j}{P_i}=\frac{Y_j}{Y_i}\frac{P_j}{P_i}$
Output price – Yield i to Cost j	$\varepsilon_{P_iC_j}=\frac{\partial P_i}{\partial C_j}\frac{C_j}{P_i}=\frac{-1}{Y_i}\frac{C_j}{P_i}$
Output price – Yield i to Common input price j	$\varepsilon_{P_iR_j}=\frac{\partial P_i}{\partial R_j}\frac{R_j}{P_i}=\frac{X_i-X_j}{Y_i}\frac{R_j}{P_i}$
Output price – Yield i to Uncommon input price j	$\varepsilon_{P_iR_j}=\frac{\partial P_i}{\partial R_j}\frac{R_j}{P_i}=\frac{-X_j}{Y_i}\frac{R_j}{P_i}$
Output price – Yield i to Common or uncommon input requirement j	$\varepsilon_{P_iR_j}=\frac{\partial P_i}{\partial X_j}\frac{X_j}{P_i}=\frac{-R_j}{Y_i}\frac{X_j}{P_i}$
Cost i to Output price – Yield j	$\varepsilon_{C_iP_j}=\frac{\partial C_i}{\partial P_j}\frac{P_j}{C_i}=-Y_j\frac{P_j}{C_i}$
Cost i to Cost j	$\varepsilon_{C_iC_j}=\frac{\partial C_i}{\partial C_j}\frac{C_j}{C_i}=\frac{C_j}{C_i}$
Cost i to Common input price j	$\varepsilon_{C_iR_j}=\frac{\partial C_i}{\partial R_j}\frac{R_j}{C_i}=(X_j-X_i)\frac{R_j}{C_i}$
Cost i to Uncommon input price j	$\varepsilon_{C_iR_j}=\frac{\partial C_i}{\partial R_j}\frac{R_j}{C_i}=X_j\frac{R_j}{C_i}$
Cost i to Common or Uncommon input requirement j	$\varepsilon_{C_iX_j}=\frac{\partial C_i}{\partial X_j}\frac{X_j}{C_i}=R_j\frac{X_j}{C_i}$
Common input price i to Output price – Yield j	$\varepsilon_{R_iP_j}=\frac{\partial R_i}{\partial P_j}\frac{P_j}{R_i}=\frac{-Y_j}{X_iY_j}\frac{P_j}{R_i}$
Common input price i to Cost j	$\varepsilon_{R_iC_j}=\frac{\partial R_i}{\partial C_j}\frac{C_j}{R_i}=\frac{1}{X_i-Y_j}\frac{C_j}{R_i}$

To be continued...

APPENDIX: Table A2 (continued)

Between enterprises breakeven elasticity for [a]	Equation
Common input price i to Common input price k [b]	$\varepsilon_{R_iR_k}=\frac{\partial R_i}{\partial R_k}\frac{R_k}{R_i}=\frac{-X_{ik}+X_{jk}}{X_i-X_j}\frac{R_k}{R_i}$
Common input price i to Uncommon input price k	$\varepsilon_{R_iR_k}=\frac{\partial R_i}{\partial R_k}\frac{R_k}{R_i}=\frac{X_{jk}}{X_i-X_j}\frac{R_k}{R_i}$
Common input price i to Common or uncommon requirement k [c]	$\varepsilon_{R_iX_{jk}}=\frac{\partial R_i}{\partial X_{jk}}\frac{X_{jk}}{R_i}=\frac{R_k}{X_i-X_j}\frac{X_{jk}}{R_i}$
Uncommon input price i to Output price − Yield j	$\varepsilon_{R_iP_j}=\frac{\partial R_i}{\partial P_j}\frac{P_j}{R_i}=\frac{-Y_j}{X_i}\frac{P_j}{R_i}$
Uncommon input price i to Cost j	$\varepsilon_{R_iC_j}=\frac{\partial R_i}{\partial C_j}\frac{C_j}{R_i}=\frac{1}{X_i}\frac{C_j}{R_i}$
Uncommon input price i to Common input price k	$\varepsilon_{R_iR_k}=\frac{\partial R_i}{\partial R_k}\frac{R_k}{R_i}=\frac{-X_{jk}+X_{ik}}{X_i}\frac{R_k}{R_i}$
Uncommon input price i to Uncommon input price k	$\varepsilon_{R_iR_k}=\frac{\partial R_i}{\partial R_k}\frac{R_k}{R_i}=\frac{X_{jk}}{X_i}\frac{R_k}{R_i}$
Uncommon input price i to Common or uncommon input requirement k	$\varepsilon_{R_iX_{jk}}=\frac{\partial R_i}{\partial X_{jk}}\frac{X_{jk}}{R_i}=\frac{R_k}{X_i}\frac{X_{jk}}{R_i}$
Input requirement i to Output price − Yield j	$\varepsilon_{X_iP_j}=\frac{\partial X_i}{\partial P_j}\frac{P_j}{X_i}=\frac{-Y_j}{R_i}\frac{P_j}{X_i}$
Input requirement i to Cost j	$\varepsilon_{X_iC_j}=\frac{\partial X_i}{\partial C_j}\frac{C_j}{X_i}=\frac{1}{R_i}\frac{C_j}{X_i}$
Input requirement i to Common input price k [d]	$\varepsilon_{X_iR_k}=\frac{\partial X_i}{\partial R_k}\frac{R_k}{X_i}=\frac{-X_{ik}+X_{jk}}{R_i}\frac{R_k}{X_i}$
Input requirement i to Uncommon input price k	$\varepsilon_{X_iR_k}=\frac{\partial X_i}{\partial R_k}\frac{R_k}{X_i}=\frac{X_{jk}}{R_i}\frac{R_k}{X_i}$
Input requirement i to Common or Uncommon input requirement k	$\varepsilon_{X_iX_{jk}}=\frac{\partial X_i}{\partial X_{jk}}\frac{X_{jk}}{X_i}=\frac{R_k}{R_i}\frac{X_{jk}}{X_i}$

where ε the breakeven elasticity of component i to component j, P_i output price of commodity i, Y_i yield of output i, R_i input price for input X for the production of commodity i, X_i the level of input X required for the production of commodity i, C_i variable, fixed, or total costs for production of commodity i, C_i' variable, fixed, or total costs for production of commodity i exclusive of costs for input X, R_k input price for input X_k, X_{ik} the level of input X_k required for the production of commodity i, and X_{jk} the level of input X_k required for the production of commodity j.

[a] Breakeven elasticities are calculated by applying the definition formula to the appropriate breakeven equation between enterprises to derive a computational formula. Output price and yield results are parallel. In the interest of brevity only the output price calculation is provided but the end results are identical for yield.

[b] This equation holds true unless $R_i = R_k$, in which case:

$$\varepsilon_{R_i R_k} = \frac{\partial R_i}{\partial R_i} \frac{R_i}{R_i} = 1.00$$

[c] This equation holds true except for the X_k, associated with R_i, in which case (for $\mathrm{NR}'_i = P_i Y_i - \mathrm{VC}'_i - \mathrm{FC}_i$ and $\mathrm{NR}'_j = P_j Y_j - C'_j - \mathrm{FC}_j$):

$$\varepsilon_{R_i X_k} = \frac{\partial R_i}{\partial X_j} \frac{X_j}{R_i} = \frac{(\mathrm{NR}'_i - \mathrm{NR}'_j)}{(X_i - X_j)^2} \frac{X_j}{R_i}$$

[d] This equation holds true except for the R_k associated with X_i, in which case (since $R_i = R_j$):

$$\varepsilon_{X_i R_k} = \frac{\partial X_i}{\partial R_j} \frac{R_j}{X_i} = \frac{(\mathrm{NR}_j - \mathrm{NR}_i)}{R_i^2} \frac{R_i}{X_i} = \frac{(\mathrm{NR}_j - \mathrm{NR}_i)}{R_i X_i}$$