Economic evaluation of new technologies for pork producers: Examples of all-in–all-out and segregated early weaning

John D. Lawrence, PhD

Summary

Objective: *To describe a method to evaluate both the profitability and feasibility of potential investments in a pork-raising enterprise.*

Design and procedure: *Formulas are given to allow an economic analysis addressing both the feasibility and profitability of a project. Data from a hypothetical farm considering whether to adopt an all-in–all-out and a segregated early weaning scheme are used as examples to illustrate the formulas.*

Implications: *When considering whether to adopt a new technology, it is important to first calculate both the profitability and feasibility of the investment.*

Emerging technologies, which have significantly improved animal performance and product quality, are the primary drivers of our rapidly evolving swine industry. However, it can be difficult for producers to determine whether it would be beneficial to make the investment necessary to adopt new technology. Several measures can be used to evaluate an investment in a new technology, but investments must meet two basic criteria:

- The investment must be economically feasible—it must result in a positive cash flow. Even if adopting the new technology will ultimately improve profits, if cash flow over operating expenses cannot meet the commitments to principle and interest payments, the operation will not be in business to earn the improved profits.

- The investment must be profitable. If the cumulative stream of future earnings expressed in today's dollars is not larger than the initial investment, the project will erode equity and the net worth of the operation will decline over time.

Economic analysis of an investment compares the costs and benefits associated with a particular decision. The costs of adopting a new technology typically involve a large initial investment (i.e., building a new finisher) and possibly higher cost (higher property taxes, insurance, maintenance) in future years. Benefits accrue from additional revenue (marketing heavier hogs in the same number of days) and cost savings (reduced labor, improved feed efficiency). Comparing alternative investments is complicated because the investment occurs first and is followed by additional net cash flow that occurs over a number of time periods.

To illustrate the economic analysis methods described in this paper, I constructed a computer spreadsheet model of a hypothetical farrow-to-finish enterprise to assess the economic impact of adopting all-in–all-out (AIAO) and segregated early weaning (SEW) techniques at the commercial farm level. Because the focus of this paper is to describe the investment evaluation process rather than to identify the most profitable production system, hypothetical construction costs are used as the starting point. The actual costs of remodeling and/or new construction will differ greatly across operations.

Example model inputs

The hypothetical baseline production system is a high-capital, low-labor, intensively managed 660-sow operation (Table 1).[1] Performance is modeled[2] as the average of three databases: PigCHAMP® (1990), Swine Graphics™ (1991), and PigTales™ (1992) (Table 2). This hypothetical baseline farm is average in every category and has none of the specific strengths or weaknesses that will exist in actual farms, which makes individual modeling essential. For this exercise, market hog prices are projected at $46.00 per cwt, corn at $2.30 per bushel, and protein supplement (soybean meal plus vitamins, minerals, etc.) at $320 per ton.

The hypothetical farm is a continuous-flow single-site operation that is considering either changing to AIAO on one site or SEW on three sites. Table 1 describes four alternative strategies to the baseline:

- The AIAO strategy assumes a change in management with relatively little investment in remodeling facilities. The breeding herd performance is unchanged, but grow-finish performance improves.
- SEW1 assumes an 11-day weaning and breeding on the first heat after weaning;
- SEW2 assumes an 11-day weaning and breeding on the second heat after weaning;
- SEW3 uses 17-day weaning and breeding on the first heat.

The SEW systems require that additional nursery and grow-finish facilities be built or remodeled off-site. The sow herd is expanded in the existing facility by converting finishing to gestation and gilt development. The number of farrowing crates are held constant in this analysis.

JDL: Agricultural Economics Department, 468 Heady Hall, Iowa State University, Ames, Iowa, 50011-1070

Determining profitability

Calculating net cash flow

To determine the profitability of any of these investment models, we must first calculate the net cash flow (NCF) of each possible scenario.

Net cash flow for each individual period under consideration is calculated in Formula 1:

Formula 1 : Calculating net cash flow

$$NCF_t = CI_t - CE_t - (CI_t - (CE_t + D_t))\, TR_t$$

where:

CI_t = cash income at a given period ($_t$),
CE_t = cash expenses at that given period,
D_t = depreciation at that given period, and
TR_t = the marginal tax rate.

The term in parentheses captures the tax shield of depreciation. This NCF is before principal and interest payments.[3]

Using the data from Table 1, we can then see that for our hypothetical farm, NCF should be calculated as follows:

The baseline operation markets 13,163 head per year with a revenue of $115.47 per head and expenses of $57.52 (feed expenses) + 27.08 (operating expenses) + 7.57 (labor expenses) = $92.17 (total expenses). Depreciation is 10% on the initial investment of $1,988,390 and the tax rate is 28%:

CI_1 = 13,164 head × $115.47 per head = $1,519,932
CE_1 = 13,163 head × $92.17 per head = $1,213,234
D_1 = $1,988,390 × 10% = 198,839
TR_1 = 28%

Thus:

NCF_1 = 1,519,932 − 1, 213,234 −
(1,519,932 − (1,213,234 + 198,839)) × 0.28
= $276,497

Once the NCF for a given period has been calculated, the total NCF across all the periods of interest (say, the 10 years you anticipate to be

---

Table 1

Production parameters and resulting performance for baseline and alternative hog production sytems

	Baseline	AIAO[1]	SEW1[2]	SEW2[3]	SEW3[4]
Breeding herd					
Farrowing capacity (crates)	120	120	120	120	120
Weaning age (days)	20	20	11	11	17
Litters per year	1564	1564	2086	2086	1825
Nonproductive sow days	47	47	54	93	50
Average sow inventory	664	664	845	966	765
Replacement rate per litter (%)	25	25	25	25	25
Litters per sow per year	2.36	2.36	2.47	2.16	2.39
Pigs weaned per litter	9.0	9.0	8.2	9.0	9.0
Pigs weaned per sow per year	21.20	21.20	20.24	19.43	21.48
Pigs weaned per crate per year	117	117	143	156	137
Pigs weaned per year	14,079	14,079	17,103	18,771	16,425
Nursery and grower-finisher					
Mortality %	6.50	3.25	2.50	2.50	2.50
Pigs sold per litter	8.42	8.71	8.00	8.78	8.78
Pigs sold per sow per year	19.82	20.51	19.73	18.94	20.94
Pigs sold per year	13,163	13,621	16,675	18,302	16,014
Weaning weight (lb)	13	13	8	8	11
Slaughter weight (lb)	241	241	241	241	241
Average daily gain (lb)	1.22	1.39	1.54	1.54	1.55
Days to market	207	183	162	162	165
Feed:Gain	3.21	2.99	2.82	2.82	2.84
Whole operation					
Feed:Gain	3.50	3.34	3.23	3.24	3.20

1 All-in–all-out on one site
2 Segregated early weaning at 11 days; bred on first heat
3 Segregated early weaning at 11 days; bred on second heat
4 Segregated early weaning at 17 days; bred on first heat

the life of the project) should be calculated. This is done by adding the investment at a given starting point ('time 0') to the NCFs for each time period under consideration (Formula 2):

Formula 2: Calculating NCFs over several time periods

$$-I_0 + NCF_1 + NCF_2 + NCF_3 + \ldots + NCF_T$$

where:

I = investment,
NCF = net cash flow for each individual time period $(_{1,2,3}\ldots)$, and
$_T$ = the final time period under consideration.

Other ways to calculate profitability

There are alternative measures of profitability, including the payback period and simple rate of return, but the most desirable are the net present value (NPV) and internal rate of return (IRR) methods.[3] In addition to providing a ranking of investments, the NPV and IRR methods explicitly account for the timing of cash inflows and outlays, which is important because net income has "time value." A dollar is worth more today than a dollar received in the future because it has opportunity cost equal to the return that could be earned if it were invested elsewhere. To account for the time value of money, the stream of future income is discounted to the present $(_t = 0)$ time period to arrive at its present value. Subtracting the initial investment (I_0) determines the NPV.

Calculating net present value

To calculate the net present value, the NCFs from Formulas 1 and 2 need to be plugged into Formula 3:

Formula 3: Calculating net present value

$$NPV_0 = -I_0 + \frac{NCF_1}{(1+r)} + \frac{NCF_2}{(1+r)^2} + \ldots + \frac{NCF_T + S_T}{(1+r)^T}$$

$$= -I_0 + \sum_{t=1}^{T} \frac{NCF_t}{(1+r)^t} + \frac{S_T}{(1+r)^T}$$

Where:

r = the appropriate discount rate for the period,
^{T} = the total number of time periods being considered for the life of the project.

If the time periods are years then r is the annual discount rate. If there are m periods per year (for example, 12 months), then the rate can be approximated by r per m and there are T × m periods. Typically, analysis of modern swine enterprises relies on monthly cash flows and may require monthly principle and interest payments. In that case, m = 12 makes sense. An investment in a crop enterprise, which has one income per year (m = 1), is more common. The number of periods to consider for the life of the project is the choice of the individual investing in the operation. However, the life of the investment is often tied to the useful life of the facility, i.e., 10–15 years.

S_T is the salvage value of the investment at the end of the proposed project. The salvage value of hog facilities is often greatly discounted and could be negative if a site cleanup is required to shut down a facility. Conversely, if the site is properly chosen and the facility has remodeling potential, it may have a relatively high salvage value for resale or remodeling at the end of its expected life.

Net present value for our four different model scenarios is shown in Table 3. If the NPV is positive, it means that the future income from the project more than offsets the initial investment and pays the rate of return chosen for this project. If the NPV is negative it means that the project, at a minimum, did not return a rate as large as the discount rate, and it is possible that it did not cover its initial investment.

Producers can also use the relative size of NPV to rank the profitability of two or more alternative investments. Thus, we can see that NPV is highest for the SEW3 scenario, indicating that it would be the most profitable scenario for this hypothetical farm.

NPV results are sensitive to the discount rate used so you should take care to chose the appropriate rate (Table 4). The discount rate reflects the minimum acceptable rate of return chosen by a producer for an investment. A common approach is to use the cost-of-capital discount rate. This rate reflects the long-run cost of debt and equity funds used to finance the investment. The long-run cost of capital incorporates the after-tax opportunity cost of equity that could be used to finance this project and the interest rate on debt. Boehlje and Eidman[3] calculate the discount rate as:

Formula 4: Calculating discount rate

$$r = k_e W_e + k_d(1-x)W_d$$

where:

k_e = the after-tax rate of return on equity $(_e)$,
W_e = the proportion of equity funds used to finance the firm (long run capital structure),
k_d = the interest rate on borrowed funds $(_d)$, x is the marginal tax rate, and
W_d (equal to $1-W_e$) = the percent debt used in the firm.[1]
$_e$ = equity
$_d$ = debt

Formula 4 results in a discount rate that accurately reflects the long-run direct cost of debt financing and the opportunity cost of equity funds invested elsewhere. The interest

Table 2					
Average cash flow costs and returns per head for baseline and alternative hog production systems. Dollars ($) per head.					
	Baseline	AIAO	SEW1	SEW2	SEW3
Total revenue	115.47	115.32	115.75	115.22	115.29
Feed costs	57.52	53.67	53.45	53.56	51.89
Operating costs	27.08	24.27	25.64	23.95	23.97
Labor cost	7.57	7.31	7.60	7.92	7.16
Principal & interest (P&I)	23.54	23.60	23.72	23.74	23.73
Cash cost	115.71	108.85	110.41	109.17	106.75
Net cash flow	23.30	30.07	29.06	29.79	32.27
Cash after P&I	-0.24	6.47	5.34	6.05	8.54

rate on debt is reduced by the marginal tax rate because interest expense is deductible. For our model, we used a 7.5% discount rate (Table 3).

Calculating internal rate of return

Another measure of an investment's profitability is internal rate of return (IRR). Veterinarians can use it to rank projects in the same way they use the NPV. Figure 1 shows the relationship between NPV and IRR. The IRR is the discount rate at which NPV= 0 (i.e., the discounted stream of future earnings equals the initial investment). That is, solve Formula 4 for r such that:

Formula 5: Calculating IRR

$$-I_0 + \sum_{t=1}^{T} \frac{NCF_t}{(1+r)} + \frac{S_T}{(1+r)^T} = 0$$

The discount rate is an iterative process found by trying different levels of r to solve the equation, which can be tedious.

Veterinarians can rank alternative investments by their IRR and select those with an IRR above the minimum acceptable rate as candidates for investment. One advantage of IRR is that it is easily compared to rates of returns on alternative investments (i.e., stocks, bonds, farm land, etc.).

The IRRs in the example are relatively high compared to alternative investments. In particular, adopting all-in–all-out in this example produced an IRR of 2016% because it invested only $75,000 and it increased cashflow $76,000 per year.

Determining financial feasibility

Once a profitable investment is identified, the producer must still determine whether it is financially feasible. Will the investment generate enough cash flow after operating expenses to service principle and interest payments? If the investment is made from equity, feasibility is not an issue, but if it is financed it will have to meet its debt obligations or be subsidized from other sources.

Table 3

Annual average projected cash flows for baseline and analysis of additional investment in alternative systems assuming 7.5% discount rate. Measured in $1000

Year:	1	2	3	4	5	6	7	8	9	10
Baseline										
Net cash flow (NCF)	277	277	277	277	277	277	277	277	277	277
Cash after principal and interest (P&I)	-33	-33	-33	-33	-33	-33	-33	-33	-33	-33
AIAO										
Additional investment	75									
Change in NCF	-4	76	76	76	76	76	76	76	76	76
Discounted cash flow	-4	66	61	57	53	49	46	43	40	37
Net present value	449									
Internal rate of return	2016%									
Cash after P&I	26	31	31	31	31	31	31	31	31	31
SEW1										
Additional investment	550									
Change in NCF	-443	143	143	143	143	143	143	143	143	143
Discounted cash flow	-412	124	115	107	100	93	86	80	75	70
Net present value	438									
Internal rate of return	29%									
Cash after P&I	-12	24	24	24	24	24	24	24	24	24
SEW2										
Additional investment	800									
Change in NCF	-601	269	269	269	269	269	269	269	269	269
Discounted cash flow	-559	232	216	201	187	174	162	151	140	130
Net present value	1,035									
Internal rate of return	43%									
Cash after P&I	-53	-3	-3	-3	-3	-3	-3	-3	-3	-3
SEW3										
Additional investment	450									
Change in NCF	-199	240	240	240	240	240	240	240	240	240
Discounted cash flow	-185	208	193	180	167	156	145	135	125	116
Net present value	1,239									
Internal rate of return	120%									
Cash after P&I	50	42	42	42	42	42	42	42	42	42

Financial feasibility is relatively simple once the NPV analysis is complete because the expected NCFs (NCF$_t$) (before discounting) have already been generated. Use Formula 1 to be sure that annual cash flows have been properly adjusted for taxes. If a profitable investment does not generate a positive cash flow, it doesn't mean that it should not be undertaken. However, it does indicate that an alternative financial structure is needed (i.e., additional equity infusion, longer financing terms, or subsidies from other income sources). For example, spreading debt repayment over additional years may reduce the payments enough for the project to have a positive cash flow. Likewise, simply because a project will have a positive cash flow does not mean that it will be profitable. If there is a large amount of equity, an extended loan term, or if the investment is subsidized from other sources (the rest of the hog operation) it may be feasible, but not profitable enough to stand on its own. To be advisable, a project must be both profitable and feasible.

The importance of examining both profitability and feasibility is illustrated in Table 3. SEW2 has an NPV over $1 million but it fell $3000 short of principle and interest payments each year. It is profitable but not feasible because it fails to meet financial commitments. The opposite can happen if the life of the project is too short. SEW1 has a $24,000 positive cash flow after principle and interest, but it is not profitable unless operated beyond the third year (–412 + 124 + 115 + 107 < 0).

Performing sensitivity analysis

The final step in an investment analysis is to ask "what if" — i.e., to perform sensitivity analysis. Sensitivity analysis is based upon:

- assumptions about the cost of the investment,
- the expected change in production cost and returns, and
- prices for inputs and outputs.

How sensitive are the profitability and feasibility of the investment to changes (both positive and negative) in key assumptions? Some of the changes are under the manager's control (the ability to effectively adopt a new technology), but others are largely beyond the control of the firm (prices). Sensitivity analysis allows the producer to

- test the underlying assumptions before the investment is made;
- identify which variables are most important to the success of the project; and
- determine how susceptible returns are to small changes in these variables.

As a result, sensitivity analysis is typically only accurate for small changes in the variable in question (± 5% or less). If the success or failure of an investment is particularly sensitive to factors outside the control of the business (such as market prices), the decision maker may want to take action to reduce the variation in that variable (hedging, packer contract, etc.) or choose not to undertake the investment.

Table 4 shows the sensitivity of NPV to 1% lower hog prices, higher corn prices, and higher discount rate. Because AIAO requires relatively little investment, its NPV is not as sensitive as the other strategies in our hypothetical model. In fact, it shows a positive gain from higher feed prices because it is compared to the baseline, which suffers considerably more from higher feed prices than does AIAO. As may be expected, NPV is more sensitive to hog prices than corn prices.

Discussion

We used the hypothetical farm model to illustrate how NCF, NPV, and IRR can be used to determine the profitability and feasibility of various

Table 4

Sensitivity of net present value to a 1% change in hog and feed prices and discount rates. Measured in $1000

| | Net Present Value | | | |
Change	AIAO	SEW1	SEW2	SEW3
Hog prices –1%	446	419	968	1,187
Feed prices +1%	450	432	1,006	1,219
Discount rate +1%	447	435	1,029	1,233

Figure 1
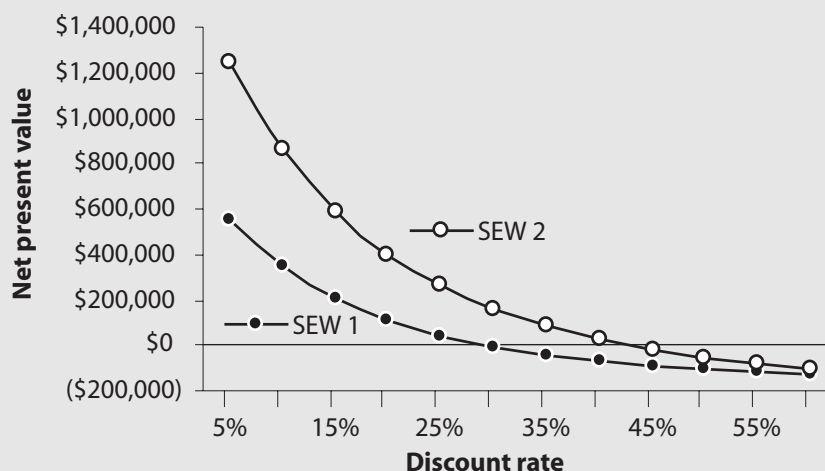
Relationship between net present value and discount rate

technology investments. Because the alternatives we used in our hypothetical farm model differed in investment cost, performance, and sow productivity, it made side-by-side comparisons difficult. However, NPV and IRR serve as common denominators to compare the net change in the business's net worth expected from adopting each strategy. These calculations can be used to help your clients assess the advisability of investing in a new technology.

Implications

- Each operation is different and should be analyzed separately considering both feasibility and profitability measures.
- Relatively simple capital budgeting tools can make meaningful comparisons of alternative technologies and investments to improve the decision-making process.
- Sensitivity analysis identifies how susceptible a management decision it to changes in key variables. These variables may be beyond the producer's control and can change a profitable decision to an unprofitable one.

References

1. Stanislaw C, Zering K, Parker J. Pork production systems with business analyses: The high-investment, high-intensity system. Pork Industry Handbook Bulletin No. 83 Revised. Iowa State University. April 1991.

2. Lazarus W, Nordquist D, and Eidman V. Economics of some swine production systems with reference to animal welfare. Staff paper, University of Minnesota, St. Paul, Minnesota. 1991:49-91.

3. Boehlje MD, Eidman VR. *Farm Management*. New York: John Wiley and Sons, 1984, Chapter 8.