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ECONOMIC ANALYSIS OF ALTERNATIVE SNAKEHEAD *CHANNA STRIATA* FEED

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☐ *The use of low-value small-sized fish (LVSSF) both as aquaculture feedstuff for snakehead and for human consumption in Vietnam and Cambodia could result in demand outstripping supply as human population and aquaculture production grow. Replacing LVSSF for snakehead aquaculture with pelleted feed would reduce the pressure on stocks of LVSSF. This study addresses the economics of this replacement strategy for snakehead culture in Vietnam. Economic engineering methods were used to assess the effects of pelleted feed for low, medium and high-productivity scenarios. The study compared net present values (NPV), internal rates of return (IRR) and differences in NPV between farms using pelleted feed and those using LVSSF. It also included sensitivity analyses that related NPV and IRR to increased snakehead prices. Results demonstrated strong economic incentives for high-productivity farms to use pelleted feed. However, pelleted feed was too expensive for medium- and low-productivity farms. NPVs were more sensitive to reductions in the cost of pelleted feed than to increases in the cost of LVSSF or the cost of capital.*

Keywords farm management, price analysis, snakehead, technology transfer, Vietnam

INTRODUCTION

Aquaculture is an important industry in Vietnam, and the government recognizes its potential through direct supports that include research, trade incentives, and bank loans to fund both producers and processors (De Silva

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& Davy, 2009; FAO, 2012). It is estimated that aquaculture directly employs 700,000 people; indirectly, it affects employment in affiliated industries such as feed, equipment, fish processing and marketing (FAO, 2012). As of 2010, this industry accounted for 16% of the gross domestic product (FAO, 2012) and between 2001 and 2009, it grew on the order of 10%–13% per year (Navy et al., 2009) (Table 1). In 2008, Vietnam placed third in the world for aquaculture production with a value of $4.51 billion USD (FAO, 2012) (Table 1). It is also an important source of household income. Half of the aquaculture farmers in a survey stated they derived 75% of their income from aquaculture (FAO, 2012).

Cambodia has also been experiencing growth in the aquaculture sector. Over the last two decades, the average growth rate has been 16.3% (FAO, 2005). By 2009, 50,000 metric tons of fish produced from aquaculture represented 9.7% of country's total fisheries production (FAO, 2012). However, infrastructure limitations on the distribution of seed, feed, and products in this industry (FAO, 2012) pose challenges to expanding aquaculture. Despite these challenges, aquaculture in Cambodia continues to grow.

Protein is one of the largest inputs in aquaculture and it usually is obtained from fishmeal or low-value small-sized fish (LVSSF). Fishmeal is a processed powder or cake produced by cooking, grinding and extracting oil from fish and is often used in formulated pelleted feed as a protein source. LVSSF, also a protein source, are typically small fish of little value or juveniles of higher-value fish (Asia-Pacific Fishery Commission, 2005) that are fed whole or are cut into pieces and fed directly to farmed fish. As the global human population continues to grow, so does the demand for fish, resulting in increased demand for fishmeal and LVSSF to supply fish production. Between 2000 and 2011, average fish quantity supplied increased from 19.9 kg/capita/yr to 33.2 kg/capita/year (FAOSTAT, 2014) in Vietnam. The population increased from 80,888,000 to 89,000,000; thus, it is likely that demand for fish will increase (FAOSTAT, 2014). In Cambodia, the average per capita fish consumption was 33.0 kg/year

TABLE 1 Vietnam Fishery and Aquaculture Statistics

Descriptions	Values
Annual aquaculture growth[a]	10–13%
Country ranking for aquaculture production[b]	3rd
Aquaculture production value[c]	$ 4.6 billion USD
Fish-related exports[d]	$4.510 billion USD
Annual fish-related export growth[e]	47.50%

[a]Annual growth from 2001 to 2009 (Navy et al., 2009).
[b]Ranking in 2008 (Lymer et al., 2010).
[c]Value in 2008 (Lymer et al., 2010).
[d](FAO, 2010).
[e]Calculated from 1998 value of $0.8 billion USD and 2008 value of $4.6 billion USD (FAO 2010).

in 2007, and in some areas with large-scale fisheries it is now as high as 124 kg/year (FAO, 2012). Considering a population of 14.46 million in 2008 and a growth rate of 1.65% per year, Cambodian demand for fish will increase. Although the industry is so far keeping pace with per capita demand and population in these two countries, it is limited by LVSSF catch.

Fish have lower feed conversion ratios (FCR) than domesticated farm animals, and require fewer inputs than land animals to produce the same amount of food for human consumption. Nevertheless, the practice of feeding fish with other fish is both an environmental issue and a food security issue in Vietnam for several reasons: (1) LVSSF are diverted from human consumption to fish feed, (2) the supply of fishmeal and LVSSF fluctuates and is finite, and (3) this type of aquaculture promotes the overexploitation of wild local fish.

Snakehead is a popular and highly valued food fish in the lower Mekong Delta, which includes parts of Vietnam and Cambodia (Sinh et al., 2014). It is often grown in earthen ponds, especially in the Mekong Delta of Vietnam (Sinh et al. 2014). Fry or fingerling are stocked into ponds and grown out using either LVSSF as feed or pelleted feed. Farmers using pelleted feed frequently use a small amount of LVSSF first to wean the snakehead onto the pelleted feed. The snakehead are then harvested after 6 months when they reach market size and sold for human consumption. Generally, this cycle is repeated twice, producing two crops of snakehead per year (Sinh, personal communication, 2012).

In 2009, Vietnam produced 30,000 tons of snakehead (Navy et al., 2009) and this grew to 40,000 tons in 2010, according to the summary of annual reports of the Delta provinces (Sinh et al., 2011). Using an FCR of about 4, as reported by Navy et al. (2009), Nam and Pomeroy (2011) calculated that to produce those quantities of snakehead would have required 120,000 tons of LVSSF amounting to17% of the total annual freshwater production in the Mekong Delta in 2009, and 160,000 tons of LVSSF or the equivalent of 23% of the annual total in 2010 (Nam & Pomeroy, 2011).

Concern about the overexploitation of LVSSF has led to projects that promote alternative sources of protein (e.g., soybean meal) for fish feed. One such project is the Development of Alternatives to the Use of Freshwater Low Value Fish for Aquaculture in the Lower Mekong Basin of Cambodia and Vietnam: Implications for Livelihoods, Production, and Markets. This project was supported by the AquaFISH Collaborative Research Support Program (CRSP), funded by the U.S. Agency for International Development (USAID). It aimed to improve the feed used for snakehead murrel (*Channa striata*) aquaculture in Vietnam and giant snakehead (*Channa micropeltes)* aquaculture in Cambodia. This project formulated a pelleted feed to serve as a substitute for LVSSF (Bengston & Hien, 2009). The formulated feed also replaces 50% of the fishmeal used for protein in pelleted feeds with soybean meal. The hope is that if this technology is successful in Vietnam, it could also be used in Cambodia, where there is currently a ban on snakehead aquaculture due to its intense use of LVSSF.

Snakehead farming has been illegal in Cambodia since 2005 because the government decided that snakehead aquaculture has a negative impact on juvenile fish of future commercial value as well as on the smaller fish used for fermented fish paste, a dietary staple in the region (Nam, 2011). However, snakehead generates significantly more profit than other fish species, so there is a strong incentive to continue fishing and/or culturing snakehead despite the ban. Ironically, the ban has increased pressure on native snakehead stocks to supply local and external markets in Vietnam through illegal fishing (Nam, 2011).

The purpose of this article is to present the results of a study that measures the economic impact of the new feed technology on snakehead farms in Vietnam. We present projected cash flows and cost–benefit analyses for model farms based on data from field surveys conducted by the College of Aquaculture and Fisheries (CAF) at Can Tho University in Vietnam. The article concludes with a discussion of the future use of pelleted feed for snakehead aquaculture in Vietnam.

METHODOLOGY

Data Collection

CAF provided survey data from snakehead farms in An Giang and Dong Thap provinces of Vietnam used for this financial analysis. Due to the limited number of farms that used pelleted feed, a quota sampling method was used (Sinh, personal communication, 2012). Farms were placed into mutually exclusive subgroups based on the provinces where they were located, and using a non-probability sampling method, 83 farms were chosen. Surveys included information on revenue, capital costs, and variable costs. The data were entered into SPSS by CAF and were then exported to Microsoft Excel for this study.

Farms were discarded for this analysis if they: (1) did not provide enough data required for this analysis; (2) did not produce exactly two crops per year; (3) had extreme production values; and/or (4) had extreme values for farm size. In order to avoid outliers, a graph of total production versus farm size for farms using LVSSF and for farms using pelleted feed was created (Figure 1). A natural break in the data was observed, and a diagonal line was drawn from 160,000 kg on the *y*-axis to 10,000 m^3 on the *x*-axis. Most of the data points were closely clustered to the left of this line; therefore, every data point to the right of the line was considered an outlier and was dropped to prevent the undue influence of extreme values.

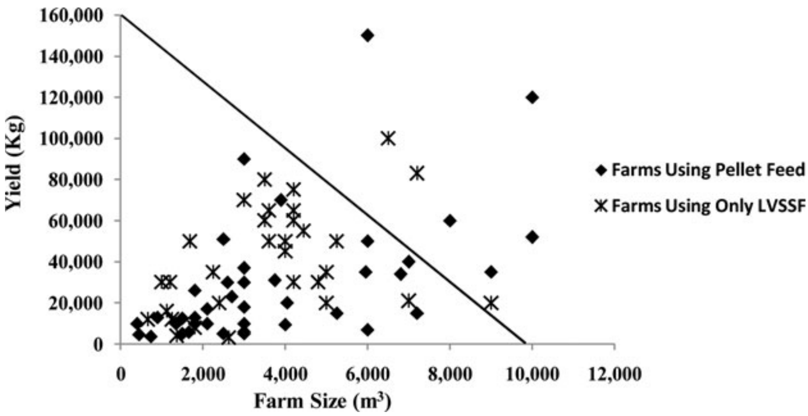

FIGURE 1 Yield versus farm size for farms using different feed technologies. Farms to the right of the downward sloping line were considered outliers and not used in the analysis. (Some outliers were too extreme to be shown in this figure.)

Farms were separated into three groups based on their productivity using three percentiles (first percentile: 0–33.32%, second percentile: 33.33–66.65%, and third percentile: 66.66–100%). Productivity was defined as kilograms of snakehead produced per cubic meter in one crop. Farms falling within the first percentile were defined as low-productivity (LP), the second percentile, medium-productivity (MP), and the third percentile, high-productivity (HP). Farms were further separated within each level of productivity based on whether they used pelleted feed or LVSSF to feed snakehead. It was important to test statistically for differences in productivity between farms within the same productivity level to determine if feed type had biased the percentile groupings. If productivity was not statistically different within a specific productivity level regardless of feed type used, concern that feed type influenced percentile groupings could be ignored.

To determine which *t*-test to use, three separate two-sample *F*-tests were used for each productivity level to test the null hypothesis that farms with the same productivity using different feed types have equal variances. All *F*-values were less than the *F* critical value (Table 2) and the null hypothesis could not be rejected for each of the productivity levels. Thus, three

TABLE 2 Summary Statistics Include *F*-value, and *F* Critical Value for a Two-Sample *F* Test, the *P*-value From a Two-Sample, Two-Tailed, Equal Variance *t*-Test, and the Means with Standard Deviations for Each Productivity

Productivity	*F*-value	F crit.	*P*-value	Mean and Stdev. (kg/m^3)[a]
Low	1.038	5.912	0.85	3.025 ± 1.502
Medium	1.382	4.655	0.52	7.620 ± 2.424
High	1.985	3.106	0.94	15.251 ± 7.041

[a]Means are on a per crop basis.

separate two-tailed *t*-tests for equal variance were conducted for each productivity level to examine the null hypothesis that farms with the same productivity but different feed types had equal means. All *P*-values were greater than 0.05 (Table 2) and the null hypothesis could not be rejected for each productivity level. Based on the statistical output, it was determined that it was unlikely that feed type influenced productivity level groupings and averaging productivity within a percentile was acceptable for this analysis.

Economic Engineering and Representative Farms

Economic engineering is the process of developing a hypothetical farm model that utilizes available and appropriate data from secondary sources. It has been extensively used in aquaculture studies because the industry frequently incorporates new technologies without the benefit of extensive research data (Engle, 2010). Pounds et al. (1992) used this method to create five baitfish farm models that were used to measure the impact of intensifying and increasing production within a given area. Economic engineering was also used by Engle (2007) to develop a catfish production budget that is now updated annually. It used survey data as well as data from appropriate outside sources to build model catfish farms or a representative farm.

A representative farm model can be created by clustering farms with similar production levels and averaging their production variables (Solis and Bravo-Ureta, 2005). This technique, widely used in agricultural economic analysis, is useful for observing how policy or price changes impact cash flows and profitability (Taylor et al., 2010). For example, Solis and Bravo-Ureta (2005) used this method to evaluate the sustainability of Farm Management Centers in El Salvador for a range of economic scenarios. Taylor et al. (2010) used representative farm models to predict how debt-to-asset ratios for small and large farms would be impacted by policy changes in North Dakota. This study uses them to observe profitability.

There are six representative model farms in this analysis, constructed from a total of 57 surveyed farms: 13 LP farms that use pelleted feed, 5 LP farms that use LVSSF, 14 MP farms that use pelleted feed, 6 MP farms that use LVSSF, 6 HP farms that use pelleted feed and 13 HP farms that use LVSSF. Each production variable (Table 3) for a model farm is based on average values from farms that fall within one of the six groups. These include costs of boxes for market, other costs, quantity of seed, price of seed, cost of pumping water, cost of prevention or treatment disease, total quantity of feed, total quantity of pelleted feed, and labor expenses.

Exceptions to this include the price of pelleted feed (US $1.09 per kilogram) and the farm gate price of snakehead (US $2.10 per kilogram), which are based on a total average of all the farms. Obviously, the price of pelleted feed is an average based only on those farms that use pelleted feed. These

TABLE 3 Average Values of Each Production Variable for the Six Representative Farms

Item	Unit	LP		MP		HP	
		Pellet	LVSSF	Pellet	LVSSF	Pellet	LVSSF
Box cost	USD/m^3	0.063	0.049	0.048	0.160	0.171	0.277
Other costs	USD/m^3	0.064	0.016	0.070	0.034	0.200	0.037
Seed	indiv./m^3	11.494	9.452	32.000	25.204	52.835	51.95
Pump water	USD/m^3	0.099	0.125	0.137	0.696	0.339	0.267
Treatment	USD/m^3	0.215	0.187	0.307	0.440	0.610	0.426
LVSSF	USD/m^3	0.634	6.128	1.167	12.319	1.190	29.897
Pelleted feed	kg/m^3	6.370		18.534		18.839	
Labor	USD/m^3	0.072	0.089	0.196	0.179	0.352	0.285

variables were provided by Can Tho Aquaculture and Fisheries Center (CAF) and they are used to calculate operating costs, which are incorporated into one of six, 10-year cash flows for each model farm. The cash outflows consist of operating and capital expenses while inflows include revenues from fish sales and residual values from capital items that did not depreciate to zero in the final operating year.

An exchange rate of VND 20,000 per US dollar is used for all the costs and revenues. An example of an LP farm cash flow using LVSSF is shown in

TABLE 4 Undiscounted Cash Flow Budget for an LP Farm Using LVSSF with Values Shown in USD per Cubic Meter

	Year	0	1	2	3	4	5	6	7	8	9	10
Income	Revenue	0.00	6.36	12.72	12.72	12.72	12.72	12.72	12.72	12.72	12.72	12.72
	Residual	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
	Total Income	0.00	6.36	12.72	12.72	12.72	12.72	12.72	12.72	12.72	12.72	12.77
Oper. Exp.	Boxes	0.00	0.05	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	Other	0.00	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	Seed	0.00	0.14	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	Pumping	0.00	0.12	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Treatment	0.00	0.19	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
	LVSSF	0.00	6.13	12.26	12.26	12.26	12.26	12.26	12.26	12.26	12.26	12.26
	Pellet	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Labor	0.00	0.09	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
	Total Oper. Exp.	0.00	6.73	13.46	13.46	13.46	13.46	13.46	13.46	13.46	13.46	13.46
Cap. Exp.	Pond	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Net	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
	Sm. Equip.	0.02	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.02	0.00
	Pump	0.05	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
	Total Cap. Exp.	1.11	0.00	0.00	0.02	0.00	0.00	0.11	0.00	0.00	0.02	0.00
	Total Inflow[a]	0.00	6.36	12.72	12.72	12.72	12.72	12.72	12.72	12.72	12.72	12.77
	Total Outflow[b]	1.11	6.73	13.46	13.49	13.46	13.46	13.57	13.46	13.46	13.49	13.46
	Net Flow	−1.11	−0.37	−0.74	−0.76	−0.74	−0.74	−0.85	−0.74	−0.74	−0.76	−0.70

[a]Total inflow equals total income.
[b]Total outflow is the sum of total operating expenditure and total capital expenditure.
Note: Results show it is not profitable and is unfeasible due to the negative net flow.

Table 4. In year zero, there is no production. In year 1, there is one crop produced because it is assumed farmers are still setting up their facility in the first half of the year. In years 2–10, two crops are produced each year. The cost of seed purchased, either fry or fingerling, is calculated by averaging the price of seed for all 57 farms multiplied times the average quantity of seed purchased by each representative farm. The average price is about $1.46 per 100 hundred snakehead seed.

The quantity of seed were not accurate according to personal communication with Sinh (personal communication, 2012) so feed conversion ratios could not be calculated. Moreover, data collected by CAF did not contain all the necessary information required for a full-farm budget to be created; therefore, the capital items and costs in the cash flows are obtained from Petersen et al. (2007) and from personal communication with Sinh in 2012.

Capital costs consist of pond construction, net, small equipment, and a pump. The cost of constructing a pond is approximately $1.00 per cubic meter, and each pond has a useful life of 10 years (Sinh, personal communication 2012). Capital costs other than pond construction were obtained from Petersen et al. (2007), based on their research on tilapia farms in Vietnam. Petersen et al. (2007) provided the average farm size for tilapia culture in southern Vietnam and the average cost for nets, small equipment, and pumps. The costs of these capital items were divided by the average farm size in order to calculate the cost per cubic meter for each item because individual price data was not available from external sources.

Capital costs are not handled in this way but due to the limited data available and the way data was presented in Pertersen el al. (2007), this was the only option. The useful life of a pond is typically 10 years, nets are six years, small equipment is three years and pumps are six years. It was assumed that snakehead farmers had available cash to purchase the capital items at the end of year zero. Residuals were incorporated into year 10 when the farmer liquidated capital items that had not depreciated to zero. The items were sold for a price equal to the value per cubic meter minus its depreciation using the straight-line method.

Revenues from snakehead sales were calculated by multiplying the average price received by all farmers on the 57 farms by the weight of the snakehead sold for the model farm.

The analysis ignores the costs of transporting seed and feed to the farm, the cost of transporting snakehead to market and taxes. It also assumes that farmers already own the land where the farm operates and that they use their own capital without loans.

In order to measure profitability, a cost–benefit ansalysis that uses cash flows and compares the net present value (NPV) and internal rate of return (IRR). NPV is calculated using Equation (1) and IRR is calculated with

Equation (2) as follows (Engle, 2010):

$$NPV = \sum\nolimits_{t=0}^{n} (B_t - C_t - I_t) \left(\frac{1}{1+r} \right)^t \quad (1)$$

$$0 = \sum\nolimits_{t=0}^{n} (B_t - C_t - I_t)/(1 + IRR)^t \quad (2)$$

where:

B_t is the benefit in year t;
C_t is the cost in year t;
I_t is the investment in year t; and
r is the discount rate.

The annual discount rate used to calculate the NPVs is 13% and corresponds to what farmers would have received if they had invested in a savings account with Vietnam's Agribank in 2011 instead of starting a snakehead farm. The NPV represents the profit or loss per cubic foot of water that snakehead are grown in each crop. The IRR is the rate of return that yields a NPV equal to zero, and serves as an estimate of the average earning power of the model farm for its lifespan. If returns are negative, then IRR cannot be calculated and it is unfeasible. When the NPV is negative and the IRR cannot be calculated, costs are higher than benefits, and the farm is operating at a loss. When the NPV is positive and IRR is positive, benefits are higher than costs, and the farm is operating with a profit. The difference in NPV between farms with the same productivity using different feeds is driven by the cost per unit of feed. Undiscounted net cash flows for LP farms, MP farms and HP farms using either pelleted feed or LVSSF are depicted in Figure 2.

Sensitivity Analysis

An important consideration in a cost–benefit analysis is to conduct a sensitivity analysis in order to determine the robustness of the results obtained under a base case scenario. Five economic scenarios are simulated:

1. Adjustment to the discount rate;
2. Adjustment to the cost of capital;
3. Increasing the price of snakehead;
4. Increasing the cost of LVSSF; and
5. Decreasing the price of pelleted feed.

It should be noted that the last two scenarios are done with a 15% higher snakehead price to simulate an optimistic scenario. NPVs, IRRs, and differences

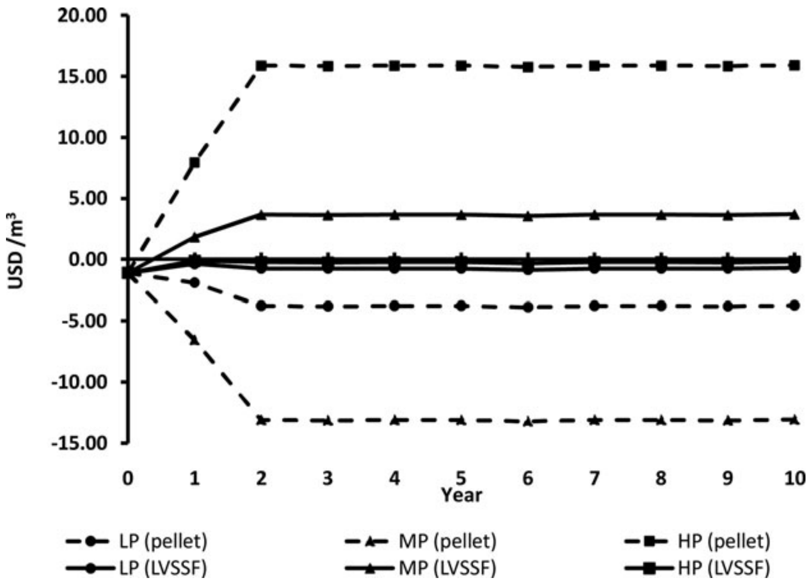

FIGURE 2 Undiscounted net cash flows on a per cubic meter basis in USD for three different productivities that used either pelleted feed or low value small-size fish for feed.

between NPVs among farms with the same productivities but different feed technologies are compared. Elasticity of NPV with respect to a change in price, which measures the percent change in NPV as a result of a one percent change in the price, is measured for scenarios 3 and 5. Elasticity of NPV with respect to change in cost, which measures the percent change in NPV as a result of a 1% change in the cost, is measured for scenarios 2 and 4. Elasticity of NPV with respect to a change in price or cost uses Equation (3):

$$E_{NPV,P} = \frac{\%\Delta \mathrm{NPV}}{\%\Delta \mathrm{P}} \tag{3}$$

where:

$E_{NPV,\ P}$ is the elasticity of *NPV* with respect to the 1% change in price;
P is price or cost when calculating the elasticity of *NPV* with respect to a 1% increase in LVSSF.

RESULTS AND DISCUSSION

Base Case Analysis

The base case, which represents the 2011 survey data, shows many snakehead farms operating at a loss and is displayed in Table 5. The NPV is negative for four out of the six model farms. Both the LP farm and the

TABLE 5 NPV and IRR for Each of the Six Representative Farms

				Increase Snakehead Price			Increase LVSSF Cost[a]			Decrease Pelleted Feed Price[a]		
Prod.	Feed	Measure	Base Case	5%	10%	15%	10%	20%	30%	−5%	−10%	−15%
Low	Pellet	NPV	−19.97	−16.80	−13.63	−10.46	−11.09	−11.72	−12.35	−7.00	−3.55	−0.09
		IRR										
	LVSSF	NPV	−4.86	−1.96	1.48	4.65	−1.45	−7.56	−13.67			
		IRR			39%	81%						
		NPV_I	−15.11[b]				−9.63	−4.16	1.32	−11.66	−8.20	−4.74
Med.	Pellet	NPV	−66.41	−58.43	−50.44	−42.25	−43.62	−44.78	−45.95	−32.40	−22.34	−12.29
		IRR										
	LVSSF	NPV	17.05	25.04	33.03	41.01	28.73	16.45	4.17			
		IRR	217%	297%	375%	451%	333%	211%	75%			
		NPV_I	−83.47[b]				−72.35	−61.23	−50.12	−73.41	−63.36	−53.30
High	Pellet	NPV	77.89	93.87	109.86	125.84	124.66	123.47	122.28	136.06	146.28	156.51
		IRR	796%	944%	1091%	1237%	1226%	1215%	1204%	1330%	1424%	1517%
	LVSSF	NPV	−2.30	13.68	29.67	45.65	15.85	−13.95	−43.75			
		IRR		182%	342%	495%	205%					
		NPV_I	80.19†				108.80	137.42	166.03	90.41	100.63	110.86

In the base case, increased snakehead price, increased LVSSF cost, and decreased pelleted feed price along with the difference in NPV (NPV_I) for each of the three productivities in the base case, increase in LVSSF cost, and decrease in pelleted feed cost.

[a]Scenario done with a 15% higher snakehead price than represented in the survey data.

[b]The values in the base case and when the price of snakehead is increased are the same because NPV increases equally independent of the feed type being used within a productivity level.

TABLE 6 NPV for Each of the Six Representative Farms and the Difference in NPV (NPV_I) Between the Two Different Feeding Methods when the Discount Rate is Adjusted

Productivity	Feed	Measure	9%	11%	13%[a]	15%	17%
Low	Pellet	NPV	−23.66	−21.69	−19.97	−18.46	−17.12
	LVSSF	NPV	−5.59	−5.20	−4.86	−4.56	−4.29
		NPV_I	−18.07	−16.49	−15.11	−13.90	−12.83
Med.	Pellet	NPV	−79.19	−72.37	−66.41	−61.17	−56.55
	LVSSF	NPV	20.61	18.71	17.05	15.60	14.31
		NPV_I	−99.80	−91.09	−83.47	−76.77	−70.86
High	Pellet	NPV	93.35	85.10	77.89	71.55	65.96
	LVSSF	NPV	−2.53	−2.41	−2.30	−2.21	−2.12
		NPV_I	95.88	87.51	80.19	73.76	68.08

[a]Discount rate used to calculate the NPVs in the base case, which corresponds to what farmers would have received if they had invested in a savings account with Vietnam's Agribank in 2011 instead of a snakehead farm.

MP farm using pelleted feed operate at a loss. The IRRs cannot be calculated for negative NPVs (Table 5). However, the MP farm that uses LVSSF is profitable and has a NPV of 17.05 and an IRR of 217% (Table 5). The HP farm using pelleted feed has an NPV of 77.89 and an IRR of 796% (Table 5), while the HP farm using only LVSSF is not profitable. The average snakehead price is 2.10/kg in this study; however, it tends to vary considerably (15–20%) between seasons, and this price may be low (Sinh, personal communication 2013).

Sensitivity Analysis

It is important to conduct a sensitivity analysis on the discount rate, especially since the opportunity cost of the capital investment can change on a yearly basis. Table 6 presents the NPVs for the baseline discount rate

TABLE 7 NPV and IRR for Each of The Six Representative Farms Between the Two Different Feeding Methods When the Cost of Capital is Adjusted

			Percent Capital Cost Adjustment								
Prod.	Feed	Measure	−20%	−15%	−10%	−5%	0%	5%	10%	15%	20%
Low	Pellet	NPV	−19.75	−19.80	−19.86	−19.91	−19.97	−20.02	−20.08	−20.14	−20.19
		IRR									
	LVSSF	NPV	−4.64	−4.69	−4.75	−4.80	−4.86	−4.91	−4.97	−5.02	−5.08
		IRR									
Med.	Pellet	NPV	−66.19	−66.25	−66.30	−66.36	−66.41	−66.47	−66.52	−66.58	−66.63
		IRR									
	LVSSF	NPV	17.28	17.22	17.17	17.11	17.05	17.00	16.94	16.89	16.83
		IRR	263%	250%	238%	227%	217%	208%	200%	193%	186%
High	Pellet	NPV	78.11	78.06	78.00	77.95	77.89	77.83	77.78	77.72	77.67
		IRR	979%	925%	877%	835%	796%	761%	730%	701%	674%
	LVSSF	NPV	−2.08	−2.13	−2.19	−2.25	−2.30	−2.36	−2.41	−2.47	−2.52
		IRR									

of 13% and for scenario 1, when the discount rate is adjusted down to 9% and 11% in two percent increments and up to 15% and 17% in 2% increments. As would be expected, when the discount rate is decreased, the NPVs increase and when the discount rate is increased, the NPVs decrease.

Capital Costs were also subject to a sensitivity test in scenario 2, which presents the NPVs and IRRs when the cost of capital is adjusted from negative 20% to positive 20% in five percentage point increments (Table 7). Because capital investment was such a small expenditure in this model, no changes in the signs for NPVs occurred. The elasticity was +0.01 if the cost of capital was decreased by one percent and −0.01 if the cost of capital was increased by 1% (Table 8). IRR can only be calculated for the MP farm using LVSSF and the HP farm using pelleted feed. These values vary from 263% to 186% and 979% to 674% respectively between a negative 20% and positive 20% change in the cost of capital.

Since four out of the six model farms are not profitable, scenario 3 analyzes the change in NPV and IRR when the price of snakehead increases by 5%, 10%, and 15%. The resulting NPVs and IRRs are displayed in Table 5. The LP farm that uses pelleted feed does not become profitable even with a 15% increase in snakehead price. The LP farm using LVSSF becomes profitable only after a 10% increase in snakehead price. They both have an elasticity of 0.63 (Table 8). Similarly, the MP farm using pelleted feed does not become profitable. The MP farm using LVSSF increases its profitability. They have an elasticity of 1.60 (Table 8). Both HP farms increase their profit with an increase in snakehead price and have an elasticity of 3.20 (Table 8). IRRs for feasible scenarios increase with an increase in snakehead price as would be expected.

Scenario 4 simulates the expected increase in the cost of LVSSF with the price of snakehead 15% higher than the 2011 survey data. Resulting NPVs and IRRs are displayed in Table 6. Feasible model farms using pelleted feed as well as a small amount of LVSSF[1] are included in this scenario. The LP

TABLE 8 Elasticity of NPV

	Capital Cost Adj.[a]		Incr. Snkhd Price		Incr. LVSSF Cost[b]		Decr. Pelleted Feed Price[b]	
Production	Pellet	LVSSF	Pellet	LVSSF	Pellet	LVSSF	Pellet	LVSSF
Low	(±) 0.01	(±) 0.01	0.63	0.63	−0.06	−0.61	0.69	0
Med.	(±) 0.01	(±) 0.01	1.60	1.60	−0.12	−1.23	2.01	0
High	(±) 0.01	(±) 0.01	3.20	3.20	−0.12	−2.98	2.04	0

For each production-scale with respect to a one percent increase or decrease in capital costs, 1% increase in snakehead price, one percent increase in LVSSF cost, and a one percent decrease on pelleted feed price.

[a]Values for scenario 2 are positive when the cost of capital is decreased and negative when the cost of capital increased.

[b]Scenario done with a 15% higher snakehead price than represented in the survey data.

farm using pelleted feed, LP farm using LVSSF, and MP farm using pelleted feed remain infeasible in this scenario. The MP farm using LVSSF is robust and remains profitable even with a 30% increase in the cost of LVSSF. It has an elasticity of −1.23 (Table 8). The HP farm that uses LVSSF becomes unprofitable once the cost of LVSSF increases by 10%, at which point the IRR cannot be calculated. The elasticity is −2.98 (Table 8). The IRR decreases in this scenario as the cost of LVSSF increases.

Scenario 5 simulates a reduction in the price of pelleted feed for those farms that use the new feed technology, while the price of snakehead is held 15% higher than the 2011 survey data. Neither the LP farm nor the MP farm becomes profitable with a 15% decrease in the price of pelleted feed. The HP farm increases profitability and has an elasticity of 2.04 (Table 8). IRR increases as well.

Measuring the Impact of Pelleted Feed Using the Difference in NPV

Calculating the difference in NPV or the net present value index (NVP_I) between farms of the same productivity using different feed technologies is one way to measure the economic impact pelleted feed has on snakehead farms. It measures the difference in the profit per cubic meter for one crop between farms that use pelleted feed and farms that use LVSSF. To calculate the NVP_I, the NPV of a model farm with a particular productivity using pelleted feed is subtracted from that of a model farm with the same productivity using LVSSF as shown in Equation (4):

$$NPV_{X,P} - NPV_{X,L} = NPV_I \tag{4}$$

where:

X: identifies the productivity level;
P: identifies the NPV is from a farm using pelleted feed;
L: identifies the NPV is from a farm using LVSSF;
I: identifies the NPV as an index.

This is done for the base case, scenario 1, scenario 4, and scenario 5. Scenarios 2 and 3 are not included because $NVP_{X,P}$ and $NVP_{X,L}$ increase at the same rate and NVP_I would show no change from the base case. Results of these calculations are found in Table 6 for scenario 1 and Table 5 for scenarios 4 and 5. A positive value for NVP_I indicates pelleted feed has a positive impact on profitability; conversely, a negative value indicates that pelleted feed has a negative impact on farm profitability.

For the base case, pelleted feed is not economical for either the LP farms, or the MP farms and results in a negative NVP_I each. However, the HP farms have a positive NVP_I of 80.19. In scenario 1, the NVP_I remains negative for LP and MP farms, while it remains positive for HP farms despite decreasing the discount rate to 9% and increasing it to 17%. In scenario 4, the NVP_I remains negative for MP farms, while it becomes positive with a value of 1.32 for LP farms when there is a 30% increase in the cost of LVSSF. NVP_I for HP farms are positive and only increase as the cost of LVSSF increases. In scenario 5, NVP_I remains negative for LP farms and MP farms with a decrease in the price of pelleted feed. However, it is positive for HP farms as the cost of LVSSF increases.

CONCLUDING REMARKS

This study analyzed the economic impact of using pelleted feed on snakehead farms in Vietnam. Pelleted feed was too expensive for MP farms and LP farms. NPV and IRR calculations indicated that only HP farms were more profitable using pelleted feed than LVSSF. There were and continue to be strong economic incentives for these farms to switch to pelleted feed. LP farms and MP farms that used only LVSSF were more profitable than ones using pelleted feed and had positive returns only when the price of snakehead was 15% higher than the 2011 survey data. The cost of capital did not greatly impact profitability when using the limited capital cost data that was available.

As long as pelleted feed was more expensive than LVSSF per unit snakehead, it was not the most profitable choice except for HP farms. The difference in NPV indicated that the number of HP farms would only increase as the price of pelleted feed decreased and/or the cost of LVSSF increased. A decrease in the price of pelleted feed and/or an increase in the cost of LVSSF will be necessary to make pelleted feed a more economical choice for LP farms and MP farms. The impact of decreasing the price of pelleted feed was stronger and more positive than that of increasing the cost of LVSSF for all the farms. However, MP farms required a greater decrease in the price of pelleted feed and a greater increase in the cost of LVSSF than LP farms to feel a positive impact from using pelleted feed.

Many snakehead farms may also not have used efficient feeding methods because of their low stocking densities. It was unclear whether farmers attempted high densities with consequently high mortality, thus turning their operations into LP farms, or if they intentionally stocked fish at lower densities. In the latter case, efficient feeding would have been difficult, because food would be wasted on fish that would die prior to reaching market size, causing high FCRs.

HP farms in this analysis benefit from the use of pelleted feed if snakehead culture is intensified. However, with higher densities, the risk of disease and other water quality challenges increase. Appropriate training for disease prevention and management may be required if there is a move toward intensification of snakehead culture. Unobservables such as managerial skills and effective disease control most likely play a role in the profitability of snakehead farms. This study did not analyze those key factors, but should be included in future research on snakehead profitability. Future research is also needed on quantifying the cost of capital on snakehead farms.

If this new feed technology is implemented, it will likely play a part in increasing demand for imported soybeans in Vietnam. At $0.57– $0.62 per kg, imported soybeans are currently less expensive than those produced in Vietnam at $0.71 per kg (Nguyen & MacCartee, 2011). However, recognizing that economic gains can be made on soy, Vietnam opened its first two soybean crushing mills in 2011 (Nguyen & MacCartee, 2011). The country imported over one million metric tons of full-fat soybeans in 2011, a 350% increase from 2010 (Nguyen, 2013). Vietnam receives 49% of its soybeans from Brazil and 22% from the United States (Nguyen, 2013). Nguyen (2013) reported the quantity of soybeans exported to Vietnam from the United States more than doubled in 2013 (Nguyen, 2013). This will not only improve revenue for the United States but may decrease the cost of soybean meal in pelleted feed for snakehead farmers.

Vietnam appears to be strongly committed to switching its reliance from LVSSF to soy. However, this may present both societal and economic challenges and should be further explored. There is risk involved in relying on foreign commodities like soybeans, which are subject to price fluctuations unrelated to the Vietnamese economy. Despite these risks, benefits may include offering new sources of income for people in Vietnam through new employment opportunities directly and indirectly related to the soy-crushing industry as well as in the aquaculture sector.

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NOTE

1. Farms that use pelleted feed incorporate up to 16.10% of LVSSF by weight according to the 2011 survey data.

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