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Financial risks in Rwandan smallholder broiler production

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Abstract

Purpose – The purpose of this paper is to determine the stochastic net present value (NPV) of a model smallholder poultry operation in Rwanda under production and market uncertainty.

Design/methodology/approach – A discounted cash flow calculator was used to determine the NPV of operator investments and operating cash flows, including time, materials and capital. Broiler production data, market prices and variable input costs were collected from 125 smallholder operations in the Musanze District, Rwanda. These data were combined with a historical price index tracking the inflation rate of Rwanda's currency. Policies including overstocking, technical support repayment scheduling, selling broilers at a spot market price, using marketing contracts and selling poultry manure were compared using non-parametric paired comparisons and stochastic dominance.

Findings – Risk-neutral and risk-averse producers would prefer overstocking, delaying repayment of technical support services and selling manure to status quo operational policy. No differences were observed between the option to sell birds at spot market prices or through contracts.

Research limitations/implications – This analysis demonstrates how individual managerial or an intervention in smallholder broiler production affects financial performance.

Practical implications – To mitigate risk associated with this novel enterprise, producers should consider overstocking birds. If local markets for manure were developed, the risks faced by new or beginning poultry operators could be mitigated.

Originality/value – A stochastic, discounted cash flow model calculator was used to determine the NPV and discounted payback period of operator investments and operating cash flows, including time, materials and capital.

Keywords Poultry, Rwanda, Financial returns, Smallholder

Paper type Research paper

Introduction

Development of an agricultural sector creates employment opportunities, access to markets, increased income and food security (Mellor, 1976). In line with this reasoning, Rwanda's Ministry of Agriculture released a "Strategic investment plan to strengthen the poultry industry" in 2012 (MINAGRI, 2012). The plan's objective was to increase income opportunities and the nutritional status and wellbeing of women, children and poorer rural households by encouraging investment in the poultry sector. In 2016, there were 5.14m live

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chickens produced in Rwanda, yielding 17,014 tons of chicken meat (FAOSTAT, 2018). In 2012, Rwanda's share of the total quantity of poultry meat produced in the East African region was 2 percent (MINAGRI, 2012).

In an effort to encourage private investment in the livestock sector, the Government of Rwanda exempts feed mill operations from paying value added taxes. There are currently three privately owned feed mills operating in Rwanda, and because of increased demand for placement of birds, investment in hatcheries has followed (Linden, 2016). When quality feed is available, broilers are comparatively efficient relative to other livestock in terms of converting feed to protein. Broiler production does not typically compete with subsistence or cash crops for space (Assa, 2012). However, in Rwanda the barriers impeding the adoption of broilers include relatively high investment in coop materials, access to quality feed, variably in feed quality, a reliable supply of quality chicks and vaccines (Mbuza *et al.*, 2017). Local experience growing broilers in confined spaces is also limited.

In their survey of poultry farms in Kigali and surrounding provinces, Mbuza *et al.* (2017) estimated that 46 percent of the operations managed between 100 and 500 birds per cycle (~5 cycles per year). Mbuza *et al.* reported that operators slaughtered birds, on average, at day 60, which is likely uneconomical for most operations. Under ideal growing conditions, a 1.8-kg broiler is ready for market in about 43 days. Most operators (48 percent) marketed 8-week old or younger birds through contracts, and older birds through direct live market sales (Mbuza *et al.*, 2017). In a recent financial and economic cost-benefit analysis of Rwanda's poultry value chain, Jenkins *et al.* (2016) estimated an internal rate of return (IRR) of 50 percent, with an estimated net present value (NPV) of 18.75m Rwandan francs (RWF) for a 1,000-broiler per cycle operation[1]. Jenkins *et al.* concluded that while the financial analysis suggested enterprise profitability, volatility in chicken meat prices dissuades farmers from starting up or continuing broiler production.

The objective of this study is to analyze the financial feasibility of small-scale broiler operations producing five cycles per year in Musanze District, Rwanda, under input cost and broiler price uncertainty. Musanze District is located in Northwest Rwanda and borders Uganda and the Democratic Republic of Congo. Investment, cost, production and broiler price data were collected from producers participating in a pilot program. The pilot program assists producers with financing operations through loans and technical support. "Small-scale" is defined here as 100 birds per cycle operations (11 birds/m^2) with five cycles per year. Jenkins *et al.*'s financial cost-benefit model for broiler operations in Rwanda is augmented to reflect production and price risk uncertainty for this size operation. The assumed investment horizon is 20 years, consistent with previous financial poultry analysis in Rwanda (Jenkins *et al.*, 2016). Five management scenarios are compared to a baseline model, including adjusting stocking rates in anticipation of flock mortality, increasing the grace period after which participants pay to receive technical assistance, selling broilers at a spot market (farm-gate) price, selling broilers at a contract price and selling chicken manure. Stochastic dominance is used to compare the profitability corresponding with each scenario. We find that when the broiler price and the costs of inputs are stochastic, the probability of realizing a negative NPV ranges between 38 and 52 percent. Developing markets for poultry manure and using a "10-percent" stocking rule for new chicks increases the likelihood of generating positive net returns for smallholder broiler producers.

Broiler project

The target population of the broiler program is smallholder households in Musanze district, located in Rwanda's Northern Province. The objective of the program is to increase the production of broiler chickens by 750 smallholder households, enrolled over three years, with the goals of increasing rural smallholder income and improving household nutritional status by increasing protein consumption. Of the three commercial feed mills in Rwanda, one is located in Musanze. The Musanze mill is a private capital venture that manufactures quality-certified broiler feed. The feed mill assists producers with loan financing of initial capital expenses for small-scale broiler production. Participating farmers are eligible to receive one-time, zero-interest loans to finance the materials and construction of a single 9.29 m^2 (100 square foot) chicken coop, including drinkers and feeders.

Local production of quality chicks is limited; chicks are usually imported from South Africa, Uganda, Belgium or the Netherlands. The preferred broiler stock is the Cobb-500 variety, yet most flocks are the Ross-308 variety. The feed mill also provides participants a recurring line of credit for purchasing chicks and feed, payable with interest through cash earnings or live sales to the mill at an agreed price for processing and distribution. In addition, the mill provides technical assistance for farmers, including putting selected participants through a three-day training course, and logistical and technical assistance with all aspects of broiler production by assigned service technicians.

Operation investment

Details of a typical operating budget, including capacity, capital, and expected costs and prices are summarized in Table I. An enrolled farmer's broiler production target is 500 birds per year, with the number of animals evenly distributed over five cycles. A target production cycle is 63 days; 43 days for growout, interrupted by three-weeks for disinfection and pathogen control. The initial investment included a 9.29 m^2 coop, a feeder, drinker and clay pots, financed with a loan of RWF 527,861, payable in installments starting at the end of the first cycle. Day-old-chicks (DOC) were purchased from a private vendor at RWF 680/chick. The program was designed under the assumption that one person could manage a coop. In 2017, the average wage rate for labor was RWF 5,238/month. Table I also provides

Category	Variable	Units	Min.	Mean	Max.
Scale	Production capacity	birds per cycle		100	
	Production cycle	days		63	
	Number of cycles	cycles per year		5	
Investment	Coop	RWF		485,261	
	Feeder	RWF		31,600	
	Drinkers	RWF		7,600	
	Clay Pots	RWF		3,400	
Labor	Persons	#		1	
	Technician wage	RWF/mo		5,238	
Operating	Vaccines[a]	RWF/bird	2	5.17	8
	Charcoal[a]	RWF/mo.	4,285	12,960	15,714
	Water[a]	RWF/mo.	1,428	1,546	1,667
	Bedding[a]	RWF/mo.	0	1,447	2,476
	Disinfectant[a]	RWF/mo.	714	714	714
Production	Feeding per cycle	kg/bird	2.13	5.68	8.97
	Carcass weight[a]	kg/bird	1.10	2.68	3.30
	Mortality rate of flock[a]	%	0.00%	8.20%	39.00%
	Broilers sold at farm gate[a]	birds per cycle	61	91.8	100
	Poultry mix feed[a]	RWF/kg	310	350	380
	DOCs (Broilers)	RWF/bird		680	
	Broilers at farm gate[a]	RWF/kg	1,151.5	1,370.8	2,219.4
Discount rate	Interest rate	%		17%	

Notes: RWF, Rwandan Franc. [a]Stochastic variable
Source: Authors' field data

Table I.
Broiler operation production and costs

operating costs and production outputs. A projected break-even point would be the sale of 63 1.8-kg live birds per cycle, with profit of RWF 2,000 (approximately \$3) per bird sold above this point.

Broiler production and cost data

From September 16, 2017 to April 23, 2018, 74 project participants completed up to three nine-week production cycles. Project technicians assisting new farmers collected cost, production and marketing data (Table I), resulting in 125 records. Charcoal, used to warm coops during cool weather, varied in costs ranging between 4,285 and RWF 15,714/month (RWF/mo). Some producers made their own bedding, while others purchased materials (average monthly cost, RWF 1,447). Disinfectant costs were constant across operations at RWF 714/mo.

The number of birds sold at the farm gate ranged between 61 and 100, with an average of 92 birds per cycle. Restaurants made up 42 percent of the revenue generated by sales, followed by local traders (25 percent), butchers (22 percent) and hotels (11 percent). The median number of birds consumed by household members was 2. Remaining shortfalls were due to mortality. During the period of data collection, the median number of days per cycle was 48, with an average live weight per bird of 2.68 kg at market, greater than the break-even target weight. The average feed consumed per bird each cycle was 5.68 kg. The cost of feed was constant during the data collection period at RWF 350/kg, but the Musanze mill reported a two-year low (high) price of RWF 310 (380)/kg. The three feed mills in Rwanda are trying to stabilize the price of commercial feed and absorb the risk of volatile fluctuations in local markets for raw ingredients of feed by forward contracting and other risk-mitigating purchase strategies with the intent to mitigate price variability that would eventually be absorbed by smallholder producers. The feed costs we observed and used reflect these efforts by the mill in Musanze. Flock mortality rate ranged between 0 and 39 percent, with a sample average of 8.2 percent. The farm-gate price received was RWF 1,371/kg live weight, with a minimum (maximum) price of RWF 1,152 (2,219)/kg.

Methods

The study examines the feasibility and profitability of a smallholder broiler operation over a 20-year planning horizon. The measure of profitability is project NPV. Stochastic simulations are also performed. We do not compute the internal rate of return (IRR) during the stochastic simulations because the probability of forecasting negative cash flows at different points throughout the investment horizon was relatively high. In simulations where there is a high probability of generating non-normal cash flows, defined as having negative cash flows after positive cash flows have commenced (i.e. cash flows changing sign more than once), the interpretation of the IRR may be misleading or inestimable (Brigham and Houston, 2015). However, project rankings, when ordered according to NPV, will follow the same order when ranked with IRR (Boardman *et al.*, 2001).

Net present value

NPV is used to value operating and investing cash flows by discounting cash flows using the investor's expected rate of return. The NPV is calculated over a 20-year planning horizon as:

$$NPV = -C_{Inv} + \sum_{t=1}^{20} \frac{NCF_t}{(1+r)^t}, \tag{1}$$

where C_{Inv} is the initial investment cost; r is the expected rate of return (or discount rate); t are years from the first production period ($t = 1$) to the project's end, with each year including five production cycles. A 20-year planning horizon was chosen in order to more directly compare to previous analysis of poultry production in Rwanda (Jenkins *et al.*, 2016). An interest rate of 17 percent was used to discount cash flows. This interest rate was obtained from the average of monthly lending interest rates for Rwanda from July 2016 through June 2018 (National Bank of Rwanda, 2018). The assumption regarding the expected rate of return, r, is that broiler producers expect to earn an annual rate of return similar to what is expected by an average bank grating loans in Rwanda. In this particular context, we assume a capital structure close to 100 percent equity, with a 17 percent per year expected return on equity[2]. Reinvestment in a coop (e.g. board replacement, screens) is expected to occur every ten years. Equipment is also expected to be replaced every four years.

Investment costs (C_{Inv}), including the costs of adult feeders, chick feed plates, a drinker, a clay pot, and coop construction and material costs (RWF 527,861; Table I) are paid at the beginning of the project ($t=0$). Annual net cash flows (NCF) are calculated based on five production cycles, with a target of 100 broilers per cycle. The NCF earned by the operator are calculated as:

$$NCF_t = R_t - C_t + D_t - I_t, \quad (2)$$

where R_t is the revenue from live broilers sales and C_t are fixed and variable operation costs. The variable D_t is depreciation, a non-cash cost included in C_t, added back to operating profits after income taxes to estimate cash flows. The variable I_t represents subsequent investments such as re-investment in equipment every four years and in the coop building in year 10. Annual revenue is a function of the price received for broilers at the farm gate (P_t^{BR}, in RWF/kg), the average bird weight ($\overline{WT}_t$, kg/bird), DOC purchased at the beginning of the cycle (Q_t^{DOC}, birds), and the percent flock mortality (m). Data from farm records indicated that the quantity of broilers produced varied across operations. The most common cause of variation in broiler production was mortality and differences in feed conversion. Feed conversion ratios may vary due to bird stress, operator attentiveness or skill, or diminished quality in feed (Wenk *et al.*, 1980). Feed conversion ratios were calculated as the total kilograms of feed consumed divided by the total weight of the flock, per cycle. Project technicians calculated average broiler weight at sale using the weight of a sample of ten birds from the flock. Thus, annual revenue is:

$$R_t = P_t^{BR} \cdot \left(Q_t^{\mathrm{DOC}} \cdot (1-m) \cdot \overline{WT}_t \right). \quad (3)$$

Households participating in the project consumed, on average, two birds every production cycle. These consumed birds are considered revenue in kind and were excluded from the financial calculations. The costs of producing the consumed birds are included but their value is not considered in the net revenue calculations. Participants typically sell an entire flock at one price. Broiler prices vary more if operators sell their birds at spot market (farm gate) prices as opposed to a contract price offered by the feed mill.

Total costs of production in period t (in RWF) are calculated as:

$$C_t = F_t + V_t, \quad (4)$$

where F is technical support fee, and V variable operating costs, respectively. The coop building was straight line-depreciated at 5 percent. Taxes apply to revenue from private operations exceeding RWF 12m per year. Taxes are not included, given the relatively small size of the operations.

Variable costs include the costs of charcoal (a heating source), water, supply of feed, vaccines, DOC, bedding, labor and disinfectant costs (Table I). Total annual feed costs ($c_{Feed,t}$, RWF per year) are calculated with three variables: the average amount of feed consumed per bird, per cycle (*Feed*); the expected per kilogram price of broiler feed (P_t^{Feed}); and the planned annual number of birds (5 cycles×100 birds/cycle). The calculation is $c_{Feed,t} = 500 \cdot Feed_t \cdot P_t^{Feed}$. The total annual costs of DOC is determined as the expected number of broilers produced over five cycles ($Q_t^{DOC} = 500$ birds) times the per unit price of DOC (P_t^{DOC}). The number of DOCs purchased at the beginning of a cycle could be adjusted to buffer against losses due to mortality.

Labor costs include wages paid to support technicians (technical support fee, *F*). Technicians assist participants with feeding, coop cleaning and maintenance, bird health and market logistics. Participants are contractually required to pay an RWF 11,000 per cycle technician fee, starting after the third production cycle (a grace period). Averaged over all production cycle days (63), the average monthly wage (wage) paid to technicians was RWF 5,238.

Inflationary trend

All costs and prices were assumed to increase exponentially at an annual rate of inflation. An inflationary index reflecting this assumption is $I_t = (1+i) \cdot I_{t-1}$. The index is benchmarked to 2016 ($I_{2016} = 1$) and calculated to 2036. The expected rate of inflation (i) for Rwanda was 5 percent (Jenkins *et al.*, 2016). For each period, the costs and prices determining NCF to the broiler operation were adjusted with this index.

Monte Carlo simulation

On-farm data on operating costs and production were collected during the study. Variables exhibiting variation across operations included variable operation costs, bird production and farm gate prices. Stochastic operating costs included the price of charcoal, vaccines and disinfectant, bedding and water costs (Table I). Each of these inputs is vulnerable to local variations in prices. The amount of charcoal used during a cycle may also vary, depending on temperature. The average number of 50 kg bags of charcoal purchased was 2.94 ± 0.90 (2×standard deviation). Stochastic variables relating to production included average carcass weight, mortality rate, the price of broiler feed and the farm gate price of broilers (Table I). Thus, for any given period, stochastic revenues are calculated as:

$$\tilde{R}_t = \tilde{P}_t^{BR} \cdot \left[Q_t^{DOC} \cdot \left(1 - \tilde{m}\right) \cdot \widetilde{WT}_t \right], \tag{5}$$

where the "~" indicates a random variable. Annual costs are also stochastic due to variation in the operating costs of charcoal, water, bedding and disinfectant, as well as broiler feed costs.

Distributions of the stochastic variables

The stochastic price of broiler feed was simulated using a PERT distribution. The PERT distribution is parameterized with the maximum, minimum and most likely values of broiler feed prices reported by the mill (Clemen and Reilly, 2001). The feed price was relatively constant during the period of data collection, but in the medium term, broiler feed prices paid by producers might be sensitive to supply shocks in grain markets. Mills eventually pass on the higher costs of grains to broiler operators by adjusting feed mix prices. The parameters used for the PERT distribution of feed price are the mill feed prices, with minimum, expected and maximum values of RWF 310, 350 and 380/kg, respectively (Table I), observed from 2015 to 2017.

All other stochastic variables used in the financial model were bootstrapped from their observed distributions collected during the study ($n = 125$ records). The bootstrap method resamples, with replacement, prices, costs, input quantities and average bird weight observed in the data record. Each record has an equally likely chance of selection. The procedure generates an empirical distribution of a variable of interest, which, in the theoretical limit, approaches the true distribution of a population. The only distributional assumption required is that the records are independent and identically distributed. This is a reasonable assumption in this current context, given the size of the operations and their private ownership status.

Stochastic price index

The price index used to introduce inflationary effects into the NPV calculations assumes that the rate of inflation (i) is constant over the project's planning horizon. The stochastic analysis assumes that inflation in Rwanda's economy evolves as a Brownian process. The Heath-Jarrow-Morton method for simulating interest rate behavior was applied (Heath *et al.*, 1992; Jarrow and Yildirim, 2003; Mercurio, 2005). These inflation option pricing models incorporate Brownian motion to capture the randomness of inflationary trends over time (Waldenberger, 2017). Rwanda's inflation rate assumes that the series trends around a historical mean inflation rate μ with standard deviation σ (i.e. volatility). A "drift coefficient," $\delta = (1/(T-1))$ ($T = 20$, the project lifetime) determines the trajectory of the trend. The inflation rate with Brownian motion is calculated as:

$$\tilde{i}_t = \tilde{i}_{t-1} \cdot \left(1 + \mu \cdot \delta + \sigma \cdot \sqrt{\delta}\right) \cdot \gamma, \tag{6}$$

where γ is a normal random variable with mean 0 and a standard deviation of 1. The stochastic price inflators are then calculated as:

$$\tilde{I}_t = \tilde{I}_{t-1} \cdot \left(1 + \tilde{i}_t\right), \tag{7}$$

and subsequently used to calculate the stochastic NPV:

$$\widetilde{NPV} = -C_{Inv} + \sum_{t=1}^{20} \frac{\tilde{I}_t \cdot \widetilde{NCF}_t}{(1+r)^t}, \tag{8}$$

Management and market scenarios

The NPV model formulated above is a baseline scenario. Five additional scenarios are compared with the baseline results (Table II). Scenario S1 assumes that the producer adjusts coop stocking rate by an expected flock mortality of 5 percent. Producers have a prior expectation about flock mortality and adjust coop stocking accordingly. The adjustment entails purchasing five extra DOCs at the beginning of the cycle. However, flock mortality remains stochastic in the NPV calculations. The total costs of DOC purchases and feeding costs are adjusted accordingly. Thus, instead of stocking 11 DOC/m^2, the flock mortality adjustment policy increases stocking density to 12 DOC/m^2.

Scenario		Alteration from baseline
Baseline	Name	None
S1	Stocking rate adjustment	Assume 5% Mortality, increase stocking rate by 5%, adjust feed and vaccination costs
S2	Extended grace period	Increase grace period to pay a technician from 3 cycles to 5 cycles
S3	Spot price	Re-sample broiler price from producers who sold at the spot market price
S4	Contract price	Re-sample broiler price from producers who sold at a contract price
S5	Sell Manure	Sell manure produced by the broiler operation

Table II. Scenarios compared in the risk analysis of smallholder broiler operations

Scenario S2 increases the grace period before the producer pays technician salaries. Rather than the three-cycle grace period where participants were contracted to begin payments for technical services, the grace period is extended to five cycles.

Scenarios S3 and S4 consider two marketing options for producers. Of the 125 farm gate transactions recorded, 64 sales were based on prices negotiated between the broiler producer and a vendor (a "spot price," minimum = RWF 1,152, median = RWF 1,347, maximum = RWF 2,219/kg). Calculations based on broiler spot prices are called scenario S3. The stochastic distribution of the spot price was determined by randomly drawing, with replacement, prices received by the 64 spot price transactions. The remaining 61 transactions were based on a contract ("flat rate") price common to producers and a purchasing contractor. Previous research finds that contract farming may encourage smallholders to adopt best food production practices (Kumar *et al.*, 2017). However, in other cases contract farming could pass risk on to smallholder and instead encourage larger operations to adopt interventions (Mwambi *et al.*, 2016). The variation of the contract price (minimum = RWF 1,323, median = RWF 1,360, maximum = RWF 1,432/kg) was lower than that of spot price transactions. The NPVs calculated only from the contract price series are scenario 4 (S4). Due to the greater range of prices in the spot price group (S3), the variation around NCF for this scenario is expected to be greater than the NPV estimate of S4.

No manure sales were recorded during the study. However, selling manure is an opportunity to add value to broiler operations. Challenges remain, especially for smaller-scale operations, with respect to transport logistics and costs and on-site storage and handling. In scenario 5 (S5), a producer packages and sells poultry manure. In this hypothetical example, the costs associated with selling manure are expected to be negligible. It is assumed that old feed bags are used for manure bags, the household's labor is used to bag manure, and the buyer covers transportation costs. A single project coop produces five 40 kg bags of manure per cycle. Information from broiler and egg laying operations collected during field visits indicated a minimum, most likely and maximum per bag sale price of RWF 719, 1,562 and 3,199. A PERT distribution was used to model the expected price received for manure, assuming an operator could sell all bags produced. Because the sale of manure creates additional revenue for the operation, NPV is expected to increase.

Simulation software

The Monte Carlo analysis was performed using @Risk software (Palisade, 2010). The simulation was conducted using 5,000 iterations, with the expectation that this number of draws was sufficient to account for variation within the system (Dušan *et al.*, 2012). A fixed seed was used for all scenarios. Fixing the seed to a constant for all scenarios facilitates comparison of the NPVs generated under the different assumptions.

Comparison of scenarios and risk

The simulated empirical distributions of the NPV from each scenario are compared to their respective baseline scenarios. Three methods of comparison are used; chance of loss, stochastic dominance, and cash flows sensitivity to broiler price and input costs. The chance of loss accumulates the number of simulation trials where the NPV was negative (Hardaker *et al.*, 2015). This accumulated number of negative trials divided by the total 5,000 simulations is the probability that both the producer and financer would earn, on average, an annual rate of return below their expectation (i.e. 17 percent).

The second method compares the empirical distributions of the NPV of each scenario using first-degree and second-degree stochastic dominance (SDSD). Stochastic dominance ranks risky alternatives by comparing their respective cumulative distributions. The stochastic dominance method does not require assumptions about the decision maker's utility function, but does require assumptions about the decision maker (Hadar and Russell, 1969).

Assumptions made about the decision maker are: (i) they prefer more to less and (ii) they prefer to avoid lower-value outcomes (Lambert and Lowenberg-DeBoer, 2003). Assumption (ii) omits higher-value outcomes as most people enjoy the up-side variability of typical outcomes being measured such as profits and yields.

First-degree stochastic dominance (FDSD) only assumes that the decision-maker prefers more rather than less. If one NPV cumulative distribution function (CDF) lays entirely below or to the right of another, the distribution to the right dominates the other one because it results in a higher outcome at every probability level compared to the other alternative. Another way to say this is that for alternatives A and B with cumulative distribution functions (CDF's) $F_A(x)$ and $F_B(x)$, A dominates B when $F_A(x) < F_B(x)$ (Mas-Colell *et al.*, 1995).

SDSD assumes the decision maker is risk averse. A measure of the potential an alternative has for a low outcome is the area under the CDF for that alternative. An alternative is FDSD dominant over another if the area under its CDF is smaller at every level of outcome. However, with SDSD, the distributions may cross. In the case of an alternative's cumulative distribution for NPV that starts right of an alternative's CDF and crosses over only once, the distribution to the right at the horizontal axis dominates if the area between the CDFs below the crossover point is larger than the area between the distributions above the intersection (Lambert and Lowenberg-DeBoer, 2003).

A two-sample Kolmogorov-Smirnov (KS) statistical test provides additional information about distribution comparisons by providing the maximum vertical distance between the two CDFs being compared (D-statistic), and provides a statistical significance level to determine whether to reject the null hypothesis that the distributions are equal. When the "distance" between the two distributions is significantly different from zero, the null hypothesis that the distributions are the same is rejected. Note that the KS test need not indicate that two distributions are different for first or second-degree SD results to hold.

Net present value sensitivity to price and input cost

The last comparative approach analyzes the effects of a change in broiler price or input costs on the NPV of cash flows between the baseline model, and the spot price and contract scenarios (scenarios S3 and S4, respectively). The *ceteris paribus* change in prices and cost are ranked in order of their effects on NPV. The variable causing the largest range difference in the population of Monte Carlo draws (NPV maximum – NPV minimum) is ranked first, followed by the second, and so on. The variable causing the least difference between the simulation output's maximum and minimum NPV ranks last.

Results

The baseline NPV was RWF −81,062, with a corresponding chance of generating a negative NPV project of 49.8 percent (Figure 1, Table III). In the baseline scenario, NPV appears to be most sensitive to the average weight of birds at the time of sales (Figure 2). This is a counterintuitive outcome because it suggests that keeping birds longer than the 43-day grow-out target increases NPV. However, such a management strategy may be uneconomical because older, larger birds convert feed to protein less efficiently than younger, smaller birds. The low (RWF −2.79m) and high (RWF 1.5m) bars at the top of Figure 2 corresponded with an average bird weight of 1.1 and 3.03 kg/bird, respectively. In all of the simulations, feed prices appear to be a relatively minor driver in profitability (Figure 2). This occurs because of the relative variability of feed costs to other input costs and broiler prices. Feed mills in Rwanda are trying to stabilize the price of commercial feed and absorb volatile price fluctuations in local markets for raw feed ingredients. That stabilization helps to reduce the volatility of commercial feed prices. The feed costs we observed and used reflect the mill's stabilization effort, and could be the reason why feed costs were a less important driver of profitability.

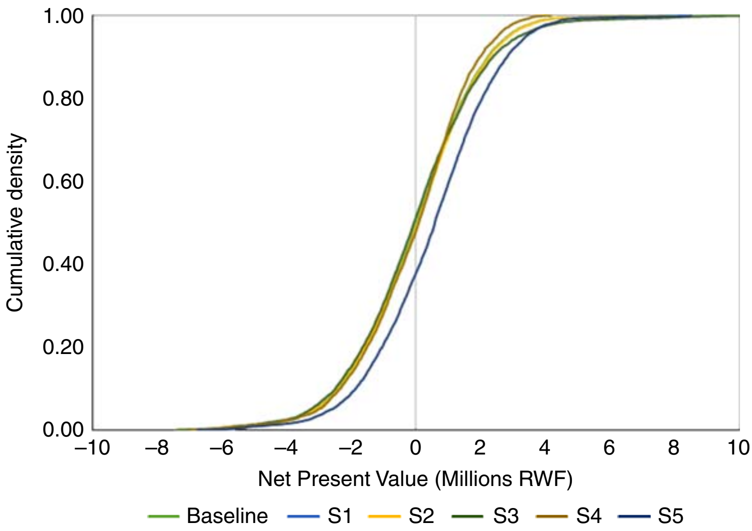
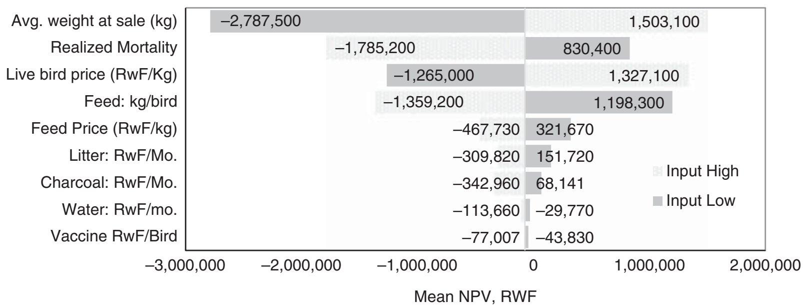


Figure 1.
Net present value distributions

Table III.
Summary statistics of net present values (NPV), in RWF

Scenario	Min.	Mean	Max.	5% lower bound	95% upper bound	SD	Chance of loss (%)
Baseline	−7,340,133	−81,062	8,131,321	−3,187,040	2,832,339	1,899,360	49.8
S1: adjust stocking	−7,256,623	314,057	8,955,230	−2,928,942	3,331,810	1,979,277	41.7
S2: extend grace period	−7,300,277	−41,205	8,171,178	−3,147,183	2,872,196	1,899,360	49.0
S3: spot price	−7,416,141	−48,293	10,410,339	−3,259,131	3,170,404	2,076,874	51.5
S4: contract price	−6,956,317	−111,192	4,577,860	−3,026,215	2,512,740	1,735,022	48.2
S5: sell manure	−6,754,150	490,042	8,950,013	−2,649,154	3,389,708	1,904,872	38.1

Note: Chance of loss is the probability that the net present value is negative



Note: Values on the left of the bar are the mean NPV when the lowest value of the stochastic input is used while values on the right of the bar are the mean NPV when the highest value of the stochastic input is used

Figure 2.
Inputs ranked by effect on mean net present value (NPV) resulting from the baseline simulation

The baseline model's NPV was highly sensitive to flock mortality. Lower realized mortality rates correspond with higher cash flows and consequently a higher NPV. The third and fourth model inputs affecting variability in NPV were the live bird market price and feed consumption. Evaluated at the low (RWF 1,152/kg) and high (RWF 2,219/kg) broiler prices, the change from the NPV mean was RWF −1.26 and 1.33m.

Comparisons of scenarios with the baseline model

Adjusting stocking rates based on prior experience with mortality rates is a preferred strategy compared with the baseline model. On average, increasing the number of birds stocked by 5 percent was enough to offset losses due to mortality, generating a positive NPV of RWF 314,057 over the 20-year planning horizon (Table III). The chance of generating a negative NPV project was also lower (41.7 percent) compared with baseline model's NPV.

The variation around the expected NPV of scenario S1 was greater than the baseline case, but the minimum value (RWF −7.26m) was higher than the minimum NPV of the baseline (RWF −7.34m). Comparison of the minimum NPVs is an important distinction because it means that strategy S1 potentially dominates the baseline scenario by the first- or second-degree criteria. Visual inspection of the cumulative density functions (CDFs) of both trials indicates that adjusting coop stocking rates by 5 percent FDSD dominates the status quo practice of stocking 100 birds (Figure 1). The Kolmogorov-Smirnoff D-statistic, which statistically compares the distributions, is significantly different from zero, supporting further the potential advantage of this strategy over the status quo practice (Table IV).

Extending the grace period from three to five cycles (7 to 12 months) had comparatively little effect on NPV relative to the business-as-usual scenario. The expected NPV under scenario 2 was about half (RWF −41,205) of the baseline's expected NPV (RWF −81,062) (Table III). The chance of a negative NPV for S2 was not appreciably different from the baseline model's chance of a negative NPV, and the variation around the expected NPVs was the same. Visual comparison suggests that the NPV distributions of S2 and the baseline are practically indistinguishable (Figure 2). The Kolmogorov-Smirnoff two-sample distribution test confirms the conclusion drawn from the graphical comparison ($D = 0.0124$, $P = 0.837$). Factored into a 20-year period and discounted, the difference in payback costs is not that great. The average operating costs from the observed data is about RWF 282,000/cycle, which totals to RWF 5.64m over the 20 years evaluation period. Paying for technical assistance over an entire year costs RWF 1.067m with a three-cycle grace period and RWF 1.045m with a five-cycle grace period. Revenue for both is not different nor are investment or finance costs.

The spot price scenario (S3) generated an expected NPV of RWF −48,293, with a corresponding chance of a negative NPV project of 51.5 percent (Table III). The variation of expected net returns over the planning horizon was largest for S3 compared to all other scenarios (standard deviation, RWF 2.076m). The comparatively large dispersion around the NPV mean of S3 is caused by the variation observed in the spot price transactions.

Table IV. Stochastic dominance analysis and Kolmogorov-Smirnoff statistics: baseline and scenarios

	Dominant scenario	Degree	*D*-statistic	*p*-value
Baseline vs S1	S1	FDSD	0.0980	< 0.0001
Baseline vs S2	S2	FDSD	0.0124	0.837
Baseline vs S3	–	–	0.0198	0.281
Baseline vs S4	–	–	0.0332	0.008
S3 vs S4	–	–	0.0456	< 0.0001
Baseline vs S5	S5	FDSD	0.1314	< 0.0001

Notes: First Degree Stochastic Dominant (FDSD); Inconclusive (–)

The spot price NPV distribution is similar to the baseline NPV's distribution up to the 85 percentile, past which the NPV of S3 is always to the right of the baseline NPV (Figure 2). This occurs because the distribution of the spot price data series is right-skewed. When the operator agreed to a contract price, the expected NPV was lower (RWF −111,192) than the spot rice and the baseline NPV, but the standard deviation of the NPV was lowest among all scenarios (RWF 1.735m). This occurs because the contract price offered to producers is less volatile than the spot price negotiated at the farm gate. The chance of loss associated with S4 NCF was 48.2 percent, which is slightly lower than the baseline chance of loss. However, examination of the upper tails of the baseline and contracted price NPV indicates that past the 70th percentile of the respective CDFs, NCF from the baseline model are always greater than S4. From the risk-averse producer's standpoint, S3 and S4 could not be differentiated from the baseline model (i.e. no strategy FDSD or SDSD-dominated) (Table IV). However, the distributions were statistically different.

Selling manure adds value to the broiler operation. The expected NPV generated under scenario 5 was RWF 0.490m with a standard deviation of RWF 1.904 (Table III). The NPV from this scenario was highest compared to the other scenarios, and the chance of loss was smallest at 38.1 percent. Visual inspection of the respective CDFs indicates that the distribution of discounted NCF from S5 is, at every probability, always to the right of the baseline. Therefore, S5 also dominates the baseline scenario by the first-degree order. The KS two-sample test confirms this result ($D = 0.13$, $p < 0.0001$).

Conclusion

Development of agriculture's private sector could increase food security, augment household income and improve access to protein. Recent efforts by several East African governments have focused on the development of poultry value chains to meet this broader development objective. A feed mill in Rwanda's Musanze District is working with farmers to develop local poultry value chains. This research developed a stochastic financial model to determine which factors affect most the returns to smallholder broiler operations based on the project parameters.

The financial risk analysis found that under the project's current structure, the probability of experiencing a negative NPV over a 20-year horizon was 49.8 percent. Changing project parameters by developing markets for poultry manure, increasing the stocking density of DOCs and increasing the grace period after which technical assistants are paid improve expected profitability compared to the baseline. For example, selling the manure produced by the operation could reduce the chance of experiencing a negative NPV by 12 percentage points from the baseline to 38 percent. The analysis also found that significant returns are possible by adjusting DOC stocking rates to compensate for flock mortality.

The sale of manure would create an additional revenue stream for smallholders, improving the likelihood of achieving a positive project NPV to 62 percent. However, local demand for manure is currently unknown, along with the extra cost of manure storage, transport and handling. This finding is consistent with the expectation that manure sales would improve revenues without much effect on the variance of discounted NCF. No labor costs were assumed for the collection, storage and distribution of manure. Those costs would reduce the benefit of this additional revenue stream to the producer, so these results may be overstated.

The extension of the grace period before the producers are responsible for paying for technical assistance by two cycles, from three to five cycles, modestly improved NPV outcomes, but the empirical CDFs were statistically different. Under the project's current structure, the technical service fee is a required payment. These results are expected, and demonstrate the value of reducing the financial burden and allow for potentially better NCF.

Overall, the analysis demonstrates how individual management or an intervention in smallholder broiler production affects broiler operation financial performance. However, the strategies considered here are not necessarily mutually exclusive. An ideal strategy may include a combination of the scenarios evaluated in this study. For example, a producer could sell the manure produced by their operation and purchase additional DOCs to safeguard against expected flock mortality. Under the project parameters evaluated in this study, the profitability of small-scale poultry production in Rwanda's Musanze District is an uncertain and risky venture, with our simulations suggesting a 50/50 chance of generating positive returns on investment. The fragile prospect of operation profitability could become even more tenuous if the mill's input purchasing policies changed. If the mill was unable to buffer smallholder producers from shocks along the feed input supply chain, then this volatility would be passed on to broiler operators who would likely switch over to lower quality feed and decrease the operation's production efficiency. Indeed, as Feder *et al.* (2011) note, while private-sector investment in the development of new value chains does circumvent some inefficiencies that may burden public extension, it does not occur in a vacuum. With experiential learning, the development of farmer-to-farmer networks, and low-cost technical support, producers can further reduce the down side risk associated with small-scale production. In addition, data used for this risk analysis were collected only from the first 125 cycles of producers in this smallholder broiler project. With the project's aim of enrolling 750 smallholders in broiler production over the course of three years, it can be expected that further production efficiencies will be identified to reduce the down side risk. Given the project's novelty, it may not be surprising that a smallholder poultry enterprise is an uncertain and risky proposition. A long-term understanding of the external drivers affecting local poultry value chain dynamics would require a more complex agent-based modeling strategy (Orr *et al.*, 2018). As with any venture, there are associated risks, but the results of the stochastic baseline and scenario analysis provides a nuanced understanding of the financial risks so that programs and policies can be more effective at achieving dietary and financial improvements in disadvantaged populations.

Notes

1. The currency exchange rate was RWF840 to USD1 in 2017 (XE, 2018).
2. This expectation is aligned with the fact that at the beginning of the project producers have "zero" equity, but equity increases rapidly as producers repay the loan. After year three, when the loan is fully re-paid, poultry producers would only have credit lines (short-term loans) payable at selling time, with the capital structure at the end of each year being approximately 100 percent equity.

References

Assa, M.M. (2012), "Poultry production and rural poverty among small-scale farmers in Mzimba District of Malawi", *Livestock Research for Rural Development*, Vol. 24, Article No. 177, available at: www.lrrd.org/lrrd24/10/assa24177.htm (accessed October 7, 2019).

Boardman, A.E., Greenberg, D.H., Vining, A.R. and Weimer, D.L. (2001), *Cost-Benefit Analysis Concepts and Practice*, 2nd ed., Prentice Hall, Upper Saddle River, NJ.

Brigham, E. and Houston, J. (2015), *Fundamentals of Financial Management*, 8th ed., Cengage Learning, Mason, OH.

Clemen, R.T. and Reilly, T. (2001), *Making Hard Decisions With Decision Tools*, South-Western Cengage Learning, Mason, OH.

Dušan, Đ.O., Slavko, J.P., Predrag, I.R. and Dragoljub, M.B. (2012), "Accuracy of reliability calculated by the Monte Carlo simulation method", *Military Technical Courier*, Vol. 60 No. 4, pp. 47-58.

FAOSTAT (2018), "Livestock production, poultry meat production", available at: http://faostat.fao.org/site/569/default.aspx#ancor (accessed October 7, 2019).

Feder, G., Birner, R. and Anderson, J.R. (2011), "The private sector's role in agricultural extension systems: potential and limitations", *Journal of Agribusiness in Developing and Emerging Economies*, Vol. 1 No. 1, pp. 31-54.

Hadar, J. and Russell, W.R. (1969), "Rules for ordering uncertain prospects", *American Economic Review*, Vol. 59 No. 1, pp. 25-34.

Hardaker, J.B., Lien, G., Anderson, J.R. and Huirne, R.B.M. (2015), *Coping with Risk in Agriculture*, CABI Publishing, Wallingford and Cambridge, MA.

Heath, D., Jarrow, R. and Morton, A. (1992), "Bond pricing and the term structure of interest rates: a new methodology for contingent claims valuation", *Econometrica*, Vol. 60 No. 1, pp. 77-105.

Jarrow, R. and Yildirim, Y. (2003), "Pricing treasury inflation protected securities and related derivatives using an HJM model", *Journal of Finance and Quantitative Analysis*, Vol. 38 No. 2, pp. 337-358.

Jenkins, G.P., Miklyaev, M., Ujeneza, N., Afra, S., Nduguste, F.-X., Hashemi, M., Bitter, M. and Nzomoi, J. (2016), "Rwanda private sector driven agricultural growth project (PSDAG)", International Resources Group, Inc. report to the United States Agency for International Development/Rwanda, AID-696-C-14-00002.

Kumar, A., Devesh, R., Tripathi, G., Joshi, P.K. and Adhikari, R.P. (2017), "Does contract farming improve profits and food safety? Evidence from tomato cultivation in Nepal", *Journal of Agribusiness in Developing and Emerging Economies*, Vol. 8 No. 3, pp. 603-624.

Lambert, D.M. and Lowenberg-DeBoer, J. (2003), "Economic analysis of row spacing for corn and soybean", *Agronomy Journal*, Vol. 95, pp. 564-573.

Linden, J. (2016), "Rwandan farmers benefit from hatchery, feed mill", available at: www.wattagnet.com/articles/27187-rwandan-farmers-benefit-from-hatchery-feed-mill,WATTAgNet.com (accessed September 21, 2018).

Mas-Colell, A., Whinston, M.D. and Green, J.R. (1995), *Microeconomic Theory*, Oxford University Press, New York, NY.

Mbuza, F., Manishimwe, R., Mahoro, J., Simbankabo, T. and Nishimwe, K. (2017), "Characterization of broiler poultry production systems in Rwanda", *Tropical Animal Health and Production*, Vol. 49 No. 1, pp. 71-77.

Mellor, J.W. (1976), *The New Economics of Growth: A Strategy For India And The Developing World*, Cornell University Press, Ithaca, NY.

Mercurio, F. (2005), "Pricing inflation-indexed derivatives", *Quantitative Finance*, Vol. 5 No. 3, pp. 289-302.

MINAGRI (2012), "Strategic investment plan to strengthen the poultry industry in Rwanda", MINAGRI, Kigali.

Mwambi, M.M., Oduol, J., Mshenga, P. and Saidi, M. (2016), "Does contract farming improve smallholder income? The case of avocado farmers in Kenya", *Journal of Agribusiness in Developing and Emerging Economies*, Vol. 6 No. 1, pp. 2-20.

National Bank of Rwanda (2018), "Interest rate structure up to June 2018", available at: www.bnr.rw/index.php?id=88 (accessed October 7, 2019).

Orr, A., Donovan, J. and Stoian, D. (2018), "Smallholder value chains as complex adaptive systems: a conceptual framework", *Journal of Agribusiness in Developing and Emerging Economies*, Vol. 8 No. 1, pp. 14-33.

Palisade (2010), *@Risk: risk analysis and simulation add-in for Microsoft Excel*, Palisade Corporation, Ithaca, NY.

Waldenberger, S. (2017), "The affine inflation market models", *Applied Mathematical Finance*, Vol. 24 No. 4, pp. 281-301.

Wenk, C., Pfirter, H.P. and Bickel, H. (1980), "Energetic aspects of feed conversion in growing pigs", *Livestock Production Science*, Vol. 7 No. 5, pp. 483-495.

XE (2018), "USD to RWF Chart", XE Currency Charts, Euronet, available at: www.xe.com/xecurrencydata/ (accessed October 7, 2019).

Further reading

Marlow, D. (2015), *A Practitioner's Guide to Economic Decision Making in Asset Management*, Background and Guidance: IWA Publishing, London.

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