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Comparisons of economic values with and without risk for livestock trait improvement

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Abstract

This paper investigates the effect of incorporating risk in the derivation of economic values for livestock trait improvement. Two ways of obtaining economic values were contrasted, without consideration of risk (traditional economic values) and with incorporation of variance of profit and risk attitudes of livestock producers (risk-rated economic values). Traditional economic values were derived using a profit model, whereas risk-rated economic values were derived using a risk-rated profit model. A simplified example was considered for selection for the feedlot phase of beef production. One output trait (average daily gain) and one input trait (daily dry matter intake) and one management variable were considered. Risk was defined as the variance of profit and producer's risk attitude. Traditional economic values and risk-rated economic values differed in both absolute and relative terms. When relative economic values were considered, differences between traditional economic values and risk-rated economic values increased with risk premium. Differences were greater without optimisation of management than with optimisation, although in the example used there was limited impact on expected responses to selection in the component traits. Including risk preferences in breeding goals affects the cost–benefit analysis of breeding programs and might affect directions for selection.

Keywords: Economic values; Risk; Profit; Genetic improvement

1. Introduction

The effects of errors in economic values on the efficiency of index selection were investigated by Vandepitte and Hazel (1977). They found that an error in a single economic value larger than 50% resulted in suboptimal genetic gain. The use of incorrect economic values resulted in an incorrect selection criterion and therefore in suboptimal direction of selection. Amer and Hofer (1994) studied the effects of uncertainty in economic values on the expected response from index selection and concluded that in some situations, failure to account for uncertainty in parameters (such as economic values)

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leads to overestimation of the value of selection because of the assumption that true parameters are known. Expected responses from selection with uncertainty indicated that estimates of the benefits from genetic improvement should account for uncertainty, at least for traits dominating the index (Amer and Hofer, 1994).

Groen (1989) indicated that product prices influence relative contributions of improvement of animal traits to (economic) efficiency of production. Uncertainty over future product prices is an important factor and must be considered when deriving economic values. Hirooka and Sasaki (1998) found that, for some traits, there are significant year to year variations in economic values. In addition, prices of farm inputs and outputs are seldom known for certain at the time that a producer must make decisions, whether selection decisions, how much of which inputs to use, or what and how much of various products to produce. Increasingly, producers are exposed to unpredictable competitive markets for inputs and outputs, so that price (market) risk is often significant and may increase over time (Hardaker et al., 1997).

Profit models have been used by animal breeders to estimate economic values of traits (e.g. Wilton and Goddard, 1996). Profit models assume perfect knowledge of all relevant parameters. Ideally, animal breeders should use economic models that take into account the fact that knowledge is imperfect and economic circumstances are dynamic in time. The aim of the present study was to consider a model that accounts for imperfect knowledge concerning risk attitude of producers and variance of market prices.

The objectives of this study were to: (1) develop risk-rated economic values and algebraically compare these values with traditional economic values derived from a profit model; and (2) apply the method of estimating risk-rated economic values to a simplified example of livestock production to illustrate the difference between traditional and risk-rated economic values.

2. Methods

2.1. Theory

The most basic assumption of a production function is that a mathematical relationship exists between inputs (for example genetics and management choice variables) and outputs.

$$q = f(\mathbf{g_o}, \mathbf{x})$$

where q is an output quantity, $\mathbf{g_o}$ a vector of genetic traits (variables determined by the genotype of the animal), and $\mathbf{x}$ a vector of input variables chosen by a producer (management variables).

The profit equation is then:

$$y_t = \mathbf{p_o}[f(\mathbf{g}, \mathbf{x})] - \mathbf{p_i}\mathbf{x} \tag{1}$$

where y_t is the profit, $\mathbf{p_o}$ a vector of output prices, $\mathbf{p_i}$ a vector of input prices, and $f(\mathbf{g}, \mathbf{x})$, $\mathbf{g}$, $\mathbf{x}$ are as defined previously.

The general formulation of risk-rated profit, y_r, following Robinson and Barry (1987) is:

$$y_r = E(y_t) - 0.5\lambda\, Var(y_t) \tag{2}$$

where y_r is risk-rated profit, $E(y_t)$ expected profit, λ is the Arrow–Pratt coefficient of absolute risk aversion, and $Var(y_t)$ the variance of profit.

The Arrow–Pratt coefficient measures the intensity of an individual's aversion to risk. A value of zero indicates that a decision maker is risk neutral, meaning that he or she ranks alternatives according to their expected profitability, without regard for the other moments of the distribution of profits. Positive values of the Arrow–Pratt coefficient indicate that an individual requires higher expected returns when the distribution of profits has a positive variance. Higher values of the Arrow–Pratt coefficient indicate more intense aversion to risk.

Under risk conditions, distributions for both output and input prices are considered, such that each price can be defined as:

$$p_o = E(p_o) + \varepsilon_{po} = \mu_{po} + \varepsilon_{po}$$

$$p_i = E(p_i) + \varepsilon_{pi} = \mu_{pi} + \varepsilon_{pi}$$

where the random variables ε_{po} and ε_{pi} are assumed to be normally distributed and have expected values 0 and variances σ^2_{po} and σ^2_{pi} and covariances $\sigma_{po,pi}$, and μ_{po} and μ_{pi} are the expected values of output price and input price.

The expectation of profit, as defined in Eq. (1), is:

$$E(y_t) = \boldsymbol{\mu}_{\mathbf{po}} f(\mathbf{g}, \mathbf{x}) - \mathbf{x}\boldsymbol{\mu}_{\mathbf{pi}}. \tag{3}$$

Then the variance of profit, based on variability in output and input prices, is,

$$Var(y_t) = E[y_t - E(y_t)]^2 \tag{4}$$

Substituting expected profit (Eq. (3)) and variance of profit (Eq. (4)) into the risk-rated profit equation (Eq. (2)) gives,

$$\begin{aligned} y_r &= E(y_t) - 0.5\lambda\, Var(y_t) \\ &= \boldsymbol{\mu}_{\mathbf{po}} f(\mathbf{g}, \mathbf{x}) - \mathbf{x}\boldsymbol{\mu}_{\mathbf{pi}} - 0.5\lambda\, E[y_t - E(y_t)]^2 \end{aligned} \tag{5}$$

Economic values can be derived for both profit and risk-rated profit models, with and without optimisation of management. A management variable, x, can be chosen to maximize profit or risk-rated profit per animal, which occurs when $\partial y_t / \partial x = 0$, for the profit maximizing model and $\partial y_r / \partial x = 0$, for the risk-rated profit model. The maximum can be assured when the second derivative of the profit function is less than zero.

In general, for the profit model, the optimal value of x (x^*) depends on prices, costs and genotype of the animals, such that $\mathbf{x^*} = \mathbf{f}(\mathbf{p_o}, \mathbf{g}, \mathbf{p_i})$.

For the risk-rated profit model, x^* depends on variance of profit (variances of output and input prices, σ^2_{po} and σ^2_{pi}, and their covariance, $\sigma_{po\ pi}$) and the Arrow–Pratt coefficient of absolute risk aversion, such that $\mathbf{x^*} = \mathbf{f}(\boldsymbol{\mu}_{\mathbf{po}}, \boldsymbol{\mu}_{\mathbf{pi}}, \mathbf{g}, \lambda, \boldsymbol{\sigma}_{\mathbf{po}}{}^2, \boldsymbol{\sigma}_{\mathbf{pi}}{}^2, \boldsymbol{\sigma}_{\mathbf{po\ pi}})$.

Substitution of the optimal management variables, $\mathbf{x^*}$, into the profit or risk-rated profit equations gives the profit or risk-rated profit function. Profit and risk-rated profit functions reflect the solution to the firm's optimization problem. The economic value of incremental improvements in each trait is then simply the partial derivative of the profit or risk-rated profit function with respect to a trait:

$$v_{gt} = \partial y^*_t / \partial g, \tag{6}$$

for profit, and

$$v_{gr} = \partial y^*_r / \partial g \tag{7}$$

for risk-rated profit.

2.2. Application example

The derivation of economic values using profit (traditional economic values) and risk-rated profit (risk-rated economic values) is illustrated with an example for a population being selected for improvement in the feedlot phase of beef production. The intent was to illustrate the approach of accounting for risk and the process of comparing traditional and risk-rated economic values, the effect of optimization of management on traditional and risk-rated economic values, and the sensitivity of traditional and risk-rated economic values to price changes and levels of risk aversion.

The following simplified scenario was considered: animals enter the feedlot (feeding period) at 7 months of age (weighing about 250 kg), are fed a typical feedlot diet (fed ad libitum) with 1.85 Mcal net energy for maintenance per kg dietary dry matter (e.g. 70% corn grain, 30% alfalfa or corn silage) and stay on feed for 212 days (without optimization of management) as used by Wilton and Goddard (1996). Revenue per animal was assumed to be determined by average daily gain (in kg per day) and price per kg live weight and cost per animal was determined by daily dry matter intake (in kg per animal per day) and price per kg dry matter. The values of economic variables assumed were as follows: live slaughter cattle price either: (a) average of monthly price averages for 1992: $\mu_{po} = 1.94$ \$/kg (adjusted by the Consumer Price Index to 1992 dollars) and variance of live slaughter cattle price computed from monthly price averages for 1992, $\sigma^2_{po} = 0.004696$ (\$^{2}/kg^2) (Agriculture and Agri-Food Canada, 1992); or (b) average of annual averages for 1981–1993: $\mu_{po} = 2.34$ \$/kg (adjusted by the Consumer Price Index to 1992) and variance of live slaughter cattle price computed from annual averages for the 13 year period (1981–1993): $\sigma^2_{po} = 0.09$ (\$^{2}/kg^2) (Agriculture and Agri-Food Canada, 1982–1993).

Feed price $p_i = 0.28$ \$/kg DM (Wilton and Goddard, 1996), adjusted by the Consumer Price Index and variance of feed price, $\sigma^2_{pi} = 0.005625$ (\$^{2}/kg^2), which was calculated assuming a coefficient of variation of 0.25. The coefficient of variation of 0.25 was chosen as a close approximation to coefficient of variation values obtained for prices of corn (0.19), wheat (0.25), and hay (0.24) for the 1981–1997 period (OMAFRA, 1999).

The profit from a slaughter animal in the feedlot phase of production was then modelled as,

$$y_t = p_o[wt(x, g_1)] - p_i[\mathrm{addmi}(x, g_2)]x \tag{8}$$

where y_t, p_o, p_i, and x are as defined previously, but now used as scalars not as vectors, $wt(x,g_1)$ is the body weight (kg) of an animal, which was modelled as a quadratic function of the management variable days on feed (x) and the genetic trait, average daily gain, g_1, expressed as a deviation from the population or herd average and addmi(x,g_2) is the average daily dry matter intake in kg of dry matter during the feeding period, which was modelled as a quadratic function of the management variable (x) and the genetic trait, g_2, expressed as a fractional change in dry matter intake per day.

The genetic trait g_1 influences the amount of carcass produced. The genetic trait g_2 influences the amount of feed consumed. This formulation is a slight departure from the more general specification of the profit equation in Eq. (1). Standard production economics notation in the profit equation models technological change as shifting the production function. The second term on the right hand side of Eq. (1) is the cost equation which is derived by multiplying the physical quantity of each input used in the production process by the unit cost of each of those inputs. The cost equation is an accounting or technical relationship and does not reflect any optimisation. The specification of the profit equation in our example reflects the fact that data available for many livestock production processes have not been collected in a manner that allows strict adherence to the approach presented in Eq. (1). In our example we model elements of the production function in both the first and second terms of the profit equation in order to best use the data available on body weight and average daily dry matter intake.

The body weight function, as based on information from Taylor (1994), was

$$wt(x,\ g_1) = 243.6 + (0.8408 + g_1)*x - 0.0005*x^2 \tag{9}$$

Average daily dry matter intake (addmi), over the growth period, was approximated as the average of starting and finishing feed intake. The values used were based on NRC (1996). The function derived was,

$$\text{addmi}(x,g_2) = (5.9677 + 0.0071*x - 0.0000045*x^2)(1 + g_2). \tag{10}$$

Note that genetic differences in feed intake (g_2) for this trait were modelled as fractional changes.

Feed price (p_i) was assumed to be constant during the growth period. For simplicity, fixed costs were not considered. The firm's risk-rated profit (y_r) was then:

$$y_r = \mu_{po}[wt(x,\ g_1)] - \mu_{pi}[\text{addmi}(x,\ g_2)]x - 0.5\lambda\ \sigma^2_{yt} \tag{11}$$

where μ_{po} is the expected price of live slaughter cattle, μ_{pi} the expected price of feed, λ the Arrow–Pratt coefficient of absolute risk aversion, and σ^2_{yt} the variance of profit, which was equal to

$$[wt(x,\ g_1)^2]\sigma^2_{po} + [\text{addmi}(x,g_2)^2]\sigma^2_{pi}x^2 - 2x[wt(x,\ g_1)]\ [\text{addmi}(x,g_2)]\sigma_{po\ pi}$$

where σ^2_{pi} is variance in live slaughter cattle price, p_o, σ^2_{po} is variance in feed price, p_i, and $\sigma_{po\ pi}$ is co-variance between p_o and p_i.

The covariance between live slaughter cattle price and feed price was $\sigma_{po\ pi}=0.001$ (\$/kg live weight, \$/kg DM) for $p_o=1.94$ \$/kg ($\sigma^2_{po}=0.004696$), and $\sigma_{po\ pi}=0.005$ for $p_o=2.34$ \$/kg ($\sigma^2_{po}=0.09$). Covariances were based on an observed correlation of 0.2 obtained from data on annual average feed prices per cow (OMAFRA, 1996), and live slaughter cattle prices (Agriculture and Agri-Food Canada, 1996).

Two levels of risk aversion were considered, Arrow–Pratt coefficients of absolute risk aversion (λ) of 0.0001 and 0.02. Since our example is hypothetical, we did not study intensity of producer risk preferences directly. Estimation of measures of the intensity of producer risk preferences is a difficult and at times controversial challenge (Raskin and Cochran, 1986) but this range of values extends from the lower to the higher end, respectively, of published estimates of Arrow–Pratt coefficients for agricultural producers in North America (Fox et al., 1999a,b; for an overview of this literature). The value of 0.0001 represents a low level of risk aversion, not appreciably different from risk neutrality, while 0.02 represents a relatively high degree of aversion to risk. Our intention is to illustrate the influence of variations in intensity of producer risk preference on the absolute and relative valuation of improvements in different types of traits and also to

Table 1
Phenotypic standard deviations, heritabilities, genetic (above diagonal) and phenotypic (below diagonal) correlations for traits in the breeding objective[a]

Trait	Phenotypic standard deviation	Average daily gain	Average daily dry matter intake
Average daily gain (kg/day)	0.271	0.31	0.57
Average daily dry matter intake (fractional change)[b]	0.110	0.51	0.34

[a] Koots (1994).
[b] Equivalent to 0.59 kg DM/day.

Table 2
The effect of risk ($\lambda = 0.0001$, $\lambda = 0.02$) on economic values for average daily gain (v_1) and feed intake (v_2) derived using the profit and certainty equivalent (risk-rated) profit models, with and without optimization of the management choice variable based on 1992 average live slaughter cattle price[a]

	Management variable not optimized			Management variable optimized		
	Profit	Risk-rated profit	Change[b]	Profit[c]	Risk-rated profit[d]	Change[b]
$\lambda = 0.0001$						
v_1	411.28	411.27	−0.003	118.34	116.39	−1.65
v_2	−431.59	−432.72	−0.26	−109.04	−107.21	+1.68
v_1/v_2	−0.95	−0.95	+0.27	−1.08	−1.086	−0.04
$\lambda = 0.02$						
v_1	411.28	408.79	−0.61	118.34	70.97[e]	−40.03
v_2	−431.59	−659.18	−52.73	−109.04	−68.57[e]	+37.11
v_1/v_2	−0.95	−0.62	+34.92	−1.08	−1.03[e]	+4.64

[a] Values of the variables used: $p_o = \mu_{po} = 1.94$ \$/kg, $x = 212$ days, $p_i = \mu_{pi} = 0.28$ \$/kgDM, $\sigma^2_{po} = 0.004696$, $\sigma^2_{pi} = 0.005625$ and $\sigma_{po\ pi} = 0.001$.
[b] Percent change in economic values (v_{yt} vs. v_{yr}) $= [(v_{yr} - v_{yt})/v_{yt}]*100$.
[c] Management optimized $x^* = 61$ days on feed.
[d] Management optimized $x^* = 60$ days on feed.
[e] Management optimized $x^* = 37$ days on feed.

show how implications of recognizing risk preference vary when production input use is optimized.

The impact of alternative economic values on response to selection was illustrated considering a linear selection index of own performance for the two traits as in the breeding objective. Selection index weights, accuracy of selection, and expected responses in component traits of the breeding objective were calculated using standard selection index theory. Heritabilities, genetic and phenotypic correlations for average daily gain and average feed intake were based on post-weaning gain and post-weaning feed intake as shown in Table 1 from Koots (1994). The economic values used were either those for traditional situations or risk-rated situations.

The correlation between the two selection indexes (index I_{yt} based on the traditional economic values and index I_{yr} based on risk-rated economic values) was calculated as: $r_{Iyt\ Iyr} = Cov(I_{yt}, I_{yr})/\sqrt{[Var(I_{yt})Var(I_{yr})]} = (\mathbf{b}'_{yt}\mathbf{P}\mathbf{b}_{yr})/\sqrt{[(\mathbf{b}'_{yt}\mathbf{P}b_{yt})(\mathbf{b}'_{yr}\mathbf{P}\mathbf{b}_{yr})]}$ in which b_{yt} and b_{yr} are the selection index weights for I_{yt} and I_{yr}, and $\mathbf{P}$ is the phenotypic variance–covariance matrix.

3. Results

An Arrow–Pratt coefficient of absolute risk aversion (λ) of 0.0001 resulted in risk-rated economic

Table 3
The effect of risk ($\lambda=0.0001$, $\lambda=0.02$) on economic values for average daily gain (v_1) and feed intake (v_2) derived using the profit and certainty equivalent profit models, with and without optimization of the management choice variable based on 1981–1993 average live slaughter cattle price[a]

	Management variable not optimized			Management variable optimized		
	Profit	Risk-rated profit	Change[b]	Profit[c]	Risk-rated profit[d]	Change[b]
$\lambda=0.0001$						
v_1	496.08	495.43	−0.13	297.18	294.49	−0.91
v_2	−431.59	−432.46	−0.2	−241.70	−239.80	+0.78
v_1/v_2	−1.149	−1.146	+0.34	−1.229	−1.228	+0.12
$\lambda=0.02$						
v_1	496.08	364.99	−26.43	297.18	83.36[e]	−71.95
v_2	−431.59	−607.31	−40.72	−241.70	−79.14[e]	+67.26
v_1/v_2	−1.149	−0.60	+47.78	−1.23	−1.05[e]	+14.63

[a] Values of the variables used: $p_o=\mu_{po}=2.34$ \$/kg, $x=212$ days, $p_i=\mu_{pi}=0.28$ \$/kg DM, $\sigma^2_{po}=0.09$, $\sigma^2_{pi}=0.005625$ and $\sigma_{po\ pi}=0.005$.
[b] Percent change in economic values (v_{yt} vs. v_{yr}) $=[(v_{yr}-v_{yt})/v_{yt}]*100$.
[c] Management optimized $x^*=127$ days on feed.
[d] Management optimized $x^*=126$ days on feed.
[e] Management optimized $x^*=45$ days on feed.

values which were very close to the traditional economic values (Tables 2 and 3). A higher risk aversion of 0.02 showed a much greater impact on absolute and relative economic values.

Variance of profit is one component that distinguishes risk-rated profit from a simple profit model. Scenarios in which average output price and ratio of output to input variance were higher (Table 3 relative to Table 2) illustrate the effect of profit variances on economic values. When using the 13 year average live slaughter cattle prices, differences in absolute values between traditional and risk-rated economic values were more pronounced than for the one-year price data (higher output price, higher variance of output price and higher covariance of output price with the input price; Table 3). The difference between traditional economic values and risk-rated economic values increased as the Arrow–Pratt coefficient of absolute risk aversion increased. For example, the percent change in relative economic values, without optimization, increased from +0.3% to +35% (Table 2), when variances of prices were lower and from +0.3% to +48% when variances of prices were higher (Table 3).

Greater differences in economic values were observed when economic values were compared based on optimization (optimization versus non-optimization). The optimized values of days on feed were lower than the non-optimized value of 212 days on feed (Tables 2 and 3). Difference in optimal values of the management variable depends on market, economic and environmental conditions in specific commercial beef operations. The example is very simplified, with only one output and one input variable, but does illustrate that optimization can have a large effect on absolute economic values.

The change in economic value of average daily gain was negative with consideration of risk (e.g. −26% without optimization and −72% with optimization of management at the higher level of risk aversion and higher output variance, Table 3). A similar effect for average daily dry matter intake was observed, although the change in economic value was positive (e.g. +67%, Table 3; with management optimized), since lower negative economic values were more desirable.

Differences between the ratios of traditional and risk-rated economic values, without optimization, were greater (i.e. +48%; Table 3) than when optimization was taken into account (+15%; Table 3). For the parameter values considered, prices (live slaughter cattle price of 1.94 \$/kg) and their variances, differences between relative traditional and risk-rated economic values, with and without optimization of the management variable, were small for low levels of risk aversion but increased as the level

Table 4
Selection index weights, accuracies, expected responses in average daily gain (ADG) and average daily dry matter intake (ADDMI), and expected total responses in aggregate genotype to 1 s.d. selection on the index derived using economic values from the profit and risk-rated profit (with optimization of the management choice variable)[a]

	Profit	Risk-rated profit
Economic values		
ADG ($/kg/day), v_1	297.18	83.36
ADDMI ($ per one fractional change in daily dry matter intake kg DM/day), v_2	−241.70	−79.14
Ratio of economic values	−1.23	−1.05
Selection index weights		
ADG, b_1	85.06	23.79
ADDMI, b_2	−53.57	−18.79
Ratio of selection index weights	−1.59	−1.27
Selection index accuracy	0.541	0.538
Response in aggregate genotype ($/animal), by objective	20.68	5.68
Response in ADG (kg/day)	0.079	0.077
Response in ADDMI (fractional change in dry matter intake per day)	0.012	0.009
Correlation between indexes, I_{yt} and I_{yr}	0.997	

[a] Values of the variables used: $p_o = \mu_{po} = 2.34$ $/kg, $x = 212$ days, $p_i = \mu_{pi} = 0.28$ $/kg DM, $\sigma^2_{po} = 0.09$, $\sigma^2_{pi} = 0.005625$, $\sigma_{po\ pi} = 0.005$, and $\lambda = 0.02$.

of risk aversion increased (Table 2). Both level of risk aversion and optimization can make a significant difference in economic values.

Selection index weights differed depending on whether they were derived using the economic values from the profit or risk-rated profit model for both daily gain and feed intake as expected (Table 4). The ratios of economic values and selection index weights differed from each other. The values of the ratios of the selection index weights were higher than the ratios of the economic values, which reflects the effect of considering phenotypic and genetic relationships between the traits. The selection index accuracy was almost the same whether derived using economic values from profit or risk-rated profit model.

The expected response in the aggregate genotype to one standard deviation selection on the index was greater when derived using traditional economic values as compared with risk-rated economic values (Table 4), reflecting a different selection objective. Responses in the components of aggregate genotype slightly decreased when risk was taken into account, moreso for one trait than the other. The correlation between indexes, one based on profit (I_{yt}) and the other based on risk-rated profit (I_{yr}) was high (Table 4). Similarity of indexes and component traits might change for other scenarios and examples of livestock production.

Differences were studied in response in risk-rated profit to selection over five generations when traditional economic values or risk-rated economic values were used (Table 5). In other words, the risk-rated profit was the objective of improvement (rather than profit as an objective) and then responses in risk-rated profit were derived for two scenarios, one when traditional economic values were used in risk-rated profit and another when risk-rated economic values were used. Response in risk-rated profit was calculated for five generations, with means reflecting improvements in traits and with economic values recalculated each generation. Differences in total responses in risk-rated profit ($ per animal) and percent changes for traditional and risk-rated economic values were small for this example. Again, larger differences might have been found with changing prices and variances over years and more complex profit functions.

4. Discussion

The difference between traditional and risk-rated economic values reflects the method used to assess

Table 5
Changes in risk-rated gross margin per animals when traditional versus risk-rated economic values are used (with optimization of management)[a]

Generation	Gross margin ($ per animal)		Percent change in response of gross margin
	Traditional economic values	Risk-rated economic values	
1	532.46	532.52	−0.01
2	540.10	540.26	−0.03
3	548.83	549.20	−0.07
4	558.51	559.21	−0.13
5	568.97	570.13	−0.20

[a] Values of the variables used: $p_o = \mu_{po} = 2.34$ \$/kg, $x = 212$ days, $p_i = \mu_{pi} = 0.28$ \$/kg DM, $\sigma^2_{po} = 0.09$, $\sigma^2_{pi} = 0.005625$, $\sigma_{po\ pi} = 0.005$, and $\lambda = 0.02$.

profit. Not accounting for risk systematically overestimated profit and economic values. From the economic point of view, accounting for risk represents a better model of real life and producer's choices. Regardless of the size of the differences between profit and risk-rated profit models (differences ranged from being very small to over 50% in the illustration used), risk should be taken into account. Of course, there might be situations, and this study showed one situation with a low level of the Arrow–Pratt coefficient of absolute risk aversion, where accounting for risk does not make a big difference. This case represents one in which the level of risk aversion is so low as almost reaching risk neutrality, which means that the risk-rated model can be approximated by the profit model.

Vandepitte and Hazel (1977) investigated the effects of errors in economic values on the efficiency of index selection. They used a selection index for multiple trait selection in a pig population as an example (traits considered were daily gain, feed efficiency, carcass backfat, dressing percentage, percent ham and loin, loin-eye area, and number of pigs weaned). They found that errors in a single economic value larger than 50% could result in considerable error of the estimated genetic gain per generation. For example, they reported that large errors in the value of feed efficiency (beyond plus and minus 50%) can result in losses in relative efficiency of a selection index up to 76%. The use of incorrect economic values resulted in an incorrect selection criterion and therefore in a suboptimal direction of selection. The magnitude of differences between traditional and risk-rated economic values depended on the values of the risk aversion coefficients and the ratio of output/input price variances. Results indicated that the differences between traditional and risk-rated economic values increased as the risk aversion coefficient increased (Table 2 and 3) and the ratio of output/input price variances increased (Table 2 vs. Table 3), although the ratios of prices were not separated from the ratios of price variances. In some cases, differences between traditional and risk-rated economic values were high (e.g. −72% for average daily gain and +67% for average daily dry matter intake with optimization of management (Table 3)). The change in relative weights and expected changes in component traits were not as large (+15% for the ratio with optimization), although they might be in other situations. The example used was simplified in that it included only two traits, and two levels of price variance, such that generalized results concerning the impact of risk on relative economic values cannot be made.

Only risk aversion was considered here, and further studies could examine the effect of accounting for risk for risk prone producers. However, most producers are risk averse and this study showed that not accounting for risk overestimates profits which might mean an overestimate of cost–benefit of a breeding program.

The risk defined in this study consisted of the Arrow–Pratt coefficient of absolute risk aversion and the variance of profit. The Arrow–Pratt coefficient of absolute risk aversion depends on the utility function used. Estimates of aversion to risk, the coefficient λ, may be obtained from the economic literature, elicited by researchers from economics, or obtained from appropriate economic methods. A number of different approaches have been developed to elicit the required information from decision makers to be able to encode their preferences into a suitable utility function (Hardaker et al., 1997). Estimating the variance of profit is a complex issue because it depends on the production functions and economic parameters (prices, price variances and covariances). Some of these functions and parameters are needed for the traditional profit model in any event and assumptions concerning variations in economic values are often made implicitly.

5. Conclusions

Risk can be incorporated into derivation of economic values. Risk can make a large difference in economic values, but may have a smaller effect on ratios of economic weights and on the magnitude and direction of genetic change. Higher risk aversion and variances of prices result in increased differences between traditional and risk-rated economic values. Overestimation of profit and economic values, even for small differences between traditional and risk-rated economic values, given the magnitude of costs and benefits from breeding schemes, should demand consideration of risk because of systematic distortion of the value of benefits from not considering risk.

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