REFEREED ARTICLE

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Application and comparison of risk adjusted performance-indicators in the context of pig production

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ABSTRACT

In the recent past, risk and risk management in agriculture has risen on the agenda of farm managers. Amongst other things, the increased interest is inter alia attributed to the Capital Requirements Directives in the 'Basel II' agreement. In this article, we apply indicators of risk-adjusted returns, well known in the valuation of equity funds, to the context of pig production. Using a large data set of pig farm performance data, we demonstrate that different indicators of risk-adjusted returns do not necessarily lead to different results in the valuation of farms. We recommend using the Treynor Ratio in practical application. Our empirical analysis did not reveal a significant relationship between returns and risk.

KEYWORDS: performance measurement; risk measurement; risk-adjusted returns

1. Introduction

Risk in agricultural businesses is often discussed in the context of default risks, e.g. as a result of poor harvests. Instruments such as insurances or weather derivatives have been developed to address this type of risk at the farm level. A standard rule in the finance world stipulates that higher risk must be compensated for by higher expected returns for the investor. On the other hand, the investor[4] must accept higher-than-average risk if he expects higher-than-average returns. Accepting above-average risk with average returns would be inefficient.

There are well established measures in the financial sector for quantifying an investment's performance. Performance measurement in this context means that the success of an investment fund or its manager is not only measured by the fund's average returns but also by the risk associated with it. An investment's risk is generally a complementary decision criterion to the investment's average return (Perridon, 2004). This means, that increasing returns normally goes hand in hand with increasing risk.

During the past decades, a number of performance indicators have been established which combine returns and risk in one figure. Returns are usually represented by excess returns and risk is mainly represented by a measure of the return's volatility.

The aim of this paper is to apply the performance indicators developed in the financial sector to the performance measurement of pig production and to identify the most appropriate performance indicator to measure a pig farm's risk-adjusted returns. Appropriate performance indicator should be applicable as a success criterion in business consulting and as a basis for intercompany comparison. Particularly in the area of credit financing, farmers are facing increasing challenges. These result in part from tighter requirements imposed by banks (e.g. as a result of the Capital Requirements Directives 2006/48/EG – Basel II) but also from increasing price volatility on input and output markets. The 'Landwirtschaftliche Rentenbank[5]' explicitly recommends employing consulting organizations as a mediator between banks and farmers in financing issues (Landwirtschaftliche Rentenbank, 2010). Consulting organizations thus need appropriate indicators that do not only reflect the operating returns but also include a measure of risk.

Such extended performance indicators are however not only of interest in the context of debt financing. Knowledge of the degree of volatility is also important in controlling income tax in the light of the lacking opportunity for farmers, at least in Germany, to forward profits or losses to subsequent fiscal years.

Against this backdrop, this article aims to answer the following specific questions:

- To what extent is it possible and useful to transfer the performance indicators typically used in the financial sector to the context of pig production?
- Do the different performance measures generate different results?

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[4] An investor can be everyone providing equity or debt to a company (e.g. owners, banks, but also any other person or institutions investing money in a company)

[5] 'Landwirtschftliche Rentenbank' is a German bank that promotes projects and investments in the agricultural sector.

- Which of the combined performance measures is the most appropriate one for the purpose of business consultation and bank-farmer mediation?
- Can a relationship between risk and returns be identified in the context of pig production? Is there a tendency that risky enterprises generate higher returns?

The following Section 2 reviews the literature and explains how the success of farms might be assessed by the different measurement concepts typically used in the financial investment sector. Section 3 sets out alternative measurements of risk and returns. Based upon these, Section 4 defines and explains alternative performance indicators combining returns and risk in one figure. Section 5 presents empirical estimates of the alternative risk-adjusted performance measures using a large data set from pig fattening enterprises. We investigate whether the different performance measures generate different results and assess their suitability for practical application. This is followed, in Section 6, by an empirical investigation of a possible relationship between the level of risk and returns in pig fattening. The final section discusses the results and concludes.

2. Literature

There is a vast literature on risk and risk management in agriculture. In the field of hog fattening, risk relates to the volatility of input and output prices and to the biological performance of the animals. The broader literature on risk in agriculture is mainly driven by the question of how the various risks can be predicted and managed. Hardaker *et al.* (2004) provide a comprehensive overview of methods of agricultural risk management and risk prediction. The methods presented there primarily focus on methods for decision-making under uncertainty and the simulation or prediction of risks. Methods such as stochastic simulation or decision trees are used to predict, simulate and manage risk. Lien (2003) uses stochastic simulation to identify important factors relating to the financial risk of Norwegian dairy farms.

Weber *et al.* (2008) illustrate the possibilities of minimizing risk through insurances and hedging instruments for arable farms. The instruments compensate the financial loss when a possible risk occurs. While these instruments do not affect the likelihood of a risky event occurring, they are designed to mitigate the (negative) financial effects associated with the occurrence of such an event: risk is managed.

The present paper, however, focuses on the benchmarking of farms taking risk aspects into account. Benchmarking of companies is usually based on the idea of efficiency. Analyses in that context use, for example, Data Envelop Analysis (DEA). DEA aims to identify productive units that are efficient and to rank inefficient units relative to the efficient ones. In the context of risk and returns, a firm is always more efficient when it is more profitable at the same level of risk or when it is less risky at the same level of profit. Tiedemann *et al.* (2011) apply DEA to investigate whether consideration of risk (fluctuations in output) changes the performance evaluation of farms compared to measures that only consider averages. They find that this is indeed the case. Diversified farms achieve on average a higher efficiency score when the fluctuations of the gross margin are taken into account. Consideration of risk may thus lead to a different assessment of that company's success.

The goal of our work is to develop a set of standardized performance measures that can be used to compare the performance of pig fattening farms. All of these measures aggregate risk and returns in one figure, albeit in a different way. Markowitz (1976) was the first to introduce a concept for the evaluation of investments which combines these two factors. While the measurement of returns is largely unproblematic, there are various ways of measuring risk. This has given rise to the development of a plethora of indicators that measure risk-adjusted returns or performance in one figure. An overview of these different measures is given by Christopherson (2009) or Knight (2002). These performance measures have been used in the finance industry for some time to evaluate investments. Basically, these performance measures can also be used for any other investment. However, the authors are not aware of applications of these measures in the context of agriculture.

3. Measuring returns and risk

Performance indicators consist basically of the two components risk and returns. In the classical measurement of a portfolio's performance[6], returns represent the 'change in wealth' (Bacon, 2004). For the purpose of this paper, we compute 'returns' as the excess return of a single farm over and above the market return on the basis of gross margins. Gross margin is defined as the difference between revenue and variable costs of an enterprise. Gross margin thus disregards fixed and overhead costs. It thus falls short of a comprehensive criterion for the operating result of a pig producer, but it is a strong indicator of a farm's success in marginal costing. Nevertheless, it must be kept in mind that fixed and overhead costs may still lead to a negative operating result.

Measuring returns

Rather than measuring returns in absolute terms, the annual return of a farm (R_i) in this paper is computed as the share of gross margin in the farm's proceeds as per the following equation:

$$R_{\mathrm{i}} = 1 - \left(\frac{fc + d + pc + ec + mc}{p}\right)$$

R_i is the share of the gross margin in proceeds (p). The following cost types (annual sums per farm) are taken into account: fc= feed costs, d= dues[7], pc= piglet costs, ec= epidemic insurance costs, mc= miscellaneous costs.

The annual market returns (R_m) are computed as the share of the sum of all farms' gross margins in all proceeds in any given year (Figure 1).

The average return of the farms ($\overline{R_i}$) and the market ($\overline{R_m}$) across all years (1999 through 2010) are computed as the geometric mean of the annual returns R_i and R_m.

[6] A portfolio is a collection of investment assets. In the context of this article all farms in the dataset.
[7] E.g. for consulting and insurances.

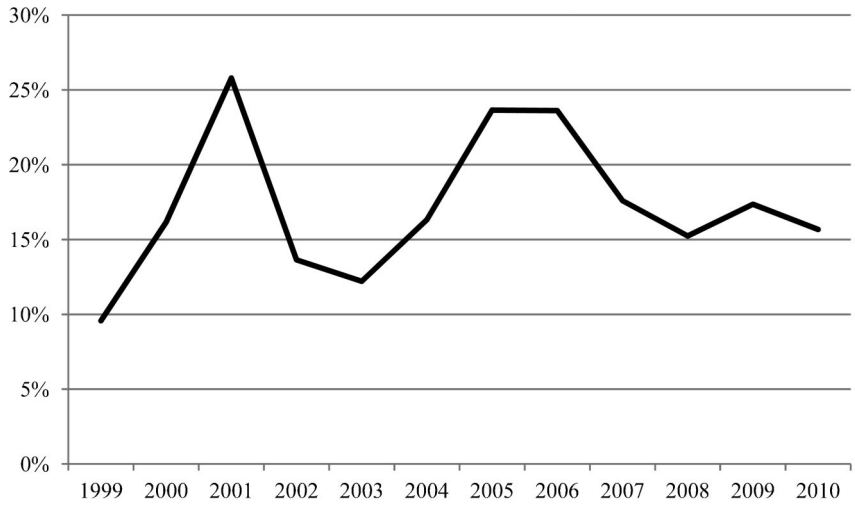

Figure 1: Annual market returns R_m (n=159)

The difference between $\overline{R_i}$ and $\overline{R_m}$ is excess return (*ER*) or, more generally, the difference between the performance of a farm and the performance of the portfolio (mean of all farms in the data set).

Measuring risk

The risk measures presented in this section are based on the mean and the variance of returns. In the context of this paper, these are based on the mean excess returns (ER) and the volatility of these excess returns. These mean-variance approaches have been criticized in the literature for not adhering to the theoretical requirement of returns being normally distributed (Leland, 1999; Eling *et al.*, 2010). For this reason, tailor-made performance measures have been developed that take higher moments of distribution (such as skewness and the kurtosis) into account. Eling *et al.* (2007, 2010) investigate several performance measures based on logistically distributed hedge-fund's returns and note very high rank correlations between traditional and tailor-made performance measures, indicating that normally distributed returns do not seem to be a prerequisite for practical purposes.

Standard deviation and variance

A basic measure of risk is the standard deviation (σ_i) or the variance (σ_i^2) of the returns on investment. These measures of volatility can be used to identify for example maximum losses or gains to be expected in a particular confidence interval of distribution. This information can also be used to identify how often good or bad events might occur (Christopherson, 2009).

Markowitz (1976) introduces the semi-variance and semi-deviation in the context of portfolio theory. Semi-variance subdivides the overall variance of an investment's returns into good (i.e. upside) and bad (i.e. downside) variance. Returns above the mean create upside variance and should not be considered as risk. Only returns below the mean – downside variance (σ_{id}) – should be taken into account when calculating the variance in the context of risk measurement.

The methodology to calculate downside variance is called lower partial moments (LPM). Downside variance is a special case of LPM where the deviation is raised to the power of 2 and the target return is set equal to the mean return of the market (Christopherson, 2009):

$$\sigma_{id} = \frac{1}{n}\sum_{i=1}^{n} d(x)(R_i - R_m)^2$$

with

$$d(x) = \text{function that returns 1 or 0;}$$

$$d(x) = \begin{cases} 1 \; if \; R_i \leq R_m \\ 0 \; if \; R_i > R_m \end{cases}$$

Skewness and kurtosis

Another indicator of risk is the ratio of downside variance and total variance of an investment. The ratio is represented by the skewness and the kurtosis of the distribution. An asymmetric distribution with a positive skewness indicates that there is a tendency to more upside variance. Negative skewness, by contrast, indicates a predominance of downside variance (Christopherson, 2009). The larger the kurtosis of the distribution, the more pronounced the positive or negative drift.

Beta

Beta reflects the systematic risk of an investment. Beta measures an investment's volatility relative to the market's volatility. Beta is based on the idea that the returns of a stock, portfolio or farm are highly correlated with the respective market returns. Beta measures the sensitivity of the stock's, portfolio's or farm's returns to market returns by relating the covariance of individual and market returns to the market return's variance (Fischer, 2001):

$$\beta = \frac{Cov\,(R_i, R_m)}{\sigma_m^2}$$

where $Cov\,(R_i, R_m)$=Covariance of R_i, R_m and σ_m^2= Variance of R_m.

In this article, market returns are represented by the average return of all farms. In other contexts, market

returns can also be represented differently, for example by the return of a stock index. A beta of greater than 1 indicates that the stock's (or farm's) returns are more volatile and therefore more risky than the market returns (Fischer, 2001).

Tracking Error

The Tracking Error (TE) is similar to the standard deviation of returns. Instead of the return's standard deviation, the Tracking Error measures the standard deviation of the excess returns (Amenc, 2003):

$$TE = \sigma(R_i - R_m)$$

Value at Risk (VaR)

Value at Risk estimates the maximum loss to be expected during a period within a certain confidence level. A one-year 99% VaR of £-5.000 means that the investor can be 99% confident that he does not lose more than £5.00 within the next 12 months. There are three different ways of calculating VaR.[8] In the present paper we use a special case of the so-called parametric VaR. The 'normal' parametric VaR is calculated as:

$$VaR_{parametric} = \overline{R_i} + Q_d\ \sigma_i$$

with Q_d representing the percentile of the normal distribution. Since some data is not normally distributed, Favre *et al.* (2002) suggest using a 'Cornish-Fisher approximation' to adjust the parametric distribution by taking the third and fourth moment, skewness and kurtosis, into account in order to approximate the empirical distribution (Lhabitant, 2004). This methodology is referred to as modified Value at Risk (mVaR).

$$mVar = \overline{R_i} + \left(Q_d + \frac{Q_d^2 - 1}{6} S_d + \frac{Q_d^3 - 3Q_d}{24} K_d - \frac{2Q_d^3 - 5Q_d}{36} S_d^2\right)\sigma_i$$

with
Q_d= Quantile of the normal distribution
S_d= Skewness of the return's distribution
K_d= Kurtosis of the return's distribution

4. Risk-adjusted performance measures

Based on the previously presented measures of risk and returns, several performance indicators have been developed. The measures differ in some preconditions and assumptions and especially in the way risk is measured.

Sharpe Ratio

The most popular performance measure is the Sharpe Ratio, which measures the ratio of excess return and standard deviation of returns (Amenc, 2003):

$$Sharpe\ Ratio = \frac{\overline{R_i} - \overline{R_m}}{\sigma_i}$$

Application of the Sharpe Ratio is not without controversy though, because it requires normally or at least elliptically distributed returns.

Sortino Ratio

The Sortino Ratio was developed against the background of non-normally distributed returns. In contrast to the Sharpe Ratio, the Sortino Ratio only uses the downside deviation as risk measure (Bacon, 2004):

$$Sortino\ Ratio = \frac{\overline{R_i} - \overline{R_m}}{\sigma_{id}}$$

Treynor Ratio

The Treynor Ratio was developed by Treynor (1965) to measure risk-adjusted returns of different portfolios by a standardized measure. The Treynor Ratio only measures the systematic risk of an investment – represented by β, but not the total (market) risk (Weingärtner, 2009):

$$Treynor\ Ratio = \frac{\overline{R_i} - \overline{R_m}}{\beta}$$

with $\beta = \frac{Cov(R_i, R_m)}{\sigma_m^2}$ as per above

Information Ratio

The Information Ratio uses the Tracking Error (TE), which is the standard deviation of the excess returns, as risk indicator. The Information Ratio is similar to the Sharpe Ratio. As a risk indicator, however, the Tracking Error makes use of the standard deviation of excess returns rather than of total returns (Bacon, 2004).

$$InformationRatio = \frac{\overline{R_i} - \overline{R_m}}{TE}$$

Risk-Adjusted Performance (RAP)

The RAP was developed by Franco and Leah Modigliani in 1997 as a performance measure that is intuitively understandable. It is also known as M^2, M2 or Modigliani-Modigliani measure. The RAP measures the risk-adjusted return of an investment relative to a given benchmark. The measure implies that a risky investment should generate higher returns than the market's average returns (Knight, 2002; Amenc 2003):

$$RAP = \frac{\sigma_m}{\sigma_i}\left(\overline{R_i} - \overline{R_m}\right) + \overline{R_m}$$

where σ_m is the standard deviation of annual market returns and σ_i is the standard deviation of the investment's returns.

Modified Sharpe Ratio

The Modified Sharpe Ratio takes into account the issue of non-normally distributed returns. In contrast to the Sharpe Ratio, risk is represented by the modified Value at Risk (mVaR). The mVaR takes the first 4 moments of the distribution into account in order to correctly estimate the empirical distribution (Gregoriou, 2004):

[8] Parametric Var, historical simulations and Monte Carlo simulations.

Table 1: Comparison of the different performance measures

Performance measure	Preference Driver	Distribution Assupmtion	Risk measure	Inter market comparability
Sharpe Ratio	Mean Variance	Elliptical	Overall variance	yes
Information Ratio	Mean Variance	Elliptical	Variance of excess returns	yes
RAP	Mean Variance	Elliptical	Overall variance	yes
Sortino Ratio	Downside Variance	Assymetric	Overall downside variance	yes
Treynor Ratio	Mean Variance	Elliptical	Systematic risk	no
Modified Sharpe Ratio	Extreme loss aversion	Assymetric	Expected losses	yes

Table 2: Descriptive Statistics of the Dataset (N=1908, equivalent to 159 farms over 12 years)

	MEAN	Std. Dev.	MEDIAN	MIN	MAX
proceeds	358,554.78 €	321,436.38 €	281,819.00 €	29,159.02 €	4,530,712.00 €
share of dues deducted from proceeds	0.49%	0.28%	0.43%	0.03%	2.76%
share of piglet costs deducted from proceeds	43.79%	5.54%	44.02%	21.46%	64.13%
share of feed costs deducted from proceeds	35.85%	7.16%	35.21%	19.11%	90.22%
share of epidemic insurance costs deducted from proceeds	0.16%	0.08%	0.14%	0.02%	0.86%
Share of miscellaneous costs deducted from proceeds	0.38%	0.47%	0.20%	0.00%	4.15%
contribution margin	16.68%	7.27%	16.16%	-49.08%	40.51%

$$Modified\ Sharpe\ Ratio = \frac{\overline{R_i} - \overline{R_m}}{mVaR}$$

Table 1 provides an overview of the performance measures described above. The performance measures can generally be subdivided according to their underlying distribution assumption, the risk measure and whether the measure can only be used in one market or in various markets.

5. Empirical estimates of the alternative performance measures in the context of pig production

In this section, we compute the above performance measures with data from pig fattening farms in Germany. The data was made available by 'Erzeugerring-Westfalen', a consulting organization which advises pig farmers in the federal state of North Rhine-Westphalia. 'Erzeugerring-Westfalen' collects on an annual basis technological and economic data from its member farms. The dataset comprises both data on farm structural features and data relating to the pig fattening enterprise. The latter include biological performance data, annual proceeds including inventory changes[9] and the costs directly attributable to the enterprise such as piglet costs, feed costs, epidemic insurance costs, dues and miscellaneous costs. The data set allows us to compute the share of gross margin in proceeds. Table 2 shows the descriptive statistics of the data set. It displays the proceeds, the shares of costs in proceeds and the share of gross margin in proceeds. It is clear from the table that piglets and feeds represent the two most important cost components in pig fattening, with 43.79% and 35.85%, respectively. Other direct costs play a minor role. On average, gross margin accounts for 16.68% of proceeds. The gross margin is available to cover fixed and overhead costs as well as the farmer's labour input.

'Erzeugerring-Westfalen' collects data from about 650 member farms. We used this data source to create a balanced panel of pig farms for the period 1999 through 2010. Balanced panel means that each farm is observed in each of the 12 years. This resulted in 159 farms being included in the analysis. Multiple years are required to compute the measures of volatility that enter the performance measures presented in section 4.

As explained in section 3.2, knowledge of the distribution of the returns is important for choosing the appropriate performance measure. For that reason, we carried out a test of fit on the returns data provided by 'Erzeugerring-Westfalen'. We used the Palisade @Risk software to identify which of the 22 given distribution types best fit the data. All three test statistics (Chi-Square, Anderson-Darling and Kolmogorov-Smirnov) identified a logistic distribution as the one with the best fit. Figure 2 shows a histogram of the empirical and fitted logistic distribution. It is clear from visual inspection that returns are not normally distributed.

The empirical distribution of $\overline{R_i}$ has a negative skewness of -1.18 and a kurtosis of 10.3, indicating a slight predominance of downside variance in pig production. The kurtosis reinforces the evidence that returns are not normally distributed. This in itself violates the (strict) preconditions of the Sharpe Ratio and supports application of one of the tailor-made

[9] In the following 'proceeds' is used equal to 'proceeds including evaluated changes in inventory'.

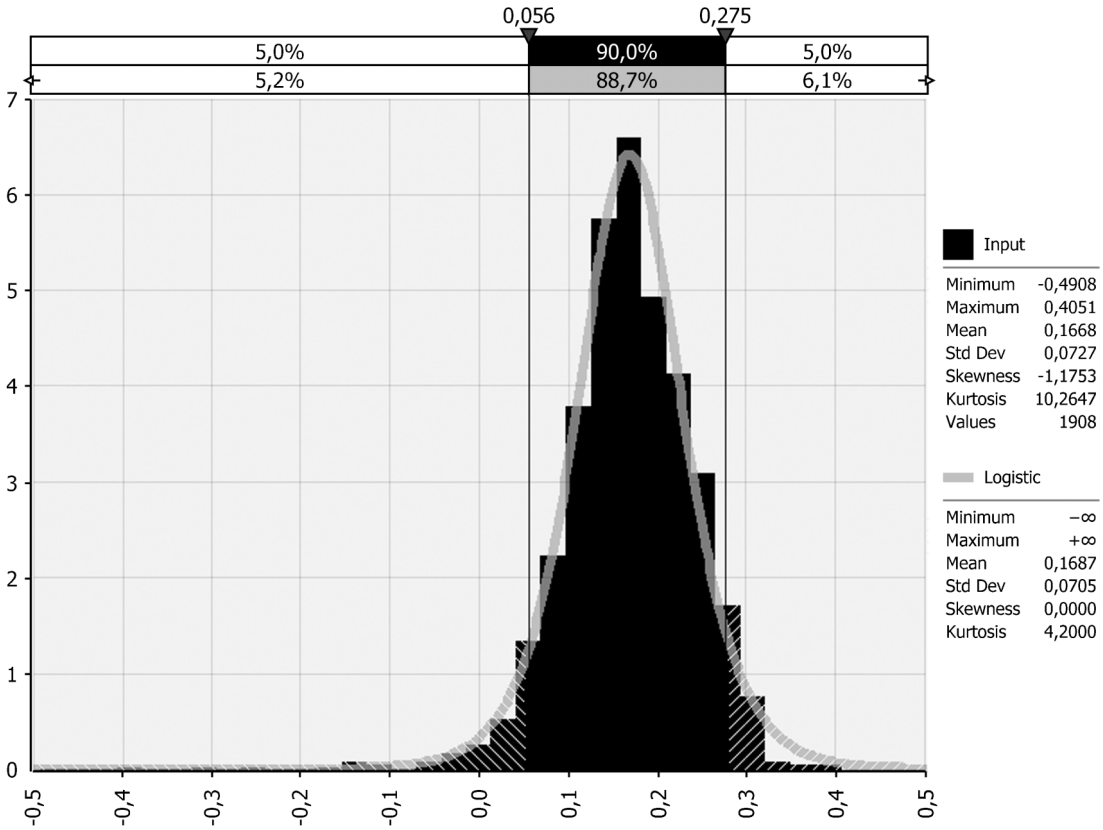

Figure 2: Distribution of returns $\overline{R_i}$ (N=1908, equivalent to 159 farms over 12 years)

performance measure such as the 'Modified Sharpe Ratio'.

Nevertheless we computed all performance measures presented in section 3 for each of the 159 farms. Table 3 shows the mean, standard deviation, minimum and maximum of the computed performance measures. The values of the Sharpe Ratio and the Sortino Ratio are consistently very close to each other. The Sortino Ratio, which is based on the Sharpe Ratio, thus seems to provide no fundamentally different results. The other performance measures cannot be compared directly with the Sharpe ratio by their absolute values.

For this purpose, we calculated the Spearman Rank Order Correlation Coefficients between the different performance measures (Table 4). The performance measures are highly correlated. All coefficients are >0.960. This shows that a ranking of the farms, regardless of the choice of the performance measure, would lead to (nearly) identical results.

To check the robustness of results, we carried out bootstrapping on over 10.000 samples of the empirical data. With the bootstrapping method, we randomly sampled our empirical dataset with replacement, in order to create a separate dataset. We finally computed the correlation coefficients for the new dataset. Bootstrapping is used inter alia to verify statistics based on small samples (Berger 2006). We produced 10.000 samples and determined a 95% confidence interval for the correlation coefficients. The correlation coefficients within the confidence interval between the different measures were always >0.94. The correlation coefficients calculated on the basis of our empirical data can thus be regarded as significant and robust.

Eling *et al.* (2007, 2010) also found, in their analysis of logistically distributed hedge funds returns, that – although the performance indicators have specific requirements concerning the distribution of returns – the different performance measures were very highly correlated. Pedersen *et al.* (2003) also estimated pairwise rank correlations of different performance measures for 400 financial services companies and also found a high correlation between the different measures.

The rank order correlation coefficients in Table 4 confirm the results of Eling *et al.* (2007) and Pedersen

Table 3: Descriptive statistics of the performance measures (N=159)

	Mean	Std. Deviation	Minimum	Maximum
Sharpe Ratio	0.0736	0.5579	-1.2219	1.7748
Sortino Ratio	0.0899	0.5883	-1.3809	1.6411
Treynor Ratio	0.0014	0.04	-0.2471	0.1097
Information Ratio	0.1707	0.9203	-1.7119	2.7848
RAP Measure	0.1678	0.026	0.1074	0.2471
Modified Sharpe Ratio	0.0235	0.1011	-0.2579	0.4691

Table 4: Spearman Rank Correlation Coefficient between performance measures

	Sharpe Ratio	Sortino Ratio	Treynor Ratio	Information Ratio	RAP Measure	Modified Sharpe Ratio
Sharpe Ratio	1.000					
Sortino Ratio	0.996	1.000				
Treynor Ratio	0.996	0.992	1.000			
Information Ratio	0.987	0.986	0.971	1.000		
RAP Measure	1.000	0.996	0.996	0.987	1.000	
Modified Sharpe Ratio	0.968	0.973	0.960	0.970	0.968	1.000

et al. (2003) in the context of hog fattening. The different performance measures are very highly correlated, implying that the ranking of farms would not be sensitive to the underlying performance measures. For this reason, non-normally distributed data does not seem to preempt application of traditional mean-variance based performance measures such as the Sharpe Ratio. In terms of an inter-company comparison, based on a ranking of the performance measures, no difference in the result can be expected, no matter which performance measure is used.

6. Relationship between risk and return in the data set

We now turn to the question of whether higher returns are always associated with higher risk. In an efficient market, increasing risk would always correlate with increasing returns – otherwise the farms can be separated into efficient and inefficient farms. A farm is considered efficient if no other farm exists that obtains higher returns with the same or a lower level of risk.

Figure 3 shows a scatterplot of the farms' mean returns and the variance of returns. It is clear from the figure that there are farms with different levels of risk at the same level of returns and vice versa. This graph illustrates that there are inefficient farms in our show case market of pig production.

We tested the mean returns $\overline{R_i}$ and the variance of returns R_i by a Chi-Square, Anderson-Darling and Kolmogorov-Smirnov test for a normal distribution. All tests rejected the normal distribution. For this reason, we also calculated the Spearman Rank Order Correlation Coefficient between the mean returns and the variance of the returns. The correlation coefficient of -0.0353 indicates no correlation between risk and returns and confirms the results of the graphical analysis in Figure 3. These results are clear evidence for the existence of inefficient farms in the market. An investor who intends to invest in this market would have to expect different levels of risk at the same level of returns, depending on the individual farm in which he invests. A rational investor would then always choose the highest return on investment. All other investments are inefficient.

7. Conclusions

In this paper, we have demonstrated the applicability of performance indicators used in the finance industry to the context of pig production. By aggregating risk and return into one figure, the indicators provide a more comprehensive basis for assessing farm performance than singular performance criteria. The risk-adjusted performance measures can be used for inter-company comparisons of pig farms or for assessing farms in the context of loan applications. Banks may be willing

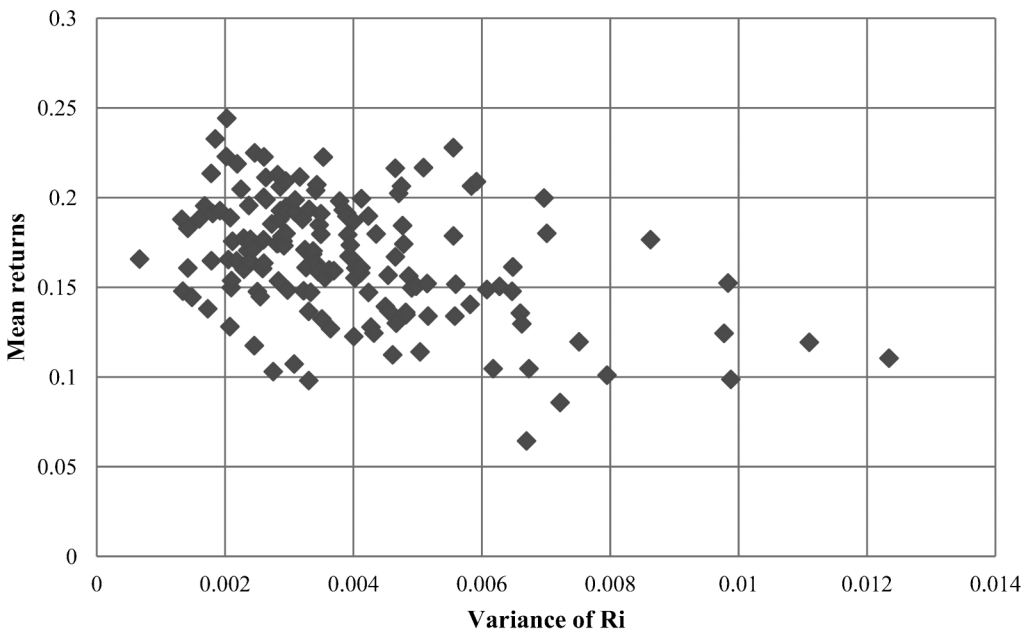

Figure 3: Scatterplot of returns and variance of returns (N=159)

to offer farms with above-market performance more attractive loan conditions than farms performing below the market average. Likewise, farm consulting organizations may use highly performing farms as benchmarks for less well performing farms. Obviously, the advantages of using performance measures which explicitly cater for risk are greater the more volatile the markets are.

We have further demonstrated that, even if the condition of normally distributed returns is violated, there is no practical need for tailor-made performance measures which do not rely on the assumption of normally distributed returns. Such measures take higher moments of distribution into account in order to approximate the empirical distribution. The ranking of the farms in our data set – investigated with the use of Spearman Rank Order Correlation Coefficients – turned out not to be sensitive to the performance measure used. This finding confirms the results of Eling *et al.* (2007, 2010) who showed the same outcome for hedge funds returns. We can thus conclude that the scientific debate as to the need of tailor-made performance measures for non-normally distributed returns does not seem to be of great relevance for practical applications.

For practical purposes it seems more important that the performance indicator is intuitive and easily understood by the relevant stakeholders. Risk measures that represent the volatility of returns are of limited use, because they are not intuitively understood by the farmer. We rather recommend for practical application the beta factor. The beta factor represents the systematic risk of a particular farm and not – as most other risk measures do – the overall risk which may be seen as being too abstract in practical farm consulting. The message of the beta factor is straightforward:

- $\beta>1$: the risk of the particular farm is higher than the market risk
- $\beta<1$: the risk of the particular farm is lower than the market risk
- $\beta=1$: the risk of the particular farm is equal to the market risk

The same applies to returns. In all performance indicators, returns are measured as excess returns $(\overline{R_i}-\overline{R_m})$. As with the beta factor, the farmer can also quickly recognize whether his or her returns are above or below that of the market:

- Positive excess return: the returns of the particular farm exceed market returns. The farm has 'beaten' the market.
- Negative excess return: the returns of the particular farm are below market returns. The farm has underperformed relative to the market.

These two relative indicators of risk and returns are combined in the Treynor Ratio. As stated above, the empirical analysis in this paper has revealed no major differences between the performance measures, so that we can focus on the comprehensibility of the performance indicator. The fact that the Treynor Ratio is based on relative figures with respect to both returns and risk seems to be a key advantage over alternative performance measures in terms of intelligibility.

The downside of the relative assessment of returns and risk is that the Treynor Ratio can only be used for comparisons within a market. For comparisons among different markets, e.g. pig fattening and breeding, absolute performance measures such as the Sharpe Ratio must be used. In that case, the excess return cannot be based on the returns of the respective market. Rather, some neutral third-party return, such as that of a government bond, is needed.

Finally we demonstrated the existence of inefficient farms in the pig fattening industry in that higher risk is not always associated with higher returns. This finding highlights the importance of the presented performance measures. Investments in the pig fattening industry should be consistently thought out and should, like all investments, be based on a comprehensive analysis including risk considerations. While the performance measures presented in this paper can reveal such inefficiencies, they provide no information as to the underlying causes. This aspect warrants further research.

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