WORKING PAPER 2016:3

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Impact of management practices on persistent and overall technical efficiency – a study of Swedish pig farming

AgriFood economics centre

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AgriFood Economics Centre working paper

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Abstract

Managerial capacity builds over the years and the accumulated knowledge and practice affect the outcome of the period that follows, with long-run/permanent effects on inefficiency. Therefore predictions of the influence of managerial capacity on the time-varying inefficiency, regularly estimated as overall efficiency, may be biased. This study analysed the influence of farm management practices on both the persistent and overall efficiency. It also evaluated how conclusions drawn about the effect of management practices are assessed if overall efficiency, instead of permanent efficiency, is evaluated. The empirical application in the study was pig farms in Sweden. Data from the Swedish Farm Accounting Survey (FAS) 2002-2012 and information from a survey related to managerial practices in Sweden were used. The results suggest that managerial practices shape/are related with the permanent efficiency of farms. Managerial experience, agricultural education, and economy-driven goals were found to have positive effect, whereas managerial courses, use of updated budgets, and PigWin software were found to be positively related with the persistent efficiency on the farms. Farmers' focusing on meeting market demand in terms of quality was found to be negatively related with the persistent efficiency. OTE was positively related only with the use of PigWin software, therefore a hidden causality effect on overall technical efficiency was obtained for managerial experience, agricultural education and economy-driven goals.

Key words: managerial practices, overall efficiency, permanent efficiency, pig farms, Sweden.

1. Introduction

Farmers' management practices, such as approach to management control and type of human capital, are widely perceived as key determinants of the technical efficiency (TE) of farms (e.g. Rougoor, Trip et al., 1998; Hansson, 2008; Manevska-Tasevska and Hansson, 2011). For instance, management control approaches can influence the type of information available for decision-making and can thereby directly influence the use of farm production factors (e.g. Puig-Junoy and Argiles, 2004; Hansson, 2008). Furthermore, factors such as farmers' experience (e.g. Puig-Junoy and Argiles, 2004), knowledge (e.g. Galanopoulos, Aggelopoulos et al., 2006; Manevska-Tasevska, 2013), business goals (e.g. Willock, Deary et al., 1999; Wilson, Hadley et al., 2001) and intensity of data recording, budgeting and monitoring of results (Trip, Thijssen et al., 2002; Manevska-Tasevska and Hansson, 2011) have been found to affect TE. A likely reason is that these factors affect how information is interpreted and attention is directed, which also affects decision-making and consequently use of production factors. Hence, understanding how differences in management practices affect efficiency may also help explain why some farms are more efficient than others and how farmers running less efficient farms can change their behaviour in order to become more efficient.

Previous studies examining how farmers' management practices affect TE have typically estimated overall TE scores for each farm and based their evaluations about the management practices on these overall TE scores. Overall TE scores can be used for understanding the potential improvement in overall production that can be achieved by proportionally reducing production factors or proportionally expanding production output. From a conceptual point of view, however, overall technical efficiency is likely to consist of a component related to farm-specific factors (persistent TE; PTE), such as farmers' management practices, and a component related to time-varying residual factors (residual TE; RTE) (Kumbhakar and Heshmati, 1995; Kumbhakar, Lien et al., 2014). Ignoring this in any evaluation of management practices may affect the findings about how those factors affect farm efficiency. PTE is likely to be persistent over time and subject to change only if there are profound changes in the management practices on the farm (Kumbhakar, Lien et al., 2014). Therefore, PTE reflects the impact of persistent conditions on the farm that

predetermine the farm to operate at a particular level of efficiency. RTE, on the other hand, may change over time and is likely to do so due to random factors such as weather conditions, market and policy changes, etc. but also due to the farmer's experience (Kumbhakar, Lien et al., 2014), reflecting that the farmer can learn how to adapt e.g. to the market conditions. Thus, RTE can be considered to reflect the ability of the farmer to incorporate conditions of a time-varying basis upon which the farm is run.

Notwithstanding the contribution made by previous literature, basing studies about the effect of management practices on TE on estimates of overall TE may not be successful in distinguishing a clear effect of management practices. This may especially be the case in situations when the random impact of the business cycle significantly impacts upon TE, and where thus TE is by large an effect to those random factors. Basing the analysis on overall TE estimates may in those situations even dismiss certain characteristics of management practices as insignificant because their impact is blurred due to the existence of RTE. Distinguishing between PTE and OTE in an analysis of the impact of management practices would enable the effect of these factors to be more clearly assessed.

Accordingly, in this paper we distinguish between PTE and OTE, estimate both types of efficiency and assess the effect of farmers' management practices on these two types of efficiency. For comparison, we evaluate the conclusions drawn about the effect of management practices if overall efficiency, instead of PTE, is evaluated.

The empirical application in this study was pig farms in Sweden. Data from the Swedish Farm Accounting Survey (FAS) 2002-2012 and information from a survey related to managerial practices in Sweden were used. In Sweden and in other EU countries, the pig sector is undergoing significant structural change and experiencing problems in becoming profitable (Swedish Board of Agriculture, 2014), requiring reorganisation of pig farms. Farms are typically operating increasingly larger herds, while the number of pig farms is decreasing. For instance, during the period 2005-2010, the average pig herd size increased by 38% in Sweden and similar increases occurred in other EU countries (Eurostat, 2015). At the same time, the number of farms producing pigs decreased by 39% in Sweden and by 28% in other EU countries (Eurostat, 2015).

This study makes a novel contribution to the literature by highlighting the importance of separating PTE and OTE when the influence on efficiency of variables with an accumulated effect, such as management practices, is being analysed. Although it has been

postulated that the influence of management practices differs for persistent, and overall efficiency (Kumbhakar, Lien et al., 2014), to the best of our knowledge the existence of such an influence has never been proven, but would be an important step in improving our understanding of how management practices affect efficiency. The findings presented here are also of practical importance for the farming industry. When policy makers are interested in creating measures to assist farms to operate more efficiently, PTE efficiency thus reflect a separate dimension that need different measures to reduce inefficiency, which the overall efficiency measure may not be able to capture. Furthermore, by evaluating the impact of management practices, insights are provided about how PTE is shaped by management practices and how these types of efficiency can be improved by changes in management practices. Such knowledge can be used by farm advisors to improve advisory services and by agricultural policy makers interested in formulating measures to help farmers become more efficient.

2. Managerial practices – theoretical background

Previous literature has paid significant attention to issues related to management practices and their effects on business outcomes in both agricultural and other types of companies. A review of this literature suggests that issues related to management practices can be viewed in two dimensions: who the manager (in our case the farmer) is and what the manager does.[1] This way of conceptualising management practices also fits well with the framework proposed by Rougoor, Trip et al. (1998), where personal aspects and decision making are at the core of understanding what they call "managerial capacity" and its impact on farm efficiency. Previous literature has found that factors related to type of experience and education (Hansson, 2008; Rivera and Alex, 2008; Manevska-Tasevska, 2013), as well as participation in continuing education (Hansson, 2008) affect the outcome of a business. Factors related to human capital have also been suggested to influence the entrepreneurial process in businesses (Shane, Locke et al., 2003). Such factors can be taken as indicating *who the manager is* and are likely to influence efficiency through differences in human

[1] We are aware that variables explaining who the manager is and variables explaining what the manager does may be correlated and thereby causing problems related to multicollinearity in the empirical estimation of the model. We discuss this at page 14.

nature, while all other factors would remain the same. Farmers with a certain level of knowledge in the field of interest would have the advantage of being able to distinguish a more efficient way of organising the business and thus achieve higher performance. Equally, having the necessary knowledge and experience makes some activities of the business less demanding, permitting activities to become routine, so less effort and processing capacity are required (Kahneman, 2003). This leaves time and remaining cognitive resources for more complicated and elaborate plans to achieve goals (Frese et al., 2009).

The literature also reports that factors such as strategy type (in terms of prospector/defender), deliberate strategy formulation and market orientation (Cadez and Guilding, 2008) and goal orientation (Kahneman, 2003; Hansson, 2008) directly or indirectly influence business performance. Furthermore, factors such as intensity of data recording and level of evaluation (Trip, Thijssen et al., 2002), level of detail in the budget used and monitoring of results and accounting records (Manevska-Tasevska and Hansson, 2011) have been found to be associated with higher efficiency levels. Such factors can be taken as *what the manager does*, i.e. managerial choices undertaken in operating the business. While some of these factors relate to the strategic orientation of the business, others are related to deliberate formulation of plans and provision and use of information in the business. The economic rationale for why this affects efficiency is that management deals with allocating scarce resources to reach goals by taking decisions on how to reach them. In complex decision making, having a sound system of planning, implementation and control can be the difference between success and failure. This strategy can also help in detecting problems or correcting paths of action before the actual outcome is known and in that way help achieve better results (Rougoor, Trip et al., 1998). In their literature review, Cadez and Guilding (2008) argue that using strategic management accounting means having appropriate information at the right time that would improve resource allocation and enhance the outcome of the company. They also see this process as adding value to decision-making that can positively influence the results. Managers that use written proactive plans and budgets and follow up on decisions have been found to have better knowledge of the situation and can react to the external environment adequately (Cadez and Guilding, 2008; Frese, 2009). Cadez and Guilding (2008) define prospector and defender types of strategies in light of market and efficiency orientation, respectively. When managers adapt the prospector type of strategy, they are always looking for opportunities, adjusting to consumer demands and

looking at what their competitors are doing. This places market-oriented companies a step ahead of the less dynamic, efficiency-seeking defender companies. However in other studies, economy-driven farming has been found to contribute to optimal utilisation of inputs to produce outputs and thus to maximise returns (e.g. Galanopoulos, Aggelopoulos et al., 2006)

The two dimensions of management practices can be linked together and boost the effect on efficiency of the business. As mentioned by Rougoor et al. (1998), Shane et al. (2003) and Frese et al. (2009), a certain level of cognition is a prerequisite for successful planning, goal setting and actions by managers in pursuit of higher efficiency or performance of the company. Thus it is suggested that the level of human capital (who the manager is) influences the decisions of farmers about how they run the business (what the manager does) and that in turn influences the outcome of the farm company.

3. Method

The analytical framework applied in this study builds on the literature clarifying the importance of considering the persistent efficiency when the influence of management practices on efficiency is being analysed (Kumbhakar and Heshmati, 1995; Kumbhakar, Lien et al., 2014; Kumbhakar, Wang et al., 2015). A multi-stage procedure to estimate the efficiency and to determine the influence of managerial practices on the efficiency components was used. The influence of the management practices was tested simultaneously for permanent and standard, i.e. overall, efficiency, under the assumption that managerial practices shape farm efficiency in the long run and are thus more relevant for the permanent efficiency of farms.

3.1. Persistent, residual and overall technical efficiency

To analyse efficiency, the parametric stochastic frontier random effects (generalised least squares - GLS) panel model developed by Kumbhakar, Lien et al. (2014, 2015); Kumbhakar, Wang et al. (2015), which distinguishes between the business effects (business heterogeneity), PTE, RTE and OTE was used. Although the main interest of this study is PTE and OTE, RTE is a part of the estimation procedure in order for OTE to be estimated.

Therefore efficiency estimates of PTE, RTE and OTE are provided. According to Greene (2004), fixed effects models fail to distinguish between the heterogeneity unrelated to inefficiency and the inefficiency itself. As TE is a measure showing the heterogeneity of farms and unobserved business effects might be inappropriately labelled as inefficiency, the model estimates provided for farms with different technological potential may be biased. In the present study, the heterogeneity of the pig sector needs to be considered, since farms may have different production enterprises, namely: i) piglet production, ii) finishing pig production and iii) integrated piglet and finishing pig production (for details of production enterprises, see section 4).

The three-step approach elaborated by Kumbhakar, Wang et al. (2015) was applied, using STATA (StataCorp, 2014). The inefficiency model used in this study took the form:

$$y_{it} = \alpha_0 + f(x_{it};\beta) + \mu_i + \nu_{it} - \eta_i - \upsilon_{it} \quad (1)$$

where y_{it} is a log of output for farm i at time t; α_0 is the intercept; $f(x_{it};\beta)$ is the production function, which has a translog form to give a model flexibility (Kumbhakar, Lien et al., 2014); μ_i represents the business effects capturing the unobserved time-invariant inputs and does not explain inefficiency (business heterogeneity); ν_{it} is random noise; η_i is persistent technical inefficiency; and υ_{it} is residual technical inefficiency. For estimation purposes, equation (1) is written as:

$$y_{it} = \alpha_0^* + f(x_{it};\beta) + \alpha_i + \varepsilon_{it} \quad (2)$$

Where, α_0^* is intercept of a particular producer ($\alpha_0^* = \alpha_0 - E(\eta_i) - E(\upsilon_{it})$); α_i is the time-invariant component (containing the business effect μ_i and the time-invariant inefficiency component η_i; and ε_{it} is the error term, (containing the time-variant inefficiency component υ_{it}, and the random noise ν_{it}). α_i and ε_{it} have zero mean and constant variance. Given the estimation procedure, step 1 estimates the predicted values of $\hat{\beta}$, $\hat{\alpha}_i$ and $\hat{\varepsilon}_{it}$. In step 2, the predicted values of $\hat{\varepsilon}_{it}$ from step 1 are used for estimation of the predicted residual time-varying technical inefficiency (3), as:

$$\varepsilon_{it} = \nu_{it} - \upsilon_{it} + E(\upsilon_{it}) \quad (3)$$

by assuming the random noise v_{it} is i.i.d. $N(0, \sigma_v^2)$ and the residual inefficiency term υ_{it} is $N^+(0, \sigma_\upsilon^2)$, which means $E(\upsilon_{it}) = \left(\sqrt{\frac{2}{\pi}}\sigma_\upsilon\right)$. In step 3, the predicted persistent technical inefficiency $\hat{\eta}_i$ is estimated from the best linear predictor of α_i, obtained from step 1 as:

$$\alpha_i = \mu_i - \eta_i + E(\eta_i) \quad (4)$$

by assuming the business effect μ_i is i.i.d. $N\left(0, \sigma_\mu^2\right)$ and the persistent inefficiency term η_i is $N^+\left(0, \sigma_\eta^2\right)$, which means $E(\eta_i) = \left(\sqrt{\frac{2}{\pi}}\sigma_\eta\right)$.

Residual and persistent technical efficiency are estimated from $RTE = exp(-\hat{\upsilon}_{it})$ and $PTE = exp(-\hat{\eta}_i)$, respectively, while the overall technical efficiency OTE is obtained as a product of permanent and residual efficiency: $OTE = PTE \times RTE$. The TE indices range between 0 and 1, as a proxy for a maximum attainable score, and show a farm's ability to generate output given a level of input used.

3.2. Measuring influence of management practices

The model presented by Kumbhakar, Lien et al. (2014) does not offer the possibility of estimating the effects of sources of persistent and overall inefficiency simultaneously with the efficiency scores. Therefore, an alternative regression analysis which considers the censored characters of the efficiency estimates and the possible interdependence across the efficiency estimates (PTE and OTE) was selected.

The analytical approach used to measure the impact of management practices suited the two equation seemingly-unrelated regression (SUR) BiTobit model (Huang, 1999). The model simultaneously calculated the influence of the managerial practices on PTE and OTE. The model allowed us to produce results comparable with the existing literature, where OTE is the only observed dependent variable. Parameters in SUR systems can be estimated in separate equations, but simultaneous estimation takes into account the full covariate structure (Roodman, 2009). Application of the alternative univariate Tobit which assumes two individual Tobit models was rejected due to the possible interdependency that exists between PTE and OTE (Cornick, Cox et al., 1994; Yoo, 2005). The assumption of no interdependence between PTE and OTE (which is required for univariate Tobit) was too

strong to be satisfied, because PTE, and OTE were calculated for the same production units and because the same set of explanatory variables was used in both equations. The model specification applied in the study was as follows:

$$y_{1i}^{*} = \beta_1 x_{1i} + \epsilon_{1i};\ \ y_{2i}^{*} = \beta_2 x_{2i} + \epsilon_{2i}\ ;\ the\ notations\ 1,2\ are\ for\ equation\ 1\ and\ 2 \quad (5)$$

$$y_{1i} = y_{1i}^{*}\ if\ y_{1i}^{*} > 0,\ y_{1i} = 0\ otherwise; y_{2i} = y_{2i}^{*}\ if\ y_{2i}^{*} > 0,\ y_{2i} = 0\ otherwise \quad (6)$$

Where y_{1i}^{*} and y_{2i}^{*} are latent variables in equation 1 and in equation 2 for each farm i; β_1 and β_2 are marginal effects of the vectors (set of explanatory variables) x_{1i}, x_{2i}, in the two equation system, and ϵ_{1i} ϵ_{2i} are error terms. In the BiTobit model y_{1i}^{*} and y_{2i}^{*} are represented by the estimated PTE and OTE, obtained in the first stage of the analysis (equation 1 to 4); As stated in equation (6), the observed y_{1i} and y_{2i} equal the true value if $y_{1i}^{*},\ y_{2i}^{*} > 0$; otherwise, the observed $y_{1i,}\ y_{2i}$ is left-censored to be zero (Huang, 1999). y_1^{*}, y_2^{*} have a joint bivariate normal distribution, with a correlation coefficient ρ of y_1^{*}, y_2^{*} not approaching zero, otherwise, the univariate approach with two separate normal density functions needs to be applied. Maximum likelihood estimation was conducted using the STATA code for bivariate Tobit (BiTobit) regression as formulated by Lawson (2007).

4. Data and variables

The data used for calculating the efficiency coefficients were obtained from the Swedish Farm Accounting Survey (FAS), which is carried out by Statistics Sweden on behalf of the Swedish Board of Agriculture, as the Swedish input for the EU Farm Accounting Data Network (FADN). Data are collected in the form of an unbalanced panel, where approximately 10% of farms are replaced every year. In this study we used data from 2002-2012 for farms specialising in pig production, following the FADN classification (EU Commission Regulation, 2008). In total, 1229 observations, representing 196 individual pig farms, were included in the study (of which 47% were piglet farms, 20% finishing farms and 33% farms with integrated production). The average farm appearance in the dataset was six years. Two-year appearance was taken as a threshold for the panel approach to be satisfied (Kumbhakar, Lien et al., 2014). According to Kumbhakar and Heshmati (1995) and

Kumbhakar, Wang et al. (2015), such short-term panels are of great use to reflect the effect of management in models where the existence of persistent and residual efficiency is considered.

The FAS dataset provided information on monetary and/or physical units of production, (e.g. inventory, labour, land and livestock etc.), from which one output and six input variables to estimate the efficiency were created (Table 1). The output was defined as farm revenue excluding the farm support payments (in '00 SEK), and deflated with respect to the output index obtained from the Swedish Board of Agriculture, with 2005 as the base year. Inputs were represented by: i) total livestock units (LU), estimated following the standard computational procedure for aggregation of livestock from various species and age; ii) agricultural area utilised, in hectares; iii) farm labour, represented by both family and hired workers, and expressed in total working hours; iv) costs of materials, including: feed, total costs of seeds, fertilisers, crop protection, other variable livestock-specific costs; v) energy costs, including: electricity, fuel for heating and machinery, lubricants and water, and vi) total costs on capital use, represented by: depreciation, maintenance of buildings and machinery, rents, insurance, etc. In the same way as for output, the costs related to inputs (materials, energy and capital) were measured in '00 SEK, deflated with the respective cost index, with 2005 as the base year. Descriptive statistics on the production function variables are given in Table 1.

Characteristics of the management practices assumed to affect the efficiency of pig production are not included in the FAS data, and such data were obtained from a mail survey (Appendix 1, in Swedish). Questions relating to managerial practices were part of a larger collection of primary data from pig farms that participated in FAS in 2010. Data collection was performed by the Swedish Board of Agriculture in 2012, on behalf of the research group. As the respondents provided information on the current managerial practices, panel data on such characteristics could not be obtained. In total 138 questionnaires were distributed, followed by two reminders and where necessary by telephone calls. This yielded 87 responses (response rate 63%). Responding farmers were rewarded with a 300 SEK gift voucher (1 EURO = 6.7 SEK) for a local garden centre, as a token of our appreciation for their time and effort. Of the 87 responses, 75 complete responses were obtained (representing 38% of the farms included in the FAS dataset), 35 for piglet, 18 for finishing and 22 for integrated pig enterprises.

Table 1. Summary statistics of production function and management practice variables

Variable	Unit/Scale	Value (St. dev)
Production function		
Total revenue	SEK (million)*	2.75 (3.18)
Total livestock units	LU	234 (277)
Agricultural area utilised	Ha	83 (87)
Labour	Hours ('000)	3.73 (2.49)
Materials	SEK (million)*	1.00 (1.19)
Energy	SEK (million)*	0.18 (.17)
Capital	SEK (million)*	0.60 (.67)
1. Production enterprise		
Piglets	1 if yes; 0 if not	45.33%
Finishing (base)	1 if yes; 0 if not	24.00%
Integrated	1 if yes; 0 if not	30.67%
Management practices		
Who the manager is:		
2. Human capital factors		
Managerial experience	Years, as a manager	22.83(9.97)
Higher agricultural education	1 if agricultural and rural management - or agronomist program; 0 if other education	23.94%
Participation in courses for managers	1= I have participated in managerial courses; 0 = no, I do not usually participate in any,	85%
What the manager does:		
3. Objectives		
Economy-driven farming	1 for aiming at as high as possible profit; 0 if other goals (such as, agriculture as a passion, fulfil dreams and visons, social interaction, to sell the farm with high profit)	33.33%
4. Strategy		
Focus on quality	1 if focus on high quality meat, taste, smell structure; 0 if other prioritized focus	45.83%
Focus on animal welfare	1 if focus on work for as good as possible animal welfare; 0 if other prioritized focus	44.59%
5. Use of strategic management accounting		
		2.37
Budget	1 = budget is made for every coming year; 0 = budget is not needed due to the farm's stable income and costs	33.78
Use of PigWin	1 = yes, 0 = no	49.31%
6. Deliberate strategic planning		
Written plans	1 if yes; 0 if not	50.67%
Follow up on decisions	1 if yes; 0 if no	62.67%

Note: *In the efficiency analysis, revenue, materials, energy and capital costs are observed as log values (of '00 SEK). In the table, "million" SEK is used for better clarity (1 EURO = 6.7 SEK). Production function variables are derived from FAS data and information on management practices from mail survey data.

Following the main objective of the paper, theoretical background and the conceptualisation of "who farmers are", and "what farmers do", farmers' management practices were represented by both: a set of human capital factors and a set of strategic management characteristics. As noted in the theoretical background the two dimensions of

management practices can be linked together and boost the effect on efficiency of the business. Rougoor et al. (1998), Shane et al. (2003) and Frese et al. (2009), claim that a certain level of cognition is a prerequisite for successful planning, goal setting and actions by managers in pursuit of higher efficiency or performance of the company. Thus "who the manager is" influences the decisions of farmers and by that "what the manager does", and that in turn influences the outcome of the farm company. From an analytical point of view interdependence between the two sets of variables may result in multicollinearity problems. This was investigated using correlation analysis (Appendix Table A2) and found not to be a problem. A detailed description of the variables used to capture the farmers' management practices is presented in Table 1.

"**Who farmers are"** is explained in terms of their human capital, namely skills and knowledge (Frese, 2009). Three separate variables were used here: managerial experience, acquisition of higher agricultural education, and participation in training activities for managers. *Managerial experience* characterises farmers' accumulated knowledge and acquired skills. This allows to managers to routinise activities so that less effort and processing capacity are required (Kahneman, 2003). In the present study, managerial experience was measured in years as manager of the farm. *Acquisitions of higher agricultural education and participation in training activities for managers* were used as measures of human capital and knowledge quality (Gloy, Hyde et al., 2002). Two separate dummy variables were constructed. In the first dummy variable a value of 1 was used if the farmer had acquired higher education in agriculture (such as agricultural and rural management or agronomist program) and 0 for other education. In the second dummy, a value of 1 was given for farmers that have participated in managerial courses and 0 otherwise.

"What farmers do" relates to farmers' objectives, strategic orientation of the business and to the deliberate formulation of plans and provision and use of information in the business (e.g. Rougoor, Trip et al., 1998; Cadez and Guilding, 2008). Four sets of variables were considered: objectives, strategy to fulfil the objectives, management accounting and deliberate planning.

Objectives on *economy-driven* farming assume optimal utilisation of inputs to produce outputs in a manner that maximises returns (Galanopoulos, Aggelopoulos et al., 2006). In the present study, economically driven farmers were assumed, and thereby asked in the

survey if they favour farm economics (profits) instead of having farming as their passion, to fulfil their dreams and visons, or because of the social interaction. One dummy variable distinguishing between the choice for active, economically driven strategy and the other non-economic alternatives (such as farming as their passion, to fulfil their dreams and visons, social interaction) was used. Where, 1 was given for the choice economically driven objectives and 0 otherwise.

Strategy based on active searching for economic prospects for the business and market needs has the potential to improve business performance (Cadez and Guilding, 2008). According to Narver and Slater (1990), *market oriented strategy* is key in modern management aiming at profitable business, where managers searching for product and market opportunities are creators of innovation and thus build the performance of the business (Miles, Snow et al., 1978). In the present study market-orientated producers were observed as farmers with a strategy/focus on: i) product quality, including taste, smell, structure, etc. and ii) as good as possible animal welfare. Two separate dummies on the alternatives i, ii with 1 for each choice and 0 otherwise, were used.

Management accounting practices facilitate more effective managerial decisions and thus improve organisational performance (Cadez and Guilding, 2008). The type of managerial control system adopted by a particular farm is an indication of the manager's interest in financial analysis (Gloy, Hyde et al., 2002), which helps farmers convert their records into important information. In this study, two variables explaining the use of management accounting were used: *development of budget* for upcoming year; and ii) *use of PigWin* software for herd recording and managing pig farms. Both variables i) and ii) are dummies, with 1 given for the applied practice and 0 otherwise.

Furthermore, continuous follow up and re-consideration of management decisions is the basis for *deliberate strategy planning* expected to have a positive impact on management accounting, and therefore on performance (Cadez and Guilding, 2008). In the present study, farmers' attitude to deliberate strategic planning was explained by their practices as regards preparing written plans and following up on major decisions related to production (e.g. major reconstruction, purchase of expensive equipment etc.). In both cases, a dummy variable was assigned 1 for the applied practice and 0 otherwise.

For the regression analysis, information on managerial practices obtained from the farms in the FAS data that participated in the mail survey (questionnaire) in 2012 were

matched with the PTE coefficients (estimated from the panel data covering the period 2002-2012), and the OTE coefficients (estimated from the cross section data for 2012, or earliest for 2010 if data for 2011 and 2012 are not available), for the corresponding farms. Although in the FAS data the average appearance of farms is 6 years, some farms occur in the data set over the whole period. From an analytical point of view panel data for estimation of PTE and OTE, and the managerial variables, would be more appropriate, since some managerial characteristics might change over time (for instance, participation in managerial courses, focus on animal welfare, use of Pigwin software). If so, it may be questioned if differences in characteristics at the end of the period can "explain" differences in efficiency between farms estimated over the whole period. Thus, for variables that are suspected to change over time, the regression results are regarded as measures of correlation, instead of causality (correlations indicate that variables move together which could be because changes in one variable causes changes in the other, but the direction of causality is not clear, or because changes in both variables are caused by changes in a third variable for which information is lacking). Differences between managers in terms of experience, higher education, and objectives, are less likely to change over time. Accordingly, absence of panel data on such characteristics may be less problematic for interpreting estimation results as causal effects though it could be argued that decisions on education are taken simultaneously with career decisions.

Production orientation characteristics were considered as control variables in the regression analysis, where the statistical significance of their influence on permanent, residual and overall technical efficiency was considered. Farm classification on production orientation was based on two criteria: 1) survey evidence, where farmers participating in the survey provided information on production orientation; and 2) herd structure and 3) revenue structure as technology-specific characteristics. For 2) and 3), two-thirds was taken as a threshold for the matching criteria. Hence, farms belonging to the group for piglet production declared a specialisation in piglet production and/or 2/3 of the total revenue/livestock units were piglets; farms belonging to the group of finishing farms declared a specialisation in finishing production and/or 2/3 of the total revenue/livestock units were pigs for slaughter, with piglets rarely present on the farm; and the integrated production farms were determined by declared integrated production and/or both piglets and pigs for slaughter found on the farm. Three dummy variables representing piglet,

finishing and integrated production were used, where 1 was given for the applied production technology and 0 otherwise. As the production orientation was determined *a priori* and the Kumbhakar, Wang et al. (2015) model accounts for latent business heterogeneity, models controlling for unobservable technologies such as cluster analysis, propensity score matching (PSM) (e.g. Pufahl and Weiss, 2009; Villano, Bravo-Ureta et al., 2015) or latent class models (LCM) (Caudill, 2003; Orea and Kumbhakar, 2004) did not need to be considered in this study.

As can be seen from the descriptive statistics (Table 1), farms specialising in piglet, finishing and integrated production represented 45%, 24%, and 31%, respectively, of the sample participating in the mail survey. These proportions were similar to those in the FAS data set (47%, 20% and 33%, respectively). Although the average efficiency scores across the production orientation may differ, characteristics of management practices included in the study were not expected to be specific for any of the production orientations. A correlation matrix showing the correlation coefficient (and the level of significance) of the variables included in the regression analysis is presented in the appendix (Table A2). No correlation was found between the management practices and the production orientation variables. The remaining descriptive statistics showed that the Swedish pig producers had on average 23 years of managerial experience and about 24% of them had acquired agricultural education. Courses for managers are attended by 85% of the farmers included in the survey. Approximately half reported that they focus on product quality (46%) and animal welfare (45%), and around a third of the respondents (33%) had economy-driven goals, 51% had written plans for strategic planning and 63% monitored their major decisions. However, only 34% believed that there is a need for a budget to be made every year. The PigWin software for herd recording and managing pig farms was used by 49% of the producers included in the analysis.

5. Results and discussion

This section presents results obtained with the multi-stage procedure estimating the: i) permanent, residual, and overall technical efficiency; and ii) effects of management practices on the efficiency differences (PTE and OTE) in the Swedish pig sector. Although the

main focus of this study is the influence of the farm management practices on the PTE and OTE, RTE is a part of the estimation procedure in order for OTE to be obtained. Therefore efficiency estimates of PTE, RTE and OTE are provided and discussed.

5.1. Efficiency estimates: sample and production orientation specifics

Efficiency estimates for PTE, RTE and OTE are produced using the FAS data for the whole period 2002-2012. Descriptive statistics on the efficiency coefficients of the aggregated FAS sample and across the pig production specialisations (with business heterogeneity considered in the model) are presented in Table 2. Details on the production function parameters and the key distributional figures on estimated PTE, RTE and OTE are given in the appendix (Table A1 and Figure A1 respectively).

Table 2. Descriptive statistics on residual, permanent and overall TE. Characteristics of the sample and production enterprises

Variable	Obs.	Mean	Std. Dev.	Min	Max
Sample characteristics					
Residual TE	1229	0.89	0.05	0.58	0.97
Permanent TE	1229	0.90	0.03	0.76	0.95
Overall TE	1229	0.80	0.05	0.52	0.91
Production enterprise					
1. Piglet production					
Residual TE	584	0.89	0.05	0.64	0.97
Permanent TE	584	0.89	0.03	0.76	0.94
Overall TE	584	0.80	0.05	0.56	0.90
2. Finishing production					
Residual TE	242	0.89	0.06	0.58	0.97
Permanent TE	242	0.92	0.02	0.86	0.95
Overall TE	242	0.82	0.05	0.52	0.91
3. Integrated production					
Residual TE	403	0.89	0.04	0.69	0.97
Permanent TE	403	0.89	0.02	0.83	0.93
Overall TE	403	0.79	0.04	0.59	0.89

Note: Based on FAS data.

Results for the aggregated FAS sample showed that both the residual (0.89) and the permanent TE (0.90) are equally important for the pig sector in Sweden. However, the estimates of RTE showed higher variation across farms and lower minimum values when

compared with the PTE, which means higher diversity and possibility for improvements across farms in terms of RTE (see appendix, Figure A1). Average estimated OTE was 0.80. Looking at the average efficiency in the respective production orientations, PTE seemed to be higher for finishing farms, with an efficiency level of 0.92, compared with 0.89 for piglet and integrated farms. The average RTE of the finishing, piglet and integrated farms was 0.89, whereas the average OTE ranged from 0.79 for the integrated farms to 0.80 for the piglet farms and 0.82 for the finishing farms. A graphical presentation of the trends for average, PTE and OTE in the selected production enterprises (sample average) is given in Figure 1.

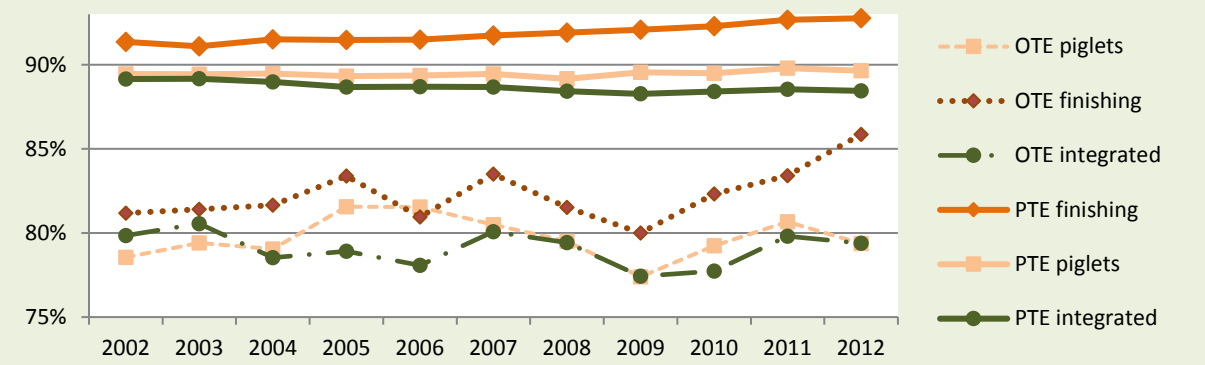

Figure 1. Dynamics of average permanent and overall TE for different pig production enterprises (sample characteristics). Based on FAS data.

To the best of our knowledge, efficiency analysis distinguishing between the permanent and residual components of overall efficiency on pig farms has not been performed previously. For grain farms in Norway during 2004-2008, Kumbhakar, Lien et al. (2014) found persistent efficiency (0.71) to be smaller than residual efficiency (0.89), suggesting that persistent inefficiency needed to be prioritised for long-term problems to be avoided. Similarly, higher RTE (0.93) than PTE (0.90) has been reported for Swedish dairy farms 1976-1988, (Kumbhakar and Heshmati, 1995).

The average estimated OTE on pig farms across Europe ranges from 0.42 to 0.55 for farrow-to-finish and finishing pig farms in Hungary (Latruffe, Desjeux et al., 2013), to 0.83 in Greece (Galanopoulos, Aggelopoulos et al., 2006), 0.86 in the Netherlands (Lansink and Reinhard, 2004) and 0.90 in Denmark (Rasmussen, 2010). With the exception of a study by Latruffe, Desjeux et al. (2013), where separate frontier analysis was conducted for farrow-to-finish and finishing technology, latent business effects have been not considered.

5.2. Impact of managerial practices on, permanent and overall efficiency

The results of the regression analysis of the influence of management practice characteristics on persistent and overall TE of Swedish pig producers are shown in Table 3.

Table 3. Summary results of the bivariate model. Effect of management practices on permanent, and overall TE

Variabels	PTE		OTE	
	Coef.	P>z	Coef.	P>z
Production enterprise				
Finishing is a base				
Piglets	-.0302	***	-.0828	***
Integrated	-.0407	***	-.0680	***
Who the manager is:				
Human capital factors				
Managerial experience	.0004	*	.0005	
Higher agric. education	.0092	*	.0010	
Participation in courses for managers	.0117	*	.0058	
What the manager does:				
Objectives				
Economy-driven farming	.0094	*	.0148	
Strategy				
Focus on quality	-.0154	**	-.0250	
Focus on animal welfare	-.0008		-.0293	
Use of strategic management accounting				
Budget	.0111	**	.0167	
Pig Win	.0142	***	.0306	**
Deliberate strategic planning				
Written plans	.0022		.0149	
Follow up of decisions	.0052		.0069	
_cons	.8973	***	.8608	***
Sigma 1&2	.0169	***	.0439	***
Atan_rho	.8724	***		
Log likelihood	282.4401			
Wald chi2(15)	53.38			
Prob > chi2	.0000			

Note: ***statistically significant at 1%, **statistically significant at 5%, *statistically significant at 10%. Permanent, residual and overall TE estimated from FAS data and information on management practices collected with the mail survey.

The parameter estimates in Table 3 indicate the direction and the "effects" of the selected management-related variables, with a positive sign for a positive influence on the technical efficiencies and a negative sign for a negative influence. Coefficients for variables where differences between individuals are unlikely to change over time (experience, education,

and objectives) are interpreted as measuring causal effects, while coefficients for variables where differences between individuals could have changed during the period (participation in managerial courses, focus on animal welfare, use of Pigwin software, updating budgets etc.), are interpreted as measures of correlation. As in previous studies applying limited dependent variables models, e.g. Galanopoulos, Aggelopoulos et al. (2006), the parameter estimates show the marginal effect at the mean of the data. The results for model fit confirmed the existence of relationships between the dependant variables, namely: PTE vs. OTE, originating from positively correlated unobservable characteristics common for both error terms (atan_rho is positive and statistically significant).

Production orientation characteristics were of great importance for the persistent and overall TE of farms. Based on the statistics representing average TE achieved (Table 2, Figure 1), finishing farms had higher permanent, and overall efficiency than farms specialising in piglet and integrated production. Characteristics of managerial practices, both in terms of "Who the farmer is", and "What the farmer does" were found to determine, or be correlated with the time-invariant, long-term PTE of the farms (see Table 3). A positive impact on PTE was found for managerial experience, applied agricultural education, and economy-driven objectives. Following the reasoning that some of the managerial practices are more likely to change over the period than others, attendance of managerial courses, use of updated budgets and PigWin software, were interpreted to be positively corelated with PTE.

The influence of managerial characteristics on PTE has not been tested separately in the literature and thus there are no results with which to compare. The marginal effects and level of significance obtained for managerial practice characteristics on OTE (Table 3) were correlated with the parameters for PTE. As with PTE, OTE was found to be positively correlated only with the use of strategic management accounting practices, namely PigWin software.

Although some researchers have found that knowledge human capital is important for efficient farming (Rivera and Alex, 2008; Manevska-Tasevska, 2013), previous findings on the influence of knowledge sources on the overall efficiency of farms are rather contradictory. For instance, experienced managers are expected to benefit from the knowledge generated (Puig-Junoy and Argiles, 2004), but may have less interest in application of updated technology (Gloy, Hyde et al., 2002). In our study, managers

benefited from their accumulated knowledge and skills obtained through experience, and education. In addition, managerial courses were found to be positively correlated with the long run farm efficiency, namely PTE. In the study by Puig-Junoy and Argiles (2004), managerial experience was expected to provide management skills and thus increase the efficiency but no significant result on OTE was obtained, with those authors claiming that the estimate must contain some hidden effects. In our study except for managerial experience, such hidden effects/correlations were also found for knowledge obtained from official educational programs (higher agricultural education) and knowledge from vocational training (courses for managers) respectively. In such cases when the influence of some factors on OTE is hidden the results obtained for OTE cannot be generalised. Farmers' strategic orientation based on active searching for improved economic potential (Galanopoulos, Aggelopoulos et al., 2006) and market opportunities (Miles, Snow et al., 1978; Narver and Slater, 1990) is expected to build business performance. In the present study, economically driven farmers were assumed to favour the economy of their farms instead of having farming as their passion/to fulfil their dreams and visions/for social interaction. The results suggest that economy-driven farming improves farm efficiency in terms of, PTE. Indeed, by optimal utilisation of inputs, farmers produce outputs in a manner that maximises returns, achieving higher efficiency in the long run. However, the expectation that all farmers can be purely economically driven is unrealistic. The strategy to focus on product quality and animal welfare is of great importance for Swedish pig producers. According to the information provided by the mail survey, about 45% of pig producers focus on product quality or animal welfare. Given the results obtained in this study, farmers focus on higher product quality is negatively correlated with farm efficiency in the long run, i.e., PTE. Concerns about meat product quality and safety are continually increasing among consumers (Bernués, Olaizola et al., 2003) and product quality instruments are regulated within the platform of the EU's common agricultural policy (CAP). However, the effects of compensation and utilisation of the benefits expected from the product quality instruments seem to be limited. Manevska-Tasevska, Rabinowicz et al. (2013) have shown that, in total, Swedish pig producers are among the highest recipients of agricultural quality support payments in Sweden, but the payments have a marginal effect in compensating for revenue losses. The product quality-orientated pig producers' efficiency problems may result from the highly competitive EU market, particularly the German and

the Danish pig industry, which contribute 41% and 34% of Swedish imports, respectively (Swedish Board of Agriculture, 2015). However, as the influence of market structure parameters, due to data limitations, was not examined in this study, the hypothesis cannot be tested.

Management grounded on accounting information may help managers facilitate more effective managerial decisions (Cadez and Guilding, 2008) and better evaluate the effects of their decisions (Puig-Junoy and Argiles, 2004), and thus enhance their efficiency. The type of accounting system adopted by the farm is an indication of managerial interest in financial analysis and thus accounts analysis on farms (Gloy, Hyde et al., 2002). In this study, use of strategic management accounting practices, including updated budgets, and PigWin software for herd registration and production management is positively correlated with PTE, while the use of PigWin is correlated with higher OTE on the farms. In a previous study, advanced computerised systems also proved to be drivers of business performance (Gloy, Hyde et al., 2002), helping farmers convert their records into important information. An influence of deliberate strategic planning on PTE, and OTE was not found in this study.

6. Conclusions and policy recommendations

Managerial capacity builds over the years and the accumulated knowledge and practice affect the outcome of the following period, giving long-term/permanent effects on efficiency (Kumbhakar and Heshmati, 1995; Kumbhakar, Wang et al., 2015). Therefore predictions about the influence of managerial capacity on the time-varying inefficiency component, regularly estimated as overall efficiency, may be biased. However, some managerial activities may also be associated with e.g. production changes (input planning), and therefore the time-varying efficiency, e.g. farmers who regularly check their accounting information are able to make yearly adjustments on input use and thus improve efficiency in the short run.

This study highlights the importance of separating the persistent and residual component of the overall efficiency when the influence on efficiency of variables with an accumulated effect, such as management practices, is being analysed. Distinguishing between these two components of efficiency is important particularly for strategic planning of sector development. By knowing where the inefficiency comes from, different policy

instruments and advisory services can be promoted.

The findings confirm the hypothesis that managerial practices such as managerial experience, agricultural education, and economy-driven goals, affect PTE. Managerial practices where variation over the period can be expected, such as for managerial courses, the practice to update budgets, and the use PigWin software were found to be positively correlated with PTE. Similarly, focusing on meeting market demands in terms of quality was found to be negatively correlated with PTE. Results showing causal effects of such variables could be obtained if panel data on the managerial practices were available. As with PTE, OTE was positively correlated only with the use of PigWin software. A hidden effect on OTE was obtained for managerial experience, agricultural education, and economy driven goals, whereas hidden correlations were found for courses for managers and focus on product quality, which were found to influence/be correlated with PTE. Furthermore, according to the results, finishing pig farms are more efficient than farms specialising in piglet or integrated production both in case of PTE and OTE.

Persistent and residual inefficiency were found to have similar scores. Therefore policy measures focusing on both PTE and RTE are important. With respect to managerial practices, policy measures strengthening the analytical capacity of farmers, such as supporting advisory services to provide training on strategic management accounting with the focus on budgeting and using software for managing farms, and developing managerial skills can be recommended in order to improve PTE. Less experienced farmers were found to have lower persistent efficiency, so support for strengthening the managerial skills of young farmers needs to be provided. Furthermore, market-orientated producers may have a need for additional advisory support in e.g. marketing/labelling/selling their products, which could improve product value and thus increase total output.

This study was based on FAS data, where farms with economic size of at least five European Standard Units (ESU, 1=1200 euro Standard Output) are included. Therefore the present findings on PTE, RTE and OTE cannot be generalised to smaller farms. The limited number of farms participating in the mail survey further reduced the generalisability of the results (38% of the farms included in the FAS data provided information on managerial practices applied on their farms). Managerial characteristics in general are not expected to change substantially over the short period of time (Kumbhakar and Heshmati, 1995; Kumbhakar, Wang et al., 2015). However some of the managerial characteristics included in

the study may have stronger potential to change over the time, such as attending courses, use of strategic management accounting practices etc. Since such changes could not be traced, due to the constraints on panel data availability, the estimated impacts of these characteristics on PTE were interpreted as correlation, instead of as causality. However, the dataset used in this study is unique and contains details of managerial practices which cannot be found in the standard datasets. A feature of great importance is that each farm from the subsample explaining the managerial practices could be matched with the corresponding farm-specific efficiency scores estimated from the FAS data.

Further research on other phenomena with a potential accumulated effect on farm efficiency, such as the effects of rural development programmes/policy measures, work by the advisory services etc. could be of great importance, especially for rural development policy evaluation and further policy instrument adjustments. Furthermore, as this study focused only on the PTE component, impact of potential time-varying factors on the time-varying RTE component could be interesting to be observed.

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Appendix 1: Bakgrunds/enkät* frågar om företagsledningen på gården

Please observe that the questionnaire sent to the farmers consisted of more questions and that only a fraction of the questions were considered useful for this study.

Del 1: Frågor om din grisproduktion

1. Vilken typ av grisproduktion bedrivs på din gård?

i) Specialiserad smågrisproduktion

ii) Specialiserad slaktsvinsproduktion

iii) Integrerad smågris- och slaktsvinsproduktion

iv) Annat, ange vad:_____

Del 2: Frågor om dig som företagsledare

2. Sedan vilket år har du bedrivit grisproduktion i egen regi?

Sedan år _ _ _ _ _ _

3. Vilka av följande utbildningar har du? *Flera alternativ kan väljas*

i) Grundskola eller liknande

ii) Lantmästarutbildning

iii) Naturbruksgymnasium

iv) Annan utbildning, vad_____

v) Agronomutbildning

vi) Annan gymnasieutbildning

vii) Annan universitetsexamen

4. Deltar du själv i någon typ av fortbildning inom ämnen sam rör din grisproduktion?

i) Ja, någon gång per kvartal eller oftare

ii) Ja, men mer sällan an en gång per ar

iii) Ja, ett par gånger om året

iv) Ja, ca en gång per ar

v) Nej, jag brukar inte delta i någon fortbildning

5. Vilket av följande alternativ skulle du säga ar absolut viktigast for dig nar du driver ditt företag? *Välj endast ett alternativ.*

i) Att fa högsta möjliga vinst i företaget

ii) Att arbeta med lantbruk

iii) Att förverkliga mina drömmar och visioner

iv) Att en dag kunna sälja gården till högsta möjliga vinst

v) Att känna att jag deltar i ett socialt sammanhang, t.ex. att arbeta tillsammans med familjemedlemmar och/eller att driva en släktgård

6. När du har fattat och genomfort ett sådant större beslut som avses i frågan ovan, brukar du då i ett senare skede göra uppföljningar av hur det gick?

i) Ja, alltid ii) Ibland iii) Nej, aldrig

7. Arbetar ditt företag aktivt med skriftliga affärs- och/eller verksamhetsplaner?

i) Ja, och planerna uppdateras regelbundet

ii) Ja, och planerna uppdateras nar t.ex. banken eller lansstyrelsen så kräver

iii) Nej, jag brukar hålla företagets planer i huvudet

8. Brukar du eller någon annan i ditt företag göra budget för det kommande arets inkomster och utgifter? *Välj endast ett alternativ.*

i) Ja, budget görs för det kommande året

ii) Nej, gårdens inkomster och utgifter är så stabila att någon budget inte behovs

9. Anvander ditt företag PigWin till journalföring och analys?

i) Ja

ii) Ja, och företaget använder också andra eller egna metoder

iii) Nej, företaget använder andra eller egna metoder

10. Vad tycker du som företagsledare ar viktigt? Rangordna de tre viktigaste av följande alternativ.

i) Att köttet ar av högsta kvalitet med avseende på mörhet, smak, lukt, saftighet etc.

ii) Att grisarna har en så hög vikt som möjligt

iii) Att konsumenterna ska uppskatta grisköttet som produceras vid min gard

iv) Att arbeta för en så god djur välfärd som möjligt

v) Att arbeta for att minimera produktionens miljöpåverkan.

Appendix Table A1: Production function parameters

	Coef.	Std. Err.	P>z	[95% Conf.	Interval]
ln1: livestock units	.6970	.2262	***	.2536	1.1404
ln2: area	.0615	.1482		-.2289	.3519
ln3: labour	-.3050	.4073		-1.1033	.4933
ln4: materials	.7245	.2573	***	.2202	1.2289
ln5: energy	.7191	.2857	***	.1591	1.2791
ln6: capital	-.8052	.3064	***	-1.4058	-.2048
ln11: livestock units* livestock units	.1335	.0248	***	.0849	.1821
ln22: area* area	.0365	.0175	**	.00224	.0707
ln33: labour* labour	-.0242	.0707		-.1628	.1144
ln44: materials* materials	.0296	.0524		-.07304	.1322
ln55: energy*energy	.1232	.0376	***	.0496	.1968
ln66: capital*capital	.1145	.0589	*	-.0009	.2299
ln12: livestock units*area	.0404	.0142	***	.0125	.0682
ln13: livestock units*labour	-.0561	.0331	*	-.1209	.0088
lnx14: livestock units*materials	-.0517	.0272	*	-.10490	.0016
lnx16: livestock units*energy	.0491	.0294	*	-.0086	.1069
lnx15: livestock units*capital	-.0997	.0310	***	-.1604	-.0389
ln23: area*labour	.0306	.0195		-.0076	.0689
ln24: area*materials	-.0332	.0216		-.0755	.0092
ln25: area*energy	-.0433	.0184	**	-.0794	-.0071
ln26: area*capital	-.0069	.0209		-.0478	.0339
ln34: labour*materials	.0785	.0462	*	-.0120	.1690
ln36: labour*energy	-.0896	.0437	**	-.1753	-.0038
ln35:labour*capital	.0680	.0436		-.0175	.1535
ln46:materials*energy	-.1024	.0422	***	-.1852	-.0196
ln45:materials*capital	-.0048	.0408		-.0848	.0752
ln56: energy*capital	.0097	.0393		-.0674	.0867
Year	-.1431	.0350	***	-.2116	-.0745
year2	.0020	.0013		-.0005	.0045
ln: livestock units*year	.0096	.0038	***	.0021	.0172
ln: area*year	.0011	.0020		-.0028	.0050
ln: labour*year	.0165	.0055	***	.0057	.0273
ln: materials*year	.0066	.0050		-.0033	.0165
ln: energy*year	-.0142	.0050	***	-.0239	-.0045
ln: capital*year	.0004	.0053		-.0100	.0107
_cons	3.1329	1.5697	**	.0564	6.2095
Sigma_u	.2298				
Sigma_e	.1642				
Rho	.6621				
Wald chi2	4765.84				
Prob > chi2	.0000				
R-sq: within/between/overall	.6656 / .9346 / .9050				

Note: ***statistically significant at 1%, **statistically significant at 5%, *statistically significant at 10%.Based on FAS data.

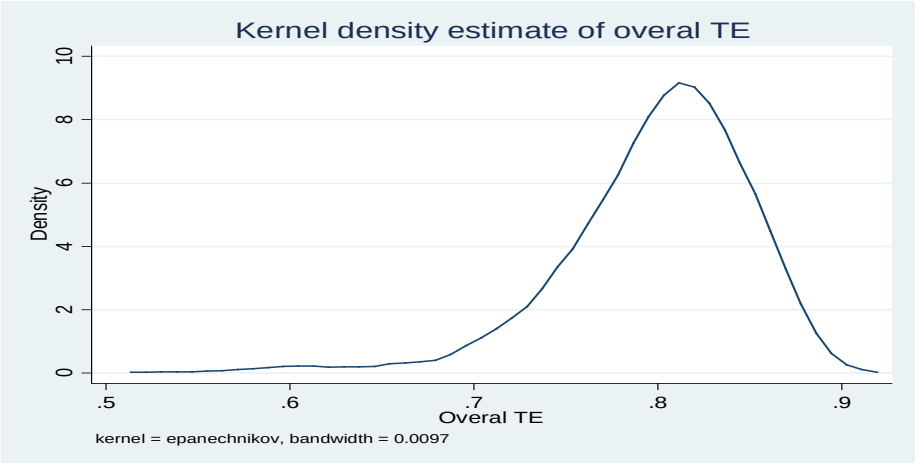
Appendix Table A2: Correlation matrix of variables included in the regression analysis

Variables	PTE	RTE	OTE	Piglets	Finishing	Integrated	Managerial experience	Higher agric. education	Courses for managers	Economy driven	Written plans	Follow-up of decisions	Budget	PigWin	Focus on quality	Focus on animal welfare
PTE	1.000															
RTE	.725*	1.000														
OTE	.984*	.836*	1.000													
Piglets	-.159	-.322*	-.209	1.000												
Finishing	.468*	.396*	.478*	-.512*	1.000											
Integrated	-.263*	-.020	-.217	-.606*	-.374*	1.000										
Managerial experience	.126	-.036	.089	-.106	.075	.045	1.000									
Higher agric. education	.161	-.025	.120	.022	-.083	.052	.210	1.000								
Courses for managers	.111	.026	.097	-.152	.057	.112	-.085	.037	1.000							
Economy driven	.124	.248*	.163	.099	-.000	-.105	-.212	-.146	.055	1.000						
Written plans	.197	.109	.184	.041	.055	-.096	.034	-.041	.119	.177	1.000					
Follow-up of decisions	-.266*	-.242*	-.274*	.038	-.276*	.214	.007	.137	-.242*	-.122	-.321*	1.000				
Budget	.233*	.135	.220	-.009	.061	-.048	-.177	.029	.218	.035	.371*	-.230*	1.000			
PigWin	-.068	-.068	-.073	.150	-.479*	.275*	-.165	.025	.109	-.051	-.014	-.067	-.135	1.000		
Focus on quality	-.169	-.147	-.173	-.206	.079	.147	-.044	.210	.236*	-.157	-.028	-.032	-.144	-.058	1.000	
Focus on animal welfare	.154	.086	.146	.180	-.002	-.191	.144	-.170	-.160	.139	.082	.002	.106	.095	-.846*	1.000

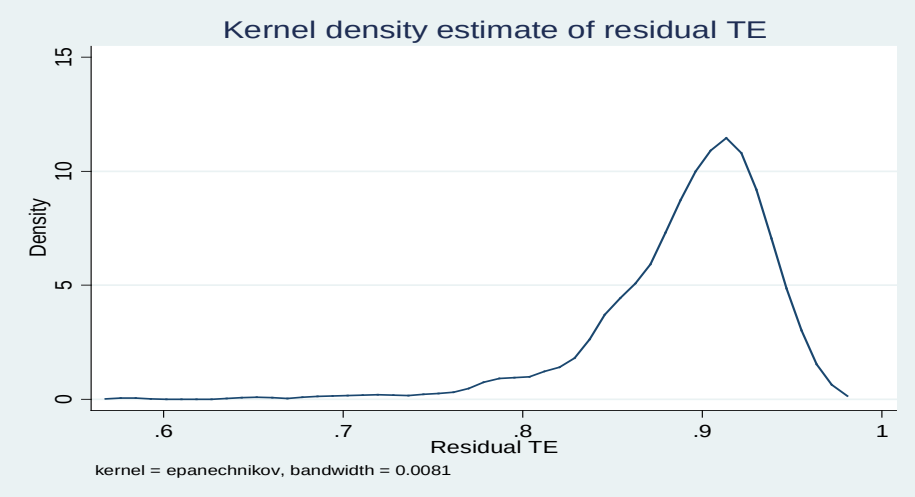
Note: *statistically significant at 5%. The correlation matrix is for the farms that participated in the mail survey.

Appendix Figure A1: Kernel density distribution of a) overall, b) permanent and c) residual efficiency

a)



b)



c)