Animal welfare and production efficiency in German pork production

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Abstract

Complexity of animal welfare and its unclear relation towards economic farm performance challenges the evaluation of animal welfare-improving measures such as labels. We target at improving the understanding of the relation between animal health, as a core dimension of animal welfare, and farm performance using a unique data set with bookkeeping data and health indicators from abattoir inspection. Second, we evaluate the German program "Initiative Tierwohl" (ITW) regarding its effectiveness in improving livestock health. We use technical and cost efficiency to measure farm performance from non-parametric data envelopment analysis. Our results do not support a trade-off between animal health and farm performance, rather indicate the possibility for high productivity at comparatively high levels of animal health. Further, we find participants to perform slightly better in both dimensions, supporting the label's claim of improved animal welfare.

Keywords Animal welfare, farm performance, pig husbandry
JEL code Q12, Q18, Q10

1. Introduction

Many consumers state that animal welfare constitutes an important dimension in their consumption decisions (e.g. Risius and Hamm, 2017) and up to 20% of the population are estimated to oppose current pig husbandry systems (Weible *et al.*, 2016). Across the European Union (EU) various state-supported and private measures, and also regulatory changes have been proposed and implemented to increase animal welfare along the meat chain. For instance, the EU decided on stepping up efforts on a phase-out of tail docking (Briyne *et al.*, 2018; Nalon and Briyne, 2019). Across countries national animal welfare labels became common sight, and in Germany, our study region, a state-supported label is in progress (BMEL, 2019). Also food retailers have introduced farm animal welfare labels (Heise, Kemper and Theuvsen, 2015); their effectiveness has, however, been subject to debate because of the public good character of animal welfare (e.g. Harvey and Hubbard, 2013). Nobody can be excluded from "enjoying" (Lusk and Norwood, 2011), offering consumers incentives to free-ride (Uehleke and Hüttel, 2019).

Against this backdrop, the sector initiative in Germany "Initiative Tierwohl" (*Initiative Animal Welfare*, ITW in the following), the example of this study, takes a different approach to improve livestock welfare. This program offers farmers enumeration for implementing stable enrichment by e.g. organic playing materials, roughage provision and for offering more space for the animals (+10% compared to the minimum of the animal protection act). The funding itself stems from a deduction of retailer's revenue from sold meat, irrespective of how much of a retailers' meat sold was actually produced at ITW conditions, and consumers do not have to pay a mark-up (Initiative Tierwohl, 2020b).

Stable enrichments create a captive environment for the livestock, which may, *inter alia*, prevent biting (Buijs and Muns, 2019) and other behavioural disorders (van de Weerd and Day, 2009; Mkwanazi *et al.*, 2019), improve animals' immune system functioning (van Dixhoorn *et al.*, 2016; Luo *et al.*, 2020), and can increase growth rates, carcass weight and backfat thickness (Beattie, O'Connell and Moss, 2000). Whether the desired impact on animal health, behavior and well-being can be achieved, however, depends on the respective farm production environment (van Staaveren *et al.*, 2017; Chou *et al.*, 2019). Therefore, the question remains, whether implementing such measures as required by the ITW have an effect on animal's welfare. Moreover, integrating such measures into farms' production systems, likely alters their labor organization, operating and fixed cost. Cost increases relate for instance to lower stocking rates that reduce turnover rates (Lusk and Norwood, 2011). Cost reductions can be achieved by increasing animal robustness and immune system, and reducing losses from sickness (Jensen *et al.*, 2008) and tail biting (van de Weerd and Ison, 2019). Cost-benefit ratios, however, also remain highly dependent on the respective farms' production environment, both of which (unclear welfare gains, unclear cost-benfit ratios) might constitute a burden to implement such measures, especially for risk averse farmers (Peden *et al.*, 2019; Carroll and Groarke, 2019; Dawkins, 2017).

Thus far, empirical evidence on whether and how animal welfare shows relevance for farm performance remains limited, especially for the pork sector. For instance Henningsen *et al.* (2018) report a weakly negative link between violations of national animal protection laws and performance for Danish pork producers. Reported violations of the legal minimum standards for livestock protection, however, may not give good insights on farm animal welfare. Studies relying on more sophisticated animal welfare measures that are intense in collection, however, suffer from a low number of observations such as Gocsik *et al.* (2016), who point to adverse cost effect with higher broiler welfare scores. Other studies rely on information on animal health, as on major dimension in animal welfare, where reproductive disorders (Lawson, Bruun *et al.*, 2004) or lameness (Lawson, Agger *et al.*, 2004) have been used. Investigations based on livestock health indicators for the pork sector seem lacking thus far.

Within this paper, we aim to contribute to closing this gap by investigating two questions empirically: first, how does animal welfare relate to the economic performance of the farm, and second, how do resource based measures for animal welfare, such as those implemented by ITW participants, actually improve livestock wellbeing and whether this has consequences for farm performance. We use the German pork sector initiative (ITW) as an example. Germany is the second largest pork meat producer in Europe[1] and the biggest exporting country of pork meat worldwide.[2] Therefore, changes in the German production sector can be influential for improving animal welfare in the pork chain, also in other regions, making this case interesting.

We use bookkeeping data for a representative sample of 483 pig fattening farms for a major pork producing area in north-western Germany with 134 ITW participants. Since animal welfare is complex and hard to measure (Fraser *et al.*, 2013), we follow the idea that animal health is an important dimension of animal welfare and use data from abattoir inspections as measures for animal health. We rely on Data Envelopment Analysis (DEA) to analyze farm performance as represented by technical efficiency and cost efficiency. We then relate farms' efficiency scores to the health index from the abattoir inspection data to answer the question whether farm performance comes at the cost of animal health (we frame this under *hypothesis 1*). Based on this framework, we are able address the second question, whether ITW farms, who implement certain measures targeted at improving animal welfare, achieve better animal health (*hypothesis 2*) and better efficiency (*hypothesis 3*). We find that participants can achieve higher performance scores for the same health score levels. Our results do not support a trade-off between animal health and farm performance, rather indicate the possibility for high productivity at

[1] https://www.dlg.org/de/landwirtschaft/themen/tierhaltung/schwein/dlg-kompakt-012019/
[2] https://oec.world/en/profile/hs92/0203/

comparatively high levels of animal health. Further, we find participants to perform slightly better in both dimensions, supporting the label's claim of improved animal welfare.

We introduce methods and data in the next section, followed by the results, discussion and conclusion.

2. Method and Data

2.1 Method

We follow Hansson, Manevska-Tasevska and Asmild (2020) and rest our analysis on two stages. First, we obtain technical and cost efficiency as measures for farm performance using DEA. Second, we relate these to animal health indicators using graphical and statistical methods.

Data envelopment analysis (DEA)[3] has already been applied in the context of relating farm performance and animal welfare (Barnes *et al.*, 2011). DEA follows the idea to estimate a best-practice frontier enveloping all observed data points; deviations between an observed point (input-output combination) and the frontier are treated as inefficiency and can be interpreted as improvement potential via input reduction or output expansion. Its non-parametric fashion does not require any specification of an underlying functional form. This we treat as a particular advantage for assessing the role of animal health in the production process.

We analyze technical efficiency in a production setting, i.e., the transformation of farm i's inputs x_i into outputs y_i with $(i = 1, \dots, I)$. Inputs x_i and outputs y_i are m and n dimensional, and the production process may transform m inputs into n outputs. We consider technical inefficiency to be the possibility to radially expand all outputs at a given input level. Our estimation follows the approach of Banker, Charnes and Cooper (1984) with variable returns to scale (VRS), imposed by the last constraint in eq. (1). This allows for increasing as well as decreasing returns to scale without imposing further assumptions on the underlying returns to scale (cf. Bogetoft and Otto, 2010, p. 84). For each observation i we solve the linear programming (LP) problem

$$\begin{aligned} &\min_{\lambda_1,\dots,\lambda_I,\theta_i} \theta_i \\ &s.t. \qquad x_i \geq \sum_{i=1}^{I} \lambda_i x_i \\ &\qquad\qquad \frac{1}{\theta_i} y_i \leq \sum_{i=1}^{I} \lambda_i y_i \\ &\qquad\qquad \sum_{i=1}^{I} \lambda_i = 1 \qquad with\, \lambda \geq 0 \end{aligned} \tag{1}$$

Solving this LP delivers weights λ, which span a piece-wise linear frontier by creating convex combinations of observed points. Efficiency is then measured against this frontier and the efficiency score θ_i expands $i's$ output level to the frontier. The score θ_i takes values smaller or

[3] We refer to Farrell (1957) and Debreu (1951)

equal one, where $\theta = 1$ indicates full efficiency, i.e., the firm is located on the frontier on no further improvement potential is identified.

Cost efficiency is obtained as a possible contraction of the costs of production c_i, with which the output vector y_i was produced, at a given output level. The respective LP is given by:

$$\begin{aligned} &\min_{\lambda_1,..,\lambda_I,\phi_i} \phi_i \\ &s.t. \qquad \phi_i c_i \geq \sum_{i=1}^{I} \lambda_i c_i \\ &\qquad\qquad y_i \leq \sum_{i=1}^{I} \lambda_i y_i \\ &\qquad\qquad \sum_{i=1}^{I} \lambda_i = 1 \qquad with\, \lambda \geq 0 \end{aligned} \tag{2}$$

Cost efficiency score, denoted by ϕ with $\phi \in (0,1]$. A value of one indicates full efficiency and $1 - \phi$ provides the cost savings potential in percentages. We note that the model estimates a cost function that assumes identical input prices across firms. That is, resulting inefficiencies may trace back to input price variations, technical inefficiencies or allocative inefficiencies.

2.2 Data

We can rely on a unique data[4] set with bookkeeping data of 483 pig fattening farms in North-Rhine Westphalia, whereof 134 participated in the Initiative Tierwohl (ITW), with animal health indices collected at the abattoir.[5] Average capacity is 1225 animals, purchases around 3,252 pigs per year, with a turnover rate of 2.6 (cf.

Table 1). ITW participating farms are on average larger (1341 vs. 1180). The turnover rate, however, is nearly identical for both groups (2.66 vs. 2.64). We note nearly no difference by participation for fodder and weight gain per animal.

Carcass inspection data are available in farm indices for respiratory diseases, organ health, health of the extremities, and physical integrity based on animal individual measures. A score of 0 means no/low health and 100 means no indications. Data show for respiratory diseases slightly higher mean and minima for participants, while the median is nearly identical across groups (cf.

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[4] The anonymized data has been provided by a farmer association in North-West Germany and the German quality scheme for food, QS.

[5] Many studies find that carcass inspections (e.g. extremity, organ and respiratory system damages) well predicted tail and skin lesions acquired 10 weeks before slaughter (Carroll *et al.*, 2018) as well as long-term chronic conditions (Grandin, 2017; van Staaveren *et al.*, 2017; Heinonen *et al.*, 2018), although the study of Carroll *et al.* (2018) found that e.g. coughing recorded during lifetime was not reflected in the carcass measures used.

Table 2). Organ health seems higher for participants at all quantiles as shown by the respective index, together with the lower standard deviation this suggests better organ health for participants. For the other two indicators, results are mixed and animal of ITW participants rate higher in terms of physical integrity but lower regarding the extremities.

Table 1: Descriptive statistics of main variables by ITW participation status

Variable [unit]	Q05	Q50	Mean	Q95	SD
Total sample (n=483)					
Fattening places [Nr]	412	1150	1225.54	2249	622.32
Feed [dt]	2,717.06	8,024.99	8,500.95	15,497.51	4,421.55
Residual costs [€]	3,996.6	12,182.74	13,926.2	29,891.31	8,820.5
Pigs [Nr]	1,049.93	3,074.06	3,252.45	5,992.30	1,706.66
Weight gain [kg]	97,572.81	288,356.39	305,177.85	566,379.01	159,110.92
Total expenditures [€]	146,242.26	423,099.34	449,733.75	824,501.20	233,216.74
ITW Participants (n=134)					
Fattening places [Nr]	493.9	1255	1,341.32	2415.5	694.11
Feed [dt]	3,193.15	8,504.31	9,234.99	1,6346.3	4,901.92
Residual costs [€]	4,668.28	131,89.14	15,611.4	31,246.32	9,728.38
Pigs [#]	1,215.43	3,196.8	3,546.4	6,371.74	1,841.96
Weight gain [kg]	114,540.13	303,237.25	334,227.17	602,698.93	174,442.93
Total expenditures [€]	145,262.84	409,857.56	434,044.75	797,765.35	221,770.41
Non-participants (n=349)					
Fattening places [Nr]	408.8	1120	1,181.08	2200	587.48
Feed [dt]	2539	7,953.04	8,219.12	15,065.72	4,196.13
Residual costs [€]	3,663.63	11,559.65	13,279.17	28,452.42	8,371.1
Pigs [#]	989.23	2,986.6	3,139.59	5,681.91	1,640.58
Weight gain [kg]	94,651.89	277,177.1	294,024.24	533,979.86	151,607.47
Total expenditures	159,035.51	462,656.03	490,595.38	854,721.97	257,094.64

Note: Q05, Q50, and Q95 indicate the 5, 50 and 95% quantiles of the distributions.

Table 2: Descriptive statistics of animal health indicators

	Q05	Q50	Mean	Q95	SD	#NA
ITW Participants (n=134)						
Respiratory	30.92	60.18	60.48	82.76	16.75	0
Organs	52.94	84.52	80.33	93.68	13.78	0
Extremities	9.84	36.00	41.46	78.44	22.93	49
Physical integrity	44.95	76.77	76.35	100	18.12	14
Non-participants (n=349)						
Respiratory	27.32	60.72	57.96	81.81	16.82	1
Organs	32.38	82.90	75.98	94.06	18.96	0
Extremities	16.04	44.01	45.54	82.73	20.1	117
Physical integrity	34.95	75.02	71.97	97.12	19.09	58

Note: Q05, Q50, and Q95 indicate the 5, 50 and 95% quantiles of the distributions. #NA indicates the number of missing values in the indicators.

We note that the sample suffers from missing observations on the status of extremities and physical integrity. We thus cannot generate health indicators using all dimensions, and note that respective health indicators with respect to respiratory diseases and organs give not the full picture.

2.3 Empirical Model and Hypotheses

We model pigs as inputs to be fattened in the production process using capital and materials to obtain the maximum weight gain and use the total weight gain as output. The number of pigs purchased in a year are used as animal input, where fodder measured in 100 kg of 88% dry substance as main material input, and the size of the stable as capital input (measured in accredited fattening places). To control for other input use, we include residual costs, which includes veterinary expenditures, water and energy related expenditures, disinfection, pest insurance, and other costs.

To evaluate farms' cost efficiency, we use operating expenditures as a single input. As in the production model, we assume that a single output is produced measured by the total weight gain. The model assumes identical prices across farms. We expect only little impact on the analysis because farms are located in the same region and have access to the same markets. Further, the cost shares of the different inputs show rather little variation, both within a cost share and across participation status (compare Appendix Table A1).

Against this backdrop we frame our hypotheses as follows:

Hypothesis 1 (H1): High technical and cost efficiency scores associate with low animal health scores.
Hypothesis 2 (H2): Animal health scores are higher for ITW participants.
Hypothesis 3 (H3): Technical and cost efficiency scores are higher for ITW participants.

To test these hypotheses, we use technical and cost efficiency scores as obtained from the two DEA models, and two health indicators relating to organic health and respiratory systems health (cf. Table 2). For testing H1, we rely on graphical and statistical procedures to test whether technical and cost efficiency scores are correlated with animal health indicators using locally estimated scatterplot smoothing (LOESS) with a polynomial of degree two. For H2, we test for differences in animal health indicators between ITW participants and non-participants, and for H3 we test whether technical efficiency and cost efficiency differs between ITW participants and non-participants. We support the tests by a LOESS estimation to investigate the relation between farm performance and animal health by ITW-participation status. The LOESS offers illustration of the expected technical and cost efficiency level conditional on an animal health score.

3. Results

Table 3 presents the results of the DEA analysis, where we present technical and cost efficiency scores. For the former, the model uses output orientation and efficiency scores indicate the degree to which maximum potential output for a given input level has been achieved. Cost efficiency is based on input orientation and indicates a farms' cost savings potential relative to a cost minimizing point with identical output level. Both models assume variable returns to scale.

Table 3: Technical efficiency and cost efficiency of pig farmers

	Q05	Q50	Mean	Q95	SD
Technical efficiency	0.902	0.945	0.946	1	0.028
Cost efficiency	0.687	0.785	0.789	0.914	0.071

With respect to technical efficiency, we observe an average efficiency score of 94.6% for the full sample indicating that farms on average produce 5% less than the most productive farms with the same farm size. The values show overall rather low variation and only 22 farms achieve efficiency scores below 90%. In total, 26 out of the 483 farms are fully efficient and shape the frontier.[6] Regarding cost efficiency, however, we observe considerably savings potentials across farms. In fact, the average cost efficiency of 78.9% indicates that the average farm could achieve the same output level, i.e., the same total weight gains with 80% of the costs.

Figure 1 relates animal health to the efficiency estimates using scatter plots, the base for testing H1. We provide an estimate of the relationship between efficiency and health based on LOESS by the red line.[7] The LOESS estimate shows the expected efficiency level conditional on the respective animal health score. For both efficiency measures, the results suggest no clear relationship between animal health and farm performance and the plots reveal a very low correlation between animal health and the performance measures. The plots further reveal that some farms performing well in at least one dimension, that is, farms that achieve either high efficiency or high animal health indicators, exist. The results also suggest that few farms are able to perform well in both dimension and obtain high indicators regarding efficiency and animal health.

[6] We note that the DEA is prone to the curse of dimensionality that can increase efficiency scores with an increasing number of dimensions of inputs and outputs. Relative to the model specification with four inputs and one output, our sample is considerably larger than indicated by conventional rules of thumb for minimum sample sizes: Bogetoft and Otto (2010) suggest minimum sample sizes of $I > 3(m + n)$ and $I > m * n$, where m and n denote the number of inputs and outputs.

[7] Alternative specifications of the polynomial as well as smooth splines lead qualitatively to the same results.

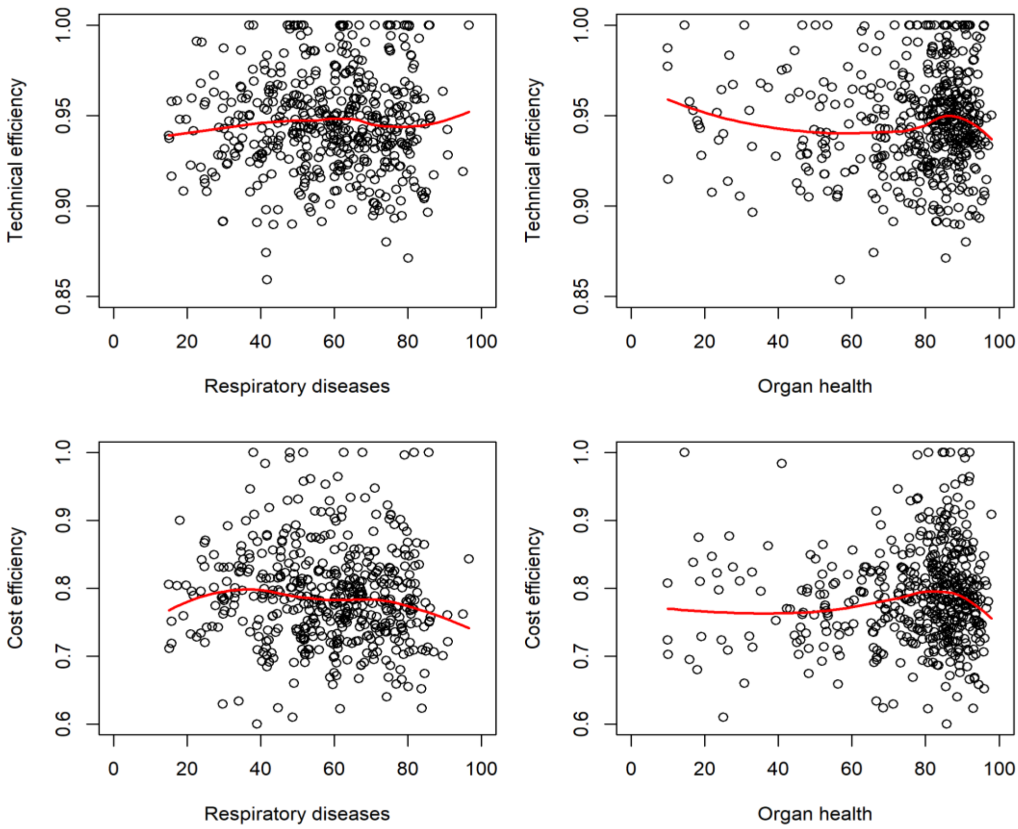

Figure 1: Relationship of technical efficiency and animal health with LOESS estimate (polynomial of degree 2)

To test whether participants show higher animal health indicators than non-participants (H2), we perform Kolmogorov-Smirnov tests. We specify the null hypothesis of test as health indicators between groups to be equal (or lower for participants) against the alternative that ITW-participants show higher health indicators (our H2). The null hypothesis for organ health ($p = 0.078$) and for physical integrity ($p = 0.059$) are rejected at conventional statistical significance levels, while for the respiratory system, the null cannot be rejected. Comparing estimated distribution functions (cf. Figure 2 left panel), reveals that ITW participants' respiratory scores to be located for most values right to the one of non-participants; this may explain the weak significance. Regarding organ health (Figure 2 right panel), the picture seems clear that overs large parts value range, participants show higher values. Both findings are in line with our hypothesis that ITW participants can achieve higher health scores.

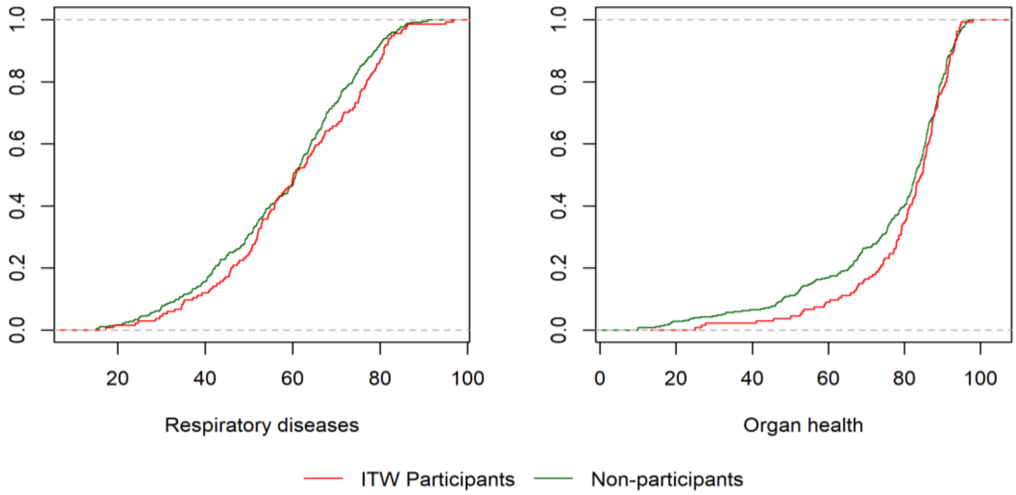

Figure 2: Empirical distributions of health scores by participation status.

Regarding the differences in farm performance between ITW-participants and non-participants (H3) we summarize in Table 4 the corresponding efficiency scores by participation status. For technical efficiency, we find overall small differences between the groups. Results indicate for both groups that on average a farm could improve output by around 10% without any input adjustments. We find slightly higher average scores for participants (0.951 vs. 0944); however, although statistically significant (t-test $p = 0.025$), differences in the means are very small. An analysis of the distribution (cf. Figure 3), however, indicates a distribution towards higher scores for the ITW-participants (Kolmogorov-Smirnov test: $p = 0.003$).

Table 4: Technical and cost efficiency scores by ITW-participation

	Q05	Q50	Mean	Q95	SD
Technical efficiency					
Participants	0.908	0.950	0.951	1	0.026
Non-participants	0.898	0.942	0.944	1	0.028
Cost efficiency					
Participants	0.704	0.790	0.801	0.937	0.074
Non-participants	0.682	0.783	0.785	0.906	0.070

With respect to cost efficiency, we find slightly larger differences between the groups: respective scores suggest that ITW-participants perform better than non-participants (0.801 vs. 0.785). The distribution of efficiency scores likewise suggests a performance distribution for ITW participants towards higher scores (Kolmogorov-Smirnov test $p = 0.017$). Taken together, these results suggest that participants in the ITW achieve higher technical and cost efficiency in line with H3.

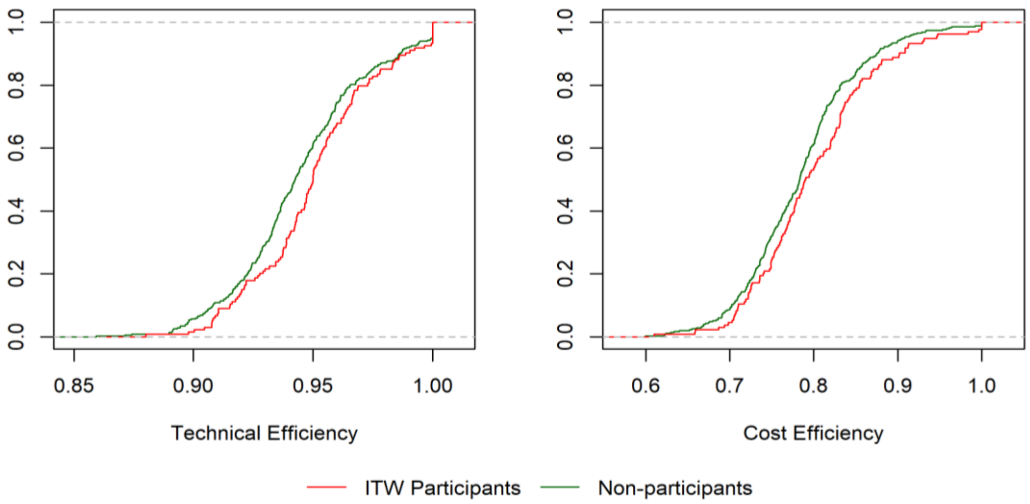

Figure 3: Empirical distributions of technical and cost efficiency scores by ITW participation

To investigate the between farm performance and animal health by group, we again rely on scatter plots and add the LOESS estimate with red for the relationship for ITW-participants and green for non-participants (cf. Figure 4). Both lines do not indicate a strong relationship between farm performance and animal health, in line with the previous results and for both groups. The LOESS estimates represent the expected technical and cost efficiency level conditional on the respective animal health score, and results show ITW-participants to obtain higher levels of efficiency at a given level of animal health with respect to organ health and respiratory diseases.

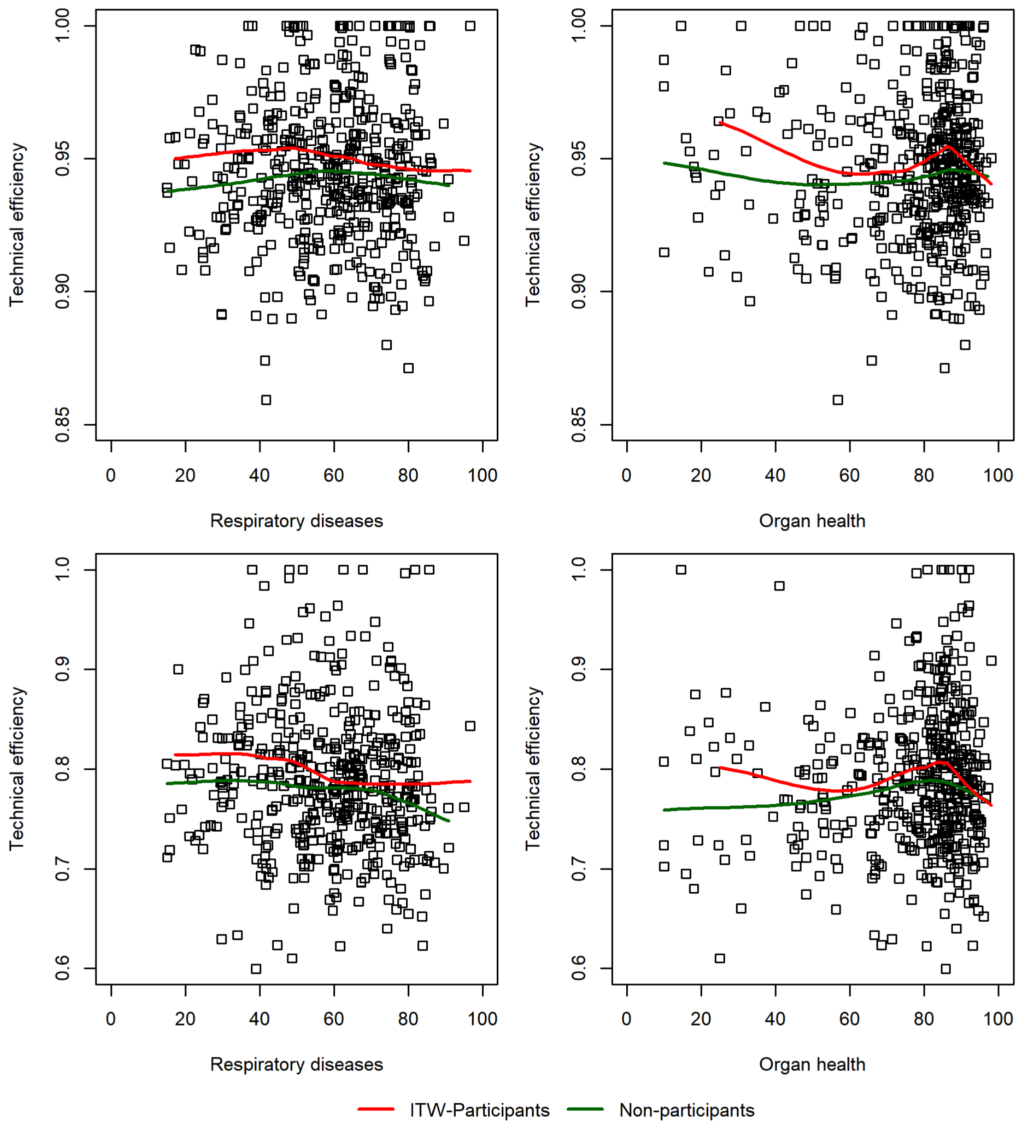

Figure 4: Relationship of technical efficiency and animal health by ITW-participation, with LOESS estimate (polynomial of degree 2)

4. Discussion

We first show that levels of animal health as represented by abattoir inspection data is not associated with cost efficiency of pig fattening farms in north-western Germany. We can therefore reject the hypothesis that a high farm performance comes at the cost of the animal health status. In other words, providing better animal health does not necessarily have to imply higher production costs (on average), but also that lower animal health does not have to reduce profitability. Our results are therefore in line with studies that indicate that the caring for of animal health depends on the intrinsic motivation and managerial ability of the farmer (Borges *et al.*, 2019).

These result are in accordance with previous studies: Henningsen *et al.* (2018) found a weakly negative relationship between farms economic performance and animal health as represented by reported violations of the animal protection act. Other studies on the dairy sector deliver similar results using other animal health indicators (e.g. Schulte *et al.*, 2018). Data inspection also reveals that many farms have improvement potentials, which underlines the necessity of such programs as the German initiative ITW with the aim to improve animal welfare along the pork chain by supporting stable enrichment and more space per animal.

Investigating program participants' average health scores reveals that these farms achieve, on average, higher animal health and higher cost efficiency scores compared to non-participants in line with our *hypotheses 2* and *3*. Regarding health, it is the physical integrity and organ health that show most pronounced differences, where for respiratory health differences seem less clear. This can be explained by the type of implemented measures within the ITW: stable enrichments can improve the physical constitution of the animals, but they cannot solve respiratory problems, which are mainly determined by stable constructions and air ventilation (Wenke *et al.*, 2018). We further find that participants can achieve higher performance scores for the same health score levels, both organ and respiratory health scores. Our results thus support the argumentation that stable enrichment measures can improve animal health, and can thereby contribute to higher efficiency. This comparison provides new insights about linkages between outcomes of enrichments programs and changes of cost structures. The results imply that the additional efforts required by the program do not result in lower efficiency and profitability. This could encourage farmers to participate in the program, or even to implement similar measures without enumeration. Likewise, the investigated program might even provide an increase in return on investment, which could offer a future incentive for adopting animal friendly production systems (van de Weerd and Ison, 2019).

The study design however, does not allow interpreting these differences across ITW participation causally because health indicators were not collected before the start of the program. If the average cost efficiency for ITW participants was higher before entering the program, participation could as well have decreased cost efficiency, but still remained higher than efficiency in the control group. This, however, does not affect our main result.

The generalizability of our results faces—besides the confinement on one region—other important limitations. First, the farm economic data only contains bookkeeping information on direct costs. Therefore, we do not observe possible increases in labor hours, which would affect the cost efficiency estimation. The provision of enrichment material and open drinking suspensors might induce higher effort for cleaning and maintaining the materials. The program measures, however, are well defined and supported by technical advice, which may keep the additional effort manageable. A second limitation relates to the narrow concept of animal welfare, where this study could use reliable health measures but these denote only one dimension of animal welfare. Although some studies showed the association between carcass inspection data and on farm animal health (Grandin, 2017; van Staaveren *et al.*, 2017; Heinonen *et al.*, 2018), other aspects of animal welfare such as behavioral disorders could not be included in this approach.

5. Concluding remarks

In this study we demonstrate that linking farm economic data with detailed abattoir inspection data can yield important insights on the role of animal health in the production process. Increasing animal health while keeping production costs at competitive levels is a core challenge for European pig husbandry (European Commission, 2018). The combination of abattoir inspection data with farm bookkeeping data could offer good opportunities for long-term assessments of animal welfare measures at large scale at little extra time and effort for data generation. The presented analysis could be a helpful tool for evaluating strategies for multifactorial challenges such as rearing pigs with intact tails.

Future research could go beyond statistical association and identify causal effects of FAW programs because abattoir carcass inspection has become more widely applied practice. Thus acquiring panel data to evaluate causal impacts for farms entering the ITW program could be feasible. Furthermore, the analysis should be augmented by data on labor hours and the antibiotics monitoring (Murphy *et al.*, 2017) in order to improve the quality of results.

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7. Appendix

Table A1: Cost shares of operating expenditures for full sample and by ITW participation with 5% and 95% quantiles

	Full sample	Participants	Non-participants
Fodder	43.72% (38.84%,50.22%)	43.59% (38.69%,50.47%)	43.77% (38.86%,50.21%)
Pigs	53.16% (46.37%,58.18%)	53.17% (45.66%,58.2%)	53.15% (46.65%,58.18%)
Veterinary	0.76% (0.06%,2.31%)	0.81% (0.06%,2.6%)	0.75% (0.07%,2.18%)
Insurance	0.04% (0%,0.07%)	0.04% (0.01%,0.07%)	0.04% (0.01%,0.07%)
Water/Energy	1.47% (0.69%,2.5%)	1.51% (0.74%,2.46%)	1.46% (0.62%,2.51%)
Desinfection	0.18% (0%,0.53%)	0.2% (0%,0.67%)	0.17% (0%,0.42%)
Cosulting	0.32% (0%,0.81%)	0.28% (0%,0.77%)	0.34% (0%,0.82%)
Other	0.34% (0.03%,0.94%)	0.4% (0.03%,1.04%)	0.32% (0.02%,0.86%)