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Is Animal Welfare Better on Small Farms? Evidence from Veterinary Inspections on Swedish Farms

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Abstract: Structural change towards more ‘industrialised’ pig farming is widely criticised for having adverse effects on farm animal welfare (FAW). This criticism implies that larger farms might be less concerned with animal welfare than smaller, more diversified farms, e.g. since small farmers would value FAW more. Based on data from veterinary pig farm inspections, various aspects of this standard criticism were empirically tested. The results showed that FAW violations were less frequent on larger farms and more frequent on pig farms with dairy cows. Violations were no less frequent in areas with more organic production, but on average less severe.

Keywords: Farm animal welfare, Zero-inflated Negative Binominal Model, Agro-Industrialisation, Propensity-Score Matching

1 Introduction: Agro-industrialisation and farm animal welfare

In recent decades the agricultural sector in Europe has undergone rapid structural change. This change has included intensification of farm animal production in terms of increasing concentration of production to fewer, larger farms and of shifting to more confined production systems (Fraser, 2005). In 2007, approximately 75% of pigs for fattening in the EU27 were kept on farms with at least 400 pigs (Marquer, 2010). In Sweden, the average number of pigs (sows and fatteners) per farm almost doubled between 2003 and 2011. The percentage of fatteners on farms with 750 pigs or more also increased between 2003 and 2010, from 63% to 79% (Statistics Sweden, 2013).

The structural change at farm and processing level has frequently been described as ‘agro-industrialisation’. This change, which has enabled farmers and processing companies to benefit from economies of scale, has frequently been criticised for having negative implications for farm animal welfare (FAW). The criticism of farm intensification following on from agro-industrialisation has followed such a consistent pattern that according to e.g. Fraser (2005) it can be considered a “standard critique”. This includes criticism of family farms being replaced by corporations, increased emphasis on corporate profit-seeking at the expense of more traditional animal welfare values and traditional farming methods being replaced by industrial production methods. Proponents of the standard critique argue that all these aspects have detrimental consequences for FAW (Fraser, 2005). This standard critique is not only widely reflected in the public debate, but is also partly supported by qualitatively oriented scientific studies (e.g. Deemer et al., 2011; Burton et al., 2012; Bolos 2013).

With respect to political decision making about FAW, surveys have shown that animal welfare is an important issue for consumers across Europe, although more pronounced in the Scandinavian countries than in most other countries (see e.g. European Commission, 2007). New EU legislation is aimed at improving FAW, but there are still major differences between national regulations on animal welfare in different member countries (Schmid and Kilchsperger, 2010).

The aim of this study was to empirically analyse several hypotheses implicit within the standard critique (Bolos, 2013). The case study chosen was the Swedish pig industry, which was considered well-suited for the purposes of the study. The standard critique (e.g. Frazer, 2005; Burton et al., 2012) can be viewed as comprising two types of problem relating to agro-industrialisation and FAW, namely:

Type A) Structural change induces the adoption of production systems that are not animal welfare-friendly.

Type B) Structural change encourages the neglect and mistreatment or ill-treatment of farm animals.

According to the standard critique, both types of problem are the result of profit-seeking incentives dominating, at the expense of cultural values related to the treatment of farm animals. Such cultural values can be interpreted in a similar way to the concept of ‘non-use

values' recently used to describe farmers' provision of FAW (Lagerkvist et al., 2011; Gocsik et al., 2013). Lagerkvist et al. (2011) argue that producers may choose a higher level of FAW quality (not reflected in the prices they receive) because of additional non-use values, i.e. the production function of a farm household, in addition to market inputs, also includes a vector of non-use values that directly enter that farm household's utility function. However, when trying to assess the provision of animal welfare on certain farms and farm types, type A and B problems may exhibit an endogenous relationship, as the adoption of less animal welfare-friendly production systems may create path dependencies that force farmers to treat their animals in a less 'friendly' way than is possible in more animal welfare-friendly production systems.

For the present study, Sweden was deemed well-suited for studying standard critique type B problems, because type A problems are very rare in Sweden compared with in other countries. This is because Sweden has a long history of FAW regulations (the first extensive animal welfare legislation was adopted in 1988), with statutory minimum standards that in several respects exceed those imposed by EU legislation (see e.g. Veissier et al., 2008) and by the national legislation in many European countries (Schmid and Kilchsperger, 2010). As Swedish legislation guarantees a comparatively high level of FAW and, among other things, includes all new animal houses to be certified as fulfilling the legal requirements (Swedish Board of Agriculture, 2011), the potential endogeneity between type A and type B problems might be lower in Sweden than in most other countries.

This study did not set out to determine what statutory FAW requirements are 'right' or 'wrong' (type A problems). Furthermore, we did not examine other potential externalities of modern animal production. However, type B problems expressed in the standard critique contain several inherent assumptions about the relationship between farm structure (especially size) and FAW. In the analysis, we approximated the level of FAW that a farm provides based on recorded violations of the statutory FAW requirements (Lagerkvist et al., 2011; Czekaj et al., 2013). The empirical data for the analysis were taken from the reports of official veterinary farm inspections conducted on Swedish pig farms in 2011, which recorded compliance by farmers with statutory FAW requirements.

The most important arguments of the standard critique are summarised in a stylised way in Figure 1. According to this critique, the provision of FAW is the result of a proportional technological relationship between costs of production and FAW. Lower average production costs should therefore correspond to a relatively low level of FAW, implying that a high level of FAW can only be provided at higher average costs of production. A consequence of this reasoning is that only larger farms could produce at average costs low enough to be constrained by the statutory FAW requirements. However, it is claimed that these so-called 'industrial' farms would have an economic incentive to keep their costs below a certain FAW standard, i.e. to violate existing regulations, and to oppose and lobby against more stringent FAW regulations (compare the part of the average cost curve and the identical FAW provision curve in Figure 1, which is below the public minimum FAW standard). Conversely, according to the standard critique small farms would be less likely to be constrained by the statutory FAW requirements and might even be observed to voluntarily provide higher levels of FAW than required, e.g. if they catered for high-end consumer segments that demand locally and/or organically produced goods.

As shown in Figure 1, farmers may provide higher levels of FAW at higher than competitive average cost, as long as they feel rewarded by a certain amount of non-use values that enter their utility function. These farmers may try to capitalise on their own preferences for high FAW through self-selection into higher existing private market standards.

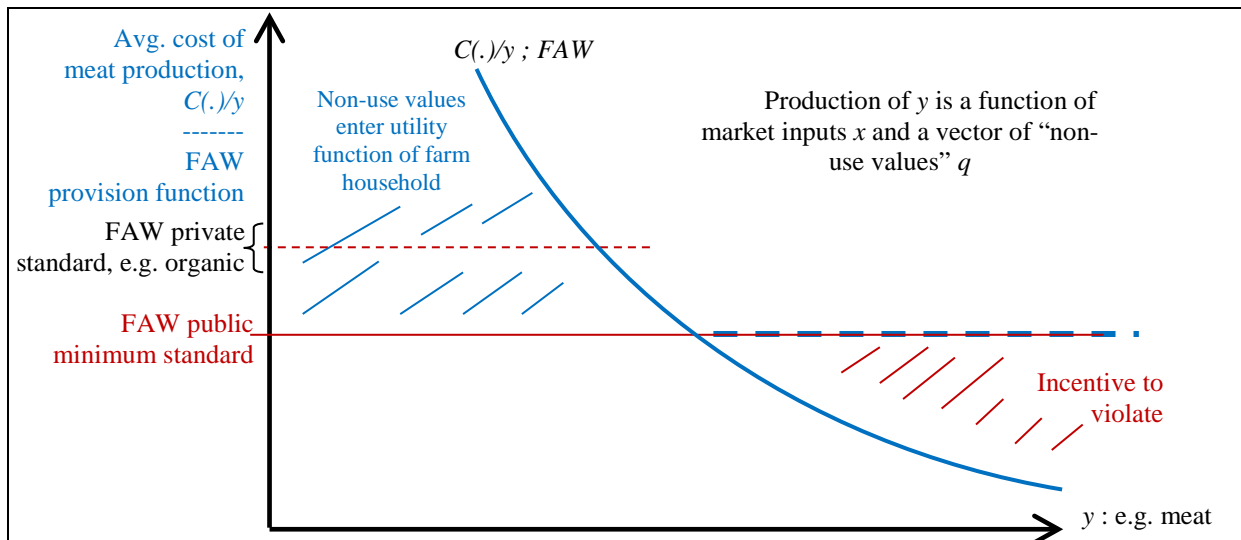


Figure 1. Stylised depiction of assumptions implied by the standard critique on farm animal welfare (FAW) and agro-industrialisation.

Based on the assumptions implicit within the standard critique (Figure 1), the following research hypotheses were tested in this study:

The statutory FAW requirements are *more likely to be violated*:

- i) by relatively large firms, due to their larger profit incentive.
- ii) by more specialised farms, since these have a lower average number of workers per animal.

The statutory FAW requirements are *more likely to be adhered to*:

- iii) by small farms, due to their relatively higher level of non-use values.
- iv) by farms with organic production, due to their self-selection into higher standards.
- v) by more diversified farms, as long as FAW is more easily provided under economies of scope from keeping multiple animal types on a certain farm.

Section 2 presents the empirical data and the Propensity Score Matching procedure to homogenize the dataset. Section 3 summarises the results from testing hypotheses i-v based on Zero-inflated Negative Binomial- and Logit models, respectively. The paper concludes with a discussion of the results with respect to their implications for policy making, the public debate and future research.

2 Data: Swedish veterinary farm inspections

2.1. The dataset

The statutory minimum level of FAW in Sweden is based on a combination of EU regulations, partly tied to the provision of subsidies under the Common Agricultural Policy (cross-compliance), and more stringent national Swedish regulations. Frequent on-farm veterinary inspections, based on a detailed protocol of different FAW aspects, are conducted in order to ensure that Swedish farmers adhere to the statutory minimum standard. The data from Swedish veterinary farm inspections (Swedish Board of Agriculture 2013) used in this study encompassed all inspections conducted on farms that kept pigs in 2011. We obtained the data in summer 2013 once permission to use these data had been obtained from all 21 Swedish counties concerned and from the Swedish Board of Agriculture (Bolos, 2013). In total, 386 inspections were conducted but unfortunately information on the number of pigs on the farm was not available for all these inspections, which forced us to omit some observations. Furthermore, some farms had an initial inspection as well as a follow-up

inspection in 2011. The data from the follow-up inspection were omitted for these cases because of the direct causal dependence between the observations, which would have violated the standard assumptions of most statistical models. However, when only a follow-up inspection was reported in 2011, those data were retained in the dataset and were treated in the same way as those from initial inspections made in 2011 which may have triggered a follow-up inspection in 2012, i.e. outside the study period. It was assumed that for large farms with pig herds at different locations, different employees work at these locations so the owner of the farm has a minor influence on the provision of FAW (compare Czekaj et al. (2013), who aggregated such observations). Hence, inspections of farm enterprises at different locations, but with the same owner, were treated as separate farms. The final sample consisted of 258 inspection reports for Swedish pig farms that were not directly dependent on each other and that included the required information concerning the number of animals on the farm (types of pigs, other animals). The final sample covered between 13-18% of all farms with sows and/or fattening pigs in Sweden and a similar proportion of the total numbers of these animals in Sweden.

The official inspections are based on a detailed checklist consisting of 43 categories that can be grouped into 15 broader categories (Bolos, 2013), as shown in the first column of Table 1. Table 1 also shows the number of violations in each of these categories and the proportion of observations with missing information in each category. Overall, these were approximately proportional to the number of violations in the full dataset. The only category in which the subsample of farm data was apparently underrepresented was ‘Hygiene and straw’. Furthermore, we found no indication that the omission of farm level data was non-random. Of the 556 violations recorded in 2011 (Table 1), information about the number of animals on the farm was available for 343 violations. Of these 343 violations, 245 related to cross-compliance conditions. On average there were 1.3 violations per inspection made, of which approximately 1.0 referred to violations of some cross-compliance condition. Despite the relatively high average violation rate per inspection (both full and cross-compliance), approximately 50% of all inspections recorded no violation at all, while in the most extreme cases violations were reported for about 10 categories out of 43.

Table 1. Aggregated animal welfare indicators in the dataset

	A: With farm data, n=258	B: Farm data missing, n=386	Proportion of violations	
			Sample A	Sample B
Space and equipment	69	98	26.7%	25.4%
Hygiene and straw	68	124	26.4%	32.1%
Supervision and care	51	88	19.8%	22.8%
Ventilation and air quality	49	63	19.0%	16.3%
Sick animals and documentation	43	60	16.7%	15.5%
Feed and water	28	59	10.9%	15.3%
Noise to (not from) the animals	9	11	3.5%	2.8%
Other	8	16	3.1%	4.1%
Pasture, runs and drives	6	16	2.3%	4.1%
Operations	5	6	1.9%	1.6%
Windows and light	4	7	1.6%	1.8%
Animals kept outdoors	3	8	1.2%	2.1%
Breeding	0	0	0.0%	0.0%
Violations total Cross-compliance only	343 245	556		
Violations total per inspection Cross-comp.	1.33 0.95	1.44		

Source: Own compilation based on data from Swedish Board of Agriculture (2013)

The number of violations per inspection was plotted against the number of sows and the number of fattening pigs per farm, respectively, in two separate scatter plots (Figure 2). These plots indicated a negative relationship between number of violations and farm size.

However, even though the number of observations for the larger farms was rather small, neither plot contained any observations in the upper right-hand corner (high animal numbers, high violation numbers). Thus there was no empirical indication of the largest farms in the sample having the highest number of violations. However, the plots did indicate that the average number of violations on medium-sized farms was higher when fattening pigs, rather than sows, were present (Fig. 2).

However, drawing conclusions solely based on the scatter plots in Figure 2 is questionable from a statistical point of view because the observations originated from different inspection types, which are only partly random selections of farms (Swedish Agency for Public Management, 2010). In general, based on exploratory statistical analysis with probabilistic regression trees (Zeileis et al., 2010), two types of inspections can be distinguished:

Normal inspections: This category includes the normal random inspections, the inspections for regular checks of cross-compliance, normal inspections targeting certain farm types, and inspections carried out in response to complaints that later turned out unjustified.

Extra inspections: These inspections are conducted e.g. in response to specific events, complaints, etc. Extra inspections can be initiated by a concerned member of the public, veterinarian or other person/organisation. They also include follow-up inspections based on an initial inspection in the previous year, and inspections based on government risk assessments. According to anecdotal evidence, this risk analysis is largely based on the same or similar farm types having been detected with violations in the past. These inspections do not represent a random sample of farms, but cover farms more likely to violate some condition.

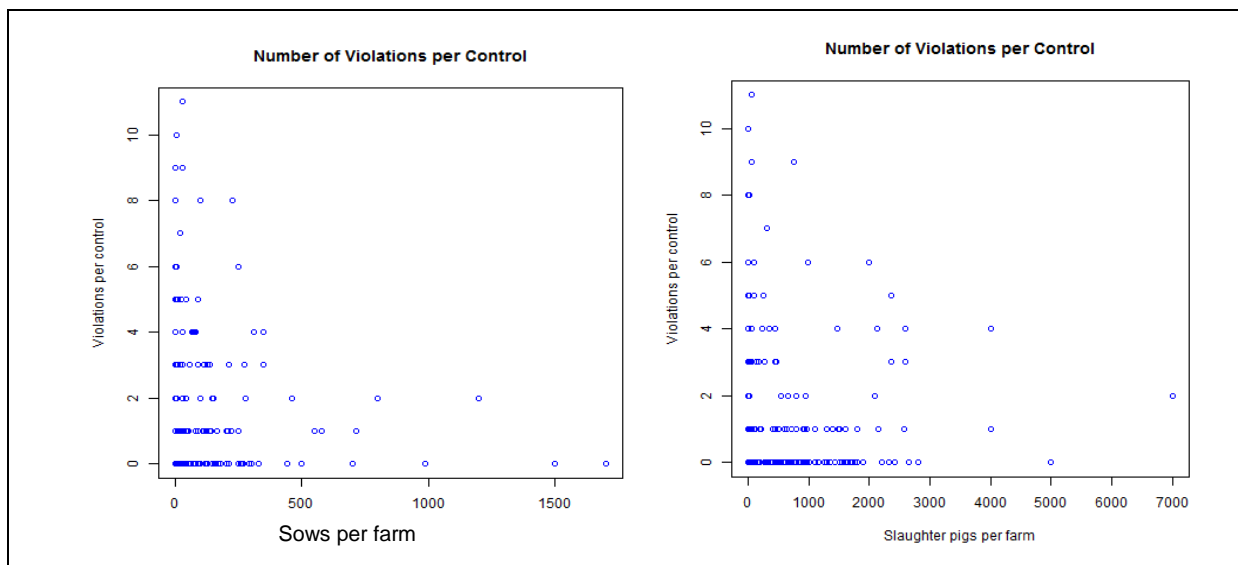


Figure 2. Violations of Swedish and EU regulations on farm animal welfare (FAW) recorded in Swedish inspections of pig farms, 2011 (n=254).

2.2 Propensity Score Matching

Ideally, the sample should consist only of randomly selected farms (e.g. Czekaj et al. 2013 used a random sample of Danish farms). However, the veterinary inspections of farms in Sweden are intended to detect a maximum of violations with a minimum of inspection capacity rather than being representative for all farms (Swedish Agency for Public Management, 2010). In order to analyse the data while not losing the information contained in the observations from the extra inspections, it was necessary to homogenise the sample for the ‘Normal’ and ‘Extra’ inspection type subsamples.

In order to make observations from both subsamples comparable with respect to the characteristics of the explanatory variables (e.g. farm size), the data from Extra and Normal inspections needed to be transformed. Propensity Score Matching (PSM) was used for this purpose. PSM is able to identify observations in two subsamples of the data that show similar covariate values (e.g. farm size). If two farms have the same probability of being subjected to an extra inspection but only one of these farms receives an inspection, PSM suggests that the difference must be random, implying that the systematic influence from the extra inspections is eliminated (Ho et al., 2007).

In the approach taken here, the propensity score (e_i) for $n=258$ controls was defined as the probability of receiving an Extra inspection given a vector X of covariates. The propensity scores $e_i = P(T_i = 1/X_i)$ were initially estimated from a logistic regression. The vector of covariates X contained all covariates that were of potential interest for later empirical interference, but it did not contain the dependent variable ‘Violations per inspection’. In the next step, the “full matching” procedure (Hansen, 2004) was applied to the propensity scores. This procedure consists of an optimisation algorithm that forms subsets. Then, for each i_{Normal} the algorithm finds at least one i_{Extra} and then minimises a weighted average of the estimated distance measure (e.g. Mahalanobis) between each i_{Extra} and each i_{Normal} within each subclass. The distance measures in each subclass were used in the present case to weight the data such that observations in the subsample of Extra inspections appeared to have a covariate structure that was statistically similar to the covariate structure in the Normal random inspections.

Table 2. Difference in sample means before (1) and after (2) Propensity Score Matching

	(1) $\bar{E}_1 - \bar{N}_1$	(2) $\bar{E}_2 - \bar{N}_2$
Distance	0.13	0.00
Sows per farm	26.30	-2.78
Fattening pigs per farm	-270.00	50.22
Utilisation share of registered house capacity (fatteners)	-0.11	0.07
Utilisation share of registered house capacity (sows)	0.03	-0.07
Dairy cows per farm	12.40	0.55
Sheep and goats per farm	-3.93	0.41
Horses per farm	-0.72	-0.03
Share of potato production in farm’s municipality	0.00	0.00
Share of bioenergy crops in farm’s municipality	0.00	0.00
Share of organic acreage in farm’s municipality	0.03	0.02
Announced inspection	-0.14	0.01
Inspection intensity in municipality r (inspections/farms in r)	0.06	0.00

Note: E and N =Extra and Normal inspections, respectively.

Table 2 shows the results of the PSM procedure based on the full matching optimisation algorithm. The first column shows the difference between the sample mean of the Extra inspections and the sample mean of the Normal random inspections before PSM was applied. The second column shows the difference in means after the PSM procedure, which brought the means of the two subsamples closer, especially for the number of sows per farm and the number of fattening pigs per farm, but also for the number of dairy cows per farm. For sows per farm and dairy cows per farm, the initial difference was almost eliminated, while for the number of fattening pigs per farm a slight mean difference remained between the inspection types. This difference indicates that farms with Extra inspections have now on average 50 more fattening pigs than the Normal random inspection. Thus after the PSM procedure, the re-weighted non-randomly selected farms in the group of Extra inspections had a very similar covariate structure to the almost randomly drawn Normal inspections. In the next step, the propensity score weights were used in different regression models as weighting factors.

3 Analysis and Results

3.1 Count of violations

In the first step of the empirical analysis, the number of violations per inspection was explained as a function of the available covariates about farm characteristics (Bolos 2013). Furthermore, the share of acreage under organic production schemes within the municipality where a farm was located was added to the covariates, as no farm-specific information about participation in organic production was available; Sweden has about 280 municipalities. Due to the structure of the dependent variable, it was necessary to employ a regression model that predicted the count of a small number of events (Bolos, 2013). We therefore considered various weighted count data models: Poisson, Zero-inflated Poisson, Negative Binomial, Zero-inflated Negative Binomial and Hurdle. Each of these models is in principle suited to model the dependent variable of count of violations per inspection, but this type of count data model is sensitive to the exact parameterisation of the actual shape of the distribution of the dependent variable (Sarker and Surry, 2004), and a potentially heterogeneous data-generating process underlying the dependent variable.

Hence, each model was estimated separately and then the performance of the different model specifications was compared based on the Vuong test (suitable for comparison of Zero-Inflated models and their non-nested counterparts, e.g. Poisson versus Zero-inflated Poisson), and the Likelihood Ratio Test (allows e.g. Zero-inflated Poisson and Zero-inflated Negative Binomial to be compared). The results of this model selection procedure showed that the Zero-Inflated Negative Binomial (ZINB) model performed best, followed by the Hurdle model, while the non-nested versions of these models were rejected. The ZINB regression equation for the conditional mean takes the following general form (Zeileis et al., 2008):

$$E[y_i / x_i] = \mu_i = \pi_i \cdot 0 + (1 - \pi_i) e^{(x_i \beta)},$$

with an indicator function determining the unobserved probability of observing a zero count. This probability is inflated according to probability π , which can be determined according to a Logit model $\pi = g^{-1}(z' \beta)$. In this setting, vector z can contain any, all or none of the elements of the explanatory variables x in the actual negative binomial model with β as the vector of coefficients to be estimated.

Table 3 presents the results obtained using the ZINB model with the total number of violations per inspection as the dependent variable. The zero inflation component of this model consisted of a Logit model and included explanatory variables that captured the relative inspection intensity. This relative inspection intensity governed the probability of observing zero violations per inspection. The explanatory dummy variable measuring whether an inspection was a follow-up from an initial inspection in the previous year was insignificant. This indicates that the PSM procedure was successful overall in eliminating the underlying differences between the two subsamples.

The main part of the model (Table 3) indicated that the number of sows per farm was significantly negatively related to the expected number of violations per inspection. In addition, the share of organic acreage in the municipality where the inspected farm was located was significantly negatively related to the number of violations per inspection, while the number of other animals per farm, including the number of fattening pigs, was insignificant. The only significant explanatory variable with a positive coefficient regarding the expected number of violations per inspection was the utilisation of sow places. This variable was computed as the ratio of the number of animals present on the farm at the time of the inspection and the farm capacity for the corresponding type of pigs as recorded in the inspection database. It was assumed that the number of animals at the farm was

approximately equivalent to the total registered capacity for pigs on the farm if the veterinarian had not added information about the number of pigs actually present at the farm at the time of the inspection. Over-utilisation of sow places can occur if more sows are kept on the available space, if the farm has recently or temporarily increased the scale of its operations, or if the farmer keeps sows under improvised conditions.

Table 3. Results of the ZINB model for ‘Total number of violations per inspection’

	Estimate	Std.	z	Pr(> z)	
(Intercept)	0.6987	0.3166	2.2100	0.0273	*
Sows per farm	-0.0024	0.0007	-3.1800	0.0015	**
Fattening pigs per farm	-0.0001	0.0002	-0.5100	0.6068	
Utilisation share of registered house capacity (fatteners)	0.0985	0.2086	0.4700	0.6369	
Utilisation share of registered house capacity (sows)	0.5731	0.2461	2.3300	0.0199	*
Dairy cows per farm	0.0012	0.0011	1.0400	0.2984	
Sheep and goats per farm	-0.0105	0.0171	-0.6200	0.5381	
Horses per farm	-0.0521	0.1260	-0.4100	0.6792	
Share of organic acreage in farm’s municipality	-2.0150	0.9064	-2.2200	0.0262	*
Log(<i>theta</i>)	0.1792	0.3305	0.5400	0.5876	
Zero-inflation (binomial with Logit link):					
(Intercept)	-1.411	0.725	-1.95	0.052	.
Announced inspection	1.246	0.6	2.08	0.038	*
Follow-up inspection	0.364	0.643	0.57	0.571	
Inspection intensity in <i>r</i> (inspections/farms in <i>r</i>)	-1.606	1.053	-1.52	0.127	
Log-likelihood: -412.1 on 14 Df. Zero-observations: in data = 131, predicted = 133					

Furthermore, the log of the estimated coefficient on the parameter *theta* (also named *alpha* in the literature) was not statistically different from zero, which implies that the antilog of this was not statistically different from 1. This does not allow rejection of the hypothesis that a decay process in the distribution of the dependent variable according to the assumed negative binominal functional form is the correct representation of the data.

3.2 Any violation?

The count data models explained the expected number of violations per inspection as a function of a vector of covariates *x*. An alternative way of analysing the results from the farm inspections would be to examine the probability of no violations being recorded during an inspection. Farms with no violations fulfil the statutory FAW requirements and may provide a higher, but unobserved, level of FAW. For this analysis, all observed violations were grouped into the combined category ‘At least one/any violation’, thus creating a binary dependent variable (Bolos 2013). With this binary dependent variable and the same set of covariates *x* and *z* as in the model in Table 3, a Weighted Logit (WL) model was estimated with weights as generated by the PSM procedure. The zero inflation part of the model in Table 3 (vector *z*) then generated opposing signs on the estimated coefficients, since these now predicted the probability of observing at least one violation (rather than zero violations as in the ZINB model).

Table 4 presents the results obtained using the WL model. Findings on the relationship between number of sows and number of fattening pigs per farm and utilisation of pig capacity appeared qualitatively the same as in the ZINB model. The results also indicated that the number of dairy cows kept on a pig farm had a significant, positive effect on the probability of at least one violation being observed. In the previous count data model this coefficient was not significant. The interpretation of this is that farms with a larger number of dairy cows are more likely to violate some FAW condition, although not more likely to violate several.

The share of organic farms in a municipality was insignificant in the WL model, but was significant in the weighted count data model (Table 3). This indicates that farms in

municipalities with a high share of organic production on average do not fulfil the legal requirements more easily. The probability of at least one violation seemed to be as high in these as in other municipalities, although the actual number of violations per farm was significantly lower. With respect to the research hypotheses derived from the standard critique, this finding suggests that for farms in municipalities with a high share of organic production, the average level of FAW provision does not seem to be significantly higher than in other municipalities. However, the violations occurring in these municipalities appeared somewhat less severe than in those with a lower share of organic production (Table 3).

Table 4: Results obtained using the Weighted Logit (WL) model with the dependent variable ‘At least one violation, yes/no?’

	Estimate	Std.E	z	Pr(> z)	
Intercept	-0.2121	0.4651	-0.4600	0.6484	
Sows per farm	-0.0030	0.0012	-2.6400	0.0082	**
Fattening pigs per farm	0.0000	0.0002	0.0100	0.9901	
Utilisation share of registered house capacity (fatteners)	0.0136	0.3304	0.0400	0.9672	
Utilisation share of registered house capacity (sows)	0.8049	0.3550	2.2700	0.0234	*
Dairy cows per farm	0.0049	0.0022	2.1800	0.0290	*
Sheep and goats per farm	-0.0185	0.0297	-0.6200	0.5341	
Horses per farm	-0.0326	0.1441	-0.2300	0.8210	
Share of organic acreage in farm’s municipality	-0.7770	1.1870	-0.6500	0.5127	
Announced inspection	-0.6034	0.2827	-2.1300	0.0328	*
Follow-up inspection	-0.2742	0.3469	-0.7900	0.4293	
Inspection intensity in <i>r</i> (inspections/farms in <i>r</i>)	0.9765	0.4644	2.1000	0.0355	*

AIC 353.96, Null deviance: 357.29 on 257 degrees of freedom

In the next step of the analysis, the dependent variable was broken down into the individual categories of FAW indicators presented in Table 1. For the expected count of violations per category, the corresponding count data models achieved numerical convergence in only a few cases. However, for each of the eight categories on the FAW checklist, the WL model showed which explanatory variables increased the probability of at least one violation being observed. These results are shown in Table 5 where, for simplicity, only the sign and the level of statistical significance of the estimated coefficient are indicated. A negative (positive) sign indicates a decreased (increased) probability of at least one violation being recorded for lower (higher) values of the explanatory variable. The results show that the relationship between violations in the different FAW categories and the corresponding explanatory variables was heterogeneous and did not fully correspond to the findings of the aggregated data presented in Tables 3 and 4.

For the number of fattening pigs, both positive and negative coefficients were found. This may partly explain the insignificant effect on the aggregated dependent variable in Tables 4 and 5. However, the number of sows showed a negative relationship with the probability of at least one violation being observed. Utilisation of sow places was significantly positively related to the risk of violating supervision and care conditions but also conditions concerning feed and water, cleaning and the quality of drives, runs and pasture. In addition, as could be expected, a high of registered house capacity (sows) was significantly related to a higher probability of observing violations of minimum space requirements. The number of dairy cows showed a significant positive effect in the categories climate, noise and quality of drives. All these three categories tend to relate to the buildings in which pigs are housed, indicating that farms with a large number of dairy cows tend to have less suitable housing for pigs.

Furthermore, a higher frequency of inspection in the area increased the probability of recording at least one violation on a farm. Announcing the inspection, on the other hand,

reduced the probability, probably because it induced farmers to improve e.g. supervision and care and adjust utilisation of available space in advance.

Table 5. Summary of results obtained using the Weighted Logit (WL) model for each specific indicator

	Supervision & Care	Sick & Document.	Space & Equip	Climate & Air	Light
(Intercept)	- ***	- *	- **	- **	- **
Sows per farm	- **	- *	-	-	-
Fattening pigs per farm	+ *	+	- *	- *	-
Utilisation share of reg. house capacity (fatteners)	-	-	+	+	+
Utilisation share of reg. house capacity (sows)	+ **	+	+ *	+	+
Dairy cows per farm	-	+	+	+ ***	-
Sheep and goats per farm	+	+	-	-	-
Horses per farm	-	-	-	-	-
Share of organic acreage in farm's municipality	+	- *	-	-	-
Announced inspection?	- *	+	- **	+ *	+ *
Inspection intensity in r (inspections/farms in r)	+ **	+ **	+ *	+	+
Follow-up inspection?	+	+	-	+	-
	Noise & Emiss.	Feed & Water	Cleaning & Straw	Pasture & Runs	Other
(Intercept)	- **	- **	- *	- ***	- **
Sows per farm	- *	- **	-	- *	-
Fattening pigs per farm	+ **	-	-	-	+
Utilisation share of reg. house capacity (fatteners)	-	+	+	+ **	+
Utilisation share of reg. house capacity (sows)	+	+ *	+ .	+ *	+ .
Dairy cows per farm	+ .	+	+	+ **	+
Sheep and goats per farm	+	+	-	-	-
Horses per farm	-	+	-	+	-
Share of organic acreage in farm's municipality	-	- *	- **	+	- *
Announced inspection?	-	+	-	+	-
Inspection intensity in r (inspections/farms in r)	+	+ .	+ **	+ *	+ ***
Follow-up inspection?	-	+	-	-	-

However, the effects of announced inspections with respect to violations of climate, air and the provision of daylight regulations are more difficult to explain. Follow-up inspections had insignificant effects throughout, indicating that the PSM procedure removed the difference between the two inspection types for the WL model too.

3.3 Cross-compliance violations

The 27 cross-compliance conditions should in principle be mandatory for all pig farmers in Europe. Given that Sweden has more stringent FAW regulations than many other countries (see e.g. Veissier et al., 2008), one could expect the cross-compliance conditions to be more easily met by Swedish farmers. In order to test this empirically, a similar analysis as before was conducted using the ZINB model and the WL models. The new dependent variable consisted of the count of violations (and equivalently the binary category 'Any violation, yes or no') from the 27 cross-compliance conditions only. Full results from this analysis are available upon request, but qualitatively the findings from the ZINB model were similar to those presented in Table 3. For the WL model, only the number of dairy cows per farm was significant, indicating that the probability of observing at least one cross-compliance violation was significantly positively influenced by more dairy cows being present on a farm with pigs. These results indicate that violations of cross-compliance conditions are more evenly distributed across the population of Swedish pig farmers than violations of national Swedish standards. Furthermore, the probability of violating at least one cross-compliance condition was independent of farm size or degree of utilisation, while the number of dairy

cows appeared again as a significant predictor for violating at least one cross-compliance condition. However, it should be noted that differences between EU member countries in recorded violations of cross-compliance conditions may also be explained by possible differences in how the inspections are conducted (compare Czekaj et al. 2013, Table 7.2).

4 Discussion & conclusions

Hypotheses relating to animal welfare derived from some of the assumptions implicit in the standard critique of farm 'industrialisation' were examined in this study. These include suggestions that larger farms have a stronger incentive to save costs, work with less labour per animal and carry a lower level of non-use values regarding the quality of animal treatment, than small, more family-based farms. This in turn suggests that regions with relatively strong agro-industrial agglomeration and a high intensity of livestock production would be more prone to violating FAW regulations. Specifically, we tested whether the legally binding minimum level of FAW was more likely to be violated *i*) by relatively large farms, due to their larger profit incentive and *ii*) by more specialised farms, since these farms have a lower average number of workers per animal. We also tested whether the statutory minimum FAW requirements were more likely to be met *iii*) by small farms, due to their relatively higher level of non-use values, *iv*) by organic farms, due to their self-selection into higher standards, and *v*) by more diversified farms, as long as FAW is more easily provided under economies of scope from keeping multiple animal types on a certain farm.

As an approximation of the degree of compliance by farms of different sizes and different degrees of specialisation with the statutory minimum FAW requirements for pig farms in Sweden, we analysed veterinary farm inspection data from all inspections of pigs carried out during 2011. These inspections covered about 13-18% of pig farms in Sweden and a similar proportion of the total Swedish pig population. The results indicate that rather small farms with sows had the highest number of violations, while farm size appeared insignificant for farms with fattening pigs. Regardless of farm size, however, over-utilisation of capacity posed a high risk of a violation being recorded on farms with sows. The number of dairy cows present on the farm had a very strong positive and statistically significant effect on the probability of at least one condition being violated and on the expected number of violations per inspection.

Small farms are according to the assumptions of the standard critique believed to provide, *ceteris paribus*, higher levels of FAW due to higher levels of non-use values. However, our empirical analysis did not provide any support for this element of the standard critique. Instead, violations were found to be slightly more likely and more severe (according to the number of violations) on small farms. In addition, we found evidence that more diversified farms had significantly more violations. This can be explained by the higher opportunity costs that these farms face for their time spent with pigs. On the other hand, larger, more specialised farms may have more specialised personnel who do not have to attend to other tasks, e.g. during peak harvest times.

With respect to policy recommendations, we suggest that the public debate should focus on the minimum requirements and on appropriate conditions and related indicators, inspection practices and fines on how to enforce the standard, rather than on questions about appropriate farm size. In future research, the present analysis would need to be extended to more years and include additional explanatory variables. Furthermore, in a European context the differences between EU member countries with respect to inspection methods and inspection frequency should be examined, not only in order to assure a publicly accepted level of FAW, but also to ensure that different levels of inspection intensity, control practices and interpretation of FAW conditions do not distort the relative competitiveness of pig producers in different European regions.

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