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How Do Animal Welfare Practices Relate to Farm Characteristics? Evidence from German Dairy Farms

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Farm animal welfare has become increasingly important in public debates. This study uses an interval regression approach to estimate German dairy farmers' willingness to change selected animal welfare-related farming practices. The analysis reveals that the highest price premiums are required for implementing cow–calf rearing and accepting a herd size limit, while farmers provide deep cubicles and ample space without premiums. Furthermore, farms with large herds require higher compensation to provide pasture grazing than smaller farms. Overall, we find no simple relationship between farm size and the willingness to change animal welfare-related practices.

Key words: animal welfare, cows, dairy farms, interval regression, willingness to change

Introduction

Animal products constitute the primary source of protein for citizens in the European Union (EU), with an average annual per capita consumption of 22 kg of animal-based protein compared to 16 kg of plant-based protein in 2013 (FAOSTAT, 2020a,b). At the same time, there is growing public concern regarding both animal welfare and the environmental footprint of livestock farming. Despite public concerns that the trend toward larger farms is detrimental to animal welfare (Pfeiffer, Gabriel, and Gandorfer, 2021), there is no clear evidence about the extent to which farm characteristics affect animal welfare.

This article evaluates farmers' willingness to change (WTC) animal-welfare related practices in the German dairy sector. To achieve this, we conducted a survey of German dairy farmers in 2018. We consider 10 animal welfare-related practices (e.g., access to pasture or outdoors, space per cow, the ratio between the number of cows and resting places).[1] The relationship between the WTC estimates and farm and farmer characteristics is explored using an interval regression approach to identify structural factors that encourage or prevent the provision of higher animal-welfare levels. The results have important policy implications since the public discussion on animal welfare often evolves in the context of the structural change toward larger farms. Furthermore, it is important to consider producer costs when assessing consumers' demands for animal welfare-related practices (Ortega and Wolf, 2018).

Consumers' demand for animal-friendly products has been studied in depth in the literature, as summarized in two meta-analyses on willingness to pay (WTP) (Lagerkvist and Hess, 2011; Yang and Renwick, 2019). Farmers' perspectives on providing animal welfare-related practices, on the

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[1] See Table 3 for definitions of the ten practices considered.

Table 1. Overview of Studies Assessing Farmers' Willingness to Accept or Change Animal Welfare Practices

Study	Country	Data Collection	Sample	Valuation Method
Latacz-Lohmann and Schreiner (2019)	Germany	Online survey in 2014, promoted through University's homepage and mailing list of a farmers' union	140 pig farmers	Discrete choice experiment
Schreiner and Hess (2017)	Germany	Paper-based survey in 2014, participants recruited at agricultural fair (*EuroTier*)	78 dairy farmers	Discrete choice experiment
Wolf and Tonsor (2017)	United States of America	Survey in 2014, participants randomly drawn from producer lists	692 dairy farmers	Contingent valuation

contrary, have received much less attention (Henningsen et al., 2018). Some production economics work has examined the relationship between farmers' attitudes toward farm animal welfare and the implementation of good welfare practices (e.g., Austin et al., 2005; Hubbard, Bourlakis, and Garrod, 2007). Another strand in this literature investigates the relationship between farm animal welfare (either measured by expert assessments or proxied by animal health) and economic performance (e.g., Lawson et al., 2004; Jensen et al., 2008; Barnes et al., 2011; Stott et al., 2012; Henningsen et al., 2018).

To our knowledge, only three studies present estimates for farmers' willingness to implement different animal welfare-related practices. Table 1 summarizes these studies and their main characteristics. Latacz-Lohmann and Schreiner (2019) use data from a discrete choice experiment in Germany to estimate farmers' willingness to accept (WTA) higher farm animal welfare standards in the pork sector. They find that animal welfare programs involving investments in housing facilities are likely to attract fewer participants than programs with less costly constraints, such as providing manipulable material. Using a sample of German dairy farmers, Schreiner and Hess (2017) likewise find that providing access to pasture and increased levels of space lowers farmers' WTA a farm animal welfare program. Finally, Wolf and Tonsor (2017) evaluate farmers' choice of production practices for the U.S. dairy sector. In contrast to Schreiner and Hess (2017) and Latacz-Lohmann and Schreiner (2019), these authors use contingent valuation and an interval regression approach to estimate farmers' WTC animal welfare-related practices, capturing both farmers' WTA (the case in which farmers require compensation for a certain practice) and farmers' WTP (the case in which farmers would pay to provide a certain practice).

Our study makes two contributions to this literature. First, it provides empirical evidence on farmers' WTC animal welfare-related practices in the EU dairy sector. Our study focusses on German dairy farms, which produce the largest share of cow milk in the EU-28 (20.5% in 2019) (Eurostat Statistical Database, 2020). In contrast to the choice experiment conducted by Schreiner and Hess (2017) for the German dairy sector, we employ an interval regression approach that allows us to distinguish between WTA and WTP (Wolf and Tonsor, 2017). This is important since animal welfare involves not only costs but also benefits for farmers, as described in the theoretical framework below. Second, unlike Wolf and Tonsor (2017), we include a set of farm and farmer attributes to evaluate the relationship between structural characteristics and WTC estimates. This helps us assess the accuracy of public perceptions about animal welfare and farm structure. For example, a survey conducted by Kayser, Schlieker, and Spiller (2012) indicates that German consumers link large-scale livestock farming (in German, "*Massentierhaltung*") to animal torture, and Miele et al. (2011) find that focus group participants associate small-scale production with higher animal welfare.

Our analysis reveals significant differences in WTC estimates across animal welfare-related farming practices, reflecting differences in their ease of implementation, economic implications, and associated nonuse values. For example, we find that farmers require an average price premium of €0.029 per kilogram of milk to provide access to pasture, which is 8% of the average raw milk price

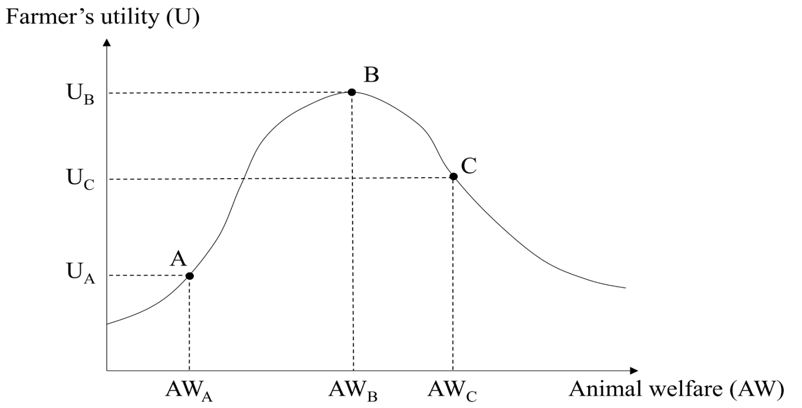

Figure 1. Relationship between Animal Welfare and Farmer's Utility

Notes: This figure is a slight modification of Figure 1 in Henningsen et al. (2018), who use economic performance instead of utility.

(€0.35/kg) in Germany in the year of our survey (Eurostat Statistical Database, 2021). Furthermore, our empirical findings suggest that no simple relationship exists between farm size and the WTC animal welfare-related practices.

Theoretical Framework

Practices that maximize animal well-being involve high costs and are usually not profit maximizing for the farm (Liljenstolpe, 2008; Vanhonacker et al., 2009). At the same time, animal health is an important determinant of income and productivity (e.g., Antle and Goodger, 1984; Lusk and Norwood, 2011; Finger et al., 2018). Therefore, improving animal welfare not only affects costs but also contributes to economic benefits derived from the direct use of livestock in the production process (use values). In addition, farmers may gain nonuse values from animal welfare resulting from the well-being of the animals (McInerney, 2004; Lagerkvist et al., 2011). These nonuse values are independent of productivity concerns and are based on principles such as "ethics in production, self-image, perceived rights of the animals and perceived legitimacy of the production process" (Hansson, Manevska-Tasevska, and Asmild, 2020, p. 4). Thus, in line with previous literature, we assume that farmers derive utility from both use values (i.e., higher productivity) and nonuse values of animal welfare.

Drawing upon Henningsen et al. (2018), Figure 1 illustrates the theoretical relationship between animal welfare and the farmer's utility. Point *A* describes a production system with relatively low animal welfare (AW_A) and low utility (U_A). The low level of animal welfare may lead to a diminished animal health status, with negative consequences for productivity. Starting at this point, improving animal welfare increases utility up to point *B*, due to either higher use values, enhanced nonuse values, or both. An optimal provision of farm animal welfare goes beyond the productivity or profit-maximizing point for those farmers who derive utility from its nonuse values. For example, Hansson and Lagerkvist (2016) find that when making decisions about animal welfare, Swedish dairy farmers attach more importance to nonuse values, especially the good feeling of "knowing that my dairy cows are well-kept," than to use values. Assuming that farmers maximize utility, animal welfare level AW_B is reached without legal interventions or market incentives. If the public demands higher levels of animal welfare, legislation must set the respective minimum standard above AW_B or farmers must be incentivized to improve it by providing higher use values (e.g., through price premiums for higher animal welfare standards).

To summarize, a farmer's utility from animal welfare increases up to a certain level of animal welfare and then declines when the additional costs outweigh the gains in use and nonuse values.

Since utility rises up to point B, farmers are willing to pay a price to provide animal welfare level AW_B, described by the term “willingness to pay” (WTP). However, they require a price premium, described by the term “willingness to accept” (WTA) to provide animal welfare above AW_B. Throughout the article we use the term “willingness to change” (WTC), adopted by Schulz and Tonsor (2010) and Wolf and Tonsor (2017), to capture both WTA (if WTC is positive) and WTP (if WTC is negative).[2] Thus, a negative value for the WTC a specific welfare-related practice implies that the farmer would pay a premium to implement the measure because it increases the utility arising from use and nonuse values.

Empirical Framework

The empirical framework in this article closely follows Wolf and Tonsor’s (2017) approach. Based on our theoretical considerations, we assume that each farmer i has a true value (WTC_{ij}) for animal welfare-related farming practice j. If $WTC_{ij} < 0$, they are willing to pay a premium for practice j, while $WTC_{ij} > 0$ indicates that they require a price premium for the same practice. However, the true value of WTC_{ij} is unobserved. It is less meaningful to ask farmers directly about the price premium they would need to provide different management practices as they would probably overstate the required premium without being confronted with specific values. Moreover, it might have been asking too much to expect the study’s participants to provide precise and definite estimates for 10 individual practices. Thus, we provided them with the list of animal welfare-related practices and started by asking which ones they already implement. In event of a negative answer, we continued by asking if they would be willing to implement the respective practice for a price premium of +€0.02 per kilogram of milk. If the answer was still negative, we proceeded with +€0.04 and finally with +€0.08. This procedure allowed us to capture the range of each farmer’s WTC (see also Wolf and Tonsor, 2017). Formally, we observe threshold values t_{ij} at which individual respondents are willing to implement the practice, so that

$$(1) \qquad I_{ij} = \begin{cases} 1 & \text{if } WTC_{ij} \leq t_{ij} \\ 0 & \text{if } WTC_{ij} > t_{ij} \end{cases},$$

where the indicator variable I_{ij} denotes whether the ith respondent agrees to implement practice j. In our application, the (unobserved) valuation is represented as

$$(2) \qquad WTC_{ij} = \beta_{0j} + \sum_{n=1}^{N} \beta_{jn} x_{in} + \varepsilon_{ij},$$

where x_{in} are farm and farmers’ characteristics, ε_{ij} is a normally distributed error term, and β are parameters to be estimated. Since all respondents are offered predetermined thresholds, we estimate equations (1) and (2) using an interval-censored regression model based on Cameron (1988) and Wolf and Tonsor (2017).[3] If the sample is truly random, the interval regression obtains the sample mean WTC without the inclusion of covariates x_n (Cameron and Quiggin, 1994), as done by Wolf and Tonsor (2017). However, the inclusion of regressors allows the model to be used for forecasting and simulation, as well as for benefits transfer. In addition, regressors contribute to the “explanation of systematic variation in fitted valuations across individuals” (Cameron and Quiggin, 1994, p. 233) and allow computation of marginal effects. For example, it is relevant for policy

[2] A related concept is producers’ willingness to supply (WTS), which is WTC but censored at 0 (Schulz and Tonsor, 2010). For example, Wossink and Swinton (2007) study farmers’ WTS ecosystem services and Skevas et al. (2016) analyze landowners’ WTS land for bioenergy production.

[3] Cameron and Quiggin (1994) propose a bivariate probit model instead of the interval data model if the thresholds are random across respondents and the second threshold is larger *or* smaller depending on the first choice of the respondent. While this question method provides richer information, it introduces endogeneity as the first and second choices are likely to be correlated.

makers to understand whether farm size or other structural characteristics explain differences in the WTC animal welfare-related farming practices. Our explanatory variables are herd size, utilized agricultural area (UAA), share of grassland, share of rented land, share of family labor, farmer's age, binary variables indicating whether the farm is a full-time operation, whether there is a farm successor, whether the farmer has a higher educational degree, and locational variables to account for regional heterogeneity. To mitigate the risk of endogeneity in our regressions, we restrict the analysis to variables that are arguably exogenous, at least in the short term. For example, this implies that we have to refrain from including milk yield as an explanatory variable because productivity is likely to be jointly determined with some of the considered farming practices. However, we cannot exclude that some typical structural variables, such as UAA or herd size, may also be endogenous to a certain extent. For example, the decision to enlarge or reduce the herd size may be influenced by omitted variables (e.g., entrepreneurial orientation or risk preferences). The estimated parameters would be biased if such variables were correlated with WTC animal welfare-related practices. This qualification must be kept in mind when interpreting the marginal effects.

We use robust standard errors for making statistical inference about the estimated parameters. Since we are testing the relationship between farm characteristics and multiple outcome variables, there is an increased probability of false rejections of the null hypothesis. To account for multiple hypothesis testing, we present sharpened false discovery rate (FDR) *q*-values as proposed by Benjamini, Krieger, and Yekutieli (2006) in addition to standard *p*-values obtained with robust standard errors. This procedure controls the proportion of rejections arising from type I errors (i.e., the probability of falsely rejecting the null hypothesis) and is well suited to exploratory studies (Anderson, 2008).

Data and Descriptive Statistics

To determine the appropriate sample size, we use the Cochran (1977) formula for sample size calculation in smaller populations.[4] Our target population consists of 63,000 dairy farms in Germany (German Federal Ministry of Food and Agriculture (BMEL), 2019). With a 5% margin of error, a confidence level of 90%, and a response distribution of 50%, the recommended sample size is 271. Data were collected using an online survey in autumn 2018. The link to the survey was distributed through the websites and social media channels of agricultural magazines (*Agrarheute, Agrarzeitung*, and *Topagrar*) and various public and private agricultural advisory agencies and organizations (e.g., *Landeskuratorium der Erzeugerringe für Tierische Veredelung*). To encourage response, the survey included an invitation to participate in a lottery to win 10 vouchers for a popular agricultural clothing shop worth €50 each. The first part of the questionnaire dealt with the main farm and farmer attributes, such as the farm's size and location and the farmer's age and education. The second part related to current husbandry conditions and practices. The third part included the contingent valuation questions.

We received 300 answers, of which 48 were incomplete and had to be dropped from the analysis. Hence, the final sample consists of 252 observations, slightly below Cochran's sample size recommendation but higher than the sample sizes in related studies in Germany (see Table 1). We assess the representativeness of our sample by comparing its key characteristics to those of the full population of German (dairy) farms in Table 2. The median values of the number of cows, milk yield, UAA, and share of grassland are all slightly above the German average. Since the population's average grassland share refers to all farm types, it is reasonable that the value for our sample of dairy farms is higher than the population's average. The mean share of family labor is also above the population's mean. The median value of the share of rented land is very similar to the German average, and the average age of the farmers lies within the range of the most common values in

[4] The formula is $n = \frac{Z^2 p(1-p)}{e^2} \Big/ \left(1 + \frac{(Z^2 p(1-p)}{e^2 N}\right)$, where n is the sample size recommendation, Z is the z-score, p is the response distribution, e is the margin of error (i.e., desired level of precision), and N is the population size.

Table 2. Descriptive Statistics for the Sample Compared to the German Average (*N* = 252)

Variable	Median	Mean	Std. Dev.	German Average	
				Value	Reference
Number of cows	80.00	137.81	186.07	65.1[c]	Dairy farms in 2018
Milk yield (kg/cow)	8738.64	8649.89	1354.74	8059[c]	Dairy farms in 2018
Utilized agricultural area (ha)	85.00	204.26	582.43	60.5[c]	All farms in 2016
Share of grassland (%)	50.00	51.90	25.80	28.3[d]	All farms in 2018
Share of rented land (%)	60.00	54.32	22.59	58.5[c]	All farms in 2016
Workforce (AWU[a])	2.30	4.12	8.19	1.8 c	All farms in 2016
Share of family labor (%)	100.00	80.59	29.65	47,8[c]	All farms in 2016
Organic farming (1 if yes, 0 otherwise)	0.00	0.09	0.28	5.9%[e]	Dairy farms in 2016
Full-time farming (1 if yes, 0 otherwise)	1.00	0.95	0.22	48,0%[c]	All farms
Farmer's age	46.75	46.09	11.10	45-55[f]	All farms
Successor (1 if yes, 0 otherwise)	1.00	0.90	0.29	n/a	–
Higher education[b] (1 if yes, 0 otherwise)	1.00	0.79	0.41	n/a	–

Notes: [a]AWU denotes annual working units.
[b]Higher education refers to having a master artisan diploma or university degree.
Sources: [c]German Federal Ministry of Food and Agriculture (BMEL) (2019), [d]German Federal Ministry of Food and Agriculture (BMEL) (2020), [e]Destatis (2017a), [f]Destatis (2017b).

Germany. Finally, full-time farms and organic farms are overrepresented in our sample. Overall, the descriptive statistics show that the sample farms are slightly larger than the population's average, which may be due to the online data collection. Given the ongoing trend toward fewer but larger farms in the EU (e.g., Wimmer and Sauer, 2020), the bias toward larger farms in our sample is not necessarily a disadvantage (see also Schreiner and Hess, 2017).

Animal welfare-related husbandry practices were selected based on requirements of relevant animal welfare programs in Germany. For example, the EU ecoregulation for organic dairy farms sets minimum requirements of 6 mÂš of floor space per cow and pasture access (whenever feasible). The provision of at least one feeding and resting place per cow is a common requirement of organic farming associations (e.g., Bioland, 2019). The animal welfare label of the German nonprofit organization *Vier Pfoten* (2020) specifies soft bedding, as provided in deep cubicles, and calf rearing with mother cows as premium standard requirements. In addition, the selection was confirmed in expert interviews conducted in spring 2018 with two representatives of a dairy farmers' association and a dairy equipment manufacturer. Table 3 defines the 10 selected practices and reports the distribution of farmers' responses to the contingent valuation questions. It must be emphasized that it is nearly impossible for humans to determine what practices are most beneficial for animal welfare (McInerney, 2004). In fact, some practices are a source of controversy. For example, separating newborn calves from the mother cows prevents a natural cow–calf relationship (von Keyserlingk and Weary, 2007), but others claim that separating them after a couple of weeks is even worse as they have built up a deeper relationship in the first weeks. Furthermore, closer contact between mother and calf may contribute to the transmission of diseases (Barth, 2020). Provision of pasture can also be a source of controversy, as it is often combined with tethering over the winter. In addition, some discordance between practitioners' and consumers' opinions and expectations regarding animal welfare practices can be expected. For example, Vanhonacker et al. (2008) find that consumers and practitioners have similar views on aspects related to animal health and animal feeding (e.g., curative medication or availability and taste of feed), but a smaller consensus is observed for aspects related to natural animal behavior or production practices (e.g., outdoor access or animal-friendly transport). Thus, while we do not claim that the selected practices lead to a demonstrable improvement in the lives of animals, they do reflect practices that society and many practitioners associate with farm animal welfare.

Table 3. Farmers' Responses Related to Animal Welfare Practices (N = 252)

Variable	Variable Definition	WTC ≤ 0 ct/kg (%) 1	0<WTC ≤ 1 ct/kg (%) 2	1<WTC≤ 2 ct/kg (%) 3	2<WTC≤ 4 ct/kg (%) 4	4<WTC≤ 8 ct/kg (%) 5	WTC > 8 ct/kg (%) 6
Pasture access	Cows have access to pasture grazing	35.3	4.4	5.6	10.7	14.7	29.4
Outdoors access	Cows have outdoor access	31.0	19.8	9.5	13.1	8.7	17.9
Deep cubicles	Cows have access to comfortable bedding systems	58.3	7.1	6.0	6.4	7.5	14.7
Space per cow > 6 m^2	The barn offers at least 6 m^2 space per cow	60.3	7.9	5.6	8.3	7.9	9.9
Consultation	Farmers accept yearly consultations related to welfare	19.4	59.1	5.6	4.0	3.6	8.3
Cow w/ calf	Calf remains with cow after birth	2.4	4.0	4.4	8.3	14.3	66.7
No dehorning	Cows and calves are not dehorned (includes hornless breeds)	13.1	19.4	9.1	13.1	17.5	27.8
Size limit	Herd size is limited to 60 cows	27.0	5.6	5.6	6.4	13.1	42.5
Resting-place-to-cow ratio >1	Ratio of resting places to number of cows above 1	61.1	13.9	7.5	7.1	3.6	6.8
Feeding-place-to-cow ratio >1	Ratio of feeding places to number of cows above 1	44.4	17.5	10.3	12.7	6.0	9.1

Notes: Columns 1–6 show the distribution of the ranges in which farmers indicate willingness to change the individual welfare-related practices. For example, the first row in column 6 indicates that 29.4% of respondents would not implement pasture grazing for any of the price premiums offered.

Table 3 illustrates the degree to which the surveyed farmers accept the proposed animal welfare practices. For example, most respondents (60.3%) already provide more than 6 m2 of floor space per cow without any price premium (i.e., WTC ≤ 0 for these farmers). For a price premium of €0.01 per kilogram of milk, 7.9% would enlarge the space provided per cow to over 6 m2, 5.6% would join at a price premium of €0.02. In contrast, the least common practice is allowing calves to stay with their mothers after birth—only 2.4% of respondents currently implement this practice. The majority of respondents (66.7%) would not keep calves with their mothers after birth, even for a price premium of €0.08/kg. Considering that the average raw milk price in Germany was €0.35/kg in the year of our survey, the rejection of such a high price premium seems surprising. As discussed in the theoretical framework, the distribution of the acceptance of specific farming practices reflects not only the specific costs and economic benefits but also the usefulness of the individual measures from the respondents' perspective (i.e., use values and nonuse values). That is, farmers in our sample either view rearing calves in contact with their mothers as very costly, not useful, or both, which explains the high rejection rate.

Results and Discussion

Regression Results

Table 4 presents the estimation results of the interval regressions described by equation (2). The dependent variables are the lower and upper limits for the price premiums required to adopt the selected practices. Independent variables are farm and farmer characteristics as described in the empirical framework. Excluding constant terms and locational dummies, 23 out of 90 parameter estimates are statistically significant at the 10% significance level or lower based on robust standard errors. When accounting for multiple hypothesis using sharpened FDR q-values, 8 parameters remain statistically significant at the conventional levels, and 7 parameters have q-values slightly above 0.10. The share of correctly predicted observations varies between 13% (outdoor access) and 65% (cow with calf).

Column 1 of Table 4 reports estimation results from the regression that explains the WTC access to pasture. The parameter estimates suggest that WTC increases with herd size and decreases with UAA and with share of grassland, although the q-value for the former is slightly above 0.10. In other words, farmers with large herd sizes require higher compensation for providing pasture grazing, while farmers with a large amount of land and a high share of grassland are willing to provide pasture grazing for lower compensation. In accordance with Robbins et al. (2016) and Danne and Musshoff (2017), this finding is in line with theoretical considerations, as pasture access requires large areas of land, particularly grassland, and is more costly to manage for large herd sizes. In monetary terms, farms with one additional cow require €0.0002 more per kilogram of milk for providing pasture access, *ceteris paribus*.

Columns 2–10 of Table 4 show that the remaining animal welfare-related practices vary with respect to the most relevant farm and farmer characteristics. Besides access to pasture, the size of the dairy herd also increases the WTC estimate for the following practices: no dehorning, herd size limit, and feeding-place-to-cow ratio above 1. Again, this is in line with expectations because dehorning is a way of reducing the risk of injuries, especially in large herds; herd size limits are more difficult to accept for farms with a large number of cows; and it is costly to increase feeding places as herd size grows. On the other hand, the amount of utilized agricultural area is negatively related to the WTC dehorning practices and providing a feeding-place-to-cow ratio above 1. The q-values indicate that all these estimates remain statistically significant after controlling the FDR, except for the relationship between land area and dehorning practices. The WTC estimates are independent of farm size variables for 6 of the 10 practices considered here, implying that farm size alone should not be used to draw conclusions on animal well-being.

Table 4. Interval Regression Results to Explain Farmers' Willingness to Change (in ct/kg) Farming Practices (N = 252)

	Pasture Access	Outdoor Access	Deep Cubicles	Space per Cow >6 m^2	Consul-tation	Cow w/ Calf	No Dehorning	Size Limit	Resting Place-to-Cow Ratio >1	Feeding Place-to-Cow Ratio >1
	1	2	3	4	5	6	7	8	9	10
Herd size	0.020***	0.002	0.003	0.006	0.001	0.004	0.009**	0.078***	0.006	0.010**
	(0.007)	(0.003)	(0.008)	(0.005)	(0.002)	(0.004)	(0.004)	(0.023)	(0.006)	(0.004)
	[0.024]	[0.624]	[0.627]	[0.300]	[0.684]	[0.484]	[0.042]	[0.011]	[0.484]	[0.028]
UAAa	−0.003**	−0.000	0.000	−0.001	−0.001	−0.000	−0.001**	0.026	−0.002	−0.003***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.018)	(0.002)	(0.001)
	[0.122]	[0.609]	[0.609]	[0.451]	[0.266]	[0.609]	[0.151]	[0.266]	[0.281]	[0.031]
Share grassland	−0.093***	−0.010	−0.016	−0.026	−0.007	−0.003	0.019	−0.014	−0.013	−0.041***
	(0.024)	(0.014)	(0.028)	(0.023)	(0.008)	(0.022)	(0.016)	(0.024)	(0.017)	(0.015)
	[0.001]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[0.024]
Share rented land	0.048*	0.004	−0.050	−0.035	−0.026***	−0.036	−0.035**	0.006	−0.016	−0.001
	(0.026)	(0.017)	(0.032)	(0.025)	(0.009)	(0.022)	(0.017)	(0.025)	(0.019)	(0.014)
	[0.247]	[0.581]	[0.250]	[0.283]	[0.053]	[0.250]	[0.220]	[0.581]	[0.383]	[0.581]
Share family labor	0.903	0.601	4.049	1.545	−0.473	−0.325	−0.491	1.596	3.127	0.963
	(3.081)	(1.807)	(3.824)	(2.512)	(0.970)	(2.672)	(1.727)	(2.479)	(2.253)	(1.661)
	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
Full-time (1 if yes,	0.993	3.729***	−1.849	2.378	0.235	0.243	0.367	−0.601	1.702	1.873
0 otherwise)	(2.908)	(1.320)	(2.081)	(1.944)	(0.836)	(2.622)	(1.949)	(2.873)	(1.511)	(1.211)
	[1]	[0.053]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
Successor (1 if	−0.603	−1.707	−4.790*	−3.762**	−1.393*	1.362	0.830	−0.314	−3.014*	−1.331
yes, 0 otherwise)	(1.764)	(1.574)	(2.551)	(1.791)	(0.815)	(1.690)	(1.238)	(1.762)	(1.660)	(1.357)
	[0.954]	[0.486]	[0.283]	[0.283]	[0.283]	[0.563]	[0.604]	[1]	[0.283]	[0.486]
Farmer's age	0.019	0.058*	0.068	0.028	0.003	−0.000	0.003	−0.063	−0.022	0.024
	(0.050)	(0.033)	(0.060)	(0.046)	(0.021)	(0.046)	(0.034)	(0.049)	(0.037)	(0.030)
	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
Higher educ.b (1 if	−2.083	−1.922*	−2.174	−2.720**	−1.000**	−1.596	0.514	2.319*	−1.990*	0.279
yes 0 otherwise)	(1.670)	(1.009)	(1.673)	(1.350)	(0.501)	(1.419)	(0.945)	(1.225)	(1.086)	(0.802)
	[0.179]	[0.155]	[0.179]	[0.155]	[0.155]	[0.195]	[0.435]	[0.155]	[0.155]	[0.435]
Constant term	6.683	−2.079	1.910	1.248	4.951**	12.071**	4.187	−3.701	0.411	−0.965
	(5.975)	(3.144)	(6.335)	(4.851)	(2.177)	(4.872)	(3.787)	(5.462)	(4.263)	(3.420)
Log likelihood	−346.294	−452.669	−326.738	−319.966	−495.475	−282.320	−462.219	−292.714	−322.569	−395.991
Wald χ^2	69.67***	22.08	25.36	97.84***	22.92	15.84	22.70	157.65***	85.37***	31.73**
Correctly predicted	39%	13%	52%	53%	33%	65%	16%	50%	54%	32%

Notes: Each column represents a separate regression. Huber–White robust standard errors are reported in parentheses. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. False discovery rate q-values are reported in brackets. Binary variables for 10 German regions according to postal codes are included to account for regional heterogeneity but not reported to save space. Their estimates are available from the authors upon request.

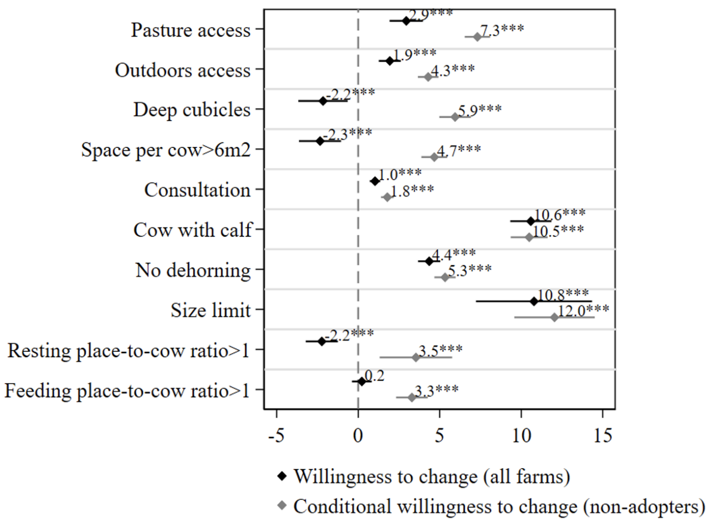

Figure 2. Estimates for Willingness to Change and Conditional Willingness to Change with Regressors (in € cents)

Notes: Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. The bars indicate 95% confidence intervals.

The share of rented land is positively related to the WTC providing access to pasture but negatively related to accepting yearly consultations to improve animal welfare and to forgo dehorning. However, only the finding regarding yearly consultations survives controlling the FDR. Furthermore, farmer age and full-time farming are positively related to the WTC outdoor access based on robust standard errors, and the latter remains statistically significant when the FDR is controlled. That is, full-time farmers require more compensation for providing access to the outdoors than part-time farmers. Finally, the results suggest that better educated farmers and those who have farm successors require less compensation for a range of welfare-related practices, but these effects do not survive controlling the FDR. In line with this, Schreiner and Hess (2017) and Latacz-Lohmann and Schreiner (2019) find no statistically significant relationships between having a successor and WTA animal welfare programs.

Farmers' Willingness to Change

Next, we evaluate the WTC our selected animal welfare-related management practices in monetary terms. The WTC of each practice is given by the predicted value of its interval regression. The WTC estimates vary across farms due to the inclusion of covariates. Figure 2 displays the WTC estimates evaluated at the sample mean. The standard errors are obtained using the delta method. In addition to WTC, we also estimate the conditional WTC (CWTC). While WTC is estimated using the entire sample, CWTC is estimated based on the subsample of farms that have not adopted the particular practice. Thus, the CWTC estimates represent the price premium required for the average nonadopter to implement the practice (Wolf and Tonsor, 2017). As seen in Figure 2, when the entire sample is evaluated, farmers require the highest price premiums for accepting a limit to the herd size (+€0.108 per kilogram of milk) and for rearing calves with the mothers (+€0.106 per kilogram of milk). Given the average milk price of €0.35, these premiums correspond to a 30% price increase. Consistent with the theoretical framework, the high values for these two practices may reflect both their high economic costs and their limited use and nonuse values. This result is in line with Latacz-Lohmann and Schreiner (2019), who find that the investments in housing facilities—which would be necessary in order to keep calves with their mothers—reduces the willingness to participate in animal welfare programs.

Abstinence from dehorning practices (+€0.044), providing access to pasture (+€0.029), outdoors access (+€0.019) and acceptance of yearly consultations (+€0.01) seem to be more easily implemented. These values correspond to a price increase of 3%–13% compared to the average milk price, and they are similar to those found in Thiele and Thiele (2020), who calculate the producers' cost for participating in a particular animal welfare program in Germany. Furthermore, the WTC for pasture access is in the range of the corresponding producer milk price premiums paid by dairy processors (€0.01–€0.05 per kilogram of milk) (Wocken and Spiller, 2007; Kühl et al., 2016).

WTC is negative for three measures: Farmers are willing to pay €0.023 on average for providing generous space and €0.022 for providing deep cubicles and a resting-place-to-cow ratio above 1, suggesting a positive sum of use and nonuse values for farmers. In fact, Wolf and Tonsor (2017) find negative WTC estimates for six out of nine practices, including the provision of clean feed and water and no hitting, which were not included in our study.

The CWTC estimates for herd size limits and rearing calves with the cows are nearly identical to those for WTC, reflecting the low implementation rates (see Table 3). Larger differences are found for providing access to pasture and outdoors, deep cubicles, ample space per cow and feeding or resting-places-to-cow ratios above 1. As CWTC are estimated for nonadopters, the values are naturally higher than those for WTC. For example, to persuade nonadopters to introduce pasture grazing, a price premium of +€0.073 per kilogram of milk is required. Likewise, €0.059 are needed to introduce deep cubicles on nonadopting farms, while the value is negative for the average farm.

Robustness Checks

We assess the robustness of our results by estimating farmers' WTC based on an interval regression (i) for the subset of conventional farms and (ii) excluding all covariates. Organic farms are excluded in the first robustness check to rule out that the regression estimates are driven by farms that may have different requirements regarding animal welfare practices. Table S1 in the online supplement (see www.jareonline.org) shows that the results for the subset of conventional farms ($N = 229$) are very similar to the results based on the full sample. Most importantly, the signs of statistically significant parameter estimates remain unchanged, and their magnitudes are similar across both samples. Some parameter estimates that were statistically significant based on robust standard errors become insignificant in the subsample of conventional farms. However, they were already insignificant in the original sample after controlling the FDR (e.g., for the farm successor and educational variables), as discussed previously.

It is important to note that if only conventional farms are considered, herd size is not significantly related to dehorning practices. This suggests that giving up dehorning practices is more attractive for organic farms, which generally have smaller herds than their conventional counterparts. Indeed, 72% of the 23 organic farms in our sample already refrain from dehorning practices, compared to only 7% of conventional farms, and the herd size on conventional farms in our sample is 34% larger than on organic farms. The remaining core results (e.g., the coefficients of variables explaining the WTC pasture grazing or the ratio between feeding places and cows) are not affected. Thus, we conclude that differences in the WTC animal welfare-related practices are not driven by organic farms, except for the case of dehorning practices.

Finally, Figure S1 in the online supplement reports the WTC estimates obtained from a regression without covariates, which mirrors the approach in Wolf and Tonsor (2017). These WTC estimates are very similar to our original specification. This confirms that the interval regression obtains the sample mean WTC without the inclusion of covariates (Cameron and Quiggin, 1994). As described above, including covariates allows us to identify relationships between farm characteristics and WTC and increases the precision of the estimation. For example, the standard error for the estimation of the WTC to provide access to pasture is 0.61 without regressors and declines to 0.52 with regressors (not shown in the figures).

Conclusion

In this article, we attempted to quantify the economic aspects of farm animal welfare-related practices for producers. To this end, we conducted a survey among German dairy farmers to evaluate their willingness to implement 10 selected practices that are considered animal friendly. Based on our final sample ($N = 252$), we estimated the WTC for each practice using an interval regression approach. The results reveal that the farmers' WTC welfare-related practices is significantly related to some farm characteristics. In particular, we find that farmers with large herd sizes require more compensation for providing access to pasture. This is in line with Robbins et al. (2016) and Danne and Musshoff (2017), who conclude that smaller farms are more likely to keep animals outside. Furthermore, we find that the amount of utilized agricultural area and the share of grassland are negatively related to the WTC access to pasture. The overall relationship between farm size and animal welfare remains inconclusive: Farmers with larger herds require more compensation for giving up dehorning, accepting a herd size limit and providing more feeding spaces than the number of dairy cows. On the other hand, farmers with more hectares of land require lower compensation for providing pasture grazing, abstaining from dehorning and providing a feeding-place-to-cow ratio above 1 than those with less land. The WTC estimates for the remaining six welfare-related practices are not significantly related to the farm size variables. Thus, our results confirm the findings of Robbins et al. (2016), which are based primarily on veterinary and animal science literature, that there is no simple relationship between farm size and farm animal welfare.

We emphasize that our study has at least three limitations. First, study participants were recruited exclusively via online channels, which may introduce sample bias (Van Selm and Jankowski, 2006). This is reflected by the fact that the key structural characteristics of our sample exceed German averages at the sample mean. Thus, the external validity of the study could be improved by employing random sampling. However, as Schreiner and Hess (2017) argue, overrepresentation of larger farms provides useful information about animal welfare aspects in the context of concentration and intensification in the dairy sector. Second, the study uses a hypothetical setting, which may be a source of bias if respondents make choices according to social desirability (see, e.g., Fisher and Katz, 2000). We tried to reduce this bias by using "cheap talk" at the beginning of the survey (e.g., Carlsson, Frykblom, and Lagerkvist, 2005; Bello and Abdulai, 2016). Although experiments do not seem to be valid in our case, this could be remedied in future studies by adding control variables reflecting concerns about appearance and strength of self-control (Wuepper, Clemm, and Wree, 2019). Third, we cannot exclude that some structural farm variables are endogenous to the WTC welfare-related practices. It is reassuring that the predicted values for farmers' WTC welfare-related practices are robust across the estimation both with and without covariates. Nevertheless, we refrain from claiming that the identified marginal effects are causal. Although identified associations between farm structure and animal welfare choices contribute to the political and scientific debate, further research is needed to identify the exact *causal* relationships and, hence, to increase the internal validity of the results.

In spite of these shortcomings, we believe that our work offers important policy implications. First, a widespread public perception is that larger farms are less animal-friendly than small farms. Our results suggest that the compensation required to provide access to pasture and a feeding-place-to-cow ratio above 1 is positively related to the size of the dairy herd. The amount of agricultural land is found to be negatively related to some practices, and the majority of our selected practices are not related to farm size variables. Based on these results, it does not seem appropriate to narrow down the discussion of animal welfare to farm size (see also Robbins et al., 2016). Instead, efforts should be made to promote animal welfare on all types of farms, regardless of their size. Along these lines, Wuepper, Wimmer, and Sauer (2020) find no simple relationship between farm size and environmentally friendly practices on German crop farms.

The second policy implication of the study relates to the alignment of consumer preferences with farm-level production methods. Comprehensive research on consumer demand has demonstrated that consumers' WTP varies across socioeconomic characteristics as well as across animal welfare-related attributes (Lagerkvist and Hess, 2011). A meta-analysis by Yang and Renwick (2019) shows that, on average, consumers are willing to pay a 32% price premium for animal welfare attributes in different types of livestock products. Conner and Oppenheim (2008) find that U.S. shoppers are willing to pay a premium of 35% for dairy milk from cows with access to pastures. Given an assumed average milk price of €0.35 per kilogram of milk, this translates to a price premium of €0.123 in our application, which is above the WTC for pasture access even among farmers who are currently nonadopters (€0.079).

While it is difficult to make a direct comparison between consumers' WTP and producers' WTC when different elicitation mechanisms are used (Wolf and Tonsor, 2017), the results indicate that there is potential for improving animal welfare through market signals. This can be achieved by using labels that can easily be understood to help consumers indicate their preferences. Price premiums for improved animal welfare have a direct impact on farmers' use values for specific attributes, so they can adjust their production methods via the price mechanism. Given heterogeneous preferences for improved animal welfare among both consumers and producers, industry-wide minimum standards combined with differentiated private labels enhance social welfare (i.e., welfare of consumers, producers and the general public as taxpayers) as they allow preferences to be expressed via the marketplace (see, e.g., Codron, Giraud-Héraud, and Soler, 2005; Harvey and Hubbard, 2013). It must be noted that for various reasons consumers' stated WTP does not necessarily reflect their actual purchasing behavior (see Harvey and Hubbard, 2013, for a detailed discussion). However, these authors also argue that public interventions are only justified if the discrepancies are caused by market failures, in particular the free-rider problem associated with consumption externalities. At present, it is unclear how far this applies to the issue of animal welfare.

Further research is also needed on the actual economic implications of different animal welfare-related farming practices. While previous studies examined the relationship between animal welfare outcomes and gross margins or technical efficiency, the economic costs and benefits of selected practices have not been studied yet in the real-world context. Understanding the economic implications of individual practices will provide additional guidance for farmers and policy makers for their response to the increasing public attention focusing on farm animal welfare.

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References

Anderson, M. L. "Multiple Inference and Gender Differences in the Effects of Early Intervention: A Reevaluation of the Abecedarian, Perry Preschool, and Early Training Projects." *Journal of the American Statistical Association* 103(2008):1481–1495. doi: 10.1198/016214508000000841.

Antle, J. M., and W. J. Goodger. "Measuring Stochastic Technology: The Case of Tulare Milk Production." *American Journal of Agricultural Economics* 66(1984):342–350. doi: 10.2307/1240801.

Austin, E. J., I. J. Deary, G. Edwards-Jones, and D. Arey. "Attitudes to Farm Animal Welfare: Factor Structure and Personality Correlates in Farmers and Agriculture Students." *Journal of Individual Differences* 26(2005):107–120. doi: 10.1027/1614-0001.26.3.107.

Barnes, A. P., K. M. D. Rutherford, F. M. Langford, and M. J. Haskell. "The Effect of Lameness Prevalence on Technical Efficiency at the Dairy Farm Level: An Adjusted Data Envelopment Analysis Approach." *Journal of Dairy Science* 94(2011):5449–5457. doi: 10.3168/jds.2011-4262.

Barth, K. "Effects of Suckling on Milk Yield and Milk Composition of Dairy Cows in Cow–Calf Contact Systems." *Journal of Dairy Research* 87(2020):133–137. doi: 10.1017/S0022029920000515.

Bello, M., and A. Abdulai. "Impact of *Ex-Ante* Hypothetical Bias Mitigation Methods on Attribute Non-Attendance in Choice Experiments." *American Journal of Agricultural Economics* 98(2016):1486–1506. doi: 10.1093/ajae/aav098.

Benjamini, Y., A. M. Krieger, and D. Yekutieli. "Adaptive Linear Step-Up Procedures That Control the False Discovery Rate." *Biometrika* 93(2006):491–507. doi: 10.1093/biomet/93.3.491.

Bioland. "Bioland Standards as of November 25th, 2019." 2019. Available online at https://www.bioland.de/richtlinien [Accessed February 2, 2021].

Cameron, T. A. "A New Paradigm for Valuing Non-Market Goods Using Referendum Data: Maximum Likelihood Estimation by Censored Logistic Regression." *Journal of Environmental Economics and Management* 15(1988):355–379. doi: 10.1016/0095-0696(88)90008-3.

Cameron, T. A., and J. Quiggin. "Estimation Using Contingent Valuation Data from a 'Dichotomous Choice with Follow-Up' Questionnaire." *Journal of Environmental Economics and Management* 27(1994):218–234. doi: 10.1006/jeem.1994.1035.

Carlsson, F., P. Frykblom, and C. J. Lagerkvist. "Using Cheap Talk as a Test of Validity in Choice Experiments." *Economics Letters* 89(2005):147–152. doi: 10.1016/j.econlet.2005.03.010.

Cochran, W. G. *Sampling Techniques*. New York, NY: Wiley, 1977, 3rd ed.

Codron, J.-M., E. Giraud-Héraud, and L.-G. Soler. "Minimum Quality Standards, Premium Private Labels, and European Meat and Fresh Produce Retailing." *Food Policy* 30(2005):270–283. doi: 10.1016/j.foodpol.2005.05.004.

Conner, D. S., and D. Oppenheim. "Demand for Pasture-Raised Livestock Products: Results from Michigan Retail Surveys." *Journal of Agribusiness* 26(2008):1–20. doi: 10.22004/ag.econ.90550.

Danne, M., and O. Musshoff. "Analysis of Farmers' Willingness to Participate in Pasture Grazing Programs: Results from a Discrete Choice Experiment with German Dairy Farmers." *Journal of Dairy Science* 100(2017):7569–7580. doi: 10.3168/jds.2017-12756.

Destatis. "Betriebe mit Ökologischem Landbau in Deutschland bis 2020. Statistisches Bundesamt. Fachserie 3 Reihe 2.2.1 - 2016." 2017a.

———. "Situationsbericht 2017. Statistisches Bundesamt. Gr 35-5." 2017b.

Eurostat Statistical Database. *Cows' Milk Collection and Products Obtained - Annual Data*. Luxembourg: Statistical Office of the European Communities, 2020. Available online at https://ec.europa.eu/eurostat/data/database [Accessed November 9, 2019].

———. *Selling Prices of Animal Products (Absolute Prices) - Annual Price (from 2000 Onwards)*. Luxembourg: Statistical Office of the European Communities, 2021. Available online at https://ec.europa.eu/eurostat/data/database [Accessed February 23, 2021].

FAOSTAT. *Food Supply - Crops Primary Equivalent*. Rome, Italy: Food and Agriculture Organization of the United Nations, Statistics Division, 2020a. Available online at https://www.fao.org/faostat/en/#data/CL [Accessed November 10, 2020].

———. *Food Supply - Livestock and Fish Primary Equivalent*. Rome, Italy: Food and Agriculture Organization of the United Nations, Statistics Division, 2020b. Available online at https://www.fao.org/faostat/en/#data/CL [Accessed November 10, 2020].

Finger, R., T. Dalhaus, J. Allendorf, and S. Hirsch. "Determinants of Downside Risk Exposure of Dairy Farms." *European Review of Agricultural Economics* 45(2018):641–674. doi: 10.1093/erae/jby012.

Fisher, R. J., and J. E. Katz. "Social-Desirability Bias and the Validity of Self-Reported Values." *Psychology & Marketing* 17(2000):105–120. doi: 10.1002/(SICI)1520-6793(200002)17:2<105::AID-MAR3>3.0.CO;2-9.

German Federal Ministry of Food and Agriculture (BMEL). "Agrarpolitischer Bericht der Bundesregierung." 2019. Available online at https://www.bmel.de/DE/themen/landwirtschaft/agrarbericht.html [Accessed November 17, 2000].

———. "Statistischer Monatsbericht des Bundesministeriums für Landwirtschaft und Ernährung." 2020. Available online at https://www.bmel-statistik.de/landwirtschaft/statistischer-monatsbericht-des-bmel-kapitel-a-landwirtschaft/ [Accessed November 17, 2000].

Hansson, H., and C. J. Lagerkvist. "Dairy Farmers' Use and Non-Use Values in Animal Welfare: Determining the Empirical Content and Structure with Anchored Best-Worst Scaling." *Journal of Dairy Science* 99(2016):579–592. doi: 10.3168/jds.2015-9755.

Hansson, H., G. Manevska-Tasevska, and M. Asmild. "Rationalising Inefficiency in Agricultural Production – The Case of Swedish Dairy Agriculture." *European Review of Agricultural Economics* (2020). doi: 10.1093/erae/jby042.

Harvey, D., and C. Hubbard. "Reconsidering the Political Economy of Farm Animal Welfare: An Anatomy of Market Failure." *Food Policy* 38(2013):105–114. doi: 10.1016/j.foodpol.2012.11.006.

Henningsen, A., T. G. Czekaj, B. Forkman, M. Lund, and A. S. Nielsen. "The Relationship between Animal Welfare and Economic Performance at Farm Level: A Quantitative Study of Danish Pig Producers." *Journal of Agricultural Economics* 69(2018):142–162. doi: 10.1111/1477-9552.12228.

Hubbard, C., M. Bourlakis, and G. Garrod. "Pig in the Middle: Farmers and the Delivery of Farm Animal Welfare Standards." *British Food Journal* 109(2007):919–930. doi: 10.1108/00070700710835723.

Jensen, T. B., N. P. Baadsgaard, H. Houe, N. Toft, and S. Østergaard. "The Association Between Disease and Profitability in Individual Finishing Boars at a Test Station." *Livestock Science* 117(2008):101–108. doi: 10.1016/j.livsci.2007.12.003.

Kayser, M., K. Schlieker, and A. Spiller. "Die Wahrnehmung des Begriffs 'Massentierhaltung' aus Sicht der Gesellschaft." *Berichte über Landwirtschaft* 90(2012):417–428.

Kühl, S., M. Fahlbusch, M. Ermann, B. Br\"{u}mmer, and B. Schulze-Ehlers. "Der Markt für Milch und Milcherzeugnisse im Jahr 2015." *German Journal of Agricultural Economics* 65(2016):18–39. doi: 10.22004/ag.econ.284967.

Lagerkvist, C. J., H. Hansson, S. Hess, and R. Hoffman. "Provision of Farm Animal Welfare: Integrating Productivity and Non-Use Values." *Applied Economic Perspectives and Policy* 33(2011):484–509. doi: 10.1093/aepp/ppr037.

Lagerkvist, C. J., and S. Hess. "A Meta-Analysis of Consumer Willingness to Pay for Farm Animal Welfare." *European Review of Agricultural Economics* 38(2011):55–78. doi: 10.1093/erae/jbq043.

Latacz-Lohmann, U., and J. A. Schreiner. “Assessing Consumer and Producer Preferences for Animal Welfare Using a Common Elicitation Format.” *Journal of Agricultural Economics* 70(2019):293–315. doi: 10.1111/1477-9552.12297.

Lawson, L. G., J. Bruun, T. Coelli, J. F. Agger, and M. Lund. “Relationships of Efficiency to Reproductive Disorders in Danish Milk Production: A Stochastic Frontier Analysis.” *Journal of Dairy Science* 87(2004):212–224. doi: 10.3168/jds.S0022-0302(04)73160-4.

Liljenstolpe, C. “Evaluating Animal Welfare with Choice Experiments: An Application to Swedish Pig Production.” *Agribusiness* 24(2008):67–84. doi: 10.1002/agr.20147.

Lusk, J. L., and F. B. Norwood. “Animal Welfare Economics.” *Applied Economic Perspectives and Policy* 33(2011):463–483. doi: 10.1093/aepp/ppr036.

McInerney, J. *Animal Welfare, Economics and Policy*. London, UK: Report on a Study Undertaken for the Farm & Animal Health Economics Division of the Department for Environment, Food & Rural Affairs, Government of the United Kingdom, 2004. Available online at https://webarchive.nationalarchives.gov.uk/20110318142209/http://www.defra.gov.uk/evidence/economics/foodfarm/reports/documents/animalwelfare.pdf.

Miele, M., I. Viessier, A. B. Evans, and R. Botreau. “Animal Welfare: Establishing a Dialogue between Science and Society.” *Animal Welfare* 20(2011):103–117.

Ortega, D. L., and C. A. Wolf. “Demand for Farm Animal Welfare and Producer Implications: Results from a Field Experiment in Michigan.” *Food Policy* 74(2018):74–81. doi: 10.1016/j.foodpol.2017.11.006.

Pfeiffer, J., A. Gabriel, and M. Gandorfer. “Understanding the Public Attitudinal Acceptance of Digital Farming Technologies: A Nationwide Survey in Germany.” *Agriculture and Human Values* 38(2021):107–128. doi: 10.1007/s10460-020-10145-2.

Robbins, J. A., M. A. G. von Keyserlingk, D. Fraser, and D. M. Weary. “Invited Review: Farm Size and Animal Welfare.” *Journal of Animal Science* 94(2016):5439–5455. doi: 10.2527/jas.2016-0805.

Schreiner, J. A., and S. Hess. “The Role of Non-Use Values in Dairy Farmers’ Willingness to Accept a Farm Animal Welfare Programme.” *Journal of Agricultural Economics* 68(2017):553–578. doi: 10.1111/1477-9552.12203.

Schulz, L. L., and G. T. Tonsor. “Cow-Calf Producer Preferences for Voluntary Traceability Systems.” *Journal of Agricultural Economics* 61(2010):138–162. doi: 10.1111/j.1477-9552.2009.00226.x.

Skevas, T., N. J. Hayden, S. M. Swinton, and F. Lupi. “Landowner Willingness to Supply Marginal Land for Bioenergy Production.” *Land Use Policy* 50(2016):507–517. doi: 10.1016/j.landusepol.2015.09.027.

Stott, A., B. Vosough Ahmadi, C. Dwyer, B. Kupiec, C. Morgan-Davies, C. Milne, S. Ringrose, P. Goddard, K. Phillips, and A. Waterhouse. “Interactions between Profit and Welfare on Extensive Sheep Farms.” *Animal Welfare* 21(2012):57–64. doi: 10.7120/096272812X13345905673683.

Thiele, S., and H. Thiele. “Zusatzkosten in der Milcherzeugung und -Verarbeitung Unter Einhaltung Verschiedener Tierwohlstandards.” In E. Rehwinkel-Stiftung, ed., *Die Künfitge der Strategien des Lebensmitteleinzelhandels in der Wertschöpfungs – Chancen, Perspektivenm, Risiken, Schriftenreihe der Rentenbank*, vol. 36. Frankfurt, Germany: Landwirtschaftlichen Rentenbank, 2020, 95–132.

Van Selm, M., and N. W. Jankowski. “Conducting Online Surveys.” *Quality and Quantity* 40(2006):435–456. doi: 10.1007/s11135-005-8081-8.

Vanhonacker, F., W. Verbeke, E. Van Poucke, S. Buijs, and F. A. M. Tuyttens. “Societal Concern Related to Stocking Density, Pen Size and Group Size in Farm Animal Production.” *Livestock Science* 123(2009):16–22. doi: 10.1016/j.livsci.2008.09.023.

Vanhonacker, F., W. Verbeke, E. Van Poucke, and F. A. M. Tuyttens. "Do Citizens and Farmers Interpret the Concept of Farm Animal Welfare Differently?" *Livestock Science* 116(2008): 126–136. doi: 10.1016/j.livsci.2007.09.017.

Vier Pfoten. "Tierschutz-Kontrolliert-Gütesiegel Richtlinie für die Haltung von Milchrindern Gold-Stufe, v. 2.0." 2020. Available online at https://www.tierschutz-kontrolliert.org/partner/milchkuehe [Accessed February 22, 2021].

von Keyserlingk, M. A. G., and D. M. Weary. "Maternal Behavior in Cattle." *Hormones and Behavior* 52(2007):106–113. doi: 10.1016/j.yhbeh.2007.03.015.

Wimmer, S., and J. Sauer. "Diversification Economies in Dairy Farming – Empirical Evidence from Germany." *European Review of Agricultural Economics* 47(2020):1338–1365. doi: 10.1093/erae/jbaa001.

Wocken, C., and A. Spiller. "Der Markt für Milch und Milcherzeugnisse." *Agrarwirtschaft* 56(2007): 26–47. doi: 10.22004/ag.econ.96740.

Wolf, C. A., and G. T. Tonsor. "Cow Welfare in the U.S. Dairy Industry: Willingness-to-Pay and Willingness-to-Supply." *Journal of Agricultural and Resource Economics* 42(2017):164–179. doi: 10.22004/ag.econ.257996.

Wossink, A., and S. M. Swinton. "Jointness in Production and Farmers' Willingness to Supply Non-Marketed Ecosystem Services." *Ecological Economics* 64(2007):297–304. doi: 10.1016/j.ecolecon.2007.07.003.

Wuepper, D., A. Clemm, and P. Wree. "The Preference for Sustainable Coffee and a New Approach for Dealing with Hypothetical Bias." *Journal of Economic Behavior & Organization* 158(2019):475–486. doi: 10.1016/j.jebo.2018.12.012.

Wuepper, D., S. Wimmer, and J. Sauer. "Is Small Family Farming More Environmentally Sustainable? Evidence from a Spatial Regression Discontinuity Design in Germany." *Land Use Policy* 90(2020):104,360. doi: 10.1016/j.landusepol.2019.104360.

Yang, W., and A. Renwick. "Consumer Willingness to Pay Price Premiums for Credence Attributes of Livestock Products – A Meta-Analysis." *Journal of Agricultural Economics* 70(2019): 618–639. doi: 10.1111/1477-9552.12323.

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doi: 10.22004/ag.econ.311031

Online Supplement: How Do Animal Welfare Practices Relate to Farm Characteristics? Evidence from German Dairy Farms

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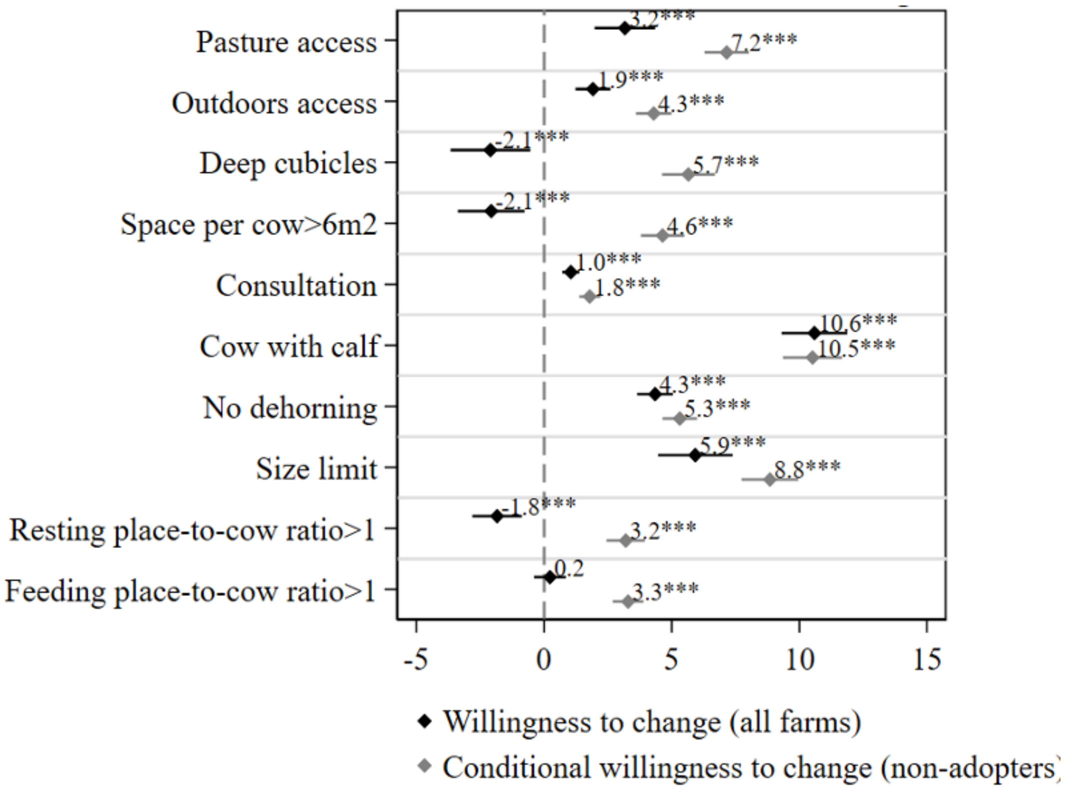

Figure S1. Estimates for Willingness to Change and Conditional Willingness to Change without Regressors (in EUR cents)

Notes: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level. The bars indicate 95% confidence intervals.

Table S1. Interval Regression Results to Explain Farmers' Willingness to Change Farming Practices, Excluding Organic Farms

	Pasture Access 1	Outdoor Access 2	Deep Cubicles 3	Space per Cow >6 m² 4	Consul- tation 5	Cow w/ Calf 6	No Dehorning 7	Size Limit 8	Resting Place-to-Cow Ratio >1 9	Feeding Place-to-Cow Ratio >1 10
Herd size	0.013**	0.001	0.005	0.003	0.000	0.000	0.006	0.065***	0.004	0.008**
	(0.006)	(0.003)	(0.009)	(0.005)	(0.002)	(0.005)	(0.004)	(0.021)	(0.007)	(0.004)
	[0.133]	[0.952]	[0.914]	[0.914]	[1]	[1]	[0.266]	[0.031]	[0.914]	[0.133]
UAA[a]	−0.002*	−0.000	−0.000	−0.000	−0.001	−0.000	−0.001	0.067***	−0.002	−0.003***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.024)	(0.002)	(0.001)
	[0.202]	[0.644]	[0.644]	[0.644]	[0.275]	[0.644]	[0.275]	[0.037]	[0.348]	[0.037]
Share grassland	−0.062***	−0.004	−0.032	−0.014	−0.000	0.025	0.033**	0.002	−0.002	−0.030*
	(0.023)	(0.014)	(0.030)	(0.023)	(0.009)	(0.023)	(0.016)	(0.027)	(0.019)	(0.015)
	[0.064]	[1]	[0.672]	[1]	[1]	[0.672]	[0.194]	[1]	[1]	[0.194]
Share rented land	0.048*	0.002	−0.051	−0.029	−0.027***	−0.050**	−0.034**	−0.004	−0.014	0.001
	(0.025)	(0.017)	(0.034)	(0.025)	(0.010)	(0.022)	(0.017)	(0.025)	(0.019)	(0.015)
	[0.130]	[0.686]	[0.199]	[0.323]	[0.053]	[0.116]	[0.130]	[0.686]	[0.511]	[0.686]
Share family labor	−1.103	−0.230	4.081	2.406	−1.064	−3.843	−1.435	1.845	2.139	0.146
	(2.888)	(1.741)	(4.039)	(2.590)	(0.946)	(2.441)	(1.572)	(2.757)	(2.207)	(1.692)
	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
Full-time (1 if yes, 0 otherwise)	0.752	3.395**	−1.085	2.450	0.302	−3.478	−0.588	−1.804	1.923	1.649
	(2.964)	(1.432)	(2.509)	(2.142)	(0.804)	(2.945)	(1.897)	(3.148)	(1.586)	(1.195)
	[1]	[0.220]	[1]	[0.837]	[1]	[0.837]	[1]	[1]	[0.837]	[0.837]
Successor (1 if yes, 0 otherwise)	−0.268	−1.573	−3.445	−3.722**	−1.374	1.207	0.764	0.532	−3.033*	−1.689
	(1.716)	(1.667)	(2.856)	(1.890)	(0.879)	(1.719)	(1.224)	(1.672)	(1.778)	(1.458)
	[0.977]	[0.674]	[0.649]	[0.649]	[0.649]	[0.871]	[0.871]	[0.977]	[0.649]	[0.649]
Farmer's age	0.061	0.075**	0.053	0.063	0.006	0.001	0.010	−0.065	0.003	0.037
	(0.048)	(0.033)	(0.065)	(0.047)	(0.021)	(0.049)	(0.032)	(0.054)	(0.038)	(0.031)
	[0.697]	[0.283]	[0.839]	[0.697]	[0.940]	[0.961]	[0.940]	[0.697]	[0.961]	[0.697]
Higher ed.[b] (1 if yes, 0 otherwise)	−1.358	−1.493	−2.923*	−2.479*	−1.088**	−0.830	0.970	2.029	−1.696	0.654
	(1.625)	(1.002)	(1.768)	(1.372)	(0.514)	(1.451)	(0.932)	(1.292)	(1.097)	(0.829)
	[0.294]	[0.294]	[0.294]	[0.294]	[0.294]	[0.294]	[0.294]	[0.294]	[0.294]	[0.294]
Constant	1.600	−0.283	4.677	1.483	5.678**	16.917***	5.289	−8.060	−0.831	*term*0.352
	(5.811)	(3.418)	(6.981)	(5.166)	(2.376)	(6.433)	(3.996)	(6.250)	(4.588)	(3.694)
Log likelihood	−321.438	−421.880	−297.455	−301.351	−451.293	−231.625	−419.199	−259.266	−310.480	−372.456
Wald χ^2	71.09***	21.49	20.97	31.31**	23.65	23.81	25.93*	141.23***	80.58***	28.68**
Correctly predicted	43%	16%	56%	54%	31%	72%	20%	55%	58%	33%

Notes: Estimation is based on 229 observations. Each column represents a separate regression. Huber-White robust standard errors are reported in parentheses. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. False Discovery Rate q-values are reported in brackets.

[a]UAA indicates utilized agricultural area.

[b]Higher education refers to having a master artisan diploma or university degree. Binary variables for 10 German regions according to postal codes are included to account for regional heterogeneity but not reported to save space. Their estimates are available from the authors upon request.