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Consumer Willingness to Pay Price Premiums for Credence Attributes of Livestock Products – A Meta-Analysis

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Abstract

Livestock products, such as dairy and beef, are increasingly regarded as resource intensive and concerns are raised about animal welfare and environmental sustainability. As a result, consumer awareness of these issues has led to an increasing demand for products with high quality credence attributes (CAs) that cannot be directly experienced or identified. A number of empirical studies have attempted to estimate consumers' willingness to pay (WTP) for CAs, which represents the additional value placed on the benefits that they derive from those products. However, there are significant differences in these WTP estimates, mainly because both consumers' perceptions of CAs and the conditions of the studies vary. We conduct a meta-analysis to examine consumers' WTP for different CAs of livestock products based on a systematic review of relevant studies. Meta-regression models are used to control for the heterogeneity of WTP estimates and investigate factors that affect the estimation of WTP. Overall 555 estimates derived from 94 papers reporting WTP are included in this study. Meta-regression results establish the presence of systematic WTP variation associated with types of products, CAs, and locations, though also indicate that WTP is subject to systematic variation associated with study methodology.

Keywords: *Meta-analysis*; *credence attributes*; *livestock products*; *price premium*; *WTP*.

JEL classifications: *Q13, P46, D12.*

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1. Introduction

Over the last 20 years there has been an increasing demand for livestock products with high quality attributes that can be directly experienced, such as colour and taste, and also those with attributes (known as credence attributes, CAs) that cannot be directly experienced or identified (Oude Ophuis and Van Trijp, 1995; Caswell, 1998). Tully and Winer (2014) identify two main drivers for consumers to purchase products with CAs: self-interest, for example, through having confidence in the safety of the food they eat; social responsibility, for example, a desire for agriculture to be environmentally sustainable. CAs have been classified into several main categories, including food safety (e.g., non-hormones, antibiotics-free), good quality (e.g., nutritional value), geographical indications (e.g., protected geographical indication, country of origin), environmental benefit (e.g., carbon emission and water quality) and animal welfare (Caswell and Mojduszka, 1996).

The abstract characteristics of CAs have driven a growing interest in studies focusing on the design and implementation of policy instruments and marketing strategies to help consumers understand CAs (Florax *et al.*, 2005). For example, food labelling, such as eco-labelling, might help better deliver information about CAs to consumers and facilitate their purchasing decisions. However, for effective decision-making by policy-makers or others, it is important to understand whether or not consumers are willing to pay and if so how much they would pay for different CAs. In addition, as most credence attributes are strongly related to the farm-level production process, understanding consumers' perceptions of credence attributes can help inform farmers about adjustment of their farm systems in response to market signals and thereby help them take advantage of any price premia.

An abundance of empirical studies have attempted to estimate consumers' willingness to pay (WTP) for food product CAs, as the additional value placed on the benefits derived from those attributes (Caswell and Mojduszka, 1996). Results of most empirical studies have shown that consumers are willing to pay a price premium for CAs of food products, but there are significant differences as to the extent of this premium (e.g., Gath and Alvensleben, 1998; Kuperis *et al.*, 1999; Kehlbacher *et al.*, 2012; Li *et al.*, 2016). Differences exist mainly because consumers' perceptions of CAs may vary (Oude Ophuis and Van Trijp, 1995) while estimates are conditional on the particular approaches adopted in any single study (e.g., Burgess *et al.*, 2003; Loureiro and Umberger, 2007). Furthermore, some studies focus on estimating consumers' WTP based on their perceptions of the labelled or verified attributes (e.g., Gath and Alvensleben, 1998; Loureiro and Umberger, 2007; Janssen and Hamm, 2012), while others are purely interested in consumers' perceptions of the attributes without consideration of labelling and verification (e.g., Lusk and Schroeder, 2004; Feldkamp *et al.*, 2005). As a consequence, the estimated values of WTP vary across different studies and are of limited generality.

To our knowledge, no study has systematically identified the value of the price premium associated with credence attributes of livestock products.[2] To fill this gap we conduct a meta-analysis of estimated consumers' WTP for different credence attributes of livestock products, based on a systematic review of relevant studies. Meta-regression models are used to control for the heterogeneity of WTP estimates and investigate

[2]We use the term livestock to refer to farmed ruminants which produce livestock products such as cattle and sheep meat and dairy products.

factors that affect the estimation of WTP, with the consideration of methodological variability of the relevant studies. This study contributes to understanding the variation of WTP estimates from relevant studies, and specifically, we aim to answer the following five questions: (1) Are there differences in the price premium across types of livestock product, including dairy and red meat? (2) Are there differences in the price premium across types of attribute, such as animal welfare, geographical indications (GIs),[3] and environment-friendly? (3) To what extent does the price premium vary over time? (4) Is the price premium sensitive to the method used to estimate WTP? (5) Are there regional differences, e.g., across different countries, in the price premium?

The paper is structured as follows. The next section describes the meta-analysis method and data collected for the analysis. Section 3 presents the empirical results of meta-regression models. Section 4 concludes and considers the potential implications of the results.

2. Method and Data

Meta-analysis is generally defined as a systematic literature review supported by statistical methods where the goal is to aggregate and contrast the findings from a number of related studies (Glass, cited in Viechtbauer, 2010). It is also known as the 'analysis of analyses' and has a long history in various research fields, including medical science, psychology and education (Del Re, 2015). Accordingly, the application of meta-analysis has been conducted in an experimental context that has offered a series of standard statistical procedures for the measurement of effect sizes across studies examining the same research question. The term 'effect sizes' denotes summary statistics such as standardised differences in means of experimental and control groups, correlations, and odds-ratios (Florax *et al.*, 2005).

Meta-analysis was first introduced to economists as a promising methodology for reviewing literature by Stanley and Jarrell (1989). They went on to develop a meta-regression analysis (MRA) method, namely the 'regression analysis of regression analyses', which has been mostly applied in environmental economics. Most analyses in economics collect a set of primary studies each of which produces a common empirical result, such as people's WTP for air pollution (Smith and Huang, 1995) and price elasticity of meat (Gallet, 2010). Notably, the quantitative measures used in economic studies are rather different from the typical effect sizes used in experimental sciences. For example, the primary studies in economics utilise different model specifications and econometric techniques (Nelson and Kennedy, 2009). In particular, economists tend to fit so-called meta-regression models, that is, linear models that examine the influence of one or more explanatory variables, also called moderators, on the outcomes (e.g., Berkey *et al.*, 1995; Van Houwelingen *et al.*, 2002).

The rapid growth in the application of MRA beyond environmental economics to other areas, such as labour economics, has led to improvements in the transparency of the methods employed and of the quality of MRA in economics research. Several studies have attempted to provide a set of 'best practices' concerning reporting guidelines and econometric techniques for MRA (Rosenberger and Loomis, 2000; Nelson

[3]In this study, GIs are categorised into Protected Designations of Origins (PDOs)/Protected Geographical Indications (PGIs) and Country of Origins (COOs)/Region of Origins (ROOs). In general, PGIs and PDOs mandate more stringent conditions (Moschini *et al.*, 2008).

and Kennedy, 2009; Stanley *et al*., 2013). Following these guidelines, we first conduct a thorough literature search to compile a list of studies that provide a complete description of the characteristics considered in the meta-regressions.

2.1. Data collection

To identify candidate studies, our literature review retrieval process consisted of two steps. The initial search involved checking several economic and non-economic databases including EconLit, AgEcon, Google Scholar, Scopus, CAB Abstracts, PubMed, Biosis, and FSTA. Key words used in the search included 'price premium', 'willingness to pay' (or 'WTP' and variations), 'meat', 'beef', 'lamb', 'dairy', 'livestock', 'credence attributes' and 'high quality'. Then, the reference sections of the qualitative and quantitative review papers identified in the initial search were examined and used to search for studies that were left out in the initial search. This produced a list of 138 studies reporting WTP. Some studies were excluded, of which 13 were qualitative and quantitative review (e.g., Anselmsson *et al*., 2007; Cicia and Colantuoni, 2010; Lagerkvist and Hess, 2010; Deselnicu *et al*., 2013; Tully and Winer, 2014; White and Brady, 2014), 15 were about other food products, such as chicken and fruits, and wood products (e.g., Aguilar and Vlosky, 2007; Janssen and Hamm, 2012; Campbell and Doherty, 2013), and 16 expressed WTP as awareness scores or a probability of WTP rather than monetary measurements. Therefore, 94 studies with 566 observations were produced for our meta-analysis. Notably, of these 11 WTP estimates were negative and were therefore excluded, as consumers' WTP are usually assumed to be positive. However, Bohara *et al*. (2001) believe that negative WTP estimates may affect the estimated price premium on average and thus should be reported. We thus controlled for this in the meta-regression models by including a dummy variable that equals one when negative WTP estimates were reported in a study, and zero otherwise. We assume studies that reported negative WTP estimates may produce a lower price premium. This produced the final list of 94 studies where 555 observations were included. A summary of the studies used in the analysis is shown in the online Appendix.

2.1.1. The dependent variable

WTP estimates used in this paper were drawn from studies across countries, years and currencies. We thus follow the example of several WTP meta-analyses to use percentage premium WTP to standardise these differences. The percentage premium was measured by the percentage change in WTP from a base price for the CAs, which allows us to quantify the increased monetary value that consumers place on CAs.[4] This method of measurement has been commonly used in WTP meta-analysis studies (e.g., Cicia and Colantuoni, 2010; Tully and Winer, 2014; White and Brady, 2014; Del Giudice *et al*., 2015). In many cases, studies presented dollar value estimates of WTP premiums and a base price was sourced from the text. Base prices were either the average of the prices used in elicitation, the market price of the base product at the time of the study, or the WTP reported for a generic product, whichever was presented within the study. Although these base prices are different from study to study, they all represent the prices of conventional products with no credence attributes in the targeted markets.

[4]For ease of exposition, we will use WTP to represent percentage change of WTP in the following discussions.

Meta-analysis may thus summarise the general extent of WTP for different CAs by using results from studies across different sample characteristics (Del Giudice *et al*., 2015). The average WTP across the 555 estimates is 46% while the median is 32%, indicating the data are right-skewed as shown in Figure 1. We thus took the natural logarithm of the WTP to smooth and normalise the data. In addition, the standard deviation of WTP is 0.53, indicating considerable variation in the WTP estimates that requires explanation. Typical of other meta-analyses, information on a variety of study characteristics that might influence WTP estimates was collected, with the frequencies, median and mean WTP for each category provided in Table 1 (definitions of the variables can be found in Table 2). When categorised according to different study characteristics, the median WTP is still smaller than the mean in each category.

Across the four categories of livestock products highlighted in Table 1, beef had the greatest number of WTP estimates and it also had the largest potential price premium. This was followed by dairy and lamb, while other products had the smallest

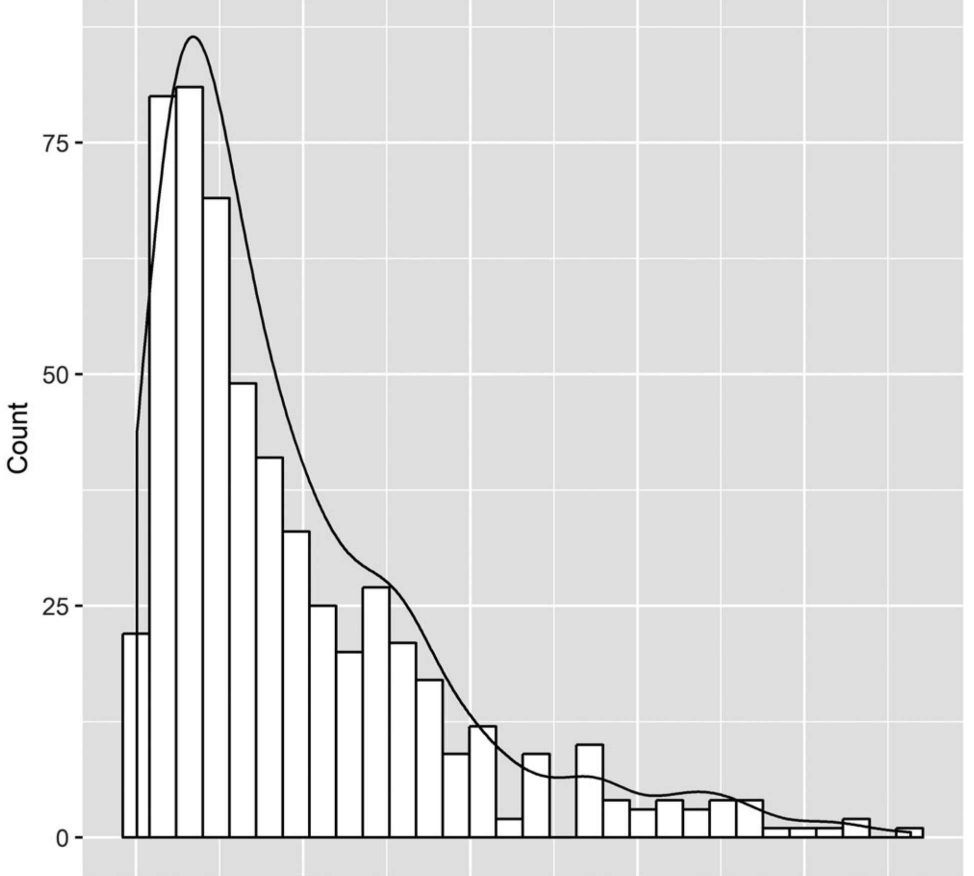

Figure 1. The distribution of percentage premium WTP

Table 1

Frequency of study characteristics, median and mean WTP

Category	Variable	Frequency[a]	Median WTP (%)	Mean WTP (%)
Product	Beef	283	28.8	53.3
	Lamb	44	19.5	39.3
	Dairy	206	40	51.3
	Other products	22	26.9	31.6
Labelling & perception	Labelled	399	34	41.1
	Perceived	156	42.1	53.9
Data collection time	Before 2000	22	14.9	16.9
	2000–2004	116	25.9	37.5
	2005–2009	239	37.4	54.3
	After 2010	178	29.9	45.9
Publication type	Journal	466	34.8	49.4
	Others	89	20	31.1
Discipline	Economics	283	32.4	43.8
	Other business	111	28	37.1
	Science	161	35.7	57.5
Estimation method	Choice Experiment (CE)	276	41.5	53.5
	Contingent Valuation (CV)	39	16.9	17
	Conjoint Analysis (CA)	63	26.1	31.6
	Hedonic	26	13.7	20.6
	Others	151	36.2	51.8
Valuation method	Hypothetical	405	32.6	49.1
	Non-hypothetical	150	32	39.3
Survey method	Mail	61	38	54.8
	Phone	28	18.4	18.9
	In person	294	38.7	53.2
	Online	150	26	34.2
	Not specified	22	33	47
Credence attribute	Environment-friendly	42	16	26.3
	Animal welfare	108	38	51
	Organic	62	24.3	44.3
	Hormone/antibiotic-free	38	51.8	60.2
	Grass-based	49	28.2	42
	Food safety	43	20	63.3
	PDOs/PGIs	27	23.4	33.8
	ROOs/COOs	102	34.3	40.3
	Traceability[b]	18	21.7	32.2
	Mixed attributes	66	23.6	33.9
Region	North America	152	27.9	33.9
	Europe	280	33.7	48.5
	Asia	72	38.5	56.1
	Australasia	6	39.1	78.4
	Other regions	45	33.2	54.4

Notes: (a) Frequency refers to the number of observations in each category. (b) Traceability is sometimes relevant to geographical information, but it is different from GIs. This attribute can also be called 'identity preservation', and is defined as the ability of a system to maintain a credible custody of identification for animals or animal products through various steps, from the farm to the retailer (Dalvit *et al.*, 2007).

Table 2
Variable definition and statistical description

Variable	Definition	Mean[a]	SD	Min	Max
Product					
Dairy	1 if study tested a dairy product, otherwise 0	0.37	0.48	0	1
Beef	1 if study tested a beef product, otherwise 0	0.51	0.5	0	1
Lamb	1 if study tested a beef product, otherwise 0	0.08	0.27	0	1
Other products	1 if study did not specify which kinds of livestock products, otherwise 0	0.04	0.2	0	1
Credence attribute					
Environment-friendly	1 if study estimated an attribute associated with environment benefit, otherwise 0	0.08	0.23	0	1
Animal welfare	1 if study estimated an attribute associated with animal welfare, otherwise 0	0.19	0.4	0	1
Organic	1 if study estimated organic product, otherwise 0	0.11	0.32	0	1
Hormone/ antibiotic-free	1 if study estimated products with no hormone, antibiotic or growth enhancing technics, otherwise 0	0.07	0.2	0	1
Grass-based	1 if study estimated grass-fed or grass-finished attribute, otherwise 0	0.09	0.28	0	1
Food safety	1 if study estimated an attribute associated with safety, otherwise 0	0.08	0.27	0	1
PDOs/PGIs	1 if study estimated an attribute associated with Protected Designations of Origins or Protected Geographical Indications, otherwise 0	0.05	0.12	0	1
COOs/ROOs	1 if study estimated an attribute associated with Country of Origins or Region of Origins, otherwise 0	0.18	0.39	0	1
Traceability	1 if study estimated an attribute associated with traceability, otherwise 0	0.03	0.2	0	1
Mixed attributes	1 if study estimated product with a vague description of credence attributes, for example ‘good’, ‘natural’ and ‘healthy’, otherwise 0	0.12	0.27	0	1

Table 2
(*Continued*)

Variable	Definition	Mean[a]	SD	Min	Max
Geographical characteristic					
Log GDP	Natural logarithm of gross domestic product per capita[b]	3.31	0.06	3.3	4.71
North America	1 if study was conducted in the US or Canada, otherwise 0	0.26	0.44	0	1
EU	1 if study was conducted in Europe, otherwise 0	0.5	0.5	0	1
Asia	1 if study was conducted in Asia, otherwise 0	0.13	0.34	0	1
Australasia	1 if study was conducted in Australia or New Zealand, otherwise 0	0.01	0.01	0	1
Other regions	1 if study was conducted in other regions, otherwise 0	0.09	0.3	0	1
Research method					
CE	1 if study used choice experiment method, otherwise 0	0.5	0.5	0	1
CV	1 if study used contingent valuation method, otherwise 0	0.07	0.26	0	1
Hedonic	1 if study used hedonic method, otherwise 0	0.05	0.21	0	1
CA	1 if study used conjoint analysis method, otherwise 0	0.11	0.32	0	1
Other methods	1 if study used other estimation method, e.g. auction, otherwise 0	0.27	0.45	0	1
Hypothetical	1 if study used a hypothetical valuation method, otherwise 0	0.73	0.45	0	1
Economics	1 if study was published/ released on a platform of economic discipline, otherwise 0	0.51	0.5	0	1
Other business	1 if study was published/ released on a platform of other business disciplines, such as management and marketing, otherwise 0	0.2	0.4	0	1
Science	1 if study was published/ released on a platform of science disciplines, otherwise 0	0.29	0.45	0	1
Mail	1 if study used mail survey to collect data, otherwise 0	0.11	0.31	0	1
Telephone	1 if study used telephone survey to collect data, otherwise 0	0.05	0.21	0	1

Table 2
(*Continued*)

Variable	Definition	Mean[a]	SD	Min	Max
Online	1 if study used online survey to collect data, otherwise 0	0.27	0.45	0	1
In person	1 if study used face-to-face survey to collect data, otherwise 0	0.53	0.5	0	1
Not specified	1 if survey method is unknown, otherwise 0				
Other characteristics					
Published type	1 if study was published in a journal, otherwise 0	0.84	0.37	0	1
Labelled	1 if study focused on labelled CAs, otherwise 0	0.72	0.45	0	1
Statistical significance	1 if the WTP estimate was statistically significant (at the 10% significance level and higher, otherwise 0	0.86	0.34	0	1
Log base WTP	Natural logarithm of base price of WTP[d]	0.63	0.04	–1.03	2.81
Negative	1 if study reported negative WTP, otherwise 0	0.07	0.26	0	1
Before 2000	1 if study collected data before 2000, otherwise 0	0.04	0.2	0	1
Y2000-2004	1 if study collected data between 2000 and 2004, otherwise 0	0.21	0.41	0	1
Y2005-2009	1 if study collected data between 2005 and 2009, otherwise 0	0.43	0.5	0	1
After 2010	1 if study collected data after 2010, otherwise 0	0.32	0.47	0	1
Sample size	The sample sizes of included studies	1,144	1,685	86	10,000

Notes: (a) Mean value for dummy and categorical variables represents percentage. (b) Gross domestic product was based on data collection year and study location and sourced from World Bank (2014). (c) For studies that did not specify data collection year, we used the study year as an approximation. (d) Base unit price of WTP was transferred to USD based on the average exchange rate of data collection year and study location from World Bank (2014).

number of estimates and lowest WTP.[5] As mentioned earlier, consumers' WTP may be different toward products that are actually labelled with the credence attribute compared to those that they simply perceive as having the attribute. In our analysis,

[5]Some studies, such as Kehlbacher *et al*. (2012), which focused on measuring consumers' WTP for improving animal welfare, did not report the specific types of livestock products for which WTP for animal welfare attributes was elicited. Thus, WTP estimates drawn from those studies were categorised into 'other products'.

nearly three quarters of the included studies focused on labelled products, while just over a quarter focused on consumers' perceptions of CAs. Interestingly the latter were associated with higher WTP estimates. The table highlights an increasing trend in the numbers of studies over time, with only 22 studies occurring before 2000. This increasing trend can also be seen in both the median and mean WTP, indicating that consumers' WTP for CAs appears to be increasing over time. Furthermore, differences in WTP exist across publication type (peer-reviewed journal or others), discipline (economics journal/conference/thesis or other disciplines), survey method (e.g., in person, online and phone), and estimation method (e.g., choice experiment, contingent valuation and hedonic). These are typical study characteristics that may reflect variations of WTP due to methodological and discipline differences, and publication bias. Lastly, because the WTP for CAs has been estimated in various parts of the world we report median and mean WTP across different regions. It is clear that most of the attention in the literature has been given to consumers' WTP in Europe and North America. However, across the five regions, consumers have the highest WTP for price premium of CAs in Australia and New Zealand, followed by Asia, Europe, and other regions (including Chile, Russia and Turkey), while the lowest WTP is associated with the North American market.

2.1.2. Potential determinants of WTP

As discussed above, WTP estimates vary across different categories of study characteristics that may be seen as potential determinants of WTP. As a result, the heterogeneity of WTP estimates in the sample data can be addressed via meta-regression where the variation is explained by regressors for study characteristics, which are expected to capture observed sources of heterogeneity. These potential determinants were therefore included in the meta-regression models as explanatory variables, and detailed definitions and descriptive statistics of these variables are specified in Table 2. As the majority of the explanatory variables are either binary or categorical, a baseline is required for the study characteristics. Specifically, for categorical variables, 'other products' was set as the base for the types of livestock products; 'mixed attributes' was the base for credence attributes; 'other regions' was the base for regional differences; 'other methods' was the base for estimation methods; 'science' was the base for discipline differences; 'not specified' was the base for survey methods; and 'before 2000' was the base for time effect. Here, in addition to the study characteristics listed in Table 1, we also included variables such as 'Log GDP' that represents gross domestic product per capita based on data collection year and study location to account for income effect (Smith and Huang, 1995; White and Brady, 2014). The variable 'Negative' represents whether or not negative WTP estimates were reported in the primary studies, as this should be addressed in the estimation process of WTP (Bohara *et al.*, 2001). The dummy variable 'labelled' indicates whether the WTP is associated with labelled attributes (=1) or with perceived attributes (=0). The variable 'statistical significance' represents whether or not the WTP estimate was statistically significant at the 10% significant level or higher. The variable 'Log base WTP' was also included to see if the level of the base price for the conventional products affected the relative percentage price premium of WTP. Lastly, 'sample size', as a weighted variable, was considered in all meta-regression models and this will be explained in the next section.

2.2. *Meta-regression models*

Early meta-analyses in economics tended to use ordinary least squares (OLS) models to estimate linear models covering areas such as estimating the WTP protection of endangered species or the price elasticity of cigarettes (e.g., Loomis and White, 1996; Gallet and List, 2003; Lusk *et al*., 2005; Richardson and Loomis, 2009). Following these studies, the meta-regression could be undertaken with a typical linear model expressed as:

$$WTP_i = \alpha + \beta X_i + \varepsilon_i, \tag{1}$$

where WTP_i is the ith WTP estimate ($i = 1, \ldots, n$) that is explained by a vector of explanatory variables X_i presented in Table 2, with the associated coefficient vector β to be estimated. α is the intercept and ε_i is a normally distributed error term with zero mean and constant variance σ_ε^2. However, the sample data used in the analysis may provide various levels of precision in measuring WTP because they are derived from several relevant studies. Simply pooling the data and using the classical OLS estimator may ignore problems, such as data heterogeneity, heteroscedasticity and non-independence of observations across and within studies, and cause serious estimation issues (Nelson and Kennedy, 2009). Models using weighted least-squares and panel-data regression techniques are highly recommended and regarded to be more appropriate to address the above estimation issues (Stanley *et al*., 2013). Hence, instead of using a typical OLS estimator, we used a robust OLS estimator as well as panel regression techniques to estimate the meta-regression models. It should also be noted that, although using a robust OLS estimator (e.g., the Huber-White method) can correct regressors for heteroscedasticity and serial correlation, it does not affect the coefficient estimates of the meta-regression model (Gallet and List, 2003).

2.2.1. *Regression weights*

Treating each WTP estimate equally in the meta-regression is not statistically efficient because it fails to account for the fact that some values are estimated with relatively more precision than others and therefore contribute more information to the meta-analysis. We thus considered combining regression weights in the estimation process.

To maximise statistical efficiency, typical meta-analysis studies combine variance estimates from the primary studies as regression weights, where each estimate of the meta-analysis would ideally be weighted by the inverse of its variance (Nelson and Kennedy, 2009). A good example is from Del Giudice *et al*. (2015) who sourced WTP estimates and associated variances and confidence intervals from relative studies and adopted meta-regression, fixed-effect meta-regression and random-effect meta-regression analysis.[6] Unfortunately, considering the non-experimental nature of economic studies, relatively few of the included studies reported variance estimates, neither did they report standard errors or confidence intervals for the WTP estimates. This makes it impossible to calculate the relevant variance. To deal with the problem, several alternative methods have been employed, and one of the most commonly used is to approximate variances with sample sizes of the included studies (e.g., De Blaeij *et al*.,

[6] It should be noted that the terms fixed-effect and random effect as used here are different from the terms used in general econometric analyses. Details of fixed-effect and random-effect meta-analysis can be found in Del Re (2015).

2003; Florax *et al*., 2005; Van Houtven *et al*., 2007). Thus, we used the weighted least-squares estimator where sample size of each included study is the weight.

2.2.2. *Panel data structure*

The sample data used in meta-analysis usually have the nature of a panel because each study may provide more than one estimate for the same research question leading to the possibility of within study autocorrelation. To address the panel data effects, panel data estimation techniques can be used to estimate an unbalanced panel with unequal panel size, and this includes the fixed effects (FE) and random effects (RE) panel data models. Specifically, the RE model provides a control for the commonality within a study and control for the dependence of observations within and across each study. In addition, as most of the explanatory variables in our meta-regression models do not vary within studies, we use the random effects counterpart to equation (1):

$$WTP_{ij} = \alpha + X_{ij}\beta + \mu_{ij} \tag{2}$$

where WTP_{ij} is the ith WTP estimate for the jth panel index (j = 1, ..., m). The most common way of creating panels is to use the primary studies included in meta-analyses as a basis, but Rosenberger and Loomis (2000) illustrated that the latent panel effects may be sourced from other relevant stratifications. Thus, we considered two stratification approaches in the RE model to form the panel index, including 'by study' (m = 94) and 'by lead author' (m = 77). Therefore, in equation (2), j represents either the jth study or the jth lead author of the study. $\mu_{ij} = v_{ij} + \varepsilon_i$ is a composite error term, where v_{ij} is the panel-specific error and ε_i is a common error, with zero mean and constant variance of σ_v^2 and σ_ε^2 , respectively.

2.2.3. *Subsamples*

The sample data for the study include WTP estimates for four livestock products, i.e., dairy, beef, lamb and other products. Using categorical variables in the meta-regression models could explain a proportion of the heterogeneity, but the variation of WTP estimates may be different among types of livestock products. For example, WTP estimates may respond to study characteristics of the primary studies differently. Therefore, a meta-regression model that pools the data for the whole sample may not provide the appropriate estimation of WTP for a specific livestock product. In addition to differences in the average values, the standard deviation of WTP for dairy products (0.46) is different from those for beef (0.59) and lamb (0.48). The distributions of WTP estimates for beef, lamb, red meat (beef and lamb) and dairy products are depicted and included in the online Appendix. All four curves are right-skewed, but the dairy curve has a relatively shorter right tail than those of the beef and lamb curves. Considering the relative small sample size of lamb products (44 observations), and the fact that the distribution of lamb WTP is similar to that of beef WTP, we disaggregate the whole sample data into two subsamples (following Nelson and Kennedy, 2009), red meat (lamb and beef) and dairy.[7]

[7]There were only 22 observations categorised as 'other products' and therefore running a meta-regression model on this small subsample was not considered appropriate.

3. Estimation Results

3.1. The whole sample model

Table 3 reports estimation results of meta-regression models on the whole sample data. For comparison purposes, we present estimation results of the pooled OLS with a robust estimator, and results of the RE model by study and the RE model by lead author. The three meta-regression models provide a reasonable goodness of fit to the sample data, with R^2 values of between 0.44 and 0.59.

Following standard practice for meta-analyses, restricted versions of the three meta-regression models were also regressed on the whole sample data, where the explanatory variables that were not individually significant at 10% level or less were excluded (e.g., some of the survey method variables). An F-test was then employed to test for the joint statistical significance of the excluded variables, where the null hypothesis was that the coefficients of the excluded variables are equal to zero (results are shown at the bottom of Table 3). According to the results, the null hypothesis must be rejected and therefore the variables were retained for all three of the meta-regression models, even though the variables were not individually significant.

In addition, we conducted two tests to verify the appropriateness of choosing the RE models. First, the Breusch-Pagan Lagrange multiplier (LM) test was used to test for the existence of panel effects, which suggests that we use the RE model for the meta-regression, regardless of random effects by study or by author. Second, the Hausman test was used to test whether to include fixed effects or random effects in the panel data models, which show that random effects are preferred over fixed effects, regardless of whether the panel index considered is by study or by author. The findings confirmed the choice of RE models for the meta-regression.

Although the robust OLS estimator should not affect the coefficient estimates of the meta-regression model, the sign and magnitude of the coefficient estimates of the OLS model are different from those estimated in the RE models. However, the sign and statistical significance of the coefficient estimates are relatively consistent across the two RE models. We thus followed the approach adopted by most meta-analyses and interpret the coefficient based on the estimation results of the RE model by study (for example see Florax *et al.*, 2005). The full table including the results of OLS model can be found in the online Appendix.

Addressing the coefficient estimates across the types of livestock products, we found that WTP is significantly higher for dairy and beef products, while lamb has the lowest WTP (relative to other products). Turning to different CAs, with the exception of ‘Grass-based’ and ‘Traceability’, the coefficient estimates of CAs are statistically significant. Compared to the product with ‘mixed’ CAs (e.g., attributes were described as ‘natural’ or ‘good’), organic products were estimated to be associated with the highest price premium, followed by hormone/antibiotic-free, animal welfare, food safety, and the two GIs, where COOs/ROOs had higher WTP estimate than PDOs/PGIs. Notably, the environment-friendly attribute was estimated to be associated with the lowest price premium by a significant margin.

The WTP for CAs varies across different regions. Australasian consumers seem to have the highest WTP, followed by the Asian market and the EU. Among all the regions, North American consumers show the lowest WTP for CAs.

Concerning the research methods, including estimation techniques and survey issues, there are a number of findings from the regression results. First, compared to other estimation methods, such as auctions, the values of WTP estimated by CE and

Table 3
Meta-regression results for full sample

Model Variable	RE–by study Coeff.	RE–by study SE	RE–by lead author Coeff.	RE–by lead author SE
Intercept	−0.15	(3.11)	−0.44	(2.89)
Dairy	0.59**	(0.39)	0.66*	(0.4)
Beef	0.55**	(0.41)	0.44**	(0.42)
Lamb	−0.05***	(0.02)	−0.04***	(0.02)
Environment-friendly	−0.15*	(0.13)	−0.1*	(0.14)
Animal welfare	0.37*	(0.19)	0.41*	(0.19)
Organic	0.67***	(0.21)	0.95**	(0.23)
Hormone/Antibiotic free	0.4**	(0.2)	0.51*	(0.23)
Grass-based	0.21	(0.25)	0.25	(0.28)
Food safety	0.36**	(0.2)	0.41**	(0.16)
PDOs/PGIs	0.28*	(0.29)	0.4	(0.09)
COOs/ROOs	0.36*	(0.26)	0.39*	(0.16)
Traceability	−0.26	(0.25)	−0.2	(0.27)
Log GDP	0.18	(0.82)	0.12	(0.83)
North America	−0.1	(0.36)	−0.12	(0.23)
EU	−0.03	(0.38)	−0.02	(0.39)
Asian	1.1**	(0.36)	0.91**	(0.36)
Australasia	1.32*	(0.72)	1.12*	(1.05)
CE	0.19**	(0.07)	0.14**	(0.11)
CV	1.2**	(0.11)	1.43**	(0.15)
Hedonic	−0.68	(0.44)	−0.58	(0.55)
CA	−0.44	(0.33)	−0.43	(0.38)
Hypothetical	0.18*	(0.24)	0.26*	(0.17)
Economics	0.05	(0.18)	0.03	(0.17)
Other business	0.3	(0.28)	0.46	(0.24)
Mail	−0.65	(0.56)	−0.5	(0.56)
Telephone	−1.65	(0.62)	−1.8	(0.61)
Online	−1.1	(0.54)	−1.13	(0.6)
In person	0.8*	(0.45)	1*	(0.42)
Published in Journal	0.28**	(0.21)	0.26**	(0.21)
Labelled	−0.16**	(0.16)	−0.31**	(0.18)
Statistical significance	0.11	(0.42)	0.18	(0.49)
Log base WTP	−0.94*	(0.11)	−0.89*	(0.13)
Negative	−1.02**	(0.44)	−1.31***	(0.34)
Y2000-2004	0.06*	(0.36)	0.09*	(0.37)
Y2005-2009	0.29*	(0.33)	0.3*	(0.38)
After 2010	0.34**	(0.42)	0.3*	(0.35)
R^2	0.47		0.44	
F test for restricted model	$F = 336.98$ ($P < 0.01$)		$F = 416.32$ ($P < 0.01$)	
LM test	$\chi^2 = 542.6$ ($P < 0.001$)		$\chi^2 = 263.5$ ($P < 0.001$)	
Hausman test	$\chi^2 = 21.6$ ($P = 0.97$)		$\chi^2 = 44.6$ ($P = 0.49$)	

Note: '***', '**', '*', indicate coefficients that are significant at 1%, 5% and 10% levels, respectively.

CV methods tend to be higher. In addition, compared to non-hypothetical analyses, such as analysis of scanned data, the price premium was estimated to be higher under the hypothetical situations for consumers' decision-making. This indicates a systematic difference between consumers' observed WTP and their intentions to pay. Intuitively, consumers may have good intentions to pay a higher price premium for CAs, such as animal welfare, but this may not occur when decisions are made in the supermarket (Lusk and Schroeder, 2004; Harvey and Hubbard, 2013; White and Brady, 2014). The chosen survey methods, however, seem to have no significant impact on WTP estimates since most of the corresponding coefficients are not statistically significant, except for 'in person'. This indicates that face-to-face surveys may produce higher WTP for CAs.

As for the remaining categories, 'published in Journal' is found to affect WTP estimates. Here, the coefficient of 'published in Journal' is positive and statistically significant. On the one hand, this may indicate that publication is an indicator of study quality, and therefore higher quality studies tend to produce higher WTP estimates. On the other hand, this variable could also be interpreted as a filter that favours larger, statistically significant values, i.e., an indication of publication bias. Products labelled with information of CAs are associated with lower WTP compared to products with perceived attributes. We consider the posisble implications of this persistently significant effect on WTP below. The statistical significance of the WTP estimates seems to have no impact on the estimated WTP value. Notably, however, higher relevant base prices tend to lower the WTP value, and when negative WTP estimates were reported in the primary studies, the values of WTP estimates tend to be lower, on average. Lastly, according to the positive and statistically significant coefficients of the time variables, there is an increasing trend of WTP for livestock products over time.

3.2. The subsample models

Two subsamples of red meat and dairy products were regressed using the RE model, with the estimation results reported in Table 4.[8] At the bottom of the table, for both models, results of the F-test reject the exclusion of variables that were not individually significant. Results of the LM test and Hausman test also verify that random effects should be included in our meta-regression models. The values of R^2 of the two models are 0.59 and 0.54, which reflects a relative good fit to the data in the two subsamples.

Comparing the subsample estimation results to those of the whole sample (RE-by study in Table 3), differences are observed in various aspects, including the sign, magnitude and statistical significance level of the coefficients. Comparison of the coefficient estimates for the red meat model and the dairy model, highlights differences between the two models, though the significance and sign of the variables is very similar between the two sub-samples. These results confirm our assumption that WTP estimates for different livestock products may respond to CAs and study characteristics differently, and thus the subsample models may provide more refined prediction of WTP for each livestock product.

[8]Here we only report estimation results of the RE model by study as the results of the RE model by author have relatively small differences in terms of magnitude and statistical significance level. The results can be provided upon request.

Table 4
Regression results of subsample models

Model Variable	Red meat model (n = 327) Coeff.	SE	Dairy model (n = 206) Coeff.	SE
Intercept	–9.56	(1.45)	–7.32*	(0.21)
Dairy				
Beef	1.19***	(0.33)		
Lamb				
Environment-friendly	–0.16*	(0.11)	–0.1*	(0.10)
Animal welfare	0.34*	(0.19)	0.59**	(0.22)
Organic	0.73***	(0.23)	0.26***	(0.02)
Hormone/Antibiotic free	0.58***	(0.17)	0.62**	(0.22)
Grass-based	0.13	(0.54)	0.26	(0.40)
Food safety	0.48**	(0.21)	0.66**	(0.24)
PDOs/PGIs	0.33	(0.27)	0.34	(0.22)
COOs/ROOs	0.45**	(0.15)	0.43**	(0.19)
Traceability	–0.23	(0.25)	0.11	(0.58)
Log GDP	1.05	(0.81)	1.21	(1.81)
North America	–0.05	(0.39)	–0.1	(0.41)
EU	0.13	(0.35)	0.16	(0.31)
Asia	0.99**	(0.31)	1.41**	(0.29)
Australasia	2.05***	(0.80)		
CE	0.25*	(0.21)	0.47*	(0.14)
CV	0.72***	(0.32)	0.91***	(0.17)
Hedonic	–2.51	(0.55)	–1.24	(0.82)
CA	–0.66*	(0.28)	0.55*	(0.26)
Hypothetical	0.35**	(0.09)	1.39**	(0.26)
Economics	0.06	(0.20)	0.24	(0.20)
Other business	0.11	(0.29)	0.1	(0.57)
Mail	–1.46	(0.82)	–1.11	(0.83)
Telephone	–1.44	(0.89)	–1.21	(0.92)
Online	–0.73	(0.41)	–1.35	(0.41)
In person	1.18***	(0.33)	0.89***	(0.33)
Published in Journal	0.18*	(0.09)	0.26**	(0.11)
Labelled	–0.17**	(0.21)	–0.22**	(0.11)
Statistical significance	0.09	(0.42)	0.08	(0.31)
Log base WTP	–1.38*	(0.21)	–1.46**	(0.16)
Negative	–1.56***	(0.53)	–0.83***	(0.18)
Y2000-2004	0.04*	(0.13)	0.08*	(0.92)
Y2005-2009	0.38**	(0.19)	2.06**	(1.30)
After 2010	0.41**	(0.22)	2.39***	(1.57)
R^2	0.59		0.54	
F test for restricted model	F = 491.6 (P < 0.01)		F = 503.9 (P < 0.01)	
LM test	χ^2 = 936.8 (P < 0.001)		χ^2 = 287.1 (P < 0.001)	
Hausman test	χ^2 = 19.9 (P = 0.82)		χ^2 = 27.6 (P = 0.77)	

Note: '***', '**', '*', indicate coefficients that are significant at 1%, 5% and 10% levels, respectively.

The red meat model captured a higher WTP for beef products than that for lamb, where the coefficient of the variable 'Beef' is positive and statistically significant. Turning to the coefficient estimates of CA variables, the sign and statistical significance level are relatively consistent across the two models, with the exception of 'Environment-friendly' and 'Grass-based'. Notably, however, the magnitudes of the CA coefficients vary across the two models. Organic was estimated to be associated with the highest price premium for red meat products, which is consistent with results from the whole sample model. Hormone/antibiotic free and food safety are also valued by consumers with a higher WTP, followed by products with COOs/ROOs, animal welfare, and PDOs/PGIs. Here, for red meat products, consumer WTP for products with environment-friendly attributes is ranked the lowest across all the significant CA variables. In contrast, for dairy products, food safety is estimated to be associated with the highest price premium, and WTP for products with animal welfare attributes is as high as that for and Hormone/antibiotic free products. Particularly, organic products are associated with relative lower consumer WTP than all other significant CA variables except for 'Environment-friendly' that again has the lowest WTP.

In terms of the coefficients associated with regional differences, Australasian consumers value red meat products with CAs the highest, followed by Asian, European and North American consumers. As for dairy products, WTP is the highest in the Asian market, followed by the EU and the North America. Concerning research method coefficients, there are similar tendencies in the regression results of the two models. As with the whole sample model, WTP estimated by CE and CV method tends to be higher than for other approaches. Significantly, 'Hypothetical' has a positive impact on both dairy and red meat products, although this impact is greater on WTP for dairy than red meat. In addition, the survey methods provide various levels of WTP estimates, but are not statistically significant (except for 'in person'). Thus, the positive and statistically significant coefficient estimates for 'in person' indicate that information collected from in-person surveys produce the highest WTP for both dairy and red meat products.

For both red meat and dairy products, we found that WTP estimates are affected by whether or not the primary studies have been published in academic journals. Here, the 'journal effect' is positive and statistically significant, which is consistent with the effect estimated by the whole sample model. Likewise, products labelled with CAs tend to produce lower WTP estimates, and the 'statistical significance' variables were not statistically significant for both the dairy and red meat models. As with the whole sample model, higher relevant base price is associated with lower WTP estimates, and studies reporting negative WTP estimates tend to produce lower WTP estimates for both the dairy and red meat model, but the coefficient of the red meat model is relative lower than that of the dairy model. Lastly, an obvious and similar trend of increasing WTP is shown by the positive and significant coefficients of the time variables in the two models. Notably, the time effect has a greater impact on dairy as the increase in WTP for dairy is significantly larger than that for red meat over time.

3.3. Sensitivity analyses

Sensitivity analyses are suggested in meta-analyses mostly in regard to the identification of outliers to ensure the consistency of estimation results (Del Re, 2015). Thus, we conducted an outlier test to identify several outliers and ran the meta-regressions for all three sample models with the outliers removed (results are included in Table S3 in the online Appendix). When the outliers were removed, the magnitude of the coefficient estimates of the three models changed slightly. However, the signs and significance levels of the coefficient estimates are consistent with those in Tables 3 and 4.

In addition to testing for outliers, we also conducted sensitivity analyses to test for those CAs that are regarded as not 'pure' but may be perceived to represent multiple benefits. When analysing consumers' WTP for environment-friendly attributes, White and Brady (2014) used the 'pure environment-friendly' attribute to describe the attribute that purely focuses on the environment benefits and used the 'impure' to represent organic and food safety that might capture some of the 'pure' environmental benefits. Hence, to test for the potential 'overlap' between those attributes, we first conducted a multicollinearity test (using variance inflation factors), and the result indicated no multicollinearity issues in all three models. We then followed White and Brady (2014) and removed the 'impure' attributes of organic and food safety, and reran the regressions. The results show that the remaining coefficient estimates of CAs are consistent in terms of signs and statistical significance (see Table S4 in the online Appendix). For example, the coefficient estimate for environment-friendly is still negative, though the magnitude increased slightly.

Overall, the sensitivity analyses show estimation results that are similar to and not statistically different from our original results, suggesting that our meta-regression models are robust.

3.4. Predicted WTP a price premium

Although the individual coefficients in Tables 3 and 4 are sensitive to a number of modelling characteristics, it is worthwhile considering the overall impact of the different meta-regression specifications on the WTP estimates for the price premium of different CAs. The WTP prediction can provide farmers with some indication of the potential price premium that they could gain from the market by delivering a specific credence attribute. To do so, we chose the meta-regression results for the RE (by study) specifications of the whole model (Table 3) and the red meat and dairy models (Table 4) to construct the predicted value of the WTP a price premium for each credence attribute. The predicted mean WTP estimates as well as the corresponding 95% confidence intervals are reported in Table 5. For all WTP predictions, the study year was set after 2010 to capture the recent market demand for livestock products with CAs. Considering the uncertainties regarding whether the variable 'published in Journal' reflects study quality or publication bias, we followed Van Houtven *et al.* (2007) and set the value of the variable at 0.5. All other variables were set at their sample means, with the exception of the categorical variables corresponding to CAs, which are set to zero when they are not the predicted attribute.

Using the whole sample model, the table shows that, for example, for a one unit change of livestock product associated with CAs, the WTP a price premium is predicted to range from 20% (for 'Traceability') to 36% (for 'Organic'). The red meat model shows us the predicted values of WTP a price premium for red meat products with CAs, and the predicted values are relatively lower than those in the whole sample model. The highest predicted WTP (31%) is associated with organic red meat products, while the lowest value (18%) is associated with 'Traceability'. When looking at the dairy model, 'Food safety' was predicted to produce the highest WTP a price premium for dairy products (39%), whereas the lowest WTP (18%) relates to

Table 5
Predicted WTP a price premium of livestock products (%)

Model CA	Whole sample model	Red meat model	Dairy model
Environment-friendly	24.1 [6.1, 42.1]	18.9 [3.7, 34.2]	25 [11.2, 38.9]
Animal welfare	31.9 [5.6, 58.2]	19.3 [3, 35.6]	31 [0.5, 61.5]
Organic	35.8 [8.1, 63.5]	31.37 [8.1, 54.5]	28.5 [9.2, 47.9]
Hormone/Antibiotic free	32.2 [4.5, 60]	24 [1.5, 46.6]	34.3 [3.8, 64.8]
Grass-based	24.9 [–3.8, 53.6]	22.3 [0.5, 44.1]	25.1 [4.5, 45.7]
Food safety	29.9 [5.3, 54.6]	23 [2.4, 43.6]	39.2 [18.8, 59.6]
PDOs/PGIs	24.7 [7.3, 42]	22.4 [6.1, 38.7]	25.7 [4.3, 47]
COOs/ROOs	29.8 [9.4, 50.3]	22.5 [7.8, 37.2]	29.9 [11.3, 48.4]
Traceability	20.1 [–2.5, 42.7]	17.7 [–3.3, 38.7]	26.1 [–1.8, 50.3]
Mixed attributes	25.68 [1.7, 49.7]	19.2 [1.8, 36.6]	25.8 [2.2, 48.8]

'Environment-friendly'. Considering the differences between the predicted values of the three models, results from the subsample models may provide more representative WTP estimates compared to the whole sample model. We also note the wide confidence intervals associated with these predicted values.

4. Discussion and Conclusions

The number of empirical studies applied to estimate consumer WTP price premium for credence attributes (CAs) of livestock products has expanded steadily since the mid-1990s. The resulting body of literature provides a potentially rich source of secondary data for designing policy instruments and marketing strategies to help understand the implications of these attributes. However, the heterogeneous results of the studies present a challenge to the provision of reliable estimates of WTP. We explore how the existing literature can be used to systematically analyse consumers' WTP a price premium across types of livestock product, taking into account the heterogeneity of study characteristics.

Across the 94 studies included in the meta-analysis, we found several important results. Beef and dairy products with CAs are associated with a higher price premium compared to lamb. In addition, to varying degrees of significance, the WTP estimates are particularly sensitive to the type of CA, chosen estimation method, publication characteristics, and time effects. All these indicated that policy instruments that focus on delivering better information about CAs to consumers should consider variations of WTP estimates from relevant studies. Thus, policy-makers should be aware of the variations and not rely on specific WTP estimates from one or several studies when designing policies. It also highlights the need for careful interpretation of the meta-regression results, especially the differences in WTP across types of CA. Specifically, the results can only provide a general indication and tendency of WTP for different CAs across different sample characteristics, and the varied WTP values should be considered especially when policy-making is involved.

Our results indicate an increasing trend of WTP a price premium over time, which could indicate a growing demand for CAs. Differences exist in the price premium between intended behaviours and real purchasing choices. This is consistent with previous study results, such as Kang *et al*. (2011), that CE and CV methods may overestimate consumers' WTP under hypothetical conditions, while the analysis of real purchasing data (e.g., scanned data) may reflect real market demand. An important factor to consider is the significant difference we find in the WTP between labelled and perceived attributes, where the latter are associated with higher WTP. Our analysis suggests that there are differences between the two types of study and that these may have different implications for both farmers and policy-makers. However, these differences have been rarely discussed in the literature. Bearing in mind the differences, we could get a relatively full view of market demands for CAs. Future exploration could focus on how labelling meets consumers' perceptions of different CAs, which might help better undersand the role of labelling in delivering information to consumers and facilitate their purchasing decisions. Finally, as several model characteristics played an insignificant role in the meta-regressions, the price premium of CAs is somewhat insulated from these characteristics. In particular the price premium is largely insensitive to survey methods and disciplines. Hence, less concern should be given to these issues when estimating the price premium in future meta-analyses.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Summary of CAs valuation studies included in the final analysis.

Table S2. Meta-regression results for full sample.

Table S3. Meta-regression results for all three sample models-outliers removed.

Table S4. Meta-regression results for all three sample models – 'impure' CAs removed.

Figure S1. The distribution of percentage premium WTP for different livestock products.

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