Impact of delivering credence attributes of dairy products on farm[1]

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Abstract

There has been an increasing demand for livestock products with credence attributes (CAs), such as environment-friendly and good animal welfare. Although most CAs are strongly related to farm-level production processes, rarely have studies explored the issue from an on-farm perspective. Therefore, this paper aims to explore whether consumers' willingness-to-pay (WTP) a price premium could incentivise farmers to deliver livestock products with CAs in New Zealand to meet the long-term environmental goal of carbon neutral. We first employ a meta-regression analysis to estimate WTP for CAs of dairy products, and then incorporate the WTP estimates into farm system models to measure the economic and environmental impact (nitrogen, phosphorous and GHG losses) for the farms. Data for the meta-regression models are sourced from a literature survey yielding 32 studies estimating WTP for CAs of dairy products. The results show that price premium ranges from 5.2% to 52.3% for environment-friendly dairy products. FARMAX and OVERSEER are used to model the farm system changes required to deliver 'green' dairy and red meat products by using data of the average Waikato dairy farm. The results show that the economic and environmental outcomes are varied over the predicted range in WTP as well as for different farm system scenarios. Findings of the study could help inform NZ farmers as to how to adjust their farm systems in response to market signals and thereby potentially gain a price premium.

Keywords: meta-regression model, credence attributes, farm system modelling, carbon neutral

1. Introduction

The New Zealand (NZ) dairy industry is facing the challenge of maintaining high productivity, and in the meantime, minimising environmental pollution due to intensive farming activities. Currently, the NZ government is seeking ways to boost trade intensity, and accordingly, the Ministry for Primary Industries (MPI) has developed the export goal to double primary exports in real terms from $32 billion in 2012 to $64 billion by 2025 (MPI, 2016). The biggest opportunity to achieve this goal rests within the pastoral sector, especially the dairy industry, as products from the pastoral sector accounted for 44 per cent of the country's total merchandise exports value, where 60 per cent came from dairy exports (Beef + Lamb New Zealand, 2017; DairyNZ, 2017). The dairy industry is NZ's largest export earner, which exports 95 per cent of its production, and historically it has held an internationally competitive position with the lowest cost and efficient pasture-based production systems. Recently this position has eroded due to the increasing cost of inputs, such as fertiliser and feed, and increasing concerns about negative environmental impact, predominantly, nutrient loss and greenhouse gas emission (GHG). Half of NZ's GHG emissions now come from agriculture where the dairy industry accounted for 46 per cent of total agricultural emissions (Ministry for the Environment, n.d.). Given the NZ government is committed to becoming a world leader in climate change action and plans to get to net zero emission (carbon neutral) by 2050, changes are expected to be made in the pastoral sector to achieve this long-term goal (Ministry for the Environment, n.d.).

Therefore, the dairy industry is expected to reduce GHG emission and work toward a path to a low carbon future. This could, however, make it difficult to maintain high dairy production for the export goal given the expectation of low carbon emission. Stringent regulations are expected to place on livestock production. Some researcher even proposed that NZ's livestock numbers will have to be cut to achieve the carbon neutral goal (Williams, 2017). Hence, dairy farmers have to bear a higher farming cost to offset carbon emission since NZ uses no production or environmental subsidies to implement mitigations (McDowell *et al.* 2017). The question is, however, how to incentivise farmers to adopt mitigation practices when the associated costs are inevitably high.

Recently, researchers have proposed that market-driven factors may incentivise farmers' adoption of good environmental practices (e.g., Oude Ophuis *et al.* 1995; White *et al.* 2014). Saunders *et al.* (2016) believe that, if the traditional ways of producing commodities are not economically and environmentally sustainable, the NZ dairy industry should consider adjusting current farm systems to produce high value-added products and meet the environmental goal. Cheung (2013) further proposes that transferring resources towards high-value added activities that leverage off NZ's strong pastoral-industry base may hold the most promise for enhancing the appealing "NZ brand story", i.e. 'Green, clean and disease-free' and addressing the growing demand for products with credence attributes (CAs). Here, relative to high quality attributes that can be directly experienced, such as colour and taste, CAs refer to those that cannot be directly experienced or identified, such as environment-friendly and good animal welfare (e.g., Oude Ophuis and Van Trijp, 1995; Caswell, 1998). The increasing demand for high-value added food products from the market has created great potentials of price premium associated with the products. This thus provides a promising direction for dairy farmers in NZ to adapt current farm systems to deliver CAs and gain the price premium.

To show farmers the market signal of demands for CAs, the first step is to estimate the price premium associated with CAs of dairy products. Literature on this question have been focused on the market side regarding a) estimation of consumer willingness to pay for credence attributes (e.g., Caswell and Mojduszka, 1996), b) construction of policy instruments and market strategies to help consumer understand credence attributes (e.g., Verbeke 2005), and c) labelling strategies (e.g., Kehlbacher *et al.* 2012). Rarely have papers explored the issue from an on-farm perspective.

An abundance of empirical studies have attempted to estimate consumers' WTP for CAs which effectively represents an additional value placed on the benefits that they derive from those products 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; Kehlbacher et al., 2012; Kuperis et al., 1999; Li et al., 2016). Differences exist mainly because consumers' perceptions of CAs may vary (Oude Ophuis and Van Trijp, 1995) and estimates are conditional on the particular approaches adopted in any single study (e.g. Burgess et al., 2003; Loureiro and Umberger, 2007). Therefore, the estimated values of WTP from these studies are of limited generalizability and could not be seen as robust WTP estimates that farmers could rely on when assessing the potential benefits associated with providing specific attributes.

In addition, previous studies have not tried to link the estimated consumer WTP to on-farm practice changes, except for Olynk *et al.* (2010) and White *et al.* (2014). It is important for farmers to see if gaining the price premium could substitute the cost of delivering the credence attribute. However, previous studies fail to relate potential price premium to farmers, who are located at the bottom of the value chain. Assuming some or most of the credence attributes require improvements or changes of on-farm practices, which is true in practice, 'high value' could not be added to products if farmers refuse changes such as the adoption of new technology and improvements in farming practises. On the other way around, farmers may not be willing to cope with the market-oriented strategy for high-value added products if they could not benefit from sharing the premium. Therefore, apart from understanding market demand, it is also important to explore benefit sharing from the bottom, i.e. farmers, all the way to the top, i.e. market. Specifically, it should be taken into account that the success of the high-value added strategy is highly dependent on on-farm practices, considering the attributes in products required by the market are animal welfare, eco-friendly, health and safe and etc.

This paper fills an important gap by investigating the impacts of delivering credence attributes on-farm. To our knowledge, no study has systematically identified the value of the price premium associated with credence attributes of dairy products and linked to identify changes on farm regarding the delivery of the CAs. In an effort to fill this gap this study firstly conducts a meta-analysis to examine consumers' WTP for different credence attributes of dairy 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, with the consideration of methodological variability of the underlying studies. To accommodate the expectation of lower carbon emission, we then consider incorporating the estimated WTP into farm system models to estimate economic and environmental outcomes of being carbon neutral and delivering environment-friendly dairy products. Farmax, Overseer and Life cycle analysis (LCA) are utilised to estimate the economic and environmental outcomes under different farm system scenarios using data of the Waikato average dairy farm. A Monte Carlo simulation is used to take into account of variation of consumer WTP estimates and uncertainty of farm share of price premium from market, when estimating farm profitability under different scenarios.

The paper is structured as follows. The next section will describe the conceptual framework of linking meta-analysis with farm system modelling, and present the data and on-farm scenarios used in the analysis. Section 3 will then present the empirical results of meta-regression models, and the economic and environmental outcomes of different on-farm scenarios. Section 4 concludes and considers the potential implications arising from the findings of the study.

2. Method and Data

2.1. Conceptual model

Two steps to model the impact of delivering the credence attributes with a price premium. As is shown in Figure 1, we firstly conducted a meta-analysis and estimate the price premium of preferred credence attributes, i.e. environment-friendly. This could provide a mean as well as a range of WTP (e.g. 95% confidence interval) for price premium from the market. In addition to the variation of price premium from market end, the uncertainty of farm share of price premium could affect the final proportion delivered to farms. Due to the lack of NZ data, we use the historical data of farm share of market price from the US as a substitute to estimate the uncertainty of farm share of price premium. These two parts constitute the Monte Carlo simulation of farm profitability for all carbon neutral scenarios in step two. In addition to economic outcomes modelled by FARMAX and Monte Carlo simulation, the environmental outcomes, including N loss and GHG, are estimated for all scenarios using OVERSEER and LCA[1].

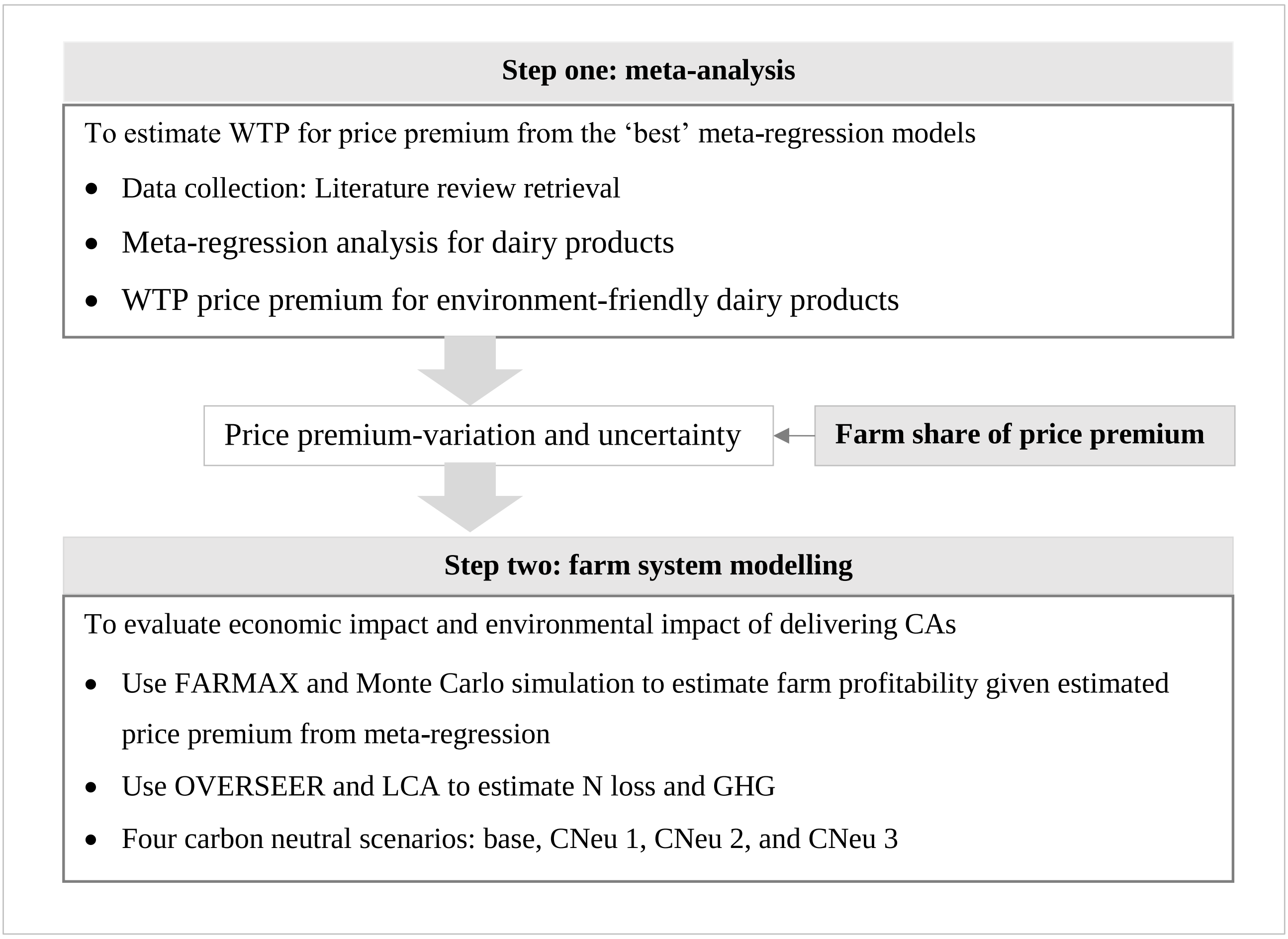

Figure 1. Conceptual modelling framework

Specifically, the analysis of the paper is based on the following assumptions:

- Consumers are willing to pay a price premium for CAs of dairy products.
- A proportion of price premium could be deliver to dairy farmers.
- The proportion of price premium delivered to farms is affected by (a) WTP estimates from meta-regression and (b) farm share of price premium.
- The price premium could substitute the cost of delivering the associated CAs.

[1] Details of the two models could be found in Hellweg & Milà i Canals (2014) and Wheeler et al. (2006).

- The US data of farm share of market price can be seen as a substitute to estimate the uncertainty of farm share of price premium in NZ. The 20-year average of farm share is calculated to be 30.5% with the standard deviation of 3.6%.
- Point estimates of WTP values and the variance of those WTP estimates were used to identify the farm share of price premium under the assumption that WTP estimates are normally distributed.
- The GHG offset cost is $25 per ton.

2.2. Meta-analysis method

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 well-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. In general, 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). With appropriate coding, such models can handle both continuous and categorical variables.

The rapid growth in the application of MRA beyond environmental economics to other areas, such as labour economics, meant that it became crucial to improve the transparency of the methods employed and to raise the quality of MRA in economics research. Therefore, several studies have attempted to provide a set of 'best practices' concerning reporting guidelines and/or econometric techniques for MRA (Nelson and Kennedy, 2009; Rosenberger and Loomis, 2000; Stanley et al., 2013). Following these guidelines, this paper first conducted a thorough literature search to compile a list of studies that provided a complete description of the characteristics considered in the meta-regressions.

2.2.1. Meta-data collection

To identify candidate studies, the 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), '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 45 studies reporting WTP. Some studies were excluded, of which 11 were qualitative and quantitative review (e.g. Anselmsson et al., 2007; Tully and Winer, 2014; Lagerkvist and Hess, 2011; Cicia and Colantuoni, 2010; Deselnicu et al., 2013; White and Brady, 2014), 15 were about other food products such as wood, chicken and fruits (e.g. Aguilar and Vlosky, 2007; Campbell and Doherty, 2013; Janssen and Hamm, 2012), and 2 expressed WTP as awareness scores or a probability of WTP instead of monetary measurements. Therefore, our final list of meta-analysis used 32 studies that produced 208 observations (WTP estimates).

2.2.1.1. 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 analyses to use percentage premium WTP to standardise these differences (e.g. Cicia and Colantuoni, 2010; Tully and Winer, 2014; White and Brady, 2014). 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.[2] In general, studies reported estimated values of WTP premiums and the associated base prices were either reported or sourced from the text. Base prices were whichever presented within the study, such as the average of the prices used in estimation, the market price of the base product at the time of the study, or the WTP reported for a generic product.

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

The average WTP across the 208 estimates is 0.46 while the median is 0.32, indicating the data is right-skewed as shown in Figure 1. We thus took the natural logarithm of the WTP to smooth and normalise the data. In addition, considering the standard deviation of WTP is 0.56, there is considerable variation in the WTP estimates that requires explanation.

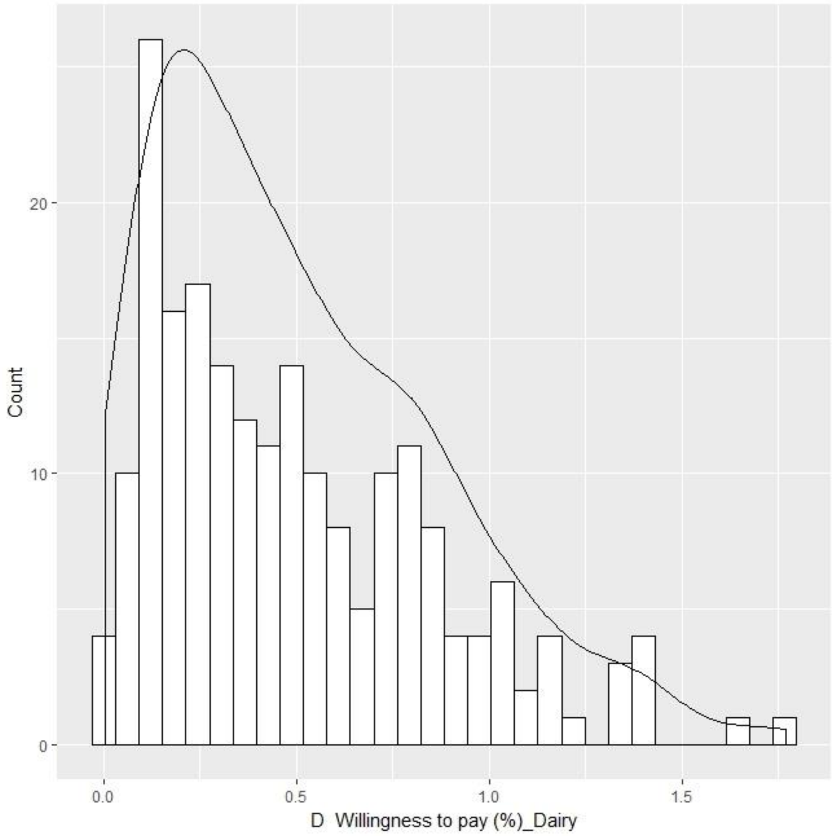

Figure 2. The distribution of percentage premium WTP for different livestock products

2.2.1.2. Potential determinants of WTP

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 could be handled 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 presented in Table 1.

[Insert Table 1]

As the majority of the explanatory variables are either binary or categorical, a baseline is required for the study characteristics. Specifically, for categorical variables, '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). Lastly, 'sample size', as a weighted variable, was considered in all meta-regression models and this will be explained in the next section.

2.2.2. Meta-regression models

Early meta-analyses in economics tended to use ordinary least squares (OLS) approach 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; Lusk et al., 2005; Richardson and Loomis, 2009; Gallet and List, 2003). Following these studies, the meta-regression could be undertaken with a typical linear model expressed as:

(1) $$WTP_i = \alpha + \beta X_i + \varepsilon_i$$

where WTP_i is the i^{th} WTP estimate $(i = 1,...,n)$ 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.

2.2.2.1. 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; Van Houtven et al., 2007). 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 WTP estimates. This makes it impossible to calculate the relevant variance. To deal with the problem, a commonly used approach is to approximate variances with sample sizes of the included studies (e.g. de Blaeij et al., 2003; Florax et al., 2005; Van Houtven et al., 2007). Thus, we used the inverse of sample sizes to proxy the variances, where each WTP estimate from the included studies was weighted in proportion to its sample size.

2.2.2.2. 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 with-in study autocorrelation. In the presence of panel data effects, the OLS assumptions of independent and identically distributed errors are likely to be violated (Van Houtven et al., 2007). In that case, using typical OLS estimator for meta-regression models may cause biased parameter estimates, leading to invalid inferences from seemingly significant factor effects (Nelson and Kennedy, 2009). Hence, if OLS is to be employed, one should use robust standard errors for inference rather than relying on those reported in simple OLS regression (Jacobsen and Hanley, 2009). 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).

An alternative approach to address the panel data effects is to use panel data estimation techniques to estimate an unbalanced panel with unequal panel size; 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 also 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):

$$WTP_{ij} = \alpha + X_{ij}\beta + \mu_{ij} \quad (2)$$

where WTP_{ij} is the i^{th} WTP estimate for the j^{th} panel index $(j = 1,...,m)$. The most common way of creating panels is to base it on the primary studies included in meta-analyses, 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 j^{th} study or the j^{th} 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.

Table 1 Variable definition and statistical description

Variable	Definition	Mean[a]	SD	Min	Max
Credence attribute					
Environment-friendly	1 if study estimated an attribute associated with environment, otherwise 0	0.05	0.23	0	1
Animal welfare	1 if study estimated an attribute associated with animal welfare, otherwise 0	0.19	0.40	0	1
Organic	1 if study estimated organic product, otherwise 0	0.11	0.32	0	1
GM free	1 if study estimated GM free product, otherwise 0	0.05	0.22	0	1
Hormone/antibiotic-free	1 if study estimated products with no hormone, antibiotic or growth enhancing technics, otherwise 0	0.04	0.20	0	1
Grass-based	1 if study estimated grass-fed or grass-finished attribute, otherwise 0	0.08	0.28	0	1
Food safety	1 if study estimated an attribute associated with safety, otherwise 0	0.08	0.27	0	1
GI	1 if study estimated an attribute associated with geographical indication, such as country of origin, otherwise 0	0.18	0.39	0	1
Traceability	1 if study estimated an attribute associated with traceability, otherwise 0	0.04	0.20	0	1
Mixed attributes	1 if study estimated product with a vague description of credence attributes, for example 'good' or 'healthy', otherwise 0	0.08	0.27	0	1
Geographical characteristic					
Log GDP	Natural logarithm of gross domestic product per capita[b]	3.31	0.06	3.30	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	0.50	0.50	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	0.30	0	1
Research method					
CE	1 if study used choice experiment method, otherwise 0	0.50	0.50	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 in a platform of economic discipline, otherwise 0	0.51	0.50	0	1
Other business	1 if study was published/released in a platform of other business disciplines, such as management and marketing, otherwise 0	0.20	0.40	0	1
Science	1 if study was published/released in 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
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	0.50	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
Negative	1 if study reported negative WTP, otherwise 0	0.07	0.26	0	1
Before 2000[c]	1 if study collected data before 2000, otherwise 0	0.04	0.20	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	0.50	0	1
After 2010	1 if study collected data after 2010, otherwise 0	0.32	0.47	0	1
Sample size	The inverse of sample sizes of included studies	0.003	0.0029	0.0001	0.026

Note: (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.

Table 2 Description of farm modelling scenarios

	Base	**CNeu S1**	**S1 Change***	**CNeu S2**	**S2 Change**	**CNeu S3**	**S3 Change**
Stocking Rate	2.9	2.9	0%	2.6	-10%	2.4	-17%
Peak Cows Milked	336	336	0%	303	-10%	282	-16%
Milk Solids total	119,677	119,927	0%	119,997	0%	108,510	-9%
Milk Solids per ha	1,032	1,034	0%	1,034	0%	935	-9%
Milk Solids per cow	356	357	0%	396	11%	385	8%
Supplements Offered per cow*	1.4	1.4	0%	1.7	21%	1.2	-14%
Supplements and Grazing/ Feed Offered*	31.8	30.8	-3%	32.9	3%	25.3	-20%
Bought Feed/ Feed Offered*	18.9	25.3	34%	30.5	61%	22.8	21%

* Note: all changes are based on the base scenario

2.3. Farm system modelling scenarios

The aim of the Carbon Neutral modelling scenarios was to reduce biological emissions without reducing milk production. Biological emissions could not be reduced to a satisfactory level so further reductions were made that included a reduction in total milk solids and per head production by reducing stocking rate and supplement intake but keeping pasture utilisation high. The FARMAX and OVERSEER scenarios do not include the carbon offset that will be required to reach Carbon Neutral status, while the offset costs are included separately in calculating the farm profitability in the Monte Carlo simulation. Table 2 shows the important physical inputs and changes of carbon neutral scenarios 1-3 from those in the base scenario.

For all scenarios cropping was removed from the farm system and the feed metabolisable energy (ME) intake of the crops was replaced by imported supplements. High Carbon and high nitrogen supplements were replaced by low carbon supplements based on ME value. Purchased maize silage grown off farm were used in Waikato scenarios. The DM intake of different supplements varied due to differences in the ME/kg DM.

Due to the high carbon cost of N fertiliser the use of N boosted pasture as a feed source was replaced with maize silage. Increasing animal efficiency will reduce the emissions proportioned to growth and maintenance and increase the proportion in animal production (milk, or meat and fibre). Per cow production was increased by 11% and replacement rates were reduced by 2%. The stocking rate was reduced (2.9 to 2.6) to match feed supply and total milk production with base.

Further reductions in emissions reduced milk production by reducing stocking rate from 2.6 cows /ha to 2.3 cows/ha and reducing supplements while keeping seasonal pasture intake high and milk production per cow 8% higher than base.

[Insert Table 2]

3. Estimation Results

3.1 meta-regression results

The sample data was regressed using the RE model, with the estimation results reported in Table 3[1]. At the bottom of the table, 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

[1] 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 to the authors.

should be included in our meta-regression models. The values of R^2 of the two models are 0.56 and 0.51, which reflects a relative good fit to the data in the two subsamples.

Table 3 Regression results of subsample models

Variable / Model	Dairy model (*n*=206)		
	Coef.		*SE.*
Intercept	-7.54	*	(0.24)
Environment-friendly	-0.09	*	(0.04)
Animal welfare	0.61	**	(0.29)
Organic	0.14	***	(0.02)
GM free	0.66	**	(0.23)
Hormone/Antibiotic free	0.65	**	(0.26)
Grass-based	0.25		(0.42)
Food safety	0.69	**	(0.25)
GI	0.45	**	(0.19)
Traceability	0.09		(0.55)
Log GDP	1.23		(1.83)
North America	-0.09		(0.39)
EU	0.17		(0.33)
Asian	1.48	**	(0.36)
CE	0.49	*	(0.15)
CV	0.93	***	(0.19)
Hedonic	-1.22		(0.84)
CA	0.59	*	(0.21)
Hypothetical	1.76	**	(0.25)
Economics	0.24		(0.21)
Other business	0.1		(0.58)
Mail	-1.12		(0.83)
Telephone	-1.23		(0.95)
Online	-1.3		(0.43)
In person	0.98	***	(0.35)
Published in Journal	0.25	**	(0.11)
Negative	-0.74	***	(0.23)
Y2000-2004	0.09	*	(0.94)
Y2005-2009	2.17	**	(1.32)
After 2010	2.42	***	(1.61)
R^2	0.51		
F test for restricted model [c]	*F=496.3* (*P* < 0.01)		
LM test	$\chi^2 = 278.5$ (*P* < 0.001)		
Hausman test	$\chi^2 = 26.9$ (*P* =0.76)		

In terms of coefficients associated with types of CAs, 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 GM-free 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 has the lowest WTP. In addition, WTP is the highest in the Asian market, followed by the EU and the North America. Concerning research methods coefficients, WTP estimated by CE and CV method tends to be higher than for other approaches. Significantly, ‘Hypothetical’ has a positive impact on dairy products. 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 survey produce the highest WTP for dairy products.

We also 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. Here, this effect may indicate that publication is an indicator of study quality, and therefore higher quality studies tend to produce higher WTP estimates. However, this variable could also be interpreted as a filter that favours larger, statistically significant values. Thus, this result may suggest the presence of publication bias. Lastly, an obvious and similar trend of increasing WTP shown by the positive and significant coefficients of the time variables.

3.1. Predicted WTP a price premium

Although the individual coefficients in Tables 3 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. And especially, the WTP for environment-friendly will be used in the farm system modelling.

To do so, we chose the meta-regression results for the RE (by study) specifications of the dairy model (Table 3) 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 4. For all WTP predictions, the study year was set after 2010 to capture the recent market demand for dairy 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.

Table 4 Predicted WTP a price premium of livestock products (%)

CAs	Price premium
Environment-friendly	**25.36 [5.2, 52.25]**
Animal welfare	31.06 [10.51, 51.61]
Organic	26.41 [3.13, 49.69]
GM free	35.64 [22.28, 59]
Hormone/Antibiotic free	34.51 [11.25, 57.77]
Grass-based	25.11[6.02, 49.55]
Food safety	39.23 [18.82, 59.54]
GI	29.87 [11.33, 48.41]
Traceability	18.39 [-1.83, 38.61]

As shown in the above table, 'Food safety' was predicted to produce the highest WTP a price premium of dairy products (39.23%), whereas the lowest WTP (18.39%) relates to 'Traceability'. The price premium associated with environment-friendly is estimated to be 25.36% with the 95% confidence interval between 5.2% and 52.25.

3.2. Farm modelling results

To achieve carbon neutral, all four scenarios have to bear an offset cost according to the estimated GHG (shown in Figure 3). It can be seen the decreasing trend of both N loss and GHG. With no price premium, the delivery of environment-friendly dairy products would lead to profit loss from the base scenario to CNeu1. However, even there is no price premium for delivering 'green' dairy, CNeu2 and CNeu3 have higher profitable level, considering lower offset costs in terms of lower GHG.

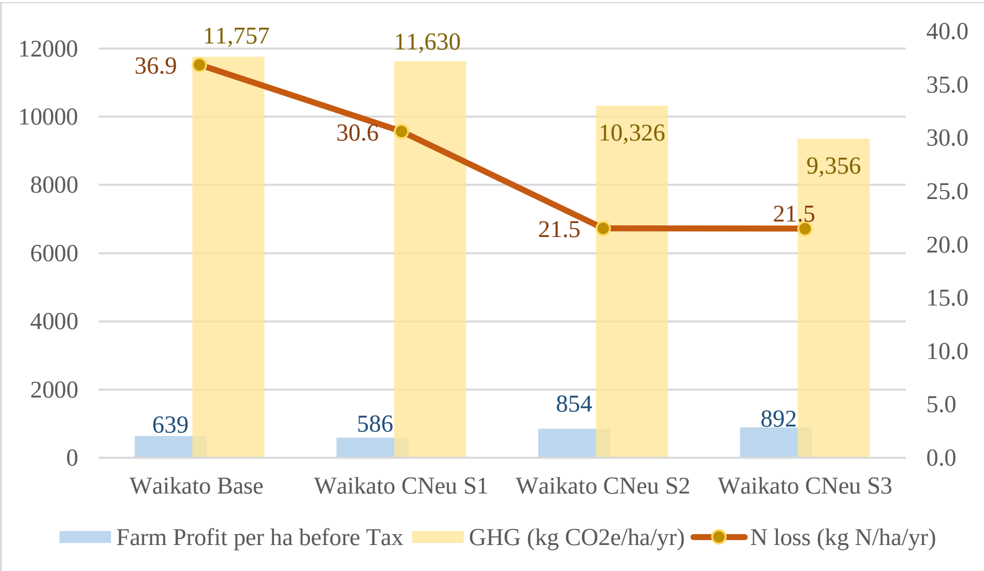

Figure 3 Comparison of farm profit, N loss and GHG across four scenarios-no price premium

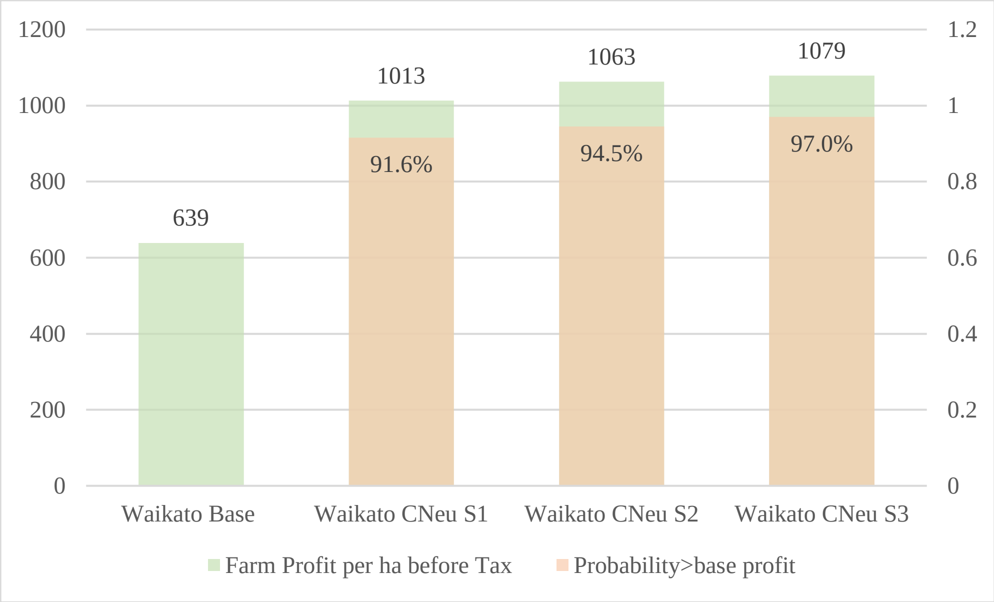

Figure 4 Comparison of farm profit and probability of higher profit than base scenario

Now considering the price premium that we estimated and sourced from the meta-regression analysis, where the estimated consumer WTP for environment-friendly dairy products is used. We assume that a price premium gained from the market could substitute farmers' cost and ensure environmental and economic sustainability. Here, we consider two sources of uncertainty and variation for delivering the expected WTP price premium for environmental-friendly dairy products. The first comes from the variation of WTP estimate, based on the WTP estimate from the meta-regression model, where the average price premium for environmental-friendly is estimated to be 25.36%, with a 95% confidence interval between 5.2% and 52.25%. Another uncertainty comes from how much of the WTP for price premium could be delivered to farms. Here, we used the historical data of farm-level share of price from the US (since 1990 till recent) as a substitute to simulate the uncertainty of share, where the average farm share is 31% with the standard deviation of 3.6%. A Monte Carlo simulation was used to model the uncertainty and variation of price premium. Figure 4 shows the simulation results of farm profit for all three scenarios, each with 1000 iterations. The possibility of profit greater than the base scenario profit is 91.6% for scenario 1, 94.5% for scenario 2 and 97% for scenario 3, given the simulated results based on WTP estimate and assumed farm-level share of price premium.

Furthermore, we are interested in how profitable under each scenario across levels of price premium, which is shown in Figure 5. The frequency of profit premium range represent how frequent the Waikato profitability falls into the price premium range. Although the average profit increases with price premium increases for all three scenarios, it is less possible to gain a high price premium, e.g. 45% and above. Notably, the simulated frequency is centred between price premium of 5% and 45%.

Significantly, with the price premium higher than 5%, all three carbon neutral scenarios outperform the base scenario in terms of profitability.

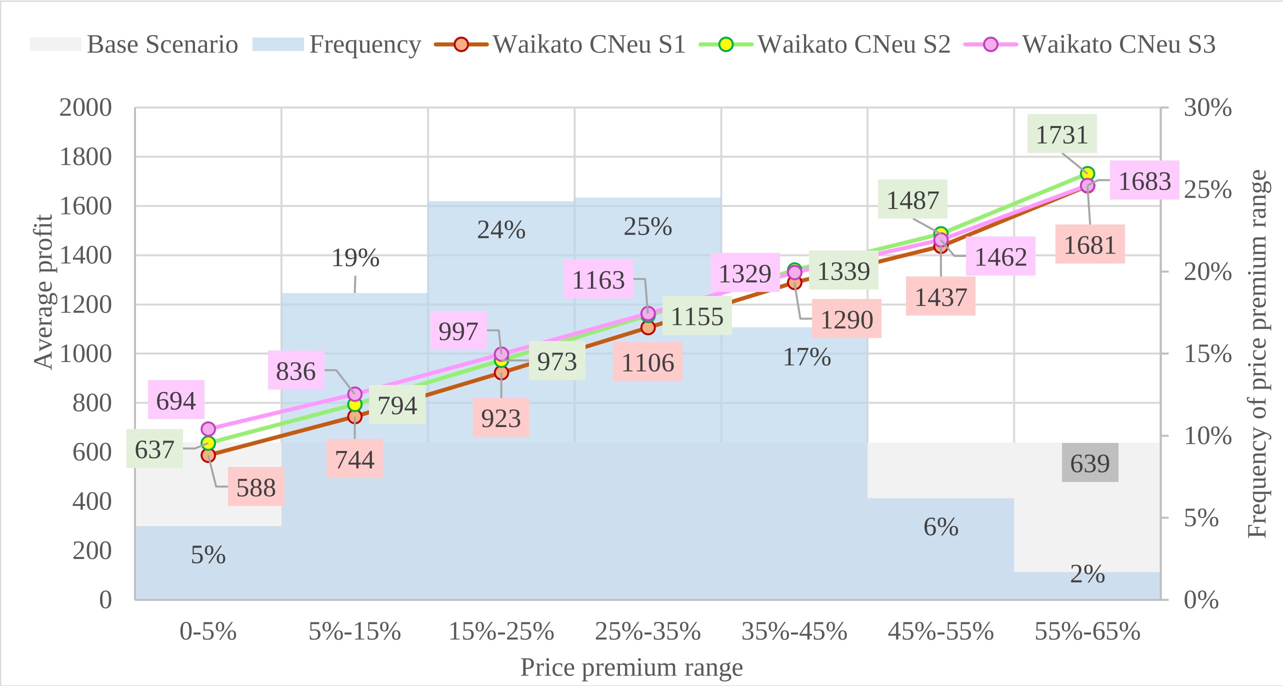

Figure 5. Average profit frequency and across ranges of price premium

4. Discussion and Conclusions

This paper incorporate results of a quantitative summary of the WTP estimates literature to farm system modelling in NZ. It fills an important gap by investigating the impacts of delivering credence attributes on-farm. The number of empirical studies applied to estimate consumer WTP price premium of 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 consumers understand CAs. However, the heterogeneous results of the studies present a challenge to the provision of reliable estimates of WTP. This paper explores how the existing literature can be used to systematically estimate consumers' WTP a price premium across types of livestock products and CAs, taking into account the heterogeneity of study characteristics.

Unlike qualitative literature reviews, which can be sensitive to the reviewer's subjective decision to emphasise particular price premium over others, our quantitative literature review statistically analysed tendencies in the literature to sway WTP estimates one way or the other. Indeed, across the studies included in the meta-analysis, we found several important results. For example, beef and dairy products with CAs are associated with higher price premium compared to lamb. In addition, to varying degrees of significance, the WTP estimates are particularly sensitive to the types of CAs, chosen estimation methods, publication characteristics, and time effects.

The results of the study provide a number of insights. To begin with, confirming the existence of price premium of CAs may motivate farmers to make changes to their farming systems or adopt good management practices and new technologies to meet the expectation of environmental regulation and the increasing demand for food products with CAs. By consider the variation and uncertainty of farm share of price premium, the simulated results show a promise that farmers could maintain profitable under carbon neutral scenarios. Specially, the gained price premium, when it is higher than 5%, could help farmer cover adaptation and offset cost and maintain profitability. Nonetheless, since the offset cost is set at 25 NZD per ton, changes of the cost may affect the profitable levels under the carbon neutral scenarios. Besides, the data used in the on-farm modelling are based on the Waikato average farm system, the profitable levels could be significantly different when based on farm systems in the South Island, for example the Southland. Thus, it is worthwhile to extend the study to explore the impact of delivering environment-friendly dairy products in other regions of NZ. In addition, other CAs estimated from the meta-analysis could also be modelled at farm level, for example 100% grass-fed. Lastly, as it is challenging to motivate farmers to make changes to adapt to requirements required for environmentally sustainable agriculture, all these evidence could assist the NZ government in achieving the expected environmental goal while maintaining the growth of the economy.

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