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Can consumers' willingness to pay incentivize adoption of environmental impact reducing technologies in meat animal production?

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ABSTRACT

This study develops a model estimating consumer willingness to pay (WTP) for environmental meat attributes and uses a multi-objective nutritional optimizer to explore the extent to which WTP can offset on-farm costs of reducing water use. Data for the WTP model are sourced from a literature survey of the Agricola and Google Scholar databases yielding 46 studies estimating WTP for pure and impure (organic, grass-fed, natural) environmental meat attributes. Bayesian analysis is used to estimate 3 models varying in independent variables. Models are evaluated by the correlation coefficient (R^2), root mean squared error of prediction (RMSPE) and posterior model probability. The most probable model is then used to estimate a confidence range of WTP for pure environmental beef. Impure environmental labels result in higher WTP than pure labels. Non-hypothetical WTP for pure environmental labeling for North American consumers ranges from 6.7% to 32.6%. A case study is conducted to identify the expected reduction in water use that can be funded from capturing WTP through labeling. A multi-objective nutritional optimizer is used to identify ideal management of beef cattle to reduce whole-system water use in three regions of the United States. Cost increases from management are varied over the predicted range in WTP and combined with the probability of a consumer purchasing beef at each WTP value to identify the theoretical effect on expected environmental impact reduction. A 10% premium is the ideal WTP, resulting in water use reductions between 24.4 L and 41.4 L.

Introduction

Global population is increasing (US Census Bureau, 2013; United Nations, 2011) and concurrent improvements in developing nations' affluence will increase global consumption of livestock products (Cranfield et al., 1998; Delgado, 2003). Livestock production is resource-intensive and agricultural water (Vorosmarty et al., 2000) and land (Lambin and Meyfroidt, 2011) availability is already limited. By 2050, food demand is predicted to outpace water availability in most regions of the world (Falkenmark et al., 2009) and the cost of agricultural land is expected to rise significantly (Hertel, 2011). Improving sustainability of livestock production is a frequently proposed solution to this global food production challenge.

Top-down regulatory policies are often suggested as a means of improving agriculture's sustainability (Deckers, 2010; Edjabou and Smed, 2013; Lybbert and Sumner, 2012). Many top-down policies mandate some reduction in environmental impact and incentivize or penalize beneficial or detrimental management practices (Golub et al., 2012). This approach often requires a substantial sacrifice of farm income (Varela-Ortega et al., 1998) because the policies fail to account for cost heterogeneity at the farm level. Improving sustainability of food production systems should balance environmental, economic and social focuses (National Research Council, 2011, 2013; WCED, 1987). Therefore a policy that has negative effects on farm revenue will not be sustainable. An alternative approach to decreasing agricultural environmental impact is manipulation of consumer purchasing decisions by policy, taxation or labeling (Deckers, 2010; Gadema and Oglethorpe, 2011; González et al., 2011). Demand for environmental labels on food products is increasing (Gadema and Oglethorpe, 2011). Before food labeling can be relied upon as an alternative policy option, studies should investigate the confidence range around estimates of consumer

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WTP for environmental meat labels and compare to cost increases associated with reducing environmental impact (e.g., White et al., 2013a, 2013b).

Consumers demonstrate willingness to pay (WTP) for meat products with perceived reductions in environmental impact (Hurley et al., 2006; Tonsor and Shupp, 2009). Much of the literature on environmental labeling focuses on impure environmental labels (organic, grass-fed, all natural, local, etc.) which have some personal health or safety attributes in addition to perceived environmental attributes. This focus makes it difficult to identify whether there is WTP for pure environmental meat attributes (i.e., reduced water use). Some studies do assess WTP for pure environmental labels (Hurley et al., 2006; Nilsson et al., 2006; Tonsor and Shupp, 2009) but variability in study methodology and the resulting effects on WTP estimates (List and Shogren, 1998) make it difficult to rely on any of these individual values as robust WTP estimate. Past studies rely on quantitative summary techniques to synthesize literature assessing WTP for a variety of attributes or utilizing several methodologies to better isolate WTP for a single attribute (Cicia and Colantuoni, 2010; Lagerkvist and Hess, 2011; Lusk et al., 2005). In this case, quantitative summary can be used to partition out WTP for health/safety from environmental attributes in impure environmental valuations to estimate WTP for pure environmental attributes while taking methodological variability into account. This WTP can be compared to estimates of production cost increases related to reducing water use within meat production systems (White et al., 2013a, 2013b). This comparison can then help assess efficacy of using a labeling approach to incentivize adoption of environmental impact reducing technologies.

In this study, we have two objectives: (1) to develop a robust estimate of consumer WTP for environmental meat attributes and (2) to use a hypothetical beef production case study to estimate whether WTP can offset on-farm costs of adopting water-reducing technologies. Section 'Theory' discusses the theoretical framework. Section 'Materials and methods' details data collection and quantitative analysis. Section 'Results and discussions' presents outcomes of the models and assesses impacts of WTP on opportunity to reduce beef's environmental impact. Finally, concluding remarks and future research directions are presented in Section 'Conclusions and policy implications'.

Theory

Standard utility theory for consumer behavior (Deaton and Muellbauer, 1980) assumes that consumers seek to maximize utility through consumption of food subject to a budget constraint. A common understanding of utility assumes that consumers value the attributes represented by a good rather than the good itself (Rosen, 1974). In a hedonic sense, consumers view individual food items as a bundle of attributes. Willingness to pay for individual food items is then based on the associated attributes of the items. Food attributes typically considered in economic analyses are those that provide private benefits in terms of nutrients and quality, the latter of which includes a range of characteristics including taste, texture, physical appearance, etc. Consumers in the United States (US) have demonstrated increasing demand and willingness to pay (WTP) for food products with pure or impure environmental good characteristics. Examples include dolphin safe tuna (Teisl et al., 2002), rainforest enhancing coffee (Rice and McLean, 1999), locally produced food (Darby et al., 2008, 2006), organic foods (Corsi and Novelli, 2002; Krystallis and Chryssohoidis, 2005), cage-free or free range eggs and poultry (Bennett and Larson, 1996) or grass-fed beef (Umberger et al., 2002). Each of these products is perceived by the consumer to contain attributes associated with some aspect of a sustainable food system. Although the existence of these markets is somewhat taken for granted now, each began with uncertainty about whether there were enough consumers willing to pay a premium for the proposed environmental good relative to conventional goods.

Materials and methods

A three part methodology was used. First, a literature search was employed to identify studies that assessed consumer WTP for pure or impure (organic, grass-fed, all natural, local, etc.) attributes of meat. Three models were then fit to these data using a Bayesian regression. The models employed different explanatory variables designed to separate WTP for pure environmental attributes from valuations assessing goods with additional health/safety attributes. The models were evaluated and compared using the correlation coefficient, R^2, the root mean squared error of prediction, RMSPE, and the posterior model probability. The models were averaged based on their posterior probabilities and used to estimate a confidence range for non-hypothetical consumer WTP for pure environmental meat attributes. Finally, a multi-objective nutritional optimizer was used to explore whether WTP could offset increases in cost associated with adopting water-reducing management practices on-farm. The optimizer identified the range in water use reduction that was achievable within the bounds of consumer WTP.

Data collection

A literature search of the Agricola and Google Scholar databases was conducted using the keywords "consumer willingness to pay meat [beef/pork]". Studies were included if they presented a numerical estimate of consumer WTP for a meat attribute. Studies assessing pure or impure environmental attributes were identified as a subset from the literature search. Conference publications, white papers and extension oriented publications relating to consumer WTP for meat attributes were identified through the AgEconSearch engine again using the keywords "consumer willingness to pay meat [beef/pork]". Authors who had published several papers on WTP were contacted for copies of their most recent work. Studies were excluded from analysis if they presented WTP estimates from a dataset already included in analysis. Studies failing to present a numerical value of consumer WTP or assessing WTP for a cut of meat rather than a meat attribute were also excluded. Percentage premium WTP estimates were used in analysis to standardize over currencies and years. Therefore, if a base comparison value was not clearly stated within a study, it was excluded to eliminate bias from incorrect assumption of a base value. The selection process returned 61 studies representing 269 treatments conducted on over 34,000 consumers in 18 different countries. A total of 46 studies contained treatments assessing pure or impure environmental goods and 26 studies contained treatments that assessed a purely private meat attribute (quality, health, safety, etc.). As the values would suggest, some studies had both environmental and non-environmental valuations. Studies are summarized in the online supplement (Tables S.1 and S.2) organized alphabetically based on the first author's last name.

Bayesian model fitting

Bayesian regression analysis was used to fit three models varying in independent variables. Bayesian model fitting was used for several reasons. A large amount of explanatory variables were employed and Bayesian regression analysis is better equipped to deal with numerous explanatory variables (Gelman et al., 2004;

Mitchell and Beauchamp, 1988). Additionally, a small sample size was anticipated and Bayesian model fitting, due to reliance on Markov Chain Monte Carlo simulation, is particularly well equipped to estimate models based on small datasets (Martin et al., 2011). Given the variability in the valuation techniques employed within the dataset, the models needed to account for study variability and differentiate between hypothetical and non-hypothetical valuation methods. Prior information was available about how study methodology influenced consumer WTP. To improve the predictive capacity of the model, the researchers wanted to include this prior information in the assessment. The use of priors in Bayesian analysis (Lenk and Orme, 2009) allowed for the information to be incorporated. Improperly specified informative priors can bias a model. To ensure this was not the case, an initial model fitting included both informative and non-informative priors. Comparison of the posterior probabilities, R^2 and RMSPE indicated informative priors improved probability, explained more variability in WTP and reduced model error.

All regression models followed the general form:

$$y = X\beta + \varepsilon \text{ where } \varepsilon \sim N(0, \sigma^2)$$

where y is a matrix of dependent variable observations, X is a matrix of independent variables with β representing the regression coefficients. The error term ε is normally distributed with mean zero and non-constant variance. The exact form of heteroskedasticity is not known but the error variances originate from the normal distribution. The coefficient b and error σ^2 priors are specified as:

$$b \sim N(b_0,\ B_0^{-1})$$
$$\sigma^2 \sim Gamma(c_0/2,\ d_0/2)$$

Bayesian analysis uses iterative simulation that supplements the data available with information from the prior distribution based on Bayes theorem (Gelman et al., 2004). After data is inputted, the uncertainty in the model parameters is estimated by summarizing a set of random draws from each parameter vector based on a posterior distribution (Gelman et al., 2004). Because the posterior distribution is unknown, the Metropolis–Hastings algorithm, a Markov chain Monte Carlo method for random sampling of a probability distribution, is commonly used to estimate the distribution (Chib and Greenberg, 1995). The Metropolis algorithm is carried out in a series of steps (Chib and Greenberg, 1995). For each coefficient β, a desired probability distribution $P(\beta)$ exists. The algorithm is initialized by selecting an arbitrary point $P(\beta_c)$ and a probability density $Q(\beta|b)$ – these are based on the mean and standard error inputted as priors to the model. During each iteration, the next candidate for β is selected from the distribution $Q(\beta|\beta_o)$. The acceptance ratio of the candidate, $P(\beta_c)/P(\beta_o)$, is then calculated. If this ratio is greater than 1, β_c is more probable than β_o and β_c is accepted as the new value of the equation coefficient β. If less than 1, then β_c is rejected and β_o is set to the new current value. This Markov process was carried out using R statistical software (Martin et al., 2011). The data from the literature search were supplemented with random samples from the prior distributions (Section 'Prior distributions') and the three models were estimated. For each model, the iteration process was continued for 500,000 iterations. To improve computational efficiency while maintaining estimation rigor, the first 5000 iterations were burned and every subsequent 2nd iteration was used for sampling. Because the algorithm accepts or rejects a value of β based on the probability of the current and previous values, it is important to ensure enough iterations to allow the algorithm to converge on a highly probable value. Geweke (1993) identified one method of post hoc analysis to determine adequate convergence by testing equality of the means in the first and last part of a Markov chain. In this analysis we compared the first 10% of the chain and the last 50% (Geweke, 1993) to ensure convergence of each parameter.

Regression models fit

Three models were fit to explore how consumers might view pure and impure environmental labels. One model (M-P/IP) looked at characterizing meat attributes as either purely public or impure public. The M-P/IP classification was formed based on the assumption that consumers view environmental goods as either purely public (no direct personal benefit) or impure (some direct personal benefit). The authors hypothesized this structure would be too simplistic and so two additional models were considered. One model (M-CA) coded meat labels based on their constituent attributes (environmental, healthy, safe, local, etc.) following the theory that consumers value goods as a bundle of attributes. The final model (M-IL) coded each labeling scheme individually (environment only, grass-fed, organic, etc.). The M-IL scheme assumed each meat label had a unique bundle of constituent attributes inadequately explained by categorical variables like health or safety. In all models, the environmental term was used to represent pure environmental labeling.

The dependent variable

For all models, the dependent variable was the natural logarithm of the percentage premium WTP for the meat product attribute isolated in any particular treatment. Percentage premiums were used following the example of several previous WTP analyses to standardize across study year and currency type. 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. The online supplement (Table S.1) specifies the base prices used for each treatment along with the source of the base price.

Explanatory variables

The explanatory variables used in each model are listed in Table 1. In all models, a series of explanatory variables were included to account for the variability in study methodology, consumers assessed and study date. Study methodology is known to have substantial influence on the valuations obtained (List and Gallet, 2001). Studies conducted in-person lead to over-stated WTP estimates. In addition, studies assessing hypothetical and non-hypothetical valuation methods find that non-hypothetical valuations are lower (List and Shogren, 1998; Little and Berrens, 2004). To account for these methodological influences on WTP estimation binary dummy variables for in-person and non-hypothetical valuations were included.

Willingness to pay was expected to vary with meat type and cut. As studies on beef and pork were included in the assessment, a binary dummy was included identify studies on pork. Most studies assessed WTP for beef steak or pork chops, studies focusing on alternative products (ground beef) were coded separately to identify how meat cut affected WTP.

The data demonstrated a general trend of increasing percentage premium WTP with publication date. Ideally, data collection date would have been included in the assessment (Nelson and Kennedy, 2009); however, many studies failed to report the collection date and thus publication date was used as a proxy. Binary dummies to indicate half decade of publication were coded and used to explain the influence of publication date on WTP. Finally, WTP was expected to vary with location and gross domestic product per capita (GDP). Studies were categorized regionally.

Table 1
Variable definitions.

Variable	Definition	Models	Mean	SD	Min	Max
GDP	Gross domestic product per capita[a]	1, 2, 3	38,542	10,472	2441	59,889
GROUND	1 If study tested a product other than beef steak or pork chops	1, 2, 3	0.167	0.3739	0	1
PORK	1 If study tested a pork product; otherwise, 0	1, 2, 3	0.331	0.471	0	1
2000	1 If study was published after 1999 and before 2005; otherwise 0	1, 2, 3	0.509	0.501	0	1
2005	1 If study was published after 2004 and before 2010; otherwise 0	1, 2, 3	0.257	0.438	0	1
2010	1 If study was published after 2010; otherwise 0	1, 2, 3	0.149	0.356	0	1
NAM	1 If study was conducted in the US or Canada; otherwise, 0	1, 2, 3	0.648	0.479	0	1
EUR	1 If study was conducted in Europe; otherwise, 0	1, 2, 3	0.272	0.446	0	1
ASIA	1 If study was conducted in Asia; otherwise, 0	1, 2, 3	0.048	0.214	0	1
INPERSON	1 If study was conducted in person; otherwise 0	1, 2, 3	0.603	0.490	0	1
NONHYP	1 If study utilized a non-hypothetical valuation method; otherwise, 0	1, 2, 3	0.369	0.484	0	1
IMPURE	1 If study assessed an impure public good; otherwise, 0	1	0.472	0.500	0	1
ENV	1 If study assessed a purely public, environmental good; otherwise, 0	1, 2, 3	0.231	0.424	0	1
GRASS	1 If study assessed grass-fed or grass-finished meat; otherwise, 0	3	0.052	0.223	0	1
ORGANIC	1 If study assessed organic meat; otherwise, 0	3	0.044	0.206	0	1
NOHAG	1 If study assessed meat produced without hormones, antibiotics and/or growth enhancing technologies; otherwise, 0	3	0.200	0.401	0	1
HEALTHY	1 If study assessed an attribute associated with health; otherwise, 0	2	0.316	0.466	0	1
SAFE	1 If study assessed an attribute associated with safety; otherwise 0	2	0.328	0.470	0	1
WELFARE	1 If study assessed animal welfare; otherwise, 0	2, 3	0.212	0.410	0	1
LOCAL	1 If study assessed traceability, COOL labeling or local production; otherwise, 0	2, 3	0.084	0.278	0	1

[a] Gross domestic product was based on publication year and study location and sourced from World Bank (2014).

Geographical dummy variables were used to identify study location (US or Canada, Europe, Asia or other locations). To account for the expected personal wealth of individuals in each study, GDP was sourced based on location and publication year (World Bank, 2014).

Prior distributions

Informative prior distributions for the methodological coefficients were derived from a meta-regression analysis. Studies identified during the literature search process that tested purely private good attributes were set aside into a secondary dataset. This collection of studies is included in the online supplement (Table S.2). Studies were coded using the same methodological variables used in the Bayesian analysis. Random-effects meta-regression was used to fit a model predicting the natural log of percentage premium willingness to pay based on the methodological variables detailed in Section 'Explanatory variables'. Model fitting was done using *R* statistical software (Viechtbauer, 2010). The resulting coefficients and variances were used to define informative prior distributions for the methodological variables. Non-informative priors were used for all subject specific variables because insufficient data was available to develop informative priors. Additionally, this helped avoid biasing the outcome with improperly specified priors. Informative priors are presented in Table 2.

Table 2
Informative priors used in analysis.

Variable	Mean	SE
Intercept[a]	1.873	1.234
GPD[a]	2.523×10^{-5}	1.854×10^{-5}
2000[a]	0.413	0.6122
2005[a]	0.964	0.728
2010[a]	1.610	0.690
GROUND[a]	0.098	0.467
PORK[a]	0.577	0.371
NAM[a]	−0.564	0.471
EUR[a]	−2.076	0.578
ASIA[a]	0.688	0.489
INPERSON[a]	−0.500	0.618
NONHYP[a]	0.152	0.585
IMPURE[b]	0	1
ENV[b]	0	1
WELFARE[b]	0	1
LOCAL[b]	0	1
SAFE[b]	0	1
HEALTH[b]	0	1
ORGANIC[b]	0	1
GRASS[b]	0	1
NOHAG[b]	0	1

[a] Priors were calculated by random effects meta-regression.
[b] Priors are weakly informative following Gelman et al. (2004).

Model evaluation and comparison

Models were evaluated using the correlation coefficient, R^2 and the root mean squared error of prediction, RMSPE. As each model was estimated, the Bayes factor of the model was calculated. After all models had been estimated, the posterior model probabilities were calculated (Kass and Raftery, 1995). The ranking of model probabilities as well as inferences from the most probable model were used to draw conclusions about consumer preferences. The best model was used to determine a range of WTP estimates for purely public and impure public environmental labeling schemes.

Impact assessment

One challenge with assessment of top-down regulatory policies is that they fail to account for cost structure at the farm level. To avoid this pitfall, we employ a multi-objective optimization model to assess how WTP could be used to offset on-farm management costs related to reducing water use. The optimizer was used to simulate beef production systems in three locations throughout the US The optimizer integrated environmental impact (Capper, 2011, 2012; White and Capper, 2013), farm economics (White and Capper, 2013), pasture management (McCall and Bishop-Hurley, 2003; Romera et al., 2009) and consumer willingness to pay. The model simulated a whole beef production system and adjusted cattle diets and pasture management strategies to reduce beef production's environmental impact while maintaining the production system within the bounds of biological, economic and practical constraints. Although presented in the context of a simulation, the cattle populations, production calendar, environmental impact and calculation of farm economics employed by this optimizer are thoroughly outlined in (White and Capper, 2013). A description of the weights and times for each cattle population is listed in the online supplement (Table S.3). Parameters used to determine the number of animals in each cattle population are given in the online supplement (Table S.4). Yield and quality of feedstuffs available in each region, as predicted by the pasture module (McCall and Bishop-Hurley, 2003; Romera et al., 2009), are included in the supplement Table S.5.

The production system was optimized using two different forms of objective function. The baseline scenario, least cost management, was simulated by optimizing:

$$Minimize(Cost) = FC + PC + LC$$

where FC (feed), PC (pasture) and LC (labor) costs were accounted based on the feedstuffs selected. After the least-cost baseline was simulated, environmental impact reducing scenarios minimizing water and land use were conducted. Both land and water were targeted because water use can easily be reduced by increasing land use (White et al., 2013a, 2013b); however, this is not practically feasible. These scenarios relied on the objective function:

$$Minimize(Obj):$$
$$Obj = (PV_{h2o} - BV_{h2o})/BV_{h2o}$$
$$Obj = (PV_{land} - BV_{land})/BV_{land}$$

The subscripts on the present (PV) and base value (BV) variables represent water use ($h2o$) or land use ($land$) per kilogram hot carcass beef produced. These values are calculated for the production system, based on the diets selected by the optimization process, following the equations enumerated in White and Capper (2013). The multi-objective function form followed Tozer and Stokes (2001). In each optimization, the choice variable was $DMI_{f,p}$. Nutrient requirements of each animal group in each month were used to ensure adequate nutrition without exceeding the maximum predicted dry matter intake:

$$\sum_f DMI_{f,p} * ME_f \geqslant MEreq_p$$
$$\sum_f DMI_{f,p} * MP_f \geqslant \text{NPreq}_p$$
$$\sum_f DMI_{f,p} \leqslant DMIx_p$$

where $DMI_{f,p}$ is intake of feed (f); ME_f is the metabolizable energy content of feed (f); $MEreq_a$ is the metabolizable energy requirement of the animal (National Research Council, 2000); MP_f is the metabolizable protein content of each feed (f); $Mpreq_p$ is the metabolizable protein requirement for an animal (National Research Council, 2000), $DMIx_p$ is maximum predicted dry matter intake. These values can be found in the online supplement (Table S.5). Increases in cost associated with reducing water use were restricted to less than WTP:

$$BV_{cost} + BV_{cost} + \text{WTP} \geq PV_{cost}$$

where PV_{cost} is cost simulated, WTP is the willingness to pay for low-environmental impact beef and BV_{cost} is baseline cost. The WTP was varied within the confidence range of the averaged regression model. Consumer WTP was back-calculated to the farm level assuming a 65% conversion of retail beef to hot carcass weight beef (Schweihofer, 2012) and a conveyance rate of 25% of consumer WTP returning to the farm-level. The reductions in water use predicted by the optimizer were assumed to be the theoretical environmental impact reduction possible.

Given that only a portion of the population will pay a premium for environmental attributes, the WTP range was used to develop a cumulative normal distribution estimating probability of purchase at any given WTP value. The product of the theoretical environmental impact reduction and the predicted probability of purchase was used as an estimate of the realistic opportunity to reduce environmental impact.

Results and discussions

The predicted model variable coefficients and standard errors are included in Table 3. Model fit parameters are also reported. Analysis of the convergence indicated significant evidence of convergence for all coefficients in all models.

Willingness to pay model comparison and evaluation

Three models were fit to explore how consumers might view pure and impure environmental labels. The M-IP model with the lowest error and highest R^2. This could be the case for several reasons; most likely, each label has its own individual bundle of goods perceived by consumers but these unique bundles were insufficiently explained by healthy, local, welfare, safe and environmental attributes. Alternatively, the combination of attributes together may be of greater value to the consumer than the sum of the individual attribute values. Evaluation of the log marginal likelihood also yielded strong evidence (Kass and Raftery, 1995) for the hypothesis that consumers view each label as an individual good over the explanations provided by other models.

Estimating consumer willingness to pay

The models indicated WTP was influenced by study methodology, meat type, location and environmental label.

Environmental labels and WTP

For the purpose of comparison, North American consumers WTP for pure and impure (local, all natural, grass-fed, organic) environmental labeling, as calculated by the most probably model, is shown in Fig. 1. On average consumers would pay a 29.1% premium for impure environmental products (range: 13.9–64.3%); pure environmental products only garnered a 14.8% premium (range: 6.7–32.6%). As was expected, the impure labels resulted in higher WTP than pure environmental labels.

When the impure environmental labels were assessed individually, some interesting dynamics were revealed. Consumer WTP for grass-fed, natural and local products were the highest of any impure environmental attribute. Martinez (2008) analyzed retail price data and found that company-specific (natural, grass-fed, organic and/or food safety) labeling schemes resulted in the highest price premiums for beef cuts compared with other labeling schemes. These branding schemes garnered premiums from 48% to 84%. The premiums for grass-fed and natural meat products predicted in this study were on the low end of this range but likely represent a realistic average WTP given that relatively small portions (collectively, 3%) of the population actually pay the listed retail premium for these specialty products (Mathews Jr. and Johnson, 2013).

Scanner data analyses consistently show high price premiums for organic products (Martinez, 2008; Schulz et al., 2012). Schulz et al. (2012) found organic labeling increased beef cost by $6.56/kg. This WTP represents a 46.7% premium when compared to the intercept (or base) price of $14.06/kg. Our model predicts premiums of 4.2–30.0% for organic products. The upper range of our confidence estimate is not within the range described by scanner data. This under-prediction could be because consumers purchasing organic are more concerned with the natural properties of the product (no hormones, no antibiotics or genetically modified organisms) and therefore the true WTP for organic products is

Table 3
Model[a] coefficients and goodness-of-fit parameters.

Parameter	M-P/IP	M-CA	M-IL
Intercept	2.24 (1.21, 3.27)	2.254 (1.236, 3.274)	1.924 (0.852, 3.004)
GDP	2.84×10^{-5} (9.57×10^{-6}, 4.72^{-5})	2.55×10^{-5} (6.48×10^{-6}, 4.48×10^{-5})	$3.14\text{x}10^{-5}$ ($1.18\text{x}10^{-5}$, $5.12\text{x}10^{-5}$)
2000	0.896 (0.314, 1.478)	0.839 (0.255, 1.427)	0.934 (0.332, 1.541)
2005	0.004 (−0.593, 0.606)	−0.081 (−0.685, 0.528)	−0.027 (−0.655, 0.610)
2010	0.467 (−0.233, 1.173)	0.524 (−0.206, 1.266)	0.650 (−0.082, 0.1392)
GROUND	−0.617 (−1.076, −0.151)	−0.627 (−1.119, −0.129)	−0.733 (−1.238, −0.220)
PORK	0.305 (−0.062, 0.674)	0.245 (−0.142, 0.637)	0.214 (−0.180, 0.613)
NAM	−0.534 (−1.201, 0.130)	−0.499 (−1.166, 0.165)	−0.545 (−1.216, 0.118)
EUR	−0.712 (1.386, −0.040)	−0.735 (−1.408, −0.065)	−0.876 (−1.558, −0.195)
ASIA	0.411 (−0.364, 1.189)	0.412 (−0.367, 1.189)	0.457 (−0.324, 1.238)
INPERSON	−0.373 (−0.841, 0.092)	−0.389 (−0.865, 0.082)	−0.348 (−0.828, 0.128)
NONHYP	−0.536 (−1.097, 0.026)	−0.541 (−1.104, 0.030)	−0.599 (−1.160, −0.031)
IMPURE	0.404 (−0.092, 0.900)		
ENV	0.045 (−0.465, 0.558)	−0.086 (−0.734, 0.562)	0.040 (−0.748, 0.830)
WELFARE		0.370 (−0.106, 0.840)	0.643 (0.51, 1.223)
LOCAL		0.389 (−0.137, 0.911)	0.457 (−0.088, 0.997)
SAFE		−0.007 (−0.600, 0.583)	
HEALTH		0.540 (−0.156, 1.236)	
ORGANIC			1.069 (0.036, 2.097)
GRASS			−0.250 (−1.227, 0.731)
NOHAG			0.578 (−0.004, 1.159)
R^2	0.403	0.429	0.455
RMSPE	49.16	42.92	28.77
LogML	−271.2	−274.2	−265.8

[a] M-P/IP assumed consumers valued goods only based on their impure/pure public good classification. M-CA assumed goods were values based on their constituent parts. M-IL assumed each good label was valued individually.

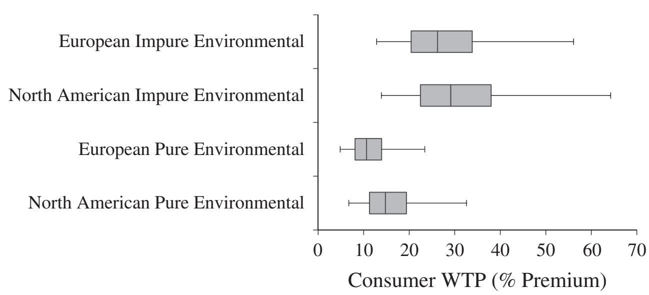

Fig. 1. 95% Confidence ranges for North American or European consumers' willingness to pay for pure and impure environmental labeling of beef products. The boxes represent the range between 25% and 75% confidence with the mean indicated by the middle bar. The error bars represent 95% confidence.

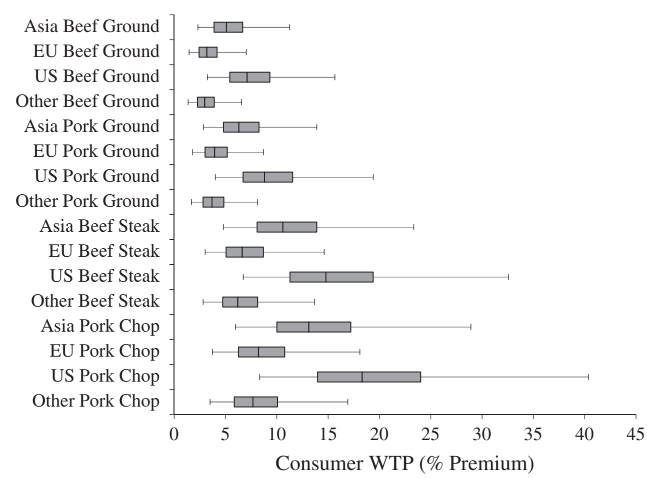

Fig. 2. A comparison of the 95% confidence ranges for pure environmental products when meat type, GDP and location parameters were varied. The boxes represent the range between 25% and 75% confidence with the mean indicated by the middle bar. The error bars represent 95% confidence.

reflected by the natural category in our model. Alternatively, there were very few studies assessing WTP for organic products (likely because they are already available on the market) and our sample may have been insufficient to adequately characterize WTP for organic meats.

Methodological and meat type effects

Previous literature indicates studies conducted in person or using non-hypothetical valuation methods result in over-estimation of WTP (List and Gallet, 2001; List and Shogren, 1998; Lusk et al., 2005). The model generated in this analysis agrees with these previous studies. When North American consumers' WTP for a pure environmental beef steak product was tested, in-person valuations lead to an 11.2% decrease in WTP and non-hypothetical valuation decreased the WTP estimate by 17.2%.

Location and beef type influences on WTP for a pure environmental product are depicted in Fig. 2. Pork chops and beef steak had similar predicted WTP premiums. Cicia and Colantuoni (2010) found that consumers were willing to pay a 5.94% lower premium for pork products. Cicia and Colantuoni studied WTP for traceable meat products. It is possible that differences in WTP for beef and pork observed in that study were due to concerns with bovine spongiform encephalopathy related to beef raised in some countries. When an environmental meat attribute was tested rather than an attribute implicitly related to human health, beef and pork environmental attributes are valued similarly. Interestingly, consumers were predicted to pay much higher premiums for chops and steaks than they would for ground products. This may be because chops and steaks are high quality and therefore consumers are prepared to ensure they purchase the best product possible.

The greater WTP for steaks and chops is of concern when exploring the options to rely on food labeling to help improve meat environmental impact. Without a substantial WTP for all products on the carcass, there may be minimal incentive to adjust production practices. Packers and retailers may prove key players in the use of labeling to improve meat production water use. As consumer preferences have become better understood, packers and retailers have adjusted their WTP for meat animals to better reflect the desires of the consumer (Igo et al., 2013). For example, consumers consistently show high WTP for tender, high quality steak grades (Schulz et al., 2012). Although an equivalent WTP does not exist for tender ground beef, packers, retailers and even feedlot operators will pay premiums for cattle with superior genetics for tenderness (Igo et al., 2013). As such, the intervention of packer or retailer WTP, in response to better understanding of consumer WTP, may help to more effectively incentivize adoption of water conserving production practices.

Gross domestic product and regional effects

When GDP was held constant, both North American and European consumers had substantially lower WTP than Asian consumers. North American consumers had higher WTP than European consumers. Similar WTP between North American and European consumers was expected because surveys conducted in Europe (Fotopoulos and Krystallis, 2002), North America (Dettmann and Dimitri, 2009) and elsewhere (Aguirre, 2007) find similar characteristics in consumers interested in environmentally-labeled products. The comparative regional dynamics in Cicia and Colantuoni (2010) and Lusk et al. (2005) concur with those outlined here; however, Yu and Gao (2010) found European consumers had lower WTP than North American consumers. Additionally, the high WTP predicted for Asian consumers does not agree well with the WTP estimates generated by Yu and Gao (2010) and Lusk et al. (2005). This may be because none of the studies had a large number of samples from Asian consumers (2 studies in Lusk et al. (2005), 3 studies in Yu and Gao (2010) and 4 in this study). With so few estimates of Asian consumers WTP, the high between-study variability in WTP estimates is to be expected.

When GDP was varied and regional dummies were held constant, GDP had a substantial, positive impact on WTP. For every $1000 increase in GDP, WTP increased 1.03%. Previous studies use GDP as a measure of welfare across countries (Jones and Klenow, 2010). It is frequently hypothesized that as GDP increases, welfare will improve, citizens will become more altruistic and more willing to donate to public goods like environmental protection (Duroy, 2008). The current body of literature finds very diverse relationships (positive linear, negative linear, marginal linear, quadratic, etc.) between GDP and environmental donations (Duroy, 2008; Menges et al., 2005) or environmental good purchases (Vigani and Olper, 2013). This study indicates that as GDP increases, consumers do appear to be willing to partition more of their budget toward impure or pure environmental goods. This differs from most previous studies finding a negative or quadratic effect possibly because impure environmental goods were included and the analysis did not strictly test donations to a purely environmental good.

Implications of WTP on beef environmental impact

Baseline scenarios by region

A multi-objective nutritional optimizer was used to explore the extent to which consumer WTP could offset increases in production costs attributed to reducing whole-system water use. Three different regions were simulated to account for some of the cost-heterogeneity that exists at the farm level. Baseline production costs, water use and land use are included in Table 4. Production costs to yield a kg of hot carcass weight (HCW) beef were relatively homogeneous (±$0.02) across regions in the least-cost baseline scenario. Land use and water use between the regions exhibited more variability. Substantial regional variability in environmental impact attributable to beef production was also found in previous studies (Pelletier et al., 2010; Peters et al., 2010a, 2010b; Stackhouse-Lawson et al., 2012). In this study, most of the variability was due to differences in pasture yield as dictated by variable rainfall and solar radiation in each region.

Table 4
Baseline operating costs, water use and land use to produce beef in each region.

Baseline	Pacific Northwest	South	Midwest
Cost ($/kg HCW)	1.47	1.45	1.46
Water (L/kg HCW)	711.3	900.4	708.8
Land (m^2/kg HCW)	31.9	16.3	61.7

Total water use reductions

The optimizer was used to assess how opportunity to decrease water use changed as WTP increased. Water use predicted by the optimizer for each region is included in Table 4. Water use decreased at a decreasing rate as WTP increased (Fig. 3). Regions demonstrated unique inflection points and different opportunities to improve water use. In the Pacific Northwest and the Midwest, substantial reductions in water use were achieved (55.4 L/kg HCW beef or 63.8 L/kg HCW beef). A premium WTP of about 20% was required in the Pacific Northwest while only a 15% premium was required in the Midwest. In the South, water use could only be reduced by 39.1 L/kg HCW beef. This reduction required a 23% premium WTP.

Effects of probability of purchase on reducing water

The cumulative normal distribution outlined by the WTP 95% confidence interval was used to calculate probability of purchase across the WTP range. The probability began to decrease substantially as WTP increased to about 10%. Probability of purchase reached nearly 0 at WTP 30%. Theoretical opportunities to reduce water use were calculated as the product of the environmental impact reduction and the probability of purchase at each WTP value. The curves for theoretical water use reduction are included in Fig. 4. Regions demonstrated different opportunities to reduce water use but the ideal WTP was 10% in all regions. For reference, a 10% premium equates to $1.10/kg given the average retail price of beef in the US (USDA/ERS, 2013). At the farm-level, this WTP translates to a $0.17 increase in operating costs per kg HCW beef produced or $52.77 per mature breeding cow per year. The Midwest had the greatest opportunity to reduce water use (41.4 L/kg

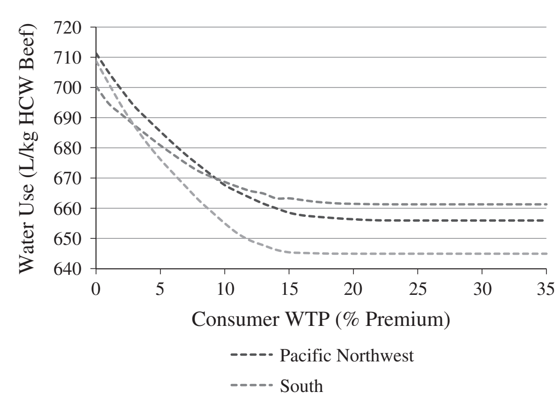

Fig. 3. Water use attributed to a whole-farm beef production system over a schedule of allowable increases in operating costs. Operating cost increases were constrained to less than consumer WTP. Consumer WTP was varied within the confidence range for North American consumers WTP for pure environmental beef products.

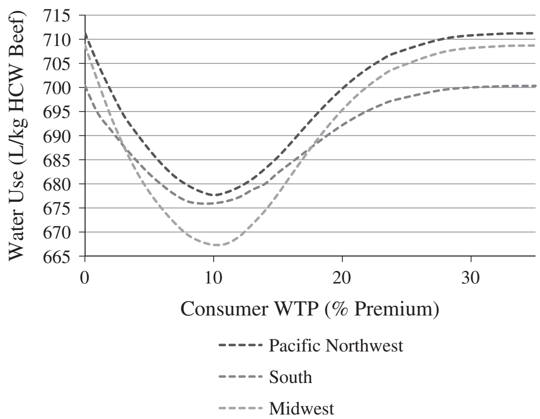

Fig. 4. Water use attributed to a whole-farm beef production system over a schedule of allowable increases in operating costs when probability of purchase was factored in. Probability of purchase was calculated from a cumulative normal distribution based on the confidence range for North American consumers WTP for pure environmental beef products.

HCW beef). The Pacific Northwest and the South had lower opportunities (33.6 L/HCW beef or 24.4 L/HCW beef).

In the US in 2013, 11.82×10^9 kg HCW beef were produced. When applied at the national scale, the water reductions calculated in this study would conserve between 2.89×10^{11} L and 4.90×10^{11} L per year. In the US, a frequent estimate of daily water use per person is 378 L (100 US gallons). In practical terms, these water use reductions would enough water to supply the annual usage of 2.09×10^6 to 3.55×10^6 people.

Conclusions and policy implications

Improving sustainability is a promising solution to the global food production challenge. Attempts to employ top-down regulatory policies to mandate improvements in meat production sustainability may be unsuccessful because these policies frequently fail to account for farm level cost heterogeneity. This study investigated opportunities to rely on food labeling as an alternative means of incentivizing adoption of water-reducing technologies in meat animal production. The approach relied on estimating a confidence range for consumers' WTP for pure environmental meat attributes and subsequently using that confidence range and a farm system optimizer to identify optimal on-farm nutritional management of beef cattle to reduce water use. The WTP assessment found WTP was significantly influenced by demographic factors and study methodology. Importantly, WTP for pure environmental products was substantially less than WTP for impure environmental products. The resulting range in consumers' WTP was then used to test the extent to which WTP could offset on-farm costs of reducing water use in three regions across the US. The optimizer detected different opportunities to decrease water use in each region. Probability of purchase was factored into the analysis to make a realistic statement about the extent to which food labeling would influence management practices. The ideal consumer WTP was 10% and water conservation of 24.4–41.4 L was possible.

This analysis identified several important points. First, there is a WTP for pure environmental meat attributes, distinct from currently available impure environmental products (organic, grass-fed, etc.). This is imperative because consumers have many misconceptions about food labeling (Gadema and Oglethorpe, 2011). Although consumers perceive that impure environmental products reduce the environmental impact of meat production, frequently these systems are less efficient than conventional meat production (Capper, 2012) and as a result, they have higher environmental impacts per kg product (Capper and Bauman, 2013). Additionally, small premiums paid at a retail level, if even conveyed 25% to the farm level, can offset operating cost increases attributable to decreasing water use. Many studies have identified management practices that will reduce environmental impact; however, producers are leery to adopt these practices because farm-level economic analysis is rarely included in the assessment. By demonstrating how WTP premiums could feed back to offset operating costs, this study integrates on-farm economic analysis with environmental impact reduction. As a final contribution, this study demonstrated moderate WTP increases that are palatable to the average consumer will have a greater aggregated impact on reducing water use than niche products with excessively high retail prices. This finding suggests that when using a labeling approach to reduce water use, the objective should not be to pioneer a new niche product but rather, to appeal to the majority of consumers.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foodpol.2014.06.007.

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