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Full Research Article

Consumers' rationality and home-grown values for healthy and environmentally sustainable food

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Abstract. Consumers' food choices often deviate from rationality. This paper explores whether deviations from rationality impact home-grown values elicited using either bid- or choice-based value elicitation techniques. The paper focuses on second-price Vickrey auctions and discrete choice experiments, which are widely used to value innovative private goods and the welfare benefits of policy interventions. The paper reports the results of an experiment that combines induced value and home-grown value elicitation procedures. Home-grown values are elicited for a public food policy. The experiment has two treatments that differ in the elicitation technique: second-price Vickrey auction and discrete choice experiment. For each technique, induced-value elicitation procedures are used to measure subjects' deviations from rationality. Deviations from rationality are more likely in the second-price Vickrey auction. Subjects who behave irrationally have higher home-grown values than rational subjects in the second-price Vickrey auction. The impact of deviations from rationality is weaker in the discrete choice experiment.

Keywords. Home-grown value, induced value, rationality, experimental auction, discrete choice experiment.

JEL codes. C91, D12, Q18, Q51.

1. Introduction

Second-price Vickrey auctions (SPVAs) (Vickrey, 1961) and discrete choice experiments (DCEs) (Lancaster, 1966) are widely used to determine the demand for innovative multi-attribute goods in marketing research and estimate welfare benefits of new agri-food, environmental, health and transportation policy interventions in public pol-

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icy research. Such value elicitation techniques are based on standard economic theory's assumptions. One of the most stringent assumption is that economic agents behave rationally and always make decisions that maximize a given utility function (Becker 1962; Simon 1986). Empirical evidence from disciplines, such as psychology, suggests that economic behavior often deviates from this definition of rationality (e.g., Camerer 1995; Camerer 1999). This is a problem in non-market valuation because departure from rational behavior "undercuts […] the non-market valuation methods used to evaluate private choice and public policies […]" (Cherry *et al.*, 2007, Scarpa *et al.*, 2007; Burton *et al.*, 2009).

This paper contributes to this literature in several ways. The main aim of this paper is to empirically test whether respondents deviate from rational choice behavior and whether deviations from rationality have an impact on respondents' home-grown values (HGVs) elicited via SPVA and DCE. HGVs are genuinely formed by people without any direct interference from researchers about the value of the good under study (Rutsröm, 1998). Our empirical application focuses on consumers' evaluations of an information-based public policy (i.e., labelling-based intervention) aiming to shift consumers choices towards healthier and more environmentally sustainable food products. More specifically, HGVs for healthier and more environmentally sustainable versions of a ready meal (i.e., beef-based lasagne) are elicited using SPVA and DCE.

In this paper, individual deviations from rationality are investigated using induced value (IV) elicitation procedures. The value is said induced because the experimenter provides subjects with the value of the fictitious good under study during the experiment (Smith, 1976). Irrationality (or rationality) is measured investigating subjects' deviations from the payoff maximizing strategy in IV settings. Rational subjects are those who consistently make demand revealing choices (DCE) or submit demand revealing bids (SPVA) in the IV experiments. Subjects who behave irrationally are those who fail to do so. The effect of departure from rational behavior on HGVs is explored within treatment.

Second, this paper aims to test if deviations from rational behavior and the impact of such deviation on elicited HGVs depend on the nature of the elicitation mechanism: bid- or choice-based (SPVA or DCE). The framing of bid- and choice-based elicitation mechanism are different and this may have an impact on behavior in IV and HGV settings (Lusk and Schroeder, 2006; Gracia *et al.*, 2011). Third, this paper aims to test if underbidding and overbidding in the IV setting is related to bidding behavior in the HGV setting. In particular, we investigate whether underbidding and overbidding behavior in the IV setting spills over to the HGV setting. For example, subjects who tend to underbid in the IV setting bid lower than others in the HGV setting. There is empirical evidence that rationality spills over from different settings, more specifically from market-like contexts to non-market ones (Cherry *et al.*, 2003; Cherry and Shogren, 2007). Here, we aim to test whether underbidding or overbidding are behavioral phenomena that are linked more to the specific individual than the type of task. Finally, in this paper, we develop and estimate a behavioral model to identify main determinants of subjects' rationality in IV settings. To the best of our knowledge, we are not aware of other studies performing this analysis in the literature.

By using the same dataset used in Cerroni *et al.* (2019), this paper generates new insight into the link between rationality, bidding and choice behavior. The study provides

new evidence on whether rationality is affected by the use of bid- and choice-based value elicitation mechanisms and whether potential deviations from rationality have an impact on HGVs across mechanisms. This evidence can generate new knowledge regarding the reliability and accuracy of HGVs elicited via SPVA and DCE and have important implications for businesses and policy makers who need reliable evidence in order to predict people's behavior and allows making cost-effective decisions (Kassas *et al.*, 2018; Ortega *et al.*, 2018).

2. Background

2.1 Healthier and more environmentally sustainable food choices

Consumers' food choices contribute to the high prevalence of diet-related diseases and climate change (e.g., Tilman and Clark, 2014). A shift towards more sustainable diets is needed to reduce the cost that obesity and climate change are having on the economy (e.g., Bryngelsson *et al.*, 2016; Santini *et al.*, 2017). Sustainable diets are very complex and were defined as: "those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources." (FAO, 2012).

A relatively substantial amount of research has focused on identifying the main traits of sustainable diets from a nutrition and environmental point of view (e.g., Macdiarmid *et al.* 2012). However, few studies have investigated consumers' acceptability of proposed sustainable diets (e.g., Macdiarmid *et al.*, 2016). The present study contributes to this literature investigating acceptability of sustainable diets by exploring consumers' trade-offs between two food attributes, namely healthiness and carbon footprint. The vast majority of research generally focused on one attribute or the other (e.g., Drichoutis *et al.*, 2006; Belcombe *et al.*, 2010; Caputo *et al.*, 2013; Akaichi *et al.*, 2017; Castellari *et al.*, 2019), but failed to investigate whether and to what extent consumers compromise between healthiness and environmental sustainability of food products when they make purchasing decisions (a noticeable exception is Koistinen *et al.* 2013). The understanding of such trade-offs is important to design information-based policy intervention aiming to promote the uptake of sustainable diets.

2.2 Home-grown values elicited via SPVA and DCE

SPVA and DCE are widely used to elicit HGVs for innovative food products and estimate net benefits of new public policies. Elicitation procedures used in SPVA and DCE are very different (Lusk and Schroeder, 2006; Gracia *et al.*, 2011). In SPVA, subjects are asked to bid for a series of goods. The bidder who submit the highest bid buys a good, which is randomly selected at the end of the experiment, at a price equal to the second highest bid for that good. In DCE, subjects are asked to make repeated purchasing choices in a series of choice scenarios that generally present a couple of goods and an opt-out alternative. Subjects buy the good that they have chosen (if any) in one

choice scenario that is selected at random. They pay the price that is associated to the chosen good.[1]

Economic theory predicts that HGVs elicited for the same good should be equal across methods when a proper incentive scheme is used (i.e., isomorphism). However, empirical evidence does not support this prediction. Lusk and Schroeder (2006) showed that WTP estimates elicited via SPVA are lower than those elicited via DCE. Grebitus *et al.* (2013) suggested that personality traits partially explain this difference.[2] Cerroni *et al.* (2019) found that this difference is due to value-formation and value-elicitation issues. Subjects form their preferences differently across mechanisms and the SPVA is less empirically demand revealing than DCE.

Differences in value formation may be driven by the fact that SPVA and DCE expose subjects to very different valuation environments and framings (Lusk and Schroeder, 2006; Gracia *et al.*, 2011). While, in DCE, subjects are asked to make private purchasing choices and each subject's outcome is independent from others' decisions, in SPVA, subjects are asked to place bid in a competitive environment and each subject's outcome depends on others' bidding behavior. While, in DCE, the price of goods is provided in the choice scenarios and represents only one additional attribute of the presented goods, in SPVA, subjects are asked to formulate the price that they are willing to pay for the auctioned good without having any reference.

2.3 Rationality in SPVA and DCE

Standard economic theory suggests that SPVA and DCE are theoretically demand revealing (incentive compatible) under a proper monetary incentive scheme. Value elicitation issues (or empirical demand revelation) can be tested by using IV experimental procedures (Smith, 1976). Experimental evidence shows that subjects often deviate from rational behavior in IV experiments. In SPVA, the weakly dominant strategy is to bid the IV associated to the fictitious good under valuation. Empirical evidence suggests that bidding behavior often deviates from the weakly dominant strategy in SPVA (e.g., Kaegel *et al.*, 1987; Kaegel and Levine, 1993; Shogren *et al.*, 2001; Lusk and Shogren, 2007; Drichoutis *et al.*, 2015). Overbidding is the most common form of departure from rationality (e.g., Kaegel *et al.*, 1987; Georganas *et al.*, 2017), however a number of studies reported underbidding (e.g., Shogren *et al.* 2001; Hong and Nishimura, 2003; Noussair *et al.*, 2004). Subjects deviate from rational behavior for two reasons. First, they fail to understand the incentives for truthful value revelation. Kagel, Harstad and Levine (1987) and, more recently, Ausubel (2004) argued that subjects find SPVAs difficult to understand. Li (2017) differentiated "obviously strategy-proof" and "not obviously strategy-proof" elicitation mechanisms. A mechanism is obviously strategy-proof when the best

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[1] We acknowledge that DCE has been mostly used in hypothetical settings. In this paper, we only focus on research using DCE in incentivised and non-hypothetical settings.

[2] Other studies showed that isomorphism is not satisfied when HG preferences are elicited using other institutions. For example, Rutström (1995) compared English auction, Vickrey auction and the Becker-DeGroot-Marschak mechanism (BDM); Gracia *et al.* (2011) compared random nth auction and DCE; Lusk *et al.* (2004) compared SPVA, English auction, random nth auctions and BDM; Akaichi *et al.* (2013) compared choice-based DCE and ranking-based DCE.

outcome that subjects can obtain by deviating from the dominant strategy is never superior to the worst outcome they can obtain by sticking to the dominant strategy. SPVA is not obviously strategy-proof and therefore becomes cognitively demanding for subjects (Lee *et al.*, 2017). Second, SPVA is not necessarily incentive compatible when subjects behave accordingly to some non-standard expected utility theories (Horowitz, 2006). For example, reference-dependent preference models such as those formulated by Köszegi and Rabin (2006).

Demand revelation in DCEs has received less scrutiny. Nevertheless, deviations from the dominant strategy, which is choosing the payoff maximizing alternative in each choice scenario, seems to be less systematic (Collins and Vossler, 2009; Luchini and Watson, 2014; Bazzani *et al.*, 2018). Collins and Vossler's (2009) found a high level of demand revelation in referenda-style DCEs. However, Luchini and Watson (2014) provided less encouraging results in a DCE for a private good. Bazzani *et al.* (2018) showed that demand revelation at individual level depends on assumptions made about the distribution of estimated marginal willingness to pay (WTP). Recently, Cerroni *et al.* (2019) found that DCEs are more empirically demand revealing than SPVAs and showed that value-elicitation issues contribute to differences in HGVs elicited via the two mechanisms in their artefactual field experiment (Harrison and List, 2004) that combines HGV and IV procedures.

3. Material and methods

3.1 Empirical application

The paper focuses on HGVs for a new food policy that aims to inform consumers about the healthiness (measured in terms of saturated fat content) and environmental sustainability (measured in terms of carbon footprint) of food products. This information is delivered using a traffic light system (TLS) related to food's carbon footprint, where red stands for high, amber for average, and green for low carbon footprint. This TLS is presented alongside a standard TLS indicating the healthiness of food products: where red stands for unhealthy, amber for average, and green for healthy food (Department of Health, 2016).[3] The experimental product is a popular ready meal in the UK: frozen beef lasagne.

During the experiment, subjects are presented with nine different lasagne that vary in terms of healthiness (3 levels) and carbon footprint (3 levels). These parameters are varied across lasagne by changing the proportions of the traditional lasagne's ingredients (e.g. beef, pasta, sauce, cheese, etc.). All lasagne have similar appearance and portion size (400 grams). Recipes were developed by nutritionists, lasagne were pre-cooked by professional cooks and kept frozen at the Rowett Institute (University of Aberdeen). The experiment was conducted at the Scottish Experimental Economics Laboratory (SEEL, University of Aberdeen).

[3] More information on how the three different levels of healthiness and carbon footprint were generated is provided in the online supplementary appendix A.

3.2 Recruitment and sample characterization

The pool of sample subjects is the same included in the study by Cerroni *et al.* (2019) and consists of 128 consumers recruited from the general population of Aberdeen and surroundings (Scotland, UK). Subjects were recruited using a variety of methods, including posters and flyers distributed in the city (e.g. University campus, community centers, local workplaces, retail outlets, community events) as well as snowball sampling. This means that we have a non-probability sample. An information sheet describing the study was sent to people who responded to the adverts. They were told that the aim of the study was to understand the decisions people make when choosing food (in this case a beef lasagne) and they would have the chance to buy one of the lasagne based on the choices they made in the experiment.

Subjects aged 18 or older were recruited. The average age was 36 years, the minimum and maximum age were 19 and 70 respectively. The sample consisted of 64% females and the average annual income was approximately £38,000. Subjects were given a show-up fee of £10 for participating to the study. Those who purchased food paid in cash and left the experiment with £10 minus the price they paid. Subjects who purchased the food were given a cooling bag to keep the food frozen during the remaining part of the day. The study received ethical approval from the Rowett Institute Ethics Committee at the University of Aberdeen.

3.3 Experimental design

The experimental design consists of two treatment groups, one for each value elicitation mechanism: SPVA or DCE. In each treatment, both IVs and HGVs are elicited. HGVs were elicited for the multi-attribute lasagne described above. The SPVA treatment consists of 63 subjects, the DCE treatment of 65. Subjects who signed up for the study were randomly assigned to treatments. Subjects were asked to complete a number of tasks in the following order: a warm-up questionnaire on self-reported level of hunger and satiety, IV task, HGV task and a questionnaire on consumption habits and socio-economic status. To avoid biases such as the earning effect, subjects were informed about earning (or losses) from the IV task at the very end of the experiment. In total, eight sessions were conducted between January 2015 and September 2017, eight for the SPVA and five for the DCE. Four of the SPVA sessions hosted eight subjects, two sessions hosted nine subjects, one session hosted seven subjects and the remaining session hosted six subjects. Two of the DCE sessions hosted nine subjects, the remaining three sessions hosted ten, eighteen and nineteen subjects. Sessions took place either at 1.30pm or 5.30pm to control for possible time and hunger effects.

3.3.1 SPVA in the induced value setting

In the IV setting, each subject participates in nine SPVAs for nine different tokens (see the supplementary online appendix B). Each token is associated with a different IV,

which ranges from £1.00 to £5.00 in £0.50 increments.[4] Subjects are informed that their profit depends on their bids for one specific token, called the binding token. The binding token is randomly draw at the end of the experiment. The highest bidder buys the binding token at a price, which is equal to the second highest bid. The profit made by the highest bidder is the difference between the IV associated to the binding token and the buying price. If the profit is positive, this is paid in addition to the show-up fee at the end of the experiment. If the market price is higher than the IV, the subject incurs a loss that is subtracted from the show-up fee. Standard economic theory suggests that the weakly dominant strategy is to place a bid equal to the IV of the token. Subjects who constantly follow the weakly dominant strategy are considered rational. The others' behavior departs from rationality. All steps faced by subjects during the experiment are reported in Figure 1.

Figure 1. All steps faced by subjects during the experiment.

	IV SPVA	HG SPVA	IV DCE	HG DCE
1	A bidding sheet for 9 numbered tokens is provided to subjects. A resale value is associated to each token	A bidding sheet for 9 lasagnes is provided to subjects.	9 choice sets are provided to subjects	9 choice sets are provided to subjects
2	Subjects are asked to bid for each token presented in the bid sheet	Subjects are asked to bid for each lasagne presented in the bid sheet	Subject are asked to choose their most preferred alternative in each choice set	Subject are asked to choose their most preferred alternative in each choice set
3	A binding token is identified using a random draw	A binding lasagne is identified using a random draw	A binding choice set is identified using a random draw	A binding choice set is identified using a random draw
4	The highest bidder is identified as the winner of the auction	The highest bidder is identified as the winner of the auction	The profit, which is equal to the induced value minus the market price, is paid	The selected lasagne (if any) is bought at the market price reported in the binding choice set
5	The second highest bid represent the market price	The second highest bid represent the market price		
6	The profit, which is equal to the induced value minus the market price, is paid	The binding lasagne is bought by the winner at the market price		

3.3.2 SPVA in the home-grown value setting

In the HGV setting, each subject bids for the nine different lasagne (all possible combinations of lasagne's healthiness and carbon footprint levels) (see the supplementary online appendix B). The order in which lasagne were presented was randomized across subjects to minimize order learning and fatigue effects. Subjects can purchase only one lasagne, the binding lasagne. They were informed that the binding lasagne is randomly draw at the end of the study. As standard in SPVA, the highest bidder buys the binding

[4] Each subject faces the whole range of induced values, but the order of induced values varied across subjects.

lasagne at a price, which is equal to the second highest bid. This amount of money is subtracted from the show-up fee. All steps faced by subjects during the experiment are reported in Figure 1.

3.3.3 DCE in the induced value setting

In the IV setting, each subject faces nine choice sets that are generated using a fractional factorial design (ChoiceMetrics 2012) (see the supplementary online appendix B for an example). Each choice set contains two tokens plus an opt-out alternative. Tokens are described using two attributes: the market price and the IV. The market prices and the IV range from £1.00 to £5.00 in £0.50 increments. Subjects are informed that their profit depends on the option they chose in the binding choice set. The binding choice set is randomly drawn at the end of the experiment. The profit is the difference between the IV and the market price associated to the chosen token in the binding choice set. If the profit is positive, this is paid in addition to the show-up fee at the end of the experiment. If the market price is higher than the IV, the subject incurs a loss that is subtracted from the initial show-up fee. The order of choice sets was randomized across subjects. Standard economic theory suggests that subjects should always choose the alternative that maximizes their payoff. Subjects who constantly follow this strategy are considered rational. The others' behavior departs from rationality.

This experimental design differs from previous studies (Collins and Vossler, 2009; Luchini and Watson, 2014; Bazzani *et al.*, 2018) where tokens with multiple attributes (i.e., color and shape) were used and marginal IVs were associated with attribute levels. While in previous studies, subjects are asked to compute the final IV of tokens mathematically, in this experiment, subjects are provided with that. This typology of design was chosen because it mirrors the design of a standard SPVA conducted in an IV setting. In the IV SPVA literature, subjects are not asked to compute the IVs of tokens, instead, they are directly provided with these.[5] All steps faced by subjects during the experiment are reported in Figure 1.

3.3.4 DCE in the home-grown value setting

In the HGV setting, each subject is presented with nine choice sets created by using a D-efficient design (ChoiceMetrics, 2012) (see the supplementary online appendix B for an example).[6,7] Each choice set contains two lasagne and an opt-out alternative. Lasagne are described by three attributes: healthiness, carbon footprint and market price. Healthiness and carbon footprint can be green, amber or red (3 levels per attribute). The market price ranges from £1.00 to £5.00 in £0.50 increments. The order of choice sets was randomized across subjects. Subjects are informed that they buy the selected option in the binding

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[5] An alternative design would involve the provision of tokens with multiple attributes (i.e., colour and shape) and marginal IVs associated with attribute levels. Subjects would be asked to mathematically compute the IVs for each token and place their bids. This design will make the SPVA mirroring the DCE as designed by Collins and Vossler (2009) and Luchini and Watson (2014).

[6] Priors were estimated using data collected from a pilot study with 10 subjects.

[7] Data from the additional nine choice sets that are presented to subjects after being provided with additional information on saturated fat and carbon footprint are not included in our analyses to avoid confounding.

choice set. The binding choice set is randomly selected at the end of the experiment. If they chose a lasagne, they buy the lasagne at the corresponding price. This amount of money is deducted from the show-up fee. If they selected the opt-out alternative, they do not purchase the lasagne. All steps faced by subjects during the experiment are reported in Figure 1.

4. Testable hypotheses, model specifications, results and discussion

4.1 Deviations from rationality and home-grown values elicited via the SPVA

4.1.1 Overview of deviations from rationality

Subjects' bidding behavior and deviations from rationality in the IV SPVA are reported in Table 1a and 1b. Subjects are considered rational if and only if they submit only demand revealing bids in the IV task, meaning that 9 demand revealing bids (out of 9) are submitted. Bids are demand revealing, if and only if, these are equal to IVs. In fact, the payoff maximizing strategy is to submit bids that are equivalent to tokens' IVs. Subjects who fail to submit only demand revealing bids deviate from rational behavior. In our sample, we have 14 rational subjects (22.22%) and 49 subjects (77.80%) who deviate from rationality (Table 1a). It is interesting to note that there are no subjects who submit 7 or 8 (out of 9) demand revealing bids. This may indicate that subjects do not make random mistakes, they simply understand the experimental procedure (when they submit 9 demand revealing bids out of 9) or not (when they submit 6 or less demand revealing bids out 9). Overall, these results seem to suggest that subjects do not easily identify the payoff maximizing strategy of SPVA as already argued by Kagel *et al.* (1987), Ausubel (2004) and Li (2017).

Among subjects who deviate from rationality, we have 22 (34.92%) who constantly underbid (9 underbids out of 9 bids) and only 2 (3.17%) who constantly overbid (9 overbids out of 9 bids). A subject underbids (overbids) when submits a bid that is lower (higher) than the associated IV. The remaining sample has a mixed behavior (25 subjects, 39.68%). In the "mixed behavior" category we have: i) those who underbid and overbid (5 subjects, 20.00%), ii) those who underbid and submit demand revealing bids (7 subjects, 28.00%), iii) those who overbid and submit demand revealing bids (6 subjects, 24.00%) and iv) those who underbid, overbid and submit demand revealing bids (7 subjects, 28.00%) (Table 1b). Despite the bulk of research reports overbidding (e.g, Kaegel *et al.*, 1987; Georganas *et al.*, 2017), there are a number of empirical studies that provide evidence for underbidding (e.g., Shogren *et al.*, 2001; Noussair *et al.*, 2004). Previous research has conjectured that overbidding arises when subjects understand that high bids increase the probability of winning, but fail to realize that high bids may generate negative payoffs (Georganas *et al.*, 2017). Our subjects seem to overestimate the additional cost of overbidding on the final payoff.

4.1.2 Testable hypotheses and model specifications

The influence of departures from rational behavior on HGVs for lasagne is explored by estimating Model 1 using a feasible generalized least-square regression with correction

Table 1a. Categorization of subjects' bidding behavior[a].

Consistent rational behavior[b]	Consistent underbidding[c]	Consistent overbidding[d]	Mixed behavior[e]
14 (22.22%)	22 (34.92%)	2 (3.17%)	25 (39.68%)

Table 1b. Categorization of subjects' bidding behavior within the mixed behavior category[a].

Underbidding and Overbidding[f]	Underbidding and rational behavior[g]	Overbidding and rational behavior[h]	Underbidding, overbidding and rational behavior[i]
5 (20.00%)	7 (28.00%)	6 (24.00%)	7(28.00%)

[a] Number of subjects per category.
[b] Consistent rational behavior = 9 demand revealing bids out of 9 submitted bids.
[c] Consistent underbidding behavior = 9 underbids out of 9 submitted bids.
[d] Consistent overbidding behavior = 9 overbids out of 9 submitted bids.
[e] Mixed behavior = all the other subjects.
[f] Underbidding and overbidding = subjects who underbid and overbid.
[g] Underbidding and rational behavior = subjects who underbid and submit demand revealing bids.
[h] Overbidding and rational behavior = subjects who underbid, overbid and submit demand revealing bids.
[i] Underbidding, overbidding and rational behavior = subjects who overbid and submit demand revealing bids.

for heteroscedasticity. This model tests whether HGVs differ between subjects who consistently submit demand-revealing bids in the IV SPVA (i.e., subjects who behave rationally) and the others (i.e., subjects whose behavior deviates from rationality).[8] Main statistics of all variables used in Model 1 are described in Table 2.[9] Model 1 takes the functional form in Equation 1:

$$BID\_HG_{i,q} = \alpha + \beta_{HEA\_A}\, HEA\_A_{i,q} + \beta_{HEA\_G}\, HEA\_G_{i,q} + \beta_{CF\_A}\, CF\_A_{i,q} + \beta_{CF\_G}\, CF\_G_{i,q} + \beta_{HEA\_A\_IRR}\, HEA\_A_{i,q} * IRR_{i,q} + \beta_{HEA\_G\_IRR}\, HEA\_G_{i,q} * IRR_{i,q} + \beta_{CF\_A\_IRR}\, CF\_A_{i,q} * IRR_{i,q} + \beta_{CF\_G\_IRR}\, CF\_G_{i,q} * IRR_{i,q} + \varepsilon_{i,q} \quad (1)$$

The dependent variable ($BID\_HG_{i,q}$) is each subject i's bids for lasagne $q \neq 1$ ($BID\_HG_{i,q\neq1}$) minus subject i's bid for the lasagne, which is red in healthiness and carbon footprint, $BID\_HG_{i,q=1}$. Therefore, $BID\_HG_{i,q} = BID\_HG_{i,q\neq1} - BID\_HG_{i,q=1}$.

The coefficients β_{HEA_A} and β_{HEA_G} indicate the average marginal willingness to pay ($mWTP$) for lasagne that are amber ($HEA\_A_{i,q}$) and green ($HEA\_G_{i,q}$) in healthiness, respectively. The coefficient β_{CF_A} and β_{CF_G} denote the average $mWTPs$ for lasagne that are

[8] This estimation procedure was used because we tested and rejected normality and homoscedasticity conducting a Shapiro-Wilk test and a Log-likelihood ratio-test, respectively. A random-effect model for panel data was not used because less efficient.
[9] Detailed summary statistics of marginal bids for each lasagne type are provided in Tables C1 in the online supplementary appendix C.

Table 2. Summary statistics of variables included in the SPVA-related Models.

Variable	Description	Obs.	Mean	St.Dev.	Min	Max
BID_HG	Marginal bid for healthy and low carbon footprint lasagne[a]	504	0.794	1.447	-4.000	5.000
HEA_R	= 1 if health is red = 0 otherwise	504	0.250	0.433	0.000	1.000
HEA_A	= 1 if health is amber = 0 otherwise	504	0.375	0.485	0.000	1.000
HEA_G	= 1 if health is green = 0 otherwise	504	0.375	0.485	0.000	1.000
CF_R	= 1 if carbon footprint is red = 0 otherwise	504	0.250	0.433	0.000	1.000
CF_A	= 1 if carbon footprint is amber = 0 otherwise	504	0.375	0.485	0.000	1.000
CF_G	= 1 carbon footprint is green = 0 otherwise	504	0.375	0.485	0.000	1.000
IRR	= 1 if subject behaves irrationally = 0 otherwise	504	0.778	0.416	0.000	1.000
UND	= 1 if subject consistently underbids = 0 otherwise	504	0.349	0.477	0.000	1.000

[a] A marginal bid is the difference between any lasagne other than a red in health and red in carbon footprint (in £) and the bid for a red in health and red in carbon footprint lasagne.

amber ($CF\_A_{i,q}$) and green ($CF\_G_{i,q}$) in carbon footprint, respectively. These *mWTP*s are estimated with respect to red levels of healthiness and carbon footprint, respectively.

The variable *IRR* is equal to 1 if subject *i* fails to submit only demand revealing bids in the IV task, meaning that less than 9 demand revealing bids (out of 9) are submitted. Hence, the variable *IRR* is equal to 1 if subject *i* behaves irrationally. The coefficient $\beta_{HEA\_A\_IRR}$, $\beta_{HEA\_G\_IRR}$, $\beta_{CF\_A\_IRR}$ and $\beta_{CF\_G\_IRR}$ measure the difference in *mWTPs* for healthy and environmental sustainable lasagne between subjects who behave irrationally (those who fail to submit only demand revealing bids in the IV task) and rationally (those who submit only demand revealing bids in the IV task).

4.1.3 Results and discussion

Results from the estimation of Model 1 are reported in Table 3. The positive and statistically significant coefficients $\beta_{HEA\_A\_IRR}$ (0.255, $p<0.05$), $\beta_{HEA\_G\_IRR}$ (0.546, $p<0.01$), $\beta_{CF\_A\_IRR}$ (0.279, $p<0.05$) and $\beta_{CF\_G\_IRR}$ (0.520, $p<0.01$) indicate that subjects who deviates from rational behavior have higher *mWTP*s for lasagne's attributes than rational ones. A Wald Test rejects the null hypothesis that coefficients $\beta_{HEA\_A\_IRR}$, $\beta_{HEA\_G\_IRR}$, $\beta_{CF\_A\_IRR}$, $\beta_{CF\_G\_IRR}$ are jointly equal to zero (100.130, $p<0.01$).[10,11] If we are willing to assume that bids

[10] Other models were estimated to test the consistency of our results. These models incorporate the rate of submitted non-demand revealing (irrational) bids. Estimation results are provided in the online supplementary appendix D.

[11] As Model 1 is estimated using feasible generalized least squares (FGLS), R^2 is not an appropriate indicator of explanatory power. Here, we report the Wald $\chi 2$ which is equal to 282.88 and is significant level at $p<0.01$. We also estimated Model 1 using the iterated GLS estimator (IGLS), which allows estimating the log-likelihood.

submitted by rational subject are most accurate, these results suggest that failure to submit demand revealing bids in the IV setting generate upwardly biased HGV estimates. This assumption appears to be reasonable, if we consider that irrational subjects are those who failed to consistently identify the payoff maximizing strategy in the IV setting. Deviations from rationality can therefore have an important impact on the evaluation of innovative food products and welfare benefits produced by new agri-food policies.

4.2 Underbidding and home-grown values elicited via SPVA

4.2.1 Testable hypotheses and model specifications

Model 2 is estimated to investigate whether underbidding in the IV setting spills over to the HGV setting. Model 2 is equivalent to Model 1, except for the addition of the interaction variable *IRR_UND = IRR * UND*. The variable *UND* denotes subjects who constantly underbid (9 underbids out of 9 bids) and hence the interaction variable *IRR_UND* denotes those subjects who consistently underbid among those categorized as irrational. A subject underbids when submits a bid that is lower than the associated IV. The subjects who constantly underbid are 22 (34.92%) (Table 1a). We refrain to investigate whether overbidding spills over from the IV to the HGV setting because only 2 subjects (3.17%) in our sample constantly overbid (9 overbids out of 9 bids) in the IV task (Table 1a).

Model 2 is estimated using a feasible generalized least-square regression with correction for heteroscedasticity and inform on whether subjects who constantly underbid in the IV task have lower HGVs for lasagne's attributes than the other subjects whose behavior deviates from rationality. Others are those who constantly overbid and those who have a mixed behavior.

Model 2 takes the form below (Equation 2):

$$BID\_HG_{i,q} = \alpha + \beta_{HEA\_A}\, HEA\_A_{i,q} + \beta_{HEA\_G}\, HEA\_G_{i,q} + \beta_{CF\_A}\, CF\_A_{i,q} + \beta_{CF\_G}\, CF\_G_{i,q} + \beta_{HEA\_A\_IRR}\, HEA\_A_{i,q} * IRR_{i,q} + \beta_{HEA\_G\_IRR}\, HEA\_G_{i,q} * IRR_{i,q} + \beta_{CF\_A\_IRR}\, CF\_A_{i,q} * IRR_{i,q} + \beta_{CF\_G\_IRR}\, CF\_G_{i,q} * IRR_{i,q} + \beta_{HEA\_A\_IRR\_UND}\, HEA\_A_{i,q} * IRR\_UND_{i,q} + \beta_{HEA\_G\_}$$

Table 3. Generalized least-square regression models with correction for heteroscedasticity for SPVA data.

Dep. Var: *BID_HG*	
Coefficients	Model 1
β_{HEA_A}	0.710***
	(0.096)
β_{HEA_G}	1.254***
	(0.0961)
β_{CF_A}	0.578***
	(0.0961)
β_{CF_G}	0.873***
	(0.0961)
$\beta_{HEA\_A\_IRR}$	0.255**
	(0.126)
$\beta_{HEA\_G\_IRR}$	0.546***
	(0.126)
$\beta_{CF\_A\_IRR}$	0.279**
	(0.126)
$\beta_{CF\_G\_IRR}$	0.520***
	(0.126)
α	-0.298***
	(0.099)
Wald Test [b]: χ^2	100.130***
Obs.	504
Subjects	63

Note: ***p<0.01; **p<0.05; *p<0.10

[a] Standard Errors in parentheses

[b] H_0: $\beta_{FAT\_A\_IRR}=\beta_{FAT\_G\_IRR}=\beta_{CF\_A\_IRR}=\beta_{CF\_G\_IRR}=0$

The latter is equal to – 676.632.

$_{IRR\_UND}\ HEA\_G_{i,q} * IRR\_UND_{i,q} + \beta_{CF\_A\_IRR\_UND}\ CF\_A_{i,q} * IRR\_UND_{i,q} + \beta_{CF\_G\_IRR\_UND}$
$CF\_G_{i,q} * IRR\_UND_{i,q} + \varepsilon_{i,q}$ (2)

4.2.2 Results and discussion

Results from the estimation of Model 2 are shown in Table 4 and suggest that underbidding spills over from the IV to the HGV task. Subjects who consistently underbid in the IV setting have lower HGVs than the other subjects who behave irrationally. The coefficients $\beta_{HEA\_A\_IRR\_UND}$, $\beta_{CF\_A\_IRR\_UND}$ and $\beta_{CF\_G\_IRR\_UND}$ are not statistically significant. However, the coefficient $\beta_{HEA\_G\_IRR\_UND}$ is negative and statistically significant (-0.361, $p<0.05$). A Wald test rejects the hypothesis that all these coefficients are jointly equal to zero (11.940, $p<0.05$).[12,13] These results are consistent with previous finding by Cherry *et al.* (2003) and Cherry and Shogren, (2007) and indicate that underbidding may be an intrinsic individual-specific behavior that does not depend on the type of task (IV or HGV). Further research is needed to investigate further this intriguing hypothesis.

4.3 Deviations from rationality and home-grown values elicited via the DCE

4.3.1 Overview of deviations from rationality

Subjects are considered rational when they submit only demand revealing choices (9 out of 9 choices) in the IV DCE task. A choice is demand revealing when it maximizes the subjects' payoff that subjects can obtain in the choice set. In other words, when it maximizes the difference between the IV and the market price. Deviations from rational choice behavior occur when subjects fail to submit only demand revealing choices. In our sample, 40 subjects out of 65 (61.50%) deviate from rational choice behavior, while 25 subjects (38.50%) are rational. Similar to the SPVA, we found that no subjects submit 7 or 8 demand revealing choices which may indicate that subjects do not make random mistakes.

4.3.2 Testable hypotheses and model specification

We estimate random-parameter logit models in WTP space to test whether HGVs elicited from subjects who behave irrationally in the IV DCE task differ from those elicited from rational subjects. Models in WTP space reduce possible biases due to the confounding of variation in scale and WTP (Train and Weeks, 2005). Some studies have shown that models in WTP space fit data better than those in preference space (e.g., Scarpa *et al.*, 2008)

In Model 3, the indirect utility function is specified as in Equation 3:

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[12] Other models were estimated which incorporate the rate of underbidding and exclude those subjects who constantly overbids (just two) from the analyses, considering them as outliers. Results are provided in the online supplementary appendix E.

[13] Models 2 is estimated using feasible generalized least squares (FGLS) and R^2 is not an appropriate indicator of explanatory power. Here, we report the Wald $\chi 2$ which is equal to 297.140 and is significant level at $p<0.01$. We also estimated Model 2 using the iterated GLS estimator, which allows estimating the log-likelihood. The latter is equal to – 660.525.

$$V_{i,j,k} = -\lambda_i PR_{i,j,k} + (\lambda_i + \boldsymbol{\omega_i})\boldsymbol{x_{i,k,j}} \quad (3)$$

In Equation 3, $\lambda_i = \alpha_i / \mu_i$, where α_i indicates subjects' preferences for the price of lasagne $PR_{i,j,k}$ and μ_i is the scale parameter. The coefficient vector $\omega_i = \theta_i / \alpha_i$ is the ratio of the vector of coefficients θ_i that are associated to the vector of non-price attributes $\boldsymbol{x_{i,j,k}}$ and the coefficient α_i. The vector ω_i indicates the *mWTPs* associated to the vector of non-price attributes $\boldsymbol{x_{i,j,k}}$.

The coefficient $\omega_{opt\text{-}out}$ is an alternative specific constant related to the opt-out alternative. The coefficients $\omega_{HEA\_A,i}$ and $\omega_{HEA\_G,i}$ denote *mWTPs* for lasagne that are amber ($HEA\_A_{i,j,k}$) and green ($HEA\_G_{i,j,k}$) in the health dimension, respectively. The coefficients $\omega_{CF\_A,i}$ and $\omega_{CF\_G,i}$ indicate *mWTPs* for lasagne that are amber ($CF\_A_{i,j,k}$) and green ($CF\_G_{i,j,k}$) in carbon footprint, respectively. These *mWTPs* are estimated with respect to red levels of healthiness and carbon footprint, respectively. To account for unobserved heterogeneity, we assume that the coefficients ω_{HEA_A}, ω_{HEA_G}, ω_{CF_A} and ω_{CF_G} are normally distributed, while the α_i is log-normally distributed with means and standard deviations to be estimated.

The variable *IRR* is equal to 1 if subject *i* behaves irrationally in the IV DCE task, meaning that she/he fails to submit only demand revealing choices (9 out of 9 choices). The coefficients $\omega_{HEA\_A\_IRR}$, $\omega_{HEA\_G\_IRR}$, $\omega_{CF\_A\_IRR}$ and $\omega_{CF\_G\_IRR}$ inform on whether *mWTPs* differ between subjects whose behavior deviates from rationality in the IV task and the others (i.e., rational). Models 3 is estimated by using methods of maximum simulated likelihood relying on 1,000 Halton draws (Train, 2009). Summary statistics of variables used in Model 3 are presented in Table 5.

4.3.3 Results and discussion

Results from estimation of Model 3 are reported in Table 6. We find that coefficients $\omega_{HEA\_A\_IRR}$ and $\omega_{HEA\_G\_IRR}$ are not statistically significant. The coefficient $\omega_{CF\_A\_IRR}$ is positive and statistically significant (0.433, $p<0.05$), which suggests that subjects who behave irrationally (in the IV DCE task) are willing to pay more than others (i.e., rational subjects) for lasagne that are amber in carbon footprint. In contrast, $\omega_{CF\_G\_IRR}$ (-0.317, $p<0.01$) is negative and statistically

Table 4. Generalized least-square regression models with correction for heteroscedasticity for SPVA data.

Dep. Var: *BID_HG*	
Coefficients	Model 2
β_{HEA_A}	0.457***
	(0.116)
β_{HEA_G}	0.710***
	(0.116)
β_{CF_A}	0.301***
	(0.116)
β_{CF_G}	0.355***
	(0.116)
$\beta_{HEA\_A\_IRR}$	0.186
	(0.142)
$\beta_{HEA\_G\_IRR}$	0.704***
	(0.142)
$\beta_{CF\_A\_IRR}$	0.245*
	(0.142)
$\beta_{CF\_G\_IRR}$	0.582***
	(0.142)
$\beta_{HEA\_A\_IRR\_UND}$	0.141
	(0.150)
$\beta_{HEA\_G\_IRR\_UND}$	-0.361**
	(0.150)
$\beta_{CF\_A\_IRR\_UND}$	0.0654
	(0.150)
$\beta_{CF\_G\_IRR\_UND}$	-0.155
	(0.150)
α	-0.300***
	(0.0980)
Wald Test [b]: χ^2	98.330***
Wald Test [c]: χ^2	11.940**
Obs.	504
Subjects	63

Note: ***p<0.01; **p<0.05; *p<0.10

[a] Standard Errors in parentheses

[b] H_0: $\beta_{FAT\_A\_IRR} = \beta_{FAT\_G\_IRR} = \beta_{CF\_A\_IRR} = \beta_{CF\_G\_IRR} = 0$

[c] H_0: $\beta_{FAT\_A\_IRR\_UND} = \beta_{FAT\_G\_IRR\_UND} = \beta_{CF\_A\_IRR\_UND} = \beta_{CF\_G\_IRR\_UND} = 0$

Table 5. Summary statistics of variables included in the DCE Model.

Variable	Description	Obs.	Mean	St.Dev.	Min	Max
CH_HG	= 1 if alternative A is selected = 0 otherwise	585	1.099	0.800	0.000	2.000
HEA_R[a]	= 1 if health is red in alternative A and B = 0 otherwise	585	0.333	0.472	0.000	1.000
HEA_A	= 1 if health is amber in alternative A and B = 0 otherwise	585	0.333	0.472	0.000	1.000
HEA_G	= 1 if health is green in alternative A and B = 0 otherwise	585	0.333	0.472	0.000	1.000
CF_R[a]	= 1 if carbon footprint is red in alternative A and B = 0 otherwise	585	0.333	0.472	0.000	1.000
CF_A	= 1 if carbon footprint is amber in alternative A and B = 0 otherwise	585	0.333	0.472	0.000	1.000
CF_G	= 1 if carbon footprint is green in alternative A and B = 0 otherwise	585	0.333	0.472	0.000	1.000
PR[b]	Price of alternative A and B	585	3.000	1.292	1.000	5
IRR	= 1 if subjects behave irrationally = 0 otherwise	585	0.615	0.486	0.000	1.000

[a] Health and environmental sustainability are not defined in the not-buy alternative (C).

[b] Price ranges from £1 to £5, it is =0 for the not-buy alternative (C).

significant which indicates that subjects who behave irrationally (in the IV DCE task) are willing to pay less than others (i.e., rational subjects) for lasagne that are green in carbon footprint. A Wald Test rejects the null hypothesis that coefficients $\beta_{HEA\_A\_IRR}$, $\omega_{HEA\_G\_IRR}$, $\omega_{CF\_A\_IRR}$, $\omega_{CF\_G\_IRR}$ are jointly equal to zero (9.570, $p<0.05$). Overall, these results show that deviations from rationality in the IV task affect estimated HGVs far less in the DCE than in the SPVA treatment group.[14] Such results may be related to the fact that DCE does not require any strategic interaction among subjects participating to the experiment and expose subjects to decision tasks that resemble "real-life" purchasing situations. These factors may lower the impact that deviations from rationality investigated using IV procedures have on HGVs elicited for lasagne.

4.4 Determinants of irrational bidding and choice behavior

A behavioral model aiming to capture variables explaining irrational bidding and choice behavior is developed (Model 4). Data from the SPVA and DCE treatment groups are pooled. The dependent variables *IRR* is a binary variable, indicating if subjects' bidding or choice behavior deviates from rationality in the IV settings. We included only independent variables that potentially affect the probability of submitting/making demand

[14] To test the consistency of estimation results, an alternative model was estimated. In this model, we incorporate the rate of non-demand revealing choices made per subjects. This variable indicates the rate of irrationality. Estimation results are provided in Tables F2 and F3 of the supplementary online appendix F.

revealing bids/choices. These are: *DCE* which indicates whether the subject belong to the DCE treatment or not; *TIME* which indicates whether the subjects participated to the 13.30 or 18.30 session; *HUNGRY* which indicates the self-reported level of hunger of subjects at the beginning of the experiment (from a minimum of 1 to a maximum of 7), *FEMALE* which indicate if the subject is female or not; *AGE* indicating each subject's age; *INCOME* which indicates each subjects' annual net income.

Summary statistics of variables incorporated in our behavioral models are provided in Table 7. The estimation results of Model 4 are presented in Table 8. We find that the coefficient β_{DCE} is negative and statistically significant (-2.282; $p<0.01$) which indicates that irrational behavior is more likely in the SPVA than in the DCE. We also find that subjects' hunger level (β_{HUNGRY}) has a negative and statistical significant (-0.260, $p<0.10$) effect on being irrational. This might indicate that subjects who were hungrier paid more attention to the tasks as they knew lasagne were at stakes during the experiment.[15]

5. Conclusions

Second-price Vickey auctions and discrete choice experiments are widely used to evaluate welfare benefits of new food policies that are not implemented yet. These evaluations are often used in benefit-cost analysis to decide whether to operationalize food policies or not. Therefore, it is important to explore the reliability and robustness of evaluations that are conducted using these value elicitation techniques. This paper contributes to this literature by testing if subjects behave rationally when exposed to these value-elicitation procedures and if deviations from rational choice behavior affect policy evaluation.

Psychologists and behavioral economists have challenged the main underlying assumption of neoclassical economics: economic agents always behave rationally to maximize utility. Simon's notions of sat-

[15] An alternative model in which the dependent variable is the rate of irrational bids/choices submitted is estimated. Results are provided in the online supplementary appendix G.

Table 6. WTP-space Multinomial Logit Models for DCE Data[a,b].

Dep. Var.: *CHOICE*	
Coefficients	Model 3
$\omega_{opt\text{-}out}$	2.332***
	(0.417)
$\omega_{HEA\_A,mean}$	0.497***
	(0.143)
$\omega_{HEA\_G.mean}$	1.583***
	(0.152)
$\omega_{CF\_A,mean}$	0.691***
	(0.145)
$\omega_{CF\_G,mean}$	1.772***
	(0.164)
$\omega_{HEA\_A,sd}$	1.051***
	(0.0981)
$\omega_{HEA\_G.sd}$	1.115***
	(0.121)
$\omega_{CF\_A,sd}$	0.547***
	(0.0589)
$\omega_{CF\_G,sd}$	1.341***
	(0.0954)
$\omega_{HEA\_A\_IRR}$	-0.193
	(0.223)
$\omega_{HEA\_G\_IRR}$	-0.590
	(0.414)
$\omega_{CF\_A\_IRR}$	0.433**
	(0.174)
$\omega_{CF\_G\_IRR}$	-0.317***
	(0.190)
λ_{mean}	-0.393
	(0.286)
λ_{sd}	2.018***
	(0.463)
Wald Test [c]: χ^2	9.570**
Log-likelihood	-433.913
Obs.	1,755
Subjects	65

Note: ***p<0.01; **p<0.05; *p<0.10
[a] Standard Errors in parentheses
[b] 1,000 Halton Draws
[c] H_0:$\omega_{HEA\_A\_IRR} = \omega_{HEA\_G\_IRR} = \omega_{CF\_A\_IRR} = \omega_{CF\_G\_IRR} = 0$

Table 7. Summary statistics of variables included in the behavioral model.

Variable	Description	Obs.	Mean	St.Dev.	Min	Max
IRR	= 1 if subjects behave irrationally = 0 otherwise	128	0.719	0.451	0.000	1.000
DCE	= 1 DCE treatment = 0 otherwise	128	0.508	0.502	0.000	1.000
TIME	= 1 if lunch session = 0 otherwise	128	0.516	0.502	0.000	1.000
HUNGRY	Reported level of hunger from 1 (not hungry at all) to 5 (extremely hungry)	128	4.102	1.502	1.000	6.000
FEMALE	= 1 female = 0 otherwise	128	0.637	0.482	0.000	1.000
AGE	Age in years	128	36.466	13.616	19.000	70.000
INC	Yearly net income in £	128	38,578.740	29,334.850	5,000.000	150,000.000

Table 8. Behavioral Binary Logit Model[a].

Model 6	
Dep. Var.: *DM*	**Coefficients**
β_{DCE}	-2.282***
	(0.509)
β_{TIME}	0.310
	(0.442)
β_{HUNGRY}	-0.260*
	(0.153)
β_{FEMALE}	0.334
	(0.475)
β_{AGE}	0.017
	(0.016)
β_{INCOME}	1.08e-05
	(1.12e-05)
α	2.069*
	(1.125)
Log-likelihood	-61.935
Obs.	128
Subjects	128

Note: ***p<0.01; **p<0.05; *p<0.10
[a] Standard Errors in parentheses

isficing and bounded rationality are classic examples (1955; 1986). Kahneman and Tversky have based part of their research on economic decision making on the idea that two types of cognitive processes exist, the well-known systems 1 and 2. The former is characterized by speed, intuition, associations, heuristics and emotions. The latter by slowness, reasoning, rules, logic and self-control. It is possible to argue that system 2 is dominated by rationality, while system 1 does not.

This paper explores the impact of deviations from rationality on the evaluation of new public policies interventions and focuses on an information-based food policy which aims to promote consumption of healthy and environmentally sustainable food products. These are two of the pillars of the notion of sustainable diets. Specifically, this study investigates the impact of deviations from rationality on consumers' home-grown values for ready meals (i.e., frozen lasagne) that are labelled using nutritional and carbon footprint labels. Home-grown values are elicited via bid- (i.e. second-price Vickey auctions) and choice-based methods (i.e. discrete choice experiments). Deviations from rationality are explored using induced value procedures.

Our results suggest that deviations from rationality are more likely to occur in second-price Vickey auctions than discrete choice experiments: 77.78% of the sample deviates from rational behavior in second-price Vickey auctions, only the 61.50% of the sample in discrete choice experiments. This result suggests that choice-based val-

ue elicitation techniques, such as discrete choice experiments, induce rationality more than bid-based methods, such as second-price Vickey auctions. This result seems to support Li's (2017) argument that second-price Vickey auction is not an obviously strategy-proof technique and hence identification of the payoff maximizing strategy is not obvious. Which method predict choice behavior better in real settings remains an open question.

The impact of irrationality on home-grown values in second-price Vickey auctions is rather substantial and systematic. Subjects whose behavior deviates from rationality have higher home-grown values for lasagne than rational ones. Also, our results indicate that underbidding spills over from induced-value to home-grown value settings, meaning that subjects who consistently underbid in the induced-value setting, tend to submit lower bids than the others in the home-grown setting. This is a very intriguing result, indicating that underbidding may be an intrinsic individual-specific behavior. Future research could explore cognitive processes or personal traits driving this phenomenon. On the other hand, deviations from rationality do not seem to follow a clear pattern and barely affect home-grown values elicited via discrete choice experiments. These results may be due to the fact that subjects are exposed to rather different valuations environments and framings in the second-price Vickery auctions and discrete choice experiments. For example, subjects may perceive the second-price Vickrey auction as a competitive institution and they may tend to adopt a strategic bidding behavior which is consistently used in both induced value and home-grown value settings. In contrast, in the discrete choice experiments, subjects make individual choices that do not generally depend on other consumers' decisions. Hence, strategic behavior is very limited in discrete choice experiments and this may explain why deviations from rationality in induced value setting have little impact on elicited home-grown values. Additionally, in second-price Vickrey auctions, subjects are asked to form their own home-grown values for different food products, while, in discrete choice experiments, subjects are asked to make choices among food products and market prices are given to subjects in each choice set. The former is a rather unusual situation for a consumer, while the latter is very familiar. Hence, it is reasonable to argue that irrationality may play a more substantial role in home-grown values elicited via second-price Vickery auctions than discrete choice experiments.

Overall, we conclude that home-grown values elicited via discrete choice experiments are rather robust. These results may be significant for policy makers who wish to use findings from second-price Vickrey auctions and discrete choice experiments in *ex ante* benefit-cost analyses of new policy interventions.

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7. References

Akaichi, F., Nayga R.M.Jr. and Nalley, L.L. (2017). Are there trade-offs in valuation with respect to greenhouse gas emissions, origin and food miles attributes? *European Review of Agricultural Economics* 44(1): 3-31.

Ausubel, L.M. (2004). An efficient ascending-bid auction for multiple objects. *The American Economic Review* 94(5): 1452-1475.

Bazzani, C., Palma, M.A. and Nayga, R.M.Jr. (2018). On the use of flexible mixing distributions in WTP space: an induced vale choice experiment. *The Australian Journal of Agricultural and Resource Economics* 62: 185-198.

Becker, G.M., DeGroot, M.H. and Marschak, J. (1964). Measuring Utility by a Single-Response Sequential Method. *Behavioral Science* 9: 226-32.

Balcombe, K., Fraser, I. and Di Falco, S. (2010). Traffic lights and food choice: A choice experiment examining the relationship between nutritional food labels and price. *Food Policy* 35(3): 211-220.

Burton, A.C., Carson, K.S., Chilton, S.M. and Hutchinson, W.G. (2009). Why do people non-demand reveal in hypothetical double referenda for public goods? *Applied Economics* 41(27): 3561-3569.

Bryngelsson, D., Wirsenius, S., Hedenus, F. and Sonesson, U. (2016). How can the EU climate targets be met? A combined analysis of technological and demand-side changes in food and agriculture. *Food Policy* 59: 152-164.

Caputo, V., Vassilopoulos, A., Nayga R.M.Jr., and Canavari, M. (2013). Welfare Effects of Food Miles Labels. *Journal of Consumer Affairs* 47(3): 311-327.

Castellari, E., Marette, S., Moro, D. and Sckokai, P. (2019). Can menu labeling affect away-from-home-dietary choices?. *Bio-Based and Applied Economics*, 7(3), 249-263.

Cerroni, S., Watson, V., Kalentakis, D. and Macdiarmid, J.I. (2019). Value-elicitation and value-formation properties of discrete choice experiment and experimental auctions. *European Review of Agricultural Economics* 46(1): 3-27.

Cherry, T.L., Crocker, T.D. and Shogren, J.F. (2003). Rationality spillovers. *Journal of Environmental Economics and Management* 45: 63–84.

Cherry, T.L. and Shogren, J.F. (2007). Rationality crossovers. *Journal of Economic Psychology* 28: 261–277

ChoiceMetrics, 2012. Ngene 1.1 User manual and reference guide. http://www.choice-metrics.com/download.html [accessed 11.23.2015]

Collins, J.P. and Vossler, C.A. (2009). Incentive compatibility tests of choice experiment value elicitation questions. *Journal of Environmental Economics and Management* 58: 226–235.

Downs, J.S., Loewenstein, G. and Wisdom, J. (2009). Strategies for Promoting Healthier Food Choices. *American Economic Review* 99(2): 159-164.

Department of Health. 2016. Guide to creating a front of pack (FoP) nutrition label for pre-packed products sold through retail outlets. https://www.food.gov.uk/sites/default/files/media/document/fop-guidance_0.pdf [accessed 18/07/2018]

Drichoutis, A.C., Lazaridis, P. and Nayga R.M.Jr. (2006). Consumers' use of nutritional labels: A review of research studies and issues. *Academy of Marketing Science Review* 9: 93–118.

Drichoutis, A.C., Lusk, J.L. and Nayga R.M.Jr. (2015). The veil of experimental currency units in second price auctions. *Journal of the Economic Science Association* 1(2), 182-196.

FAO. 2012. *Sustainable Diets and Biodiversity. Directions and Solutions for Policy, Research and Action*. Proceedings of the International Scientific Symposium Biodiversity and Sustainable Diets Against Hunger, 3–5 November 2010 FAO Headquarters, Rome.

Georganas, S., Levin, D. and McGee, P. (2017). Optimistic irrationality and overbidding in private value auctions. *Experimental Economic*s 20: 772–792

Gracia, A., Loureiro, M. and Nayga, R.M.Jr. (2011). Are valuations from non-hypothetical choice experiments different from experimental auctions? *American Journal of Agricultural Economics* 93(5): 1358–1373.

Grebitus, C., Lusk, J.J. and Nayga, R.M.Jr. (2013). Explaining differences in real and hypothetical experimental auctions and choice experiments with personality. *Journal of Economic Psychology* 36: 11-26.

Han, S., Lerner, J.S. and Keltner, D. (2008). Feelings and Consumer Decision Making: The Appraisal-Tendency Framework. *Journal of Consumer Psychology* 17(3), 158-168

Harrison, G. W. and List, J.A. (2004). Field Experiment. *Journal of Economic Literature* 42(4): 1009-1055.

Hong, C.S. and Nishimura, N. (2003). Revenue non-equivalence between the English and the Second-Price auctions: Experimental evidence. *Journal of Economic Behavior and Organization* 51: 443-458.

Just, D.R., Mancino, L. and Wansink, B. (2007). Could Behavioral Economics Help Improving Dietary Quality for Nutrition Assistance Program Participants? *USDA Economic Research Paper 4*3.

Kagel, J., Harstad, R. and Levin, D. (1987). Information impact and allocation rules in auctions with affiliated private values: A laboratory study. *Econometrica* 55: 1275–1304.

Kagel, J. and Levin, D. (1993). Independent private value auctions: Bidder behavior in first-, second- and third-price auctions with varying numbers of bidders. *The Economic Journal* 103: 868–879.

Kahneman, D. and Tversky, A. (1979). Prospect Theory: An Analysis of Decision Under Risk. *Econometrica* 47: 263-291.

Kassas, B., Palma, M.A and Anderson, D.A. (2018). Fine-tuning willingness-to-pay estimates in second price auctions for market goods. *Journal of Behavioral and Experimental Economics* 77: 50-61.

Koistinen, L., Pouta, E., Heikkilä, J., Forsman-Hugg, S., Kotro, J., Mäkelä, J. and Niva, M. (2013). The impact of fat content, production methods and carbon footprint information on consumer preferences for minced meat. *Food Quality and Preference* 29: 126–136

Köszegi, B. and Rabin, M. (2006). A Model of Reference-Dependent Preferences. *Quarterly Journal of Economics* 121(4): 1133–1165.

Lancaster, K.J. (1966). A new approach to consumer theory. *Journal of Political Economy* 74: 132–157.

Lee, J.Y., Nayga, R.M.Jr, Deck, C. and Drichoutis, A.C. (2017). Cognitive Ability and Bidding Behavior in Second Price Auctions: An Experimental Study. MPRA Paper No. 81495. https://mpra.ub.uni-muenchen.de/81495/ [accessed 25.02.2019]

Li, S. (2017). Obviously Strategy-Proof Mechanisms. *American Economic Review* 107(11): 3257-3287.

Luchini, S. and Watson, V. (2014). Are choice experiments reliable? Evidence from the lab. *Economic Letters* 124: 9–13.

Lusk, J.L., Feldkamp, T. and Schroeder, T.C. (2004). Experimental Auction Procedure: Impact on Valuation of Quality Differentiated Goods. *American Journal of Agricultural Economics*, 86(2): 389–405

Lusk, J.L. and Schroeder, T. (2006). Auction bids and shopping choices. *Advances in Economics Analysis and Policy* 6(1):1-37.

Lusk, J.L. and Shogren, JF. (2007). Experimental Auctions Methods and Applications in Economic and Marketing Research. UK: Cambridge University Press.

Macdiarmid, J.I., Kyle, J., Horgan, G.W., Loe, J., Fyfe, C. and Johnstone, A.A. *et al.* (2012). Sustainable diets for the future: can we contribute to reducing greenhouse gas emissions by eating a healthy diet? *American Journal of Clinical Nutrition* 96: 632-639.

Macdiarmid, J.I., Douglas, F. and Campbell, J. (2016). Eating like there's no tomorrow: Public awareness of the environmental impact of food and reluctance to eat less meat as part of a sustainable diet. *Appetite* 96: 487-493.

Noussair, C., Robin, S. and Ruffieux, B. (2004). Revealing consumers' willingness-to-pay: A comparison of the BDM mechanism and the Vickrey auction. *Journal of Economic Psychology* 25: 725–741.

Ortega, D.L., Shupp, R.S., Nayga R.M. Jr. and Lusk, J.J. (2018). Mitigating overbidding behavior in agribusiness and food marketing research: Results from induced value hybrid auction experiments. *Agribusiness* 34(4): 887-893.

Rutsröm, E.E. (1998). Home-grown values and incentive compatible auction design. *International Journal of Game Theory* 27: 427-441.

Santini, F., Ronzon, T., Perez Dominguez, I., Araujo Enciso, S. R. and Proietti, I. (2017). What if meat consumption would decrease more than expected in the high-income countries?. *Bio-Based and Applied Economics* 6(1): 37-56.

Scarpa, R., Thiene, M. and Train, K. (2008). Utility in WTP space: a tool to address confounding random scale effects in destination choice to the Alps. *American Journal of Agricultural Economics* 90(4): 994-1010.

Shogren, J.F., Margolis, M., Koo, C. and List, J. (2001). A random nth price auction. *Journal of Economic Behavior and Organization* 46(4):409–421.

Simon, H.A. (1986). Rationality in Psychology and Economics. *The Journal of Business* 59(4): S209-S224

Smith, V.L. (1976). Experimental economics: induced value theory. *American Economic Review* 66: 274–279.

Thaler, R. (1980). Toward a Positive Theory of Consumer Choice. *Journal of Economic Behavior and Organization* 1: 39-60.

Thaler, R. and Sunstein, C. (2008). *Nudge: Improving decisions about health, wealth, and happiness*. New Haven: Yale University Press.

Tilman, D. and Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature* 515(7528): 518-22.

Train, K. (2009). *Discrete Choice Methods with Simulation*, 2nd. ed. Cambridge, UK: University Press.

Train, K. and Weeks, M. (2005). Discrete Choice Models in Preference Space and Willingness-to-pay Space. In *Applications of Simulation Methods in Environmental and Resource Economics. The Economics of Non-Market Goods and Resources, vol. 6*, edited by R. Scarpa and A. Alberini (1-16). Springer, Dordrecht.

Tversky, A. and Kahneman, D. (1989). Rational Choice and the Framing of Decision. In Karpak, B and Zionts, S. (Eds.): *Multiple Criteria Decision Making and Risk Analysis Using Microcomputers*, NATO ASI Series (Series F: Computer and Systems Sciences), vol 56. Springer, Berlin, Heidelberg.

Vickrey, W. (1961). Counterspeculation, Auctions and Competitive Sealed Tenders. *Journal of Finance* 16: 8-37.

Wansink, B., Just, D.R. and Payne, C.R.. (2009). Mindless Eating and Healthy Heuristics for the Irrational. *American Economic Review* 99(2): 165-179.

Appendix A

Healthiness was based on the amount of saturated fat in the lasagne. The criteria for the saturated fat content of the different lasagne was based on the UK Food Standard Agency guidance; green ≤1.5g/100g, amber >1.5 to ≤5.0g/100g, red >5.0g/100g (FSA 2013). A second TLS was used for the carbon footprint. The carbon footprint was the sum of GHGE ($kgCO_2e$) for each ingredient in the lasagne (GHGE data published by Audsley *et al.* (2009)). The system boundaries for these data are from primary production to the point of the regional distribution centre. This does not include food processing, retail, household use and waste but these would be similar for all the lasagne as only the ingredients varied. There are no standardised guidelines for labelling GHGE for foods therefore the three levels were set by the researchers; green ≤0.26 $kgCO_2e$/100g, amber >0.26 to <0.4 $kgCO_2e$/100g, red ≥0.4 $kgCO_2e$/100g. The range of meat content between the lasagne was similar to commercially pre-prepared lasagne at the time of the study (7% to 20% meat).

References

Audsley, E., Brander, M., Chatterton, J., Murphy-Bokern, D., Webster, C., Williams, A., 2009. *How Low Can We Go? An assessment of greenhouse gas emissions from the UK food system and the scope for reduction by 2050*. Report for the WWF and Food Climate Research Network.

Appendix B

Induced value SPVA

	Token 1	Token 2	Token 3	Token 4	Token 5	Token 6	Token 7	Token 8	Token 9
RESALE VALUE	£3.50	£5.00	£3.00	£1.00	£4.00	£1.50	£2.50	£4.50	£2.00
YOUR BID	£_____	£_____	£_____	£_____	£_____	£_____	£_____	£_____	£_____

Home-grown value SPVA

	Lasagne 1	Lasagne 2	Lasagne 3	Lasagne 4	Lasagne 5	Lasagne 6	Lasagne 7	Lasagne 8	Lasagne 9
Healthiness									
Carbon footprint									
YOUR BID	£_____	£_____	£_____	£_____	£_____	£_____	£_____	£_____	£_____

Induced value DCE

CHOICE SITUATION 1	TOKEN 2	TOKEN 5	NO TOKEN
RESALE VALUE	£4.50	£3.50	£0.00
MARKET PRICE	£3.00	£4.00	£0.00
I want to buy:	☐	☐	☐

Home-grown value DCE

CHOICE SITUATION 1	LASAGNE 3	LASAGNE 5	NO LASAGNE
Healthiness			-
Carbon Footprint			-
MARKET PRICE	£3.50	£4.00	£0.00

Appendix C

Table C1. Summary statistics of marginal bids in the SPVA treatment[a].

Variable	Description	Obs.	Mean	St.Dev.	Min	Max
$BID\_HG_{HEA\_R\_CF\_A}$	Marginal bid for red health and amber carbon footprint lasagne	63	0.237	0.707	-3.000	1.500
$BID\_HG_{HEA\_R\_CF\_G}$	Marginal bid for red health and green carbon footprint lasagne	63	0.240	0.981	-4.000	1.950
$BID\_HG_{HEA\_A\_CF\_R}$	Marginal bid for amber health and red carbon footprint lasagne	63	0.321	1.025	-4.000	2.000
$BID\_HG_{HEA\_A\_CF\_A}$	Marginal bid for amber health and amber carbon footprint lasagne	63	0.773	1.407	-3.500	3.350
$BID\_HG_{HEA\_A\_CF\_G}$	Marginal bid for amber health and green carbon footprint lasagne	63	0.764	1.459	-4.000	3.500
$BID\_HG_{HEA\_G\_CF\_R}$	Marginal bid for green health and red carbon footprint lasagne	63	1.086	1.508	-3.500	4.000
$BID\_HG_{HEA\_G\_CF\_A}$	Marginal bid for green health and amber carbon footprint lasagne	63	1.325	1.581	-4.000	4.500
$BID\_HG_{HEA\_G\_CF\_G}$	Marginal bid for green health and green carbon footprint lasagne	63	1.606	1.922	-4.000	5.000

[a] A marginal bid is the difference between any lasagne other than a red in health and red in environmental sustainable lasagne (in £) and the bid for a red in health and red in environmental sustainable lasagne.

Appendix D

In Model 1a, we replace the variable *IRR* with *IRR_FREQ*. The latter indicates the percentage of non-demand revealing bids submitted in the IV setting by each subject. Main summary statistics of the variable *IRR_FREQ* is reported in Table D1. Results from the estimation of Model 1a indicate similar to Model 1, but weaker effects (Table D2). While, the coefficients $\beta_{HEA\_A\_IRR\_FREQ}$ and $\beta_{CF\_A\_IRR\_FREQ}$ are not statistically significant, the coefficient $\beta_{HEA\_G\_IRR\_FREQ}$ and $\beta_{CF\_G\_IRR\_FREQ}$ are positive and significant (0.422, $p<0.01$ and 0.338, $p<0.05$). This suggests that *mWTP* for healthiest and low carbon footprint lasagne (i.e., green) increases when the rate of irrational IV bids increases (i.e., the degree of irrational behavior). A Wald Test rejects the null hypothesis that coefficients $\beta_{HEA\_A\_IRR\_FREQ}$, $\beta_{HEA\_G\_IRR\_FREQ}$, $\beta_{CF\_A\_IRR\_FREQ}$, $\beta_{CF\_G\_IRR\_FREQ}$ are jointly equal to zero (37.800, $p<0.01$).

Table D1. Summary statistics of variables included in the SPVA-related Models.

Variable	Description	Obs.	Mean	St.Dev.	Min	Max
IRR_FRQ	Rate of non-demand revealing bids per subject	504	0.681	0.394	0.000	1.000

Table D2. Generalised least-square regression models with correction for heteroscedasticity for SPVA data.

Dep. Var: *BID_HG*	
Coefficients	Model 1a
β_{HEA_A}	0.525***
	(0.126)
β_{HEA_G}	0.833***
	(0.126)
β_{CF_A}	0.383***
	(0.126)
β_{CF_G}	0.483***
	(0.126)
$\beta_{HEA\_A\_IRR\_FREQ}$	0.196
	(0.146)
$\beta_{HEA\_G\_IRR\_FREQ}$	0.422***
	(0.146)
$\beta_{CF\_A\_IRR\_FREQ}$	0.175
	(0.146)
$\beta_{CF\_G\_IRR\_FREQ}$	0.338**
	(0.146)
α	-0.297***
	(0.105)
Wald Test [c]: χ^2	37.800***
Obs.	504
Subjects	63

Note: ***p<0.01; **p<0.05; *p<0.10

[a] Standard Errors in parentheses

[b] H_0: $\beta_{FAT\_A\_IRR\_FREQ}=\beta_{FAT\_G\_IRR\_FREQ}=\beta_{CF\_A\_IRR\_FREQ}=\beta_{CF\_G\_IRR\_FREQ}=0$

Appendix E

Three variations of Model 2 are estimates:

i) Model 2a: We estimate Model 2 while excluding from the sample the two subjects who constantly overbid in the IV task. These are considered as outliers.
ii) Model 2b: We specify the variable *UND* as percentage of underbids (per subject) in the IV setting. This variable measures the rate of underbidding. The main statistics for this variable are provided in Table E1.
iii) Variation 2 (Model 2c): We estimate Model 2b while excluding from the sample the two subjects who constantly overbid in the IV task.

Table E1. Summary statistics of variables included in the SPVA-related Models.

Variable	Description	Obs.	Mean	St.Dev.	Min	Max
UND_FREQ	Percentage of underbidding per subject	504	0.681	0.394	0.000	1.000

Results from the estimation of Models 2a, 2b and 2c are provided in Table E2. Results are consistent across specifications. The coefficient $\beta_{HEA\_G\_IRR\_UND}$ is always negative and statistically significant. We always reject the null that coefficients $\beta_{HEA\_A\_IRR\_UND}$, $\beta_{HEA\_G\_IRR\_UND}$, $\beta_{CF\_A\_IRR\_UND}$ and $\beta_{CF\_G\_IRR\_UND}$ are jointly equal to zero.

Table E2. Generalised least-square regression models with correction for heteroscedasticity for SPVA data.

Dep. Var: *BID_HG*			
Coefficients	Model 2a	Model 2b	Model 2b
β_{HEA_A}	0.451***	0.547***	0.531***
	(0.116)	(0.124)	(0.124)
β_{HEA_G}	0.703***	0.703***	0.786***
	(0.116)	(0.116)	(0.124)
β_{CF_A}	0.294**	0.294**	0.373***
	(0.116)	(0.116)	(0.124)
β_{CF_G}	0.348***	0.348***	0.456***
	(0.116)	(0.116)	(0.124)
$\beta_{HEA\_A\_IRR}$	0.211	0.211	0.127
	(0.143)	(0.143)	(0.184)
$\beta_{HEA\_G\_IRR}$	0.730***	0.730***	0.763***
	(0.143)	(0.143)	(0.184)
$\beta_{CF\_A\_IRR}$	0.267*	0.267*	0.135
	(0.143)	(0.143)	(0.184)
$\beta_{CF\_G\_IRR}$	0.594***	0.594***	0.420**
	(0.143)	(0.143)	(0.184)
$\beta_{HEA\_A\_IRR\_UND}$	0.114	0.114	0.116
	(0.151)	(0.151)	(0.174)
$\beta_{HEA\_G\_IRR\_UND}$	-0.388**	-0.388**	-0.507***
	(0.151)	(0.151)	(0.174)
$\beta_{CF\_A\_IRR\_UND}$	0.0435	0.0435	0.0936
	(0.151)	(0.151)	(0.174)
$\beta_{CF\_G\_IRR\_UND}$	-0.166	-0.166	-0.102
	(0.151)	(0.151)	(0.174)
α	-0.290***	-0.290***	-0.285***
	(0.0984)	(0.0984)	(0.104)
Wald Test [b]: χ^2	105.360***	105.360***	46.230***
Wald Test [c]: χ^2	13.18**	13.18**	13.490***
Obs.	488	488	488
Subjects	61	61	61

Note: *p<0.01; **p<0.05; ***p<0.10

[a] Standard Errors in parentheses

[b] H_0:$\beta_{HEA\_A\_IRR}=\beta_{HEA\_G\_IRR}=\beta_{CF\_A\_IRR}=\beta_{CF\_G\_IRR}=0$

[c] H_0: $\beta_{HEA\_A\_IRR\_UND}=\beta_{HEA\_G\_IRR\_UND}=\beta_{CF\_A\_IRR\_UND}=\beta_{CF\_G\_IRR\_UND}=0$

Appendix F

Detailed summary statistics of the choice variable (*CH_HG*) are provided in Table F1 below.

Table F1. Summary statistics of DCE choices.

Variable	Description	Obs.	Mean	St.Dev.	Min	Max
CH_HG_A	= 1 if alternative A is selected = 0 otherwise	585	0.275	0.446	0	1
CH_HG_B	= 1 if alternative B is selected = 0 otherwise	585	0.350	0.477	0	1
CH_HG_C	= 1 if alternative C is selected = 0 otherwise	585	0.374	0.485	0	1

Model 3a replaces the variable *IRR* in Model 3 with *IRR_FREQ*. This variable indicates the rate of irrational choice made by each subject. Main statistics of this variable are presented in Table F2. Results from the estimation of Model 3a are reported in Table F3. None of the coefficients $\beta_{HEA\_A\_DM\_FREQ}$, $\beta_{HEA\_G\_DM\_FREQ}$, $\beta_{CF\_A\_DM\_FREQ}$ and $\beta_{CF\_G\_DM\_FREQ}$ is statistically significant and a Wald test fails to rejects the hypothesis that these coefficients are jointly equal to zero (0.840). These results indicates that the rate of irrationality does not affect HGV elicited via DCE.

Table F2. Summary statistics of variables included in the DCE Model.

Variable	Description	Obs.	Mean	St.Dev.	Min	Max
DM_FREQ	Percentage of non-demand revealing choices	585	0.376	0.252	0.000	1.000

Table F3. WTP-space Multinomial Logit Models for DCE Data[a,b].

Dep. Var.: ***CHOICE***	
Coefficients	Model 3a
$\omega_{opt\text{-}out}$	1.884***
	(0.416)
$\omega_{HEA\_A,mean}$	0.233
	(0.277)
$\omega_{HEA\_G,mean}$	1.209***
	(0.194)
$\omega_{CF\_A,mean}$	0.626***
	(0.225)
$\omega_{CF\_G,mean}$	1.526***
	(0.192)
$\omega_{HEA\_A,sd}$	0.969***
	(0.0796)
$\omega_{HEA\_G,sd}$	1.548***
	(0.114)
$\omega_{CF\_A,sd}$	0.0816*
	(0.0450)
$\omega_{CF\_G,sd}$	1.416***
	(0.105)
$\omega_{HEA\_A\_IRR\_FREQ}$	-0.333
	(0.414)
$\omega_{HEA\_G\_IRR\_FREQ}$	0.204
	(0.298)
$\omega_{CF\_A\_IRR\_FREQ}$	0.262
	(0.353)
$\omega_{CF\_G\_IRR\_FREQ}$	-0.052
	(0.305)
λ_{mean}	-0.505
	(0.319)
λ_{sd}	1.963***
	(0.350)
Wald Test [d]: χ^2	0.840
Log-likelihood	-431.878
Obs.	1,755
Subjects	65

Note: *p<0.01; **p<0.05; ***p<0.10
[a] Standard Errors in parentheses
[b] 1,000 Halton Draws
[c] H_0:$\omega_{HEA\_A\_IRR\_FREQ}=\omega_{HEA\_G\_IRR\_FREQ}=\omega_{CF\_A\_IRR\_FREQ}=\omega_{CF\_G\_IRR\_FREQ}=0$

Appendix G

In Model 4a, the dependent variable is *IRR_FREQ* which indicates the rate of irrational bids/choices submitted per subject. Summary statistics for this variable are presented in Table G1.

Table G1. Summary statistics of variables included in the behavioral model.

Variable	Description	Obs.	Mean	St.Dev.	Min	Max
DM_FREQ	Percentage of non-demand revealing observations	128	0.588	0.345	0.000	1.000

Results from the estimation of Model 4a suggests that the rate of irrationality is higher in the SPVA treatment as compared to the DCE treatment (Table G2). The coefficient β_{DCE} is negative and statistically significant (-1.731; $p<0.01$). We find that females (β_{FEM}) are more likely to act irrationally (0.492, $p<0.10$). Interestingly, the coefficient β_{INCOME} is positive and statistical significant (1.05e-05, $p<0.10$). This may suggest that monetary payoffs in the IV tasks were not high enough to incentivise higher income subjects.

Table G2. Behavioral Binary Logit Model[a].

Generalized Linear Model	
Dep. Var.: *DM_FREQ*	Coefficients
β_{DCE}	-1.731***
	(0.260)
β_{TIME}	0.318
	(0.243)
β_{HUNGRY}	-0.048
	(0.076)
β_{FEMALE}	0.492*
	(0.279)
β_{AGE}	0.02
	(0.00827)
β_{INCOME}	1.05e-05*
	(6.31e-06)
α	0.203
	(0.578)
Log-likelihood	-60.347
Obs.	128
Subjects	128

Note: ***p<0.01; **p<0.05; *p<0.10
[a] Standard Errors in parentheses

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Full Research Article

The wellbeing of smallholder coffee farmers in the Mount Elgon region: a quantitative analysis of a rural community in Eastern Uganda

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Abstract. For many smallholder farmers in the Mount Elgon region of Uganda, Arabica coffee cultivation is the major income-generating activity. Although it is widely known that smallholder coffee farmers often live under conditions that barely assure their survival, research to date has failed to examine the composition and distribution of wellbeing within this group. In the present study, a composite indicator of wellbeing is created using information collected from interviews with 431 coffee-cultivating households to investigate wellbeing in the Mount Elgon region of Uganda. From results of an explorative Principal Components Analysis, the factors of trust, security, housing, and landholding, covering a total of ten indicators, provided a comprehensive measure of wellbeing, explaining 81.20% of the total variance. The results show substantial differences in wellbeing within the sub-counties of Bulegeni, Simu, and Namisuni, and even greater differences between these sub-counties. These differences are explained primarily by the physical wellbeing factors of housing and landholding. Efforts to improve the quality of housing, particularly in Namisuni and Bulegeni, for instance, by providing improved access to financial services, construction loans, or subsidized prices for bricks and other construction materials, as well as official land registration in all three sub-counties could improve the wellbeing of households in this area.

Keywords. Composite Indicator, Mount Elgon, smallholder coffee farmers, Uganda, wellbeing.

JEL Codes. I31, Q12, R21.

1. Introduction

Producing more than 38 thousand tons of Arabica coffee (in 2017/18), Uganda is among the most important Arabica coffee producers in the world (UCDA 2018). With around 1.3 million rural households (HH) engaged in coffee production, Uganda's coffee sector has high socioeconomic importance for the country (UBOS 2010). In most coffee cultivation areas, smallholder coffee farmers barely live above the subsistence level. In

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Uganda, extreme poverty affects more than 33% of the country's 39 million people, among them a large number of smallholder coffee farmers (BMZ 2016). However, only a few research projects have investigated the wellbeing of coffee farmers to date.

Most of the research to date dealing with the wellbeing of coffee farmers has measured the impacts of participation in specialty markets or cooperatives and focused on how certification programs affect specific aspects of coffee farmers' wellbeing (e.g., Ahmed and Mesfin 2017, Bacon *et al.* 2005, Ruben and Fort 2012). Even recent studies on coffee producers' wellbeing refer to concepts of wellbeing that have been challenged or developed further, or equate wellbeing with welfare. Ahmed and Mesfin (2017), for example, use the equivalent of consumption per adult as a wellbeing indicator. The analysis of a single dimension of wellbeing such as income or expenditure has been criticized by authors in other research fields including Decancq and Lugo (2012), who investigated inequality of wellbeing in Russia. Although some researchers have used questionnaires containing direct questions about farmers' wellbeing to assess the impacts thereof (e.g., Frank *et al.* 2011), these studies do not clarify how farmers themselves understand wellbeing. Other authors have used related terms, such as "quality of life" (see Bacon *et al.*, 2005), in their research on the impacts of participation in certification programs among coffee farmers in Nicaragua. However, results like those of Bacon *et al.* (2005) show that most coffee farmers (74% of the Nicaraguans surveyed) perceive their quality of life as independent of whether they are part of conventional or alternative trade networks, because "sales to alternative markets is not enough to offset the many other conditions that influence the quality of one's life" (Bacon 2005). Estoque *et al.* (2018) claim that wellbeing is a prerequisite for quality of life. As these diverse findings reflect, wellbeing is complex, usages of wellbeing and related terms differ widely, and research is still needed on the structure of wellbeing among HHs engaged in coffee farming. A better understanding of wellbeing will not only enable comparison between individuals within a given area or between groups of different coffee cultivation areas, but also provide the basis for better evaluation of certification programs or policy measures.

The high importance of wellbeing is widely recognized in other fields, and the research on wellbeing has been growing worldwide in recent decades (e.g., Suh *et al.* 1996, Kahnemann 1999, Allen 2001, Decancq and Lugo 2012, Keyes *et al.* 2002, Beaumont 2011, Seligman, 2011, Dodge *et al.* 2012). Disciplines including psychology, medicine, economics, and sociology have proposed different instruments for the measurement of wellbeing. One of the more recent and broadly applicable definitions is the one proposed by Dodge *et al.* (2012), who define wellbeing as "the balance point between an individual's resource pool and the challenges faced" in terms of physical, social, and psychological components of wellbeing. In other words: stable wellbeing exists "when individuals have the psychological, social and physical resources they need to meet a particular psychological, social and/or physical challenge" (Dodge *et al.* 2012). Hendry and Kloep (2002) developed this concept further. The so-called *lifespan model,* incorporates the idea that solving challenges successfully leads to development in the individual and/or environment, whereas failing to solve challenges impedes the solution of future challenges. Their model also assumes that success in meeting challenges depends on the resource pool individuals have. They conclude that research on wellbeing is not only crucial to adequately measure development; wellbeing is indeed also the prerequisite for development.

Adding the assumptions of the *lifespan model* to the theory of subjective wellbeing proposed by Headey and Waring (1992), who cite external forces as the precondition for change in the wellbeing balance, one could assume that external forces could lead to a positive or negative development in the wellbeing of individuals and groups. Humans could be faced with more challenging situations, for instance, in the environment. Considering the estimated decrease in the climatic suitability of most Ugandans' Arabica coffee cultivation areas, climate change could have a major impact on coffee farming (Damatta *et al.* 2012, Jassogne *et al.* 2012). Coffee farmers are already facing heightened environmental problems such as a higher occurrence of pests and diseases (UNDP 2012) and greater uncertainties regarding temperature and irrigation. Changing weather patterns are also expected to reduce coffee quantity and quality (e.g., Jassogne *et al.* 2012, UNDP 2012, Läderach *et al.* 2012). This will lead to lower income from coffee sales, which would also have a long-term impact on the resources' farmers have to devote to other aspects of their wellbeing. Considering the aforementioned difficulties, the Uganda Coffee Development Authority (UCDA) developed a program to counteract the challenges coffee farmers are facing. They state the ambitious aim of quadrupling Uganda's coffee production by 2040 by stabilizing coffee farmers' resources through measures such as workshops on coffee management and distribution of free coffee seedlings (UCDA 2019).

The present paper investigates the composition of wellbeing of HHs engaged in coffee farming based on data from 431 quantitative interviews. This investigation requires a definition of wellbeing that takes the coffee farmers' point of view into account as the basis for policy recommendations that will be able to improve coffee farmers' and their families' wellbeing. Using the definition of wellbeing formulated by Dodge *et al.* (2012), this paper proposes a composite indicator (CI) of wellbeing based on material wealth (physical component), the fulfillment of social needs (social component), and the fulfillment of basic psychological needs (psychological component), to enable the measurement of wellbeing in one of the three most important Arabica coffee cultivation areas of Uganda. Along with a better understanding of what wellbeing means to farmers, this paper uses a well-established CI for wellbeing and meaningful wellbeing indicators to test the hypotheses that (1) wellbeing is not equally distributed within and between sub-counties in the Mount Elgon region, and that (2) the physical wellbeing component shows a more substantial impact than the social and psychological components on the constitution of wellbeing among these HHs. Both assumptions were formulated based on the observation during previous field visits that the group under investigation is economically vulnerable and based on previous data showing high differences in income from coffee-selling activities. The results of this study show dependencies between different indicators of wellbeing and identify the impact levels of the various indicators. As such, they provide an important idea of how the living conditions of coffee-farming HHs are developing and are of high practical relevance for policy makers.

In the materials and methods section that follows this introduction, I provide information on the area in which the study was conducted, the sample and data collection, and the methodological background for the construction of the CI, and briefly explain the framework of the data analysis. In the results section, I present descriptive statistics on the wellbeing indicators and the construction and composition of the CI formula, and also provide insights into wellbeing on a factor level and an overview of the wellbeing distribu-

tion in this research area. In the final sections, I discuss potential policy implications of the findings for improving wellbeing and methodological limitations of the study.

2. Materials and methods

2.1 Study area

The study was conducted on the Western slopes of the Mount Elgon region, one of the three main Arabica coffee-producing regions in Uganda (Knutsdatter Formo and Padegimas 2012). For many farmers in the Mount Elgon region, Arabica coffee cultivation is the main source of income. In this region, Arabica varieties as Bugisu local, SL14, SL28, and KP423 are usually intercropped with bananas, beans, peas, ground nuts, vegetables, and shade trees like avocado and mango. It is estimated that 90% of coffee cultivation takes place on plots of less than 3 hectares (Chiputwa *et al.* 2015).

Data collection for this study took place in the Bulambuli district, which extends over about 809 km², reaches elevations of up to 1526 meters above sea level, and is divided into two counties, Elgon and Bulambuli County (NPHC 2014). Surveys were administered in Elgon County because 60.5% of its HHs were engaged in coffee farming, whereas coffee farmers in Bulambuli County only represented 2.2% of existing HHs (NPHC 2014). In Elgon county, the three sub-counties of Bulegeni, Simu, and Namisuni were chosen (Fig. 1).

Figure 1. Map of (b) South Uganda and (a) details of Bulambuli district with Bulambuli County (grey) and Elgon County (white) with the sub-counties Bulegeni (blue), Simu (turquoise), and Namisuni (orange).

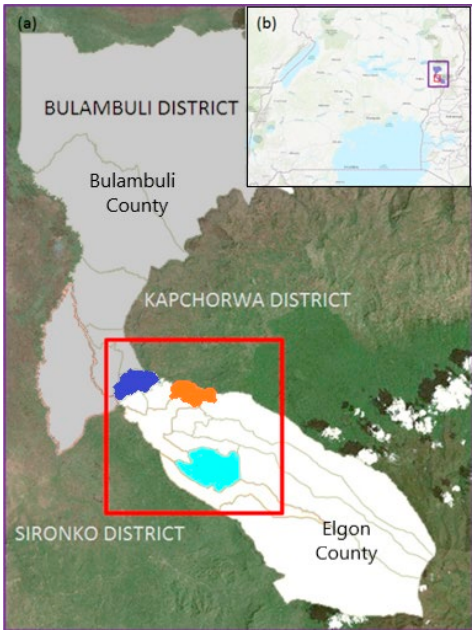


Table 1. Number of HHs participating in the study.

Sub-county	Participants HH survey
Bulegeni	156 (36.2%)
Simu	90 (20.9%)
Namisuni	185 (42.9%)
Total	431 (100%)

For data collection, 460 coffee-cultivating HHs were randomly selected and visited. The only prerequisite for participation in the study was that farmers were willing and that their HH was engaged in coffee cultivation activities. Of these 460 HH, 29 did not provide (sufficient) data for different reasons: HH heads were located but not available for an interview even on the third attempt, HH heads had died or were ill, or another person representing the HH head was unable to provide reliable answers. This left a final data set with completed questionnaires from 431 HHs (Table 1).

2.2 Sample description

Comparing the sample distribution with the average HH characteristics for the area in which the study was conducted, slight deviations in socio-demographic characteristics can be seen (Table 2). However, statistics on the area's population were either collected in 2012 (see NPHC 2014) or, for those from the most recent reliable source, only refer to the Mount Elgon region as a whole (UNHS 2018). Taking the high fertility rates in Uganda into account (5.4 children per woman in 2016), these deviations in sample characteristics can generally be accepted due to the broad similarity in socio-demographic trends (SUPRE 2018). As production of cash crops like coffee is usually male-dominated in rural areas of Sub-Saharan Africa, and only coffee farmers were included into the sample group, female-headed HHs are clearly underrepresented (e.g., Bolwig 2012, Doss 2002).[1] However, the data set can be considered largely representative for this research area, except for the small percentage of female-headed HHs and the larger number of people per HH in this study than in the statistics. Discrepancies in the data, particularly for the gender of the HH head, could not be excluded in the interpretation of the results.

2.3 Data collection

Data were collected as part of the project "Potential improvements for the income situation of smallholder coffee farmers in Mount Elgon, Uganda" developed and implemented by the Georg-August University of Göttingen, Germany, and the National Agricultural Research Organization (NARO) of Uganda.

The theoretical selection of relevant dimensions for the present study and context was conducted based on a literature review (Decancq and Lugo 2012, Dodge *et al.* 2012, among others) and on data from HH surveys implemented in the Mount Elgon region in 2015. The resulting framework was discussed with the local research team, consisting of five research assistants who had grown up in coffee-cultivating HHs in the area, in 2017. Based on that, questionnaire pre-tests were developed and implemented in the area to

[1] Only 20.7% of the female HH heads are married. The rest of the female HH heads are single (20.7%), divorced (10.3%), or widowed (48.3%), whereas only 1.5% of the male HH heads are widowed.

Table 2. Sample characteristics.

Quantitative data set		Bulegeni	Simu	Namisuni	Total	Research area
Number of HHs		n= 156	n= 90	n= 185	n=431	21,244 [1]
Gender of HH head	Male	94.2%	95.6%	93.5%	94.2%	81.4% [1]
	Female	5.8%	4.4%	6.5%	5.8%	18.6% [1]
Age of HH head	<18	0.0%	0.0%	0.0%	0.0%	1.0% [1]
	18-30	7.1%	11.1%	16.1%	11.7%	25.9% [1]
	31-59	60.3%	62.2%	65.0%	62.7%	53.9% [1]
	>60	32.7%	26.7%	18.9%	25.6%	19.2% [1]
Highest level of education for head of HH	Illiterate	3.9%	4.4%	2.2%	3.3 %	9.3% [2]
	Primary school	45.8%	41.1%	59.7%	50.7%	58.7% [2, 3]
	High school	44.4%	47.8%	34.3%	40.8%	27.8% [2, 4]
	College	3.9%	3.3%	2.8%	3.3%	8.2% [2, 5]
	University	2.0%	3.3 %	1.1%	1.9%	
People per HH	MD/SD	6.31/2.338	6.41/2.238	5.21/2.170	5.86/2.312	4.638/0.135 [2]
Coffee production is the main source of income		83.2%	93.3%	88.6%	87.7%	83.0% major economic activity is crop farming [2]

[1]Data for Elgon County from NPHC 2014.

[2]Data for Elgon Region from UNHS 2018.

[3]Sum from category: some primary and completed primary for the whole HH.

[4]Sum from category some secondary and completed secondary for the whole HH.

[5]Post-secondary and above for the whole HH.

evaluate the feasibility of the survey and to test the content and construct validity and reliability. After some revisions, the survey was finally successfully implemented in 431 coffee-cultivating HHs in the period from July to December 2018.

The final survey of the project comprised seven sections; (i) HH demographics, (ii) farm management system, (iii) access to information and extension material, (iv) general HH living conditions, (v) expected yield and income, (vi) community relations, and (vii) shortages and shocks experienced so far. Within five of these sections (ii-vi), a set of subdimensions comprising a total of 44 variable dimensions was developed to measure the wellbeing level of the HHs (Table 3).

Because of different levels of English proficiency in the population, the five local assistants (four male and one female) were trained to conduct an average number of five interviews per day in the local language Lugisu. For the time spent to complete the questionnaire (50 minutes on average), each farmer received compensation in the form of bookkeeping and small business management materials. After data cleaning, 431 interviews remained for data analysis.

Table 3. Structure of survey sections relevant to wellbeing.

Section of the survey	Dimensions
(ii) Farm management system	Area of land for agricultural activity in general, area of land for coffee cultivation, ownership of land, intercropping with other products, livestock, membership in farmer organizations, certification of coffee, farm management practices
(iii) Access to information and extension material	Main sources and interest in information on farm management, participation in meetings, workshops
(iv) General HH living conditions	Characteristics of the main house; toilet, wall material, floor material, roofing, source of lighting, cooking, source, distance and mode of treating drinking water, distance to village market, doctor/hospital, and school
(v) Expected yield and income, access to productive capital/credit	Yield, prices for coffee cherries and parchment coffee, expected income from coffee selling, other sources of income, labor input coffee production, loans, farm equipment, consumer durables, cellphone, bicycle, motorbike
(vi) Community relations	Safe from violence and crime, safe from economic disasters, level of happiness, most people can be trusted, most government officials can be trusted, local government considers concerns voiced by you, most people are willing to help, collaboration with other farmers, heterogeneity within the village, frequency of getting together with others

2.4 Methodical background for the construction of the CI for wellbeing

As pointed out in the introduction section, a CI was constructed for wellbeing based on HH material wealth (physical component), the fulfillment of social needs (social component), and the fulfillment of basic psychological needs (psychological component). In contrast to Dodge *et al.* (2012), the present paper does not investigate wellbeing at the individual level but at the HH level. The HH reflects a social construct, which leads to a high level of overlap in content between social and psychological indicators in the data set presented here (see Table 3). For the indicators that reflect the level of trust, for instance, a clear classification into either social or psychological categories cannot be made. Mistrust could reflect instability within the community, but it could also stem from fears of opportunistic behavior or from other psychological discomfort, especially when considering the economic vulnerability and dependency of the farmers in our sample group. Therefore, the social and psychological wellbeing indicators were merged into a "social-psychological" component.

To examine the fulfillment of social-psychological needs, only indicators dealing with the individual-level emotions and social interactions of farmers have been selected for the construction of the CI. All social-psychological wellbeing variables were measured with a five-point Likert scale ranging from 1 (not at all) to 5 (very much; the highest subjective wellbeing for that item), except for HH participation in meetings, workshops, and training over the last 12 months, which was measured with a binary survey question and represented as a population percentage. For the physical component, only variables that focus

on the measurable status of material wealth have been included in the analysis: indicators measuring the value of HH belongings or productive HH activities. The scales used here describe an objectively measurable condition, ranked by the status of wealth on the HH level, expressed in some cases by the number of items belonging to the HH, hectares of land, or construction materials for housing. Material for housing was ranked from reflecting low wealth (non-permanent materials like mud/soil for walls, earth for floors, and grass/banana leaves for roofing), mid-wealth status (semi-permanent materials like plaster for walls, wood for floors, and sheet metal for roofing) to high wealth (permanent materials like bricks for walls, cement for floors, and tiles for roofing) within the community[2].

Variables used for the construction of the CI were measured using different units and scales. To enable comparison within and between individual indicators and different scales, and to preserve the empirical distribution of the data, the indicators were standardized by computing z-scores (Santeramo 2015). For each individual indicator x_{qc}^{t}, the average $x_{qc=\bar{c}}^{t}$ and the standard deviation were calculated. A similar dispersion across indicators emerges when implementing into the normalization formula: $I_{qc}^{t} = \frac{x_{qc}^{t} - x_{qc=\bar{c}}^{t}}{\sigma_{qc=\bar{c}}^{t}}$

To explore whether the theoretically developed indicators of wellbeing are statistically well-balanced and whether the indicators are suitable for the underlying data structure, a principal component analysis (PCA) was performed.

Factors that meet the prerequisites of having eigenvalues larger than one and of individually contributing more than 10% to total explained variance are included in the CI for wellbeing. The square of factor loadings represents the proportion of total unit variance of the CI of wellbeing explained by the factor (JRCEC 2008).

Referring to Santeramo (2015), equal weighing does not only represent the weak assumption that all variables have the same importance; it may also induce double-counting bias because a higher number of variables in a subgroup leads to a higher weight of that subgroup. There are many weighing approaches preventing the conclusion that dimensions have similar importance, among them the PCA, which relies on data variability and variable correlation (JRCEC 2008, Nicoletti *et al.* 2000, Santeramo 2015). For the PCA-based approach of Nicoletti *et al.* (2000), the variance explained by the factor after varimax rotation could be used to calculate the weight of each factor if correlations between indicators are found.

$$\textit{Weight of the factor for the CI of wellbeing (Wq)} = \frac{\textit{Variance explained by the factor}}{\textit{Total variance of the four factors}}$$

The z-standardized scores used for the PCA were regressed for each factor, and the CI of wellbeing was calculated for each interviewed HH.

2.5 Data analysis

To compute the CI of wellbeing, I followed the methodological approaches described in the *Handbook on Constructing Composite Indicators*' of the Joint Research Centre of the

[2] The scales were developed based on estimated values of construction material quality within the community resulting from previous qualitative interviews.

European Commission to best fit the constitution of the data at hand (JRCEC 2008). SPSS Version 25 was used for tasks including to perform the required PCA for the construction of the CI of wellbeing. Pearson's correlation coefficient was used to check for correlations between individual indicators using the z-scores of the items. To assess whether sub-county had an influence on the indicators, factors, or the CI of wellbeing, a one-factor ANOVA was performed.

3. Results

3.1 Descriptive statistics of indicators

After testing all previously mentioned variables, only 19 wellbeing indicators were able to provide specific, measurable, accessible, relevant, and timely (SMART) information and fulfill the aforementioned selection criteria for wellbeing (FAO, 2013). Table 4 provides the categorization into components of wellbeing and descriptive statistics for absolute (not standardized) values of those indicators.

The social-psychological indicators with the highest scores (up to 4.56) are represented by the *willingness to help* and *intensity of collaboration with other farmers*. Whereas the *level of happiness* and *local government considers farmers' concerns* show means of approximately 3.7, *trust in government officials* shows a lower mean, and *trust in most people* represents the lowest level of satisfaction at 3.10. All social-psychological indicators show different means in different sub-counties. The lowest means for all trust-related indicators is in Bulegeni sub-county. Namisuni shows the highest mean for the indicators *local government considers farmers' concerns* and *trust in government officials*. Whereas Simu sub-county has the highest mean for *trust in most people*, it is also represented by the highest percentage (68.89%) of *HHs that have participated in meetings, workshops, and training* during the last 12 months.

The individual indicators for the physical component of wellbeing show a very high percentage of HHs (84.4% to 97.8%) with floor and wall materials consisting of earth (floors) and mud/soil (walls) that indicate the lowest level of welfare. In consequence, percentages for indicators showing mid-to high-valued housing materials are low (0.0% to 15.6%), which could also explain the presence of extreme values. HH access to belongings ranges from farm equipment, which nearly all HHs (97.45%) have access to, to *consumer durables* (mainly radio) (79.58%), *cellphone* (70.30%), *bicycle* (ranging from 37.78% to 7.03%) all the way down to *motorbikes,* which are only present in 8.35% of HHs. Only Namisuni is an exception, with a higher percentage of access to motorbikes than bicycles. For *landholding for agricultural activities* in general, the mean for the sample shows 0.95 ha, whereas the HH use on average 0.5 ha of their land for coffee cultivation. In Table 4, the wide range of landholding in Simu reveals differences in access to land within the sub-county. However, there is also evidence of a general trend of differences in all physical indicators (except from the indicator roofing material) between the sub-counties: Simu shows a higher percentage of higher values than other sub-counties. Bulegeni also shows a much lower wealth status than other sub-countries, directly followed by Namisuni.

Table 4. Descriptive statistics for the 19 wellbeing indicators.

Indicator		Bulegeni (n= 156)	Simu (n= 90)	Namisuni (n= 185)	Total (n=431)	Extreme values[1]
Social-psychological wellbeing component						
HH members participated in meetings, workshops, and training (last 12 months)		62.18%	68.89%	60.54%	62.88%	0
Trust in most people	Mean	3.08	3.17	3.09	3.10	0
	SD	1.56	1.50	1.54	1.53	
Trust in government officials	Mean	3.26	3.36	3.44	3.36	0
	SD	1.57	1.34	1.44	1.47	
Local government considers the farmers' concerns	Mean	3.61	3.71	3.77	3.70	0
	SD	1.38	1.38	1.30	1.35	
Willingness to help	Mean	4.56	4.04	4.06	4.24	0
	SD	1.09	1.52	1.49	1.39	
Intensity of collaboration with other farmers	Mean	4.06	3.97	4.31	4.15	0
	SD	1.49	1.42	1.49	1.35	
Economically secure	Mean	3.08	3.72	3.72	3.49	0
	SD	1.63	1.39	1.42	1.52	
Safe from violence and crime	Mean	3.87	3.27	3.32	3.51	0
	SD	1.16	1.60	1.69	1.52	
Level of happiness	Mean	3.85	3.77	3.68	3.76	0
	SD	1.20	1.45	1.40	1.34	
Physical wellbeing component						
Farm equipment belongs to HH		98.08%	98.89%	96.22%	97.45%	0
Consumer durables belong to HH		78.85%	86.67%	76.76%	79.58%	0
Cellphone belongs to HH		71.79%	81.11%	63.78%	70.30%	0
Bicycle belongs to HH		26.92%	37.78%	7.03%	20.65%	0
Motorbike belongs to HH		5.13%	13.33%	8.65%	8.35%	0
Wall material	Mud/soil	93.6%	84.4%	96.2%	92.8%	31
	Plaster	3.2%	3.3%	1.6%	2.6%	
	Brick	3.2%	12.2%	2.2%	4.6%	
Floor material	Earth	92.9%	84.4%	97.8%	93.3%	31
	Wood	0.6%	0.0%	0.0%	0.2%	
	Cement	6.4%	15.6%	2.2%	6.5%	
Roofing material	Grass/banana leaves	1.92%	0%	1.08%	1.16%	0
	Sheet metal	79.49%	93.33%	93.51%	88.40%	
	Tile	18.59%	6.67%	5.41%	10.44%	
Land used for coffee cultivation (ha)	Mean	0.46	0.77	0.39	0.50	26
	SD	0.48	0.99	0.42	0.62	
	Range	3.03	5.26	2.83	5.26	
	Min.	0.00	0.00	0.00	0.00	
	Max.	2.83	5.26	2.83	5.26	

Indicator		Bulegeni (n= 156)	Simu (n= 90)	Namisuni (n= 185)	Total (n=431)	Extreme values[1]
Land used for agricultural activity (ha)	Mean	0.91	1.32	0.80	0.95	24
	SD	0.81	1.29	0.61	0.88	
	Range	5.97	7.99	2.95	8.04	
	Min.	0.10	0.10	0.05	0.05	
	Max.	6.07	8.09	3.00	8.09	

[1]To ensure that all levels of wellbeing are included in the data analysis, these extreme values were not excluded.

3.2 PCA for the CI of wellbeing

A PCA was applied to these 19 variables. The best result of the PCA (shown in Fig. 2) was found for a four-factor solution that can explain 81.20% of the total variance (Kaiser-Meyer-Olkin Measure (KMO) = 0.681, Bartlett's Test of Sphericity Sig. =0.000) by including ten of the previously derived indicators.

The factor *trust* consists of the indicators *trust in most people*, *trust in government officials*, *local government considers the farmers' concerns* (Fig. 2). The factor *security* consists of the indicators *economically secure*, *safe from violence and crime,* and the *level of happiness*. The connection between happiness and security can be explained by citing one of the interviewed farmers: "[…] Well, to me, happiness is the state of being content with all the prevailing circumstances in life." For the physical component of wellbeing, the factor *housing* consists of *walls* and *floors*, whereas the factor *landholding* includes *land for agricultural activity* and *land for coffee cultivation.*

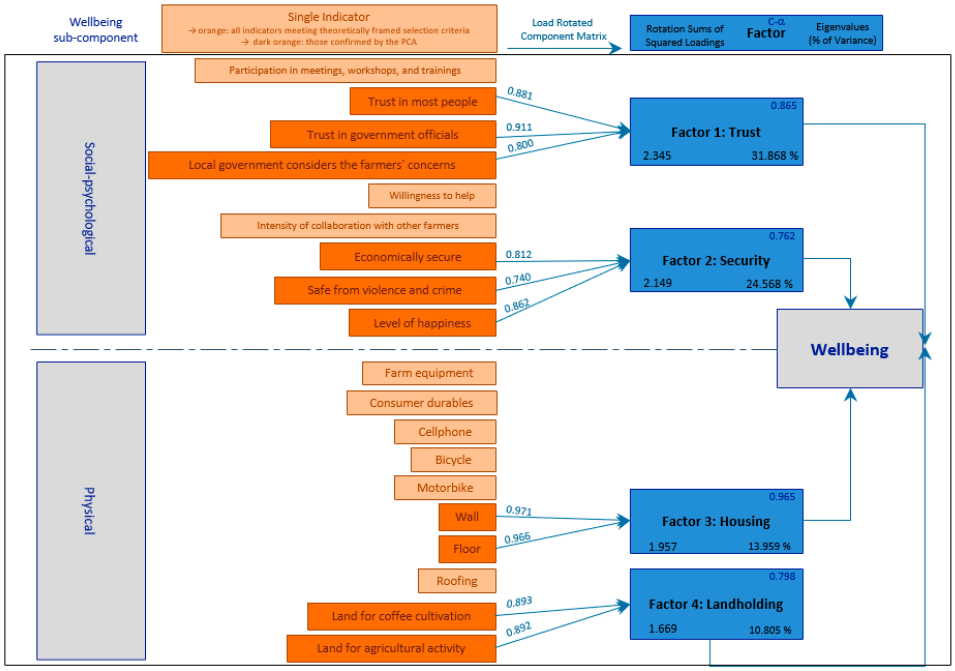
Testing the combination of the variables of the four-factor solution for reliability, the Cronbach's coefficient alpha (C-α) for the total internal consistency shows a value of 0.741, which is acceptable (Field 2009). Consequently, for the development of the CI of wellbeing, only the variables for the resulting factors *trust, security, housing,* and *landholding* are investigated further.

Factor 1 *(trust)* explains 31.868%, Factor 2 *(security)* explains 24.568 %, Factor 3 *(housing)* explains 13.959%, and Factor 4 *(landholding)* explains 10.805% of the total variance.

As a last step, the relationships between individual indicators are investigated and depicted in Table 5 in order to inspect whether correlations between indicators are present and to calculate the weight for each factor using the results of the PCA, as suggested by Nicoletti *et al.* (2000).

Correlation results yield a strong positive relationship between *trust in most people* and *trust in government officials* (corr=0.718**), between *local government considers the farmers' concerns* and *trust in most people* (corr=0.587**), and between *trust in government officials* and *local government considers the farmers' concerns* (corr=0.736**). For the indicators of the factor *security,* the positive relationship is not as strong. There is a positive relationship between *wall* and *floor* materials (corr=0.932**) and between *land used for agricultural activity* and *land used for coffee cultivation* (corr=0.480). In addition, all physi-

Figure 2. Summarizing the components of wellbeing, the indicators investigated, and the results ofthe principal component analysis (PCA).



Extraction method: principal component analysis; rotation method: varimax with Kaiser normalization, rotation converged in 5 iterations.
** highly significant P=0.01.

cal indicators have positive relationships with each other. Pearson's correlation indicates a relationship between *economically secure* and (a) *land for coffee cultivation* (corr=0.129**), (b) *land used for agricultural activity* (corr=-0.160**). Similar relationships between the *level of happiness* and the indicators of *landholding* are visible. Furthermore, all indicators of the factor *trust* show a highly significant (P≤0.01) positive correlation with the indicators of *security* and the *landholding* indicator *land used for coffee cultivation*. The perception of being *safe from violence and crime* correlates negatively with *land used for agricultural activity* (corr=-0.257**). Relationships between indicators of different factors can also be found, but their correlation is not strong (corr<0.5).

However, the correlations found between the individual indicators are strong enough to enable the calculation of weights of each factor by dividing the percentage of variance explained by the factor after varimax rotation by the total variance of all factors (JRCEC 2008). The results of the PCA, relevant for the construction of the CI of wellbeing, are shown in Table 6.

Previously indicated results from the PCA lead to the following formula for the CI of wellbeing:

Table 5. Pearson's correlation with z-scores of the ten single indicators.

Factor	Indicator	1	2	3	4	5	6	7	8	9	10
Trust	1.Trust in most people	1	0.718**	0.587**	0.152**	0.242**	0.211**	n.s.	n.s.	0.137**	n.s.
	2.Trust in government officials	**0.718****	1	0.736**	0.236**	0.309**	0.288**	n.s.	n.s.	0.146**	n.s.
	3.Local goverm. considers the farmers' concerns	**0.587****	**0.736****	1	0.363**	0.364**	0.389**	n.s.	n.s.	0.163**	n.s.
Security	4.Economically secure	0.152**	0.236**	0.363**	1	0.402**	0.589**	n.s.	n.s.	0.129**	-0.160**
	5.Safe from violence and crime	0.242**	0.309**	0.364**	0.402**	1	0.559**	n.s.	n.s.	n.s.	-0.257**
	6.Level of happiness	0.211**	0.288**	0.389**	**0.589****	**0.559****	1	n.s.	n.s.	0.117*	-0.244**
Housing	7.Wall	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	1	0.932**	0.338**	0.101*
	8.Floor	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	**0.932****	1	0.360**	0.102*
Landholding	9.Land used for coffee cultiv.	0.137**	0.146**	0.163**	0.129**	n.s.	0.117*	0.338**	0.360**	1	0.480**
	10.Land used for agricultural activity	n.s.	n.s.	n.s.	-0.160**	-0.257**	-0.244**	0.101*	0.102*	0.480**	1

*Significance for two-tailed correlation is P≤0.05, **Significance for two-tailed correlation is P≤0.01, Correlations of 0.5 and above are shown in bold.

Table 6. Variance explained by each factor and weight of each factor.

Factor	% of variance	Cumulative %	% of variance after varimax rotation	Weight of each factor
Trust	31.868	31.868	23.451	0.2888
Security	24.568	56.436	21.492	0.2647
Housing	13.959	70.395	19.567	0.2410
Landholding	10.805	**81.200**	16.689	0.2055

Extraction method: principal component analysis.
Weight of each factor = % of variance explained the factor after varimax rotation/total variance.

$$CI\ of\ wellbeing = (W_{Trust} * Trust) + (W_{Security} * Security) + (W_{Housing} * Housing) + (W_{Landholding} * Landholding)$$

Implementing the weights of each factor into the formula for the CI of wellbeing, the final CI formula is:

$$CI\ of\ wellbeing = (0.2888 * Trust) + (0.2647 * Security) + (0.2410 * Housing) + (0.2055 * Landholding)$$

3.2.1 Influence of sub-county on wellbeing

To test the first hypothesis, the first step is to conduct an investigation at the indicator level. The results of the one-factor ANOVA (shown in Table 7) confirm the hypothesis of an influence of the sub-county on the perception of being *economically secure*, and on all indicators of the physical components of wellbeing with P=0.000***. Assumptions are also confirmed by the one-factor ANOVA, with P=0.001*** for the influence of sub-county on being *safe from violence and crime*. For the other social-psychological indicators, no significant influence of sub-county could be found. However, these results should be interpreted carefully for *safe from violence and crime* (P=0.000***), *economically secure* (P=0.000***), *level of happiness* (P=0.000***), and *trust in local government officials* (P=0.011*) and for all physical indicators (P=0.000***) because Levene's test is undesirably significant, which means that homogeneity of variance cannot be assumed. In addition, the requirement for normally distributed data is not met according to the Kolmogorov-Smirnov (KS) Test (P = 0.000***).

However, to fully test the first hypothesis, I also examined to what extent this regional influence is also given for the factors. The results of the one-factor ANOVA (shown in Table 8) show a significant influence of sub-county on *housing* (P=0.004**) and on *landholding* (P=0.000***). The influence of sub-county on *trust* (P=0.858) and *security* (P=0.988) is not significant. However, due to the significance of Levene's Test for *housing* (P=0.000***), *landholding* (P=0.000***) and *security* (P=0.043*), these results should be interpreted carefully.

In the following section, I investigate factors after standardisation (z-score transformation). Using the previously specified formula for wellbeing, the wellbeing index shows a mean of 0.000 for the total group. Negative values for the CI show a lower wellbeing compared to the rest of the sample group. The greater the positive figure, the better the wellbeing relative to the mean of wellbeing index for all HHs. To better illustrate how the wellbeing distribution differs by sub-county, boxplots are provided in Fig. 3.

Regarding the wellbeing distribution between sub-counties, it can be seen that Simu has the highest mean (0.158), followed by Bulegeni (-0.026) and Namisuni (-0.055). The range indicates differences within the sub-counties: Namisuni has the lowest range (2.238), followed by Bulegeni (2.742), whereas Simu has the highest range (3.178) for the CI of wellbeing between HHs.

The last step is now to have a look at whether this relation is also evident for the overall wellbeing construct. Based on the ANOVA (Table 9), the influence of sub-counties on the wellbeing index is highly significant (P = 0.003**), but again, Levene's test is significant (P=0.006**), which points to the need for careful interpretation of this result.

Table 7. One-factor ANOVA for the influence of sub-county on the indicators of the social-psychological and physical wellbeing factors.

Factor	Indicator	Source	Partial SS	df	MS	F	P(>F)
Trust	Trust in most people	Between groups	0.475	2	0.238	0.101	0.904
		Within groups	1011.033	428	2.362		
		Total	1011.508	430			
	Trust in government officials	Between groups	2.955	2	1.477	0.684	0.505
		Within groups	924.020	428	2.159		
		Total	926.974	430			
	Local government considers the farmers' concerns	Between groups	2.289	2	1.144	0.631	0.533
		Within groups	776.101	428	1.813		
		Total	778.390	430			
Security	Economically secure	Between groups	41.164	2	20.582	9.229	0.000***
		Within groups	954.516	428	2.230		
		Total	995.680	430			
	Safe from violence and crime	Between groups	32.502	2	16.251	7.266	0.001***
		Within groups	957.220	428	2.236		
		Total	989.722	430			
	Level of happiness	Between groups	2.472	2	1.236	0.688	0.503
		Within Groups	768.948	428	1.797		
		Total	771.420	430			
Housing	Wall	Between groups	3.006	2	1.503	7.849	0.000***
		Within groups	81.959	428	0.191		
		Total	84.965	430			
	Floor	Between groups	4.346	2	2.173	9.197	0.000***
		Within groups	101.116	428	0.236		
		Total	105.462	430			
Landholding	Total hectares of land used for coffee cultivation	Between groups	9.109	2	4.555	12.448	0.000***
		Within groups	155.868	426	0.366		
		Total	164.978	428			
	Total hectares of land used for agricultural activity	Between groups	16.614	2	8.307	11.146	0.000***
		Within Groups	318.993	428	0.745		
		Total	335.606	430			

Table 8. One-factor ANOVA for the influence of sub-county on the factors trust, security, housing, and landholding.

Factor	Source	Partial SS	df	MS	F	P(>F)
Trust	Between groups	0.307	2	0.153	0.153	0.858
	Within groups	427.693	426	1.004		
	TotaI	428.000	428			
Securit y	Between groups	0.023	2	0.012	0.012	0.988
	Within groups	427.977	426	1.005		
	TotaI	428.000	428			
Housing	Between groups	11.080	2	5.540	5.661	0.004**
	Within groups	416.920	426	0.979		
	TotaI	428.000	428			
Landholding	Between groups	22.228	2	11.114	11.668	0.000***
	Within Groups	405.772	426	0.953		
	TotaI	428.000	428			

Number of observations = 431.

Figure 3. Bloxplots depicting the CI of wellbeing by sub-county.

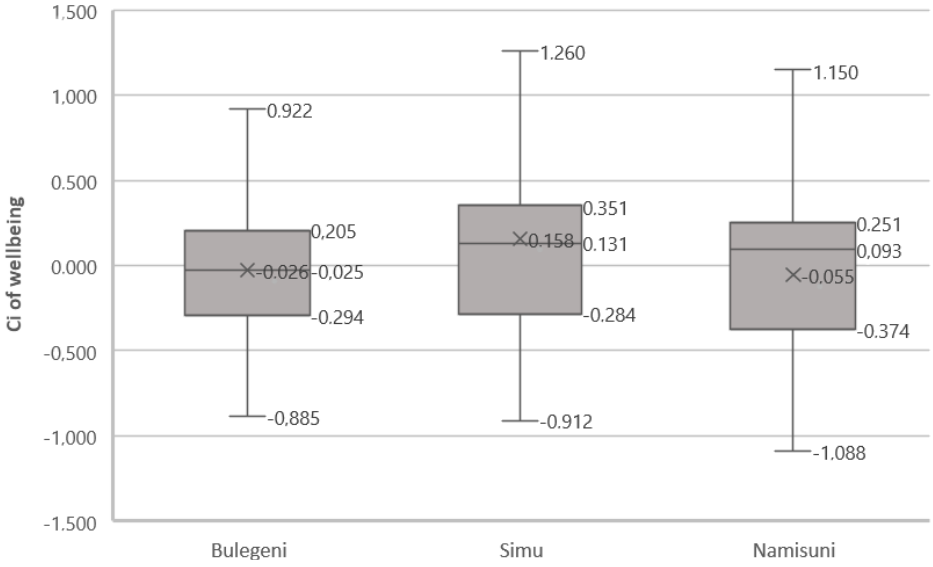


Table 9. One-factor ANOVA for the influence of sub-county on wellbeing index.

Source	Partial SS	df	MS	F	P(>F)
Between groups	2.923	2	1.462	5.891	0.003**
Within groups	105.696	426	0.248		
Total	108.619	428			

Table 10. Descriptive statistics for the four wellbeing factors (after z-score transformation).

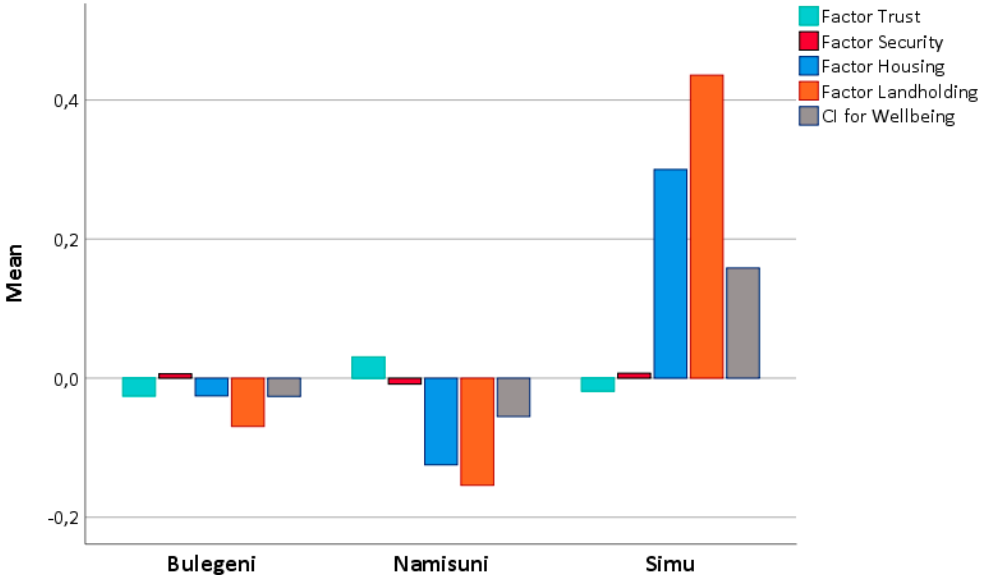
Component	Factor	Sub-county	N Valid	Mean	Median	SD	Variance	Range	Min	Max
Social-psychological	Trust	Bulegeni	156	-0.026	0.350	1.071	1.148	3.718	-2.189	1.528
		Simu	90	-0.019	0.219	0.953	0.909	3.462	-1.828	1.634
		Namisuni	185	0.031	0.311	0.964	0.930	3.810	-2.182	1.628
		Total	431	0.000	0.285	1.000	1.000	3.823	-2.189	1.634
	Security	Bulegeni	156	0.006	0.144	0.904	0.817	3.653	-2.077	1.576
		Simu	90	0.007	0.380	1.036	1.074	3.673	-1.936	1.737
		Namisuni	185	-0.008	0.289	1.062	1.127	3.828	-2.249	1.579
		Total	431	0.000	0.273	1.000	1.000	3.987	-2.249	1.737
Physical	Housing	Bulegeni	156	-0.026	-0.210	0.911	0.831	5.132	-0.885	4.247
		Simu	90	0.300	-0.236	1.490	2.221	5.953	-1.523	4.430
		Namisuni	185	-0.125	-0.221	0.708	0.501	5.467	-0.901	4.566
		Total	431	0.000	-0.221	1.000	1.000	6.089	-1.524	4.566
	Landholding	Bulegeni	156	-0.069	-0.332	0.839	0.703	6.170	-1.230	4.940
		Simu	90	0.4358	0.102	1.563	2.442	8.626	-1.632	6.993
		Namisuni	185	-0.154	-0.350	0.663	0.439	5.154	-1.636	3.518
		Total	431	0.000	-0.270	1.000	1.000	8.629	-1.636	6.993

3.2.2 Comparison of physical and social-psychological factors

To compare physical and social-psychological influences in a second step, I investigated z-standardized factors. Following the descriptive results shown in Table 10, the total range and the ranges per sub-county for z-scores of the social-psychological factors *trust* and *security* are < 4. The ranges of the z-scores of the factors *housing* and *landholding* of the physical component of wellbeing show greater (5.132 to 8.629) differences between minimum and maximum values of z-scores in total and for individual sub-counties. The physical component of wellbeing thus indicates greater variation and also a higher diversity in the percentage impact on wellbeing compared to the social-psychological component.

However, Figure 4 gives a more detailed explanation for the impacts of the individual factors on wellbeing by sub-county. It shows the means for all factors and the CI of wellbeing for the individual sub-counties and reveals that *landholding* has the strongest impact on wellbeing in all individual sub-counties, although this impact is negative (negative scores correspond to values less than the mean) in the sub-counties of Bulegeni and Namisuni. The means of the social-psychological factors *trust* and *security* are clearly smaller for all individual sub-counties, except for Bulegeni, where *trust* causes lower means for wellbeing of the HHs. With regard to the mean of total wellbeing, the results in Fig. 4 show that in Simu, the wellbeing score is the highest, followed by Bulegeni and Namisuni.

Figure 4. Means for the factors trust, security, housing, and landholding, and the CI of wellbeing for the sub-counties Bulegeni, Namisuni, and Simu (after z-score transformation).



4. Discussion

The findings presented here suggest that wellbeing can be explained mainly by the four factors *trust, security, landholding,* and *housing* quality, containing in total ten indicators divided into physical and social-psychological components that have different impacts on the wellbeing of individual HHs in the research area. In addition, an influence of the sub-county on wellbeing was found that can be explained primarily by the significant differences found for the physical factors *housing* and *landholding*.

The physical conditions of the HHs show that only a few have homes with plaster or brick walls, or wood or cement floors. This finding confirms those of the NPHC (2014), where only 6.6% of the interviewed HHs responded that their dwellings were constructed with permanent floor materials and 6.9% with permanent wall materials. The total mean for our sample group for *land used for agricultural activity* is 0.95 hectares, whereas the total mean for *land used for coffee cultivation* is about half that (0.5 ha). Other studies in the Mount Elgon region of Uganda found that the majority of their sample group had less than one hectare of land (e.g., Mugagga 2011). For both *land used for agricultural activity in general* and *land used for coffee cultivation*, the ranges of values for the area are up to ten times higher than the mean, which indicates wide disparity with regard to *landholding* in the community, especially in Simu.

The smaller means for the social-psychological factors could also be explained by the transformation into z-scores: Indicators with extreme values, such as those for *landholding,* have a greater effect on the CI, because indicators are converted to a common scale with a mean of zero and standard deviation of one. Here, extreme values were not excluded, because differences in hectares of land could not be ignored in cases where the main economic activity is farming. Nevertheless, it is widely accepted that landholdings are the major factor for HHs depending on agriculture. Even though the entire social-psychological component and also the individual factors *trust* and *security* do not significantly differ between sub-counties (quality of results from ANOVA were confirmed by Levene's and KS tests), the results still show a significant influence of the sub-county on the single indicators *economically secure* and *safe from violence and crime.*

The means for the final calculated CI of wellbeing indicate the highest wellbeing for the sub-county of Simu, followed by Bulegeni and Namisuni. The same order is found for the range of wellbeing within the sub-counties. To conclude, the results show differences in wellbeing within, and even greater differences in wellbeing between sub-counties, confirming the hypothesis stated at the outset.

Although there has been no direct research on wellbeing in the area under investigation here, findings reported by the NPHC (2014) also indicate differing levels of wealth in different sub-counties: for instance, the percentage of 6-12-year-old children not attending school is 17.6% in Bulegeni, 13.6% in Namisuni, and 12.9% in Simu. In addition, the percentage of 18-30-year-olds who are not in school and not working ranges widely, from the lowest in Bulegeni (8.7%), followed by Simu (12.5%), to the highest in Namisuni (27.1%). Looking at the percentage of people eating less than two times a day, Simu has the highest rate at 9.3%, followed by Namisuni at 7.2% and Bulegeni at 5.3% (NPHC 2014). In contrast to the results of the present paper, the findings of the NPHC (2014) do not clearly indicate distinct trends for the individual sub-counties.

The sub-counties investigated in this study do not border each other. Looking at the map of the sub-counties, it becomes clear that Namisuni and Bulegeni are closer to each other than to Simu. The geographical distances between the sub-counties correspond to similarities in the results of the wellbeing index, with sub-counties that are geographically closer showing more similar results. Further research should investigate whether geographic location really matters for wellbeing and whether there are other reasons that could explain the differences in physical wellbeing in different sub-counties. A possible explanation for the higher welfare in Simu could be the better access to roads, which enable faster and safer transport to the next town and could also lead to economic advantages. Another possible explanation could be better ecological conditions. It can be assumed that the presence of Sisiyi Falls in Simu could provide a more constant water source for crop cultivation or lessen the impact of droughts. This could lead to higher income from coffee selling or lower expenditures for food that has to be purchased in addition to self-sufficiency agriculture. Proving this assumption would require further investigation of the water sources in Bulegeni and Namisuni. Also, the *housing* quality parameter could explain the differences in wellbeing, because in Namisuni and Bulengeni, soils are too poor to make bricks, and transportation costs for bricks in both of these sub-counties with lower wellbeing far exceed the cost of the bricks themselves, whereas in Simu, the conditions for building a permanent house do not entail such high transaction costs. There could, however, be several other reasons for better physical wellbeing in Simu that should be included in further analyses. It might also be interesting to find reasons explaining the higher *trust* levels and the lower *security* perceptions in Namisuni than in the other sub-counties.

Nonetheless, several impacts of the data-driven development of the CI of wellbeing should be considered. Here, we interviewed the HH heads, who in our sample group are mainly men. Considering that based on their role within the HH, women are more likely to consider the wellbeing of the entire family, there might be differences in the indicators impacting wellbeing. A female perspective could be somewhat more representative of the wellbeing of the entire HH and might also consider more health or educational indicators, such as those found in the Women's Capabilities Index for Malawi developed by Greco (2018). Due to the widespread gendered division of labor in Uganda and the corresponding differences in men's and women's responsibilities for coffee-related tasks (Bantebya *et al.* 2014), it might be difficult to collect high-quality data from the HH heads' wives on questions about the economic or security level of the HH, realms that traditionally are the husband's responsibility. This issue does not have a major impact on the comparability within our sample group, but the higher number of male-headed HHs interviewed for this study compared to the research area reduces the representativeness of the results for the entire research area.

Nevertheless, the construction of a CI has the advantage of measuring wellbeing indirectly. Indirectly answered questions can lead to a lower impact of social desirability of the answers given by the farmers. It can further prevent low response quality due to different understandings of what complex terms like wellbeing mean. However, there are many different ways to construct a CI, starting with the definition of the term wellbeing, content-related selection criteria for indicators, the statistical analysis of reliability of indicators, all the way to the choice of a tool for measuring the weight of influencing factors. Even

if many indicators were involved here, indicators such as the HH head's health status or coffee productivity might be considered for further data collection. In the future, social and psychological components could be differentiated in more detail to provide an even better picture of what wellbeing means for the HHs investigated. Each individual step in constructing the CI influences how well the CI reflects wellbeing. Nevertheless, even the best choices in each step would lead to a loss in information due to the merging of single indicators.

However, the weighting of the factors was also calculated by the variance of the PCA and resulted in higher weighting for *trust* and *security* than for *landholding* and *housing*. Using results from (male) expert interviews would have led to higher weighting for *landholding* because "land comes first for farmers"[3], but for reasons of objectivity, the results of the PCA were used. The precondition for the calculation of weights based on results of the PCA was that the indicators identified as relevant correlate, which was given after Pearson's correlation.

Along with the measurement of suitability to use the factor weighing approach of the PCA developed by Nicoletti *et al.* (2000), correlations between indicators also provide deeper insights into the data set, which I briefly discuss in the following. From the positive relationship between the perception *economically secure* and *land used for coffee cultivation,* it can be assumed that an increase in *land used for coffee cultivation* is associated with higher income. The positive relationship between the *level of happiness* and the area for coffee cultivation may be explained by a higher level of business activities and greater freedom to spend money for the cultivation of cash crops. Food crops grown by farmers for their own consumption could improve the nutritional status of the HH. Sometimes leftovers from subsistence agriculture are sold at local markets, which yields small amounts of cash income. However, this cash income is not sufficient to cover the costs of families' basic needs such as health care, education, and shelter. One should keep in mind that coffee is only harvested once a year and coffee prices and coffee yields differ from season to season depending on weather and world market prices for coffee. It cannot be assumed that farmers are willing to switch the total area used for subsistence agriculture to coffee cultivation due to significant changes in market prices for the already low prices they get per kilo of coffee. Sometimes prices do not even cover the production costs (Sayer 2002). If, in such cases, farmers would only cultivate coffee and not engage in any subsistence agriculture, a reduction in wellbeing would likely be the result. In addition, landholding as such usually cannot be increased in this region, while access to land often decreases substantially from one generation to the next due to the high fertility rates and the division of inherited land among siblings (Mugagga 2011). This issue will become even more critical if fertility rates remain high and if inherited land continues to be split from one generation to the next (SUPRE 2018). If farmers want to increase the area for coffee cultivation, they will have to do so on the land they currently own. Otherwise, land dispossession could lead to even higher negative impacts on the wellbeing of farming HHs. Previous results from Liebig *et al.* (2016) also indicate that some of the plots in the same districts "showed no or a very low coffee productivity as a consequence of old

[3] In addition to the quantitative interviews presented here, qualitative interviews and expert interviews were conducted by the research team.

coffee bushes or inappropriate management practices". Improving farm management practices could therefore also help the UCDA to reach the goal of quadrupling Uganda's coffee production (see UCDA 2019) by improving farmers' resource situation and enabling them to increase their coffee productivity. Research on the basic conditions for this could not only help to increase coffee productivity; it could also prevent or slow down the reduction in coffee production as the suitable land for Arabica coffee cultivation in Uganda declines due to climate change (Jassogne *et al.* 2012).

Furthermore, results show that farmers' belief that their concerns are taken into consideration by the local government is stronger than their *trust in government officials*. Therefore, it can be assumed that the trust in institutions is higher than the *trust in most people* the farmers work with directly. The *level of happiness* also increases with higher values for *trust in most people*, *trust in government officials*, and consideration of farmers' concerns by the local government (and the other way around). The same correlation is visible for the relationship between all other indicators of *security* and the indicators of the factor *trust*. Research on the individuals who act as middlemen for coffee sellers (Baffes 2006) has shown that they are known to engage in unfair and exploitative business practices. This could explain, for instance, the positive relationship between *trust in most people* and the perception of being *economically secure*. Mosley and Verschoor (2005) confirmed the latter correlation in their study investigating trust levels in Sironko and Bufumbo, districts close to Bulambuli investigated here, and found that trust increases with the wealth status of a HH. However, the high knowledge and information gap in the research area could also have an impact on trust. According to the study by Sseguya *et al.* (2012), which was implemented in Southeast Uganda, information networks among farmers, extension workers, local governments, and the private sector are very uncommon and lead to a high information gap on the part of the farmers, depending on which sources of information a farmer has access to.

The positive relationship between the perception of being *safe from violence and crime* and (a) *trust in government officials* and the high positive values for (b) *local government considers the farmers' concerns* is consistent with the assumption that farmers who have trust in institutions feel more protected.

The results of the data set presented here are only suitable to provide a static specification of wellbeing at the time of data collection. To measure dynamic changes in wellbeing over time, further data collection could enable repeated evaluations and could also include medical or nutritional status or additional aspects of housing quality to increase the number of potential physical indicators. In addition, detailed investigation of factors influencing wellbeing (e.g., income, education, number of children) and of the relationship between perceived deficiencies and wellbeing should be a focus of further research.

5. Conclusions

The main aim of this paper was to understand how coffee farmers in the Mount Elgon region of Uganda perceive their wellbeing. The CI for wellbeing and the wellbeing indicators served as suitable instruments to test the hypotheses that (1) wellbeing in the investigated research area is not equally distributed within and between sub-counties and that (2) the physical wellbeing component causes a lower wellbeing level of HHs than social

and psychological indicators. The findings from these hypotheses regarding the composition of wellbeing and the dependencies between wellbeing indicators provide a sound basis for policy recommendations.

The selection of nineteen potential indicators for the resulting physical and social-psychological components of wellbeing was made according to statistical relevance. The results of the explorative PCA show that *trust*, *security*, *housing*, and *landholding*, containing in total ten of the previously selected indicators, provide the most comprehensive composite picture of wellbeing, explaining 81.20% of the total variance. The weight of each factor within the CI of wellbeing—which was calculated by the percentage of variance explained by the factor after varimax rotation divided by the total variance of all factors—was ranked from *trust*, showing the highest weight, to *security* and *housing,* all the way to *landholding* with the lowest weight.

Nevertheless, *housing* and *landholding* provided the highest z-scores in both directions, negative and positive, and were thus identified as the highest-impact factor for all sub-counties, even after the lowest weighting within the CI formula. Due to the high negative values for *landholding* in Bulegeni and Namisuni, the hypothesis that physical wellbeing causes lower wellbeing constitutions of HHs than social-psychological wellbeing can be confirmed. For Simu, a sub-county with greater access to land, the factor *landholding* also has a high impact on wellbeing, but in a positive way.

The main finding for the physical indicators is the overall low level of wellbeing. The final CI for wellbeing shows differences in wellbeing between and also within sub-counties, which confirms the previously mentioned first hypothesis.

The dependencies between indicators and different impact levels of indicators of wellbeing within the CI of wellbeing provide the basis for several policy recommendations. Because land area is a variable that cannot be increased in the area under investigation here, the only recommendation that can be made would be to mandate official registration of land to prevent potential land-grabbing motivated by the nutrient-rich volcanic soils in the Mount Elgon region (UNDP 2012). Official land registration should attempt to establish equal land rights between husbands and wives. At the moment, it is common that the man holds the land rights (even though this is not official). In cases of the male HH head's death, his male relatives inherit those rights. The loss of land often increases the economic vulnerability of the remaining HH members. This is an important issue, considering that about the half of the female-headed HHs of the HHs presented here are widowed.

The *level of happiness* and the perception of being *economically secure* could be improved by a higher percentage of *land used for coffee cultivation*. Due to the previously mentioned drawbacks for coffee farmers when increasing the percentage of land for coffee cultivation, this cannot be generally recommended. Instead, the results point to policy recommendations that farmers should be trained in methods to improve their currently low coffee productivity to increase their income from coffee production. Another recommendation to increase income from coffee selling would be to implement standardized processes for coffee-selling activities. Contracts between buyers and sellers, improved access to information about the coffee market to reduce the information gap between buyers and coffee farmers, reliable weighing scales, or even a statutory minimum price could be explored as approaches to increase income from coffee selling and mitigate issues of mistrust.

The currently low *housing* quality of the majority of HHs is also having an impact on the wellbeing of the coffee-farming HHs. Here, development activities could focus on improving *housing* quality, for instance, by improving access to financial services, providing construction loans, or offering subsidized prices for bricks and other construction materials. This might be an effective approach to improve the level of wealth in the area under investigation and could improve wellbeing levels, especially in Namisuni and Bulegeni. The results presented here could further be used to investigate the success of existing development approaches in the Bulambuli district.

To conclude, the results presented here suggest that in the future, the already low wellbeing of the HHs in this area will decrease further with each subsequent generation due to existing land inheritance structures and the steadily decreasing suitability of land for Arabica coffee cultivation as a result of changing weather conditions. Policy and market-related activities should be implemented to help the coffee farmers in the Mount Elgon region by enabling them to improve their resource levels and cope with the growing challenges (Dodge *et al.* 2012) in order to maintain—or better, increase—their current levels of wellbeing.

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7. References

Ahmed, M. H., & Mesfin, H. M. (2017). The impact of agricultural cooperatives membership on the wellbeing of smallholder farmers: empirical evidence from eastern Ethiopia. *Agricultural and Food Economics* 5(6).

Allen, R. P. (2001). The Wellbeing of Nations: A Country-by-Country Index of Quality of Life and the Environment. Washington D.C.: Island Press.

Bacon, C. (2005). Confronting the coffee crisis: Can fair trade, organic, and specialty coffees reduce small-scale farmer vulnerability in northern Nicaragua? *World development* 33(3): 497-511.

Baffes, J. (2006). Restructuring Uganda's Coffee Industry: Why going back to basics matters. *Development policy review* 24(4): 413-436.

Bantebya, G. K., Muhanguzi, F. K., and Watson, C. (2014). Adolescent girls in the balance: Changes and continuity in social norms and practices around marriage and education in Uganda. Country Report. London, UK: Overseas Development Institute..

Beaumont, J. (2011). Measuring national well-being: Discussion paper on domains and measures. *Monthly Digest od Statistics* 790: 117-150.

Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (2016). Uganda. http://www.bmz.de/de/laender_regionen/subsahara/uganda/index.html. Accessed 10 November 2019.

Bolwig, S. (2012). Poverty and gender effects of smallholder organic contract farming in Uganda. USSP Working Paper 8, Washington, D.C.: International Food Policy Research Institute (IFPRI).

Chiputwa B., Qaim M. and Spielman D. J. (2015). Food Standards, Certification, and Poverty among Coffee Farmers in Uganda. *World Development* 66: 400-412.

DaMatta F.M., Cavatte P.C. and Martins S.C.V. (2012). Coffee physiology: Growth, yield and quality. In Oberthür T., Läderach P., Pohlan J. and Cock J.H. (eds), Specialty Coffee: Managing Quality, Penang: International Plant Nutrition Institute.

Decancq, K. and Lugo, M. A. (2012). Inequality of wellbeing: a multidimensional approach. *Economica* 79(316): 721-746.

Dodge, R., Daly, A., Huyton, J. and Sanders, L. (2012). The challenge of defining wellbeing. *International Journal of Wellbeing* 2(3): 222-235.

Doss, C. R. (2002). Men's crops? Women's crops?: The gender patterns of cropping in Ghana. *World Development* 30(11): 1987-2000.

Estoque, R. C., Togawa, T., Ooba, M., Gomi, K., Nakamura, S., Hijioka, Y. and Kameyama, Y. (2018). A review of quality of life (QOL) assessments and indicators: Towards a "QOL-Climate" assessment framework. *Ambio* 48(6): 619-638.

Food and Agriculture Organization of the United Nations (FAO) (2013). The Director-General's Medium Term Plan 2014-17 and Programme of Work and Budget 2014-15. Thirty-eighth Session of the Conference 15 –22 June 2013. C2013/3. Rome.

Field A. (2009). Discovering statistics using SPSS. New York: Sage publications.

Formo R.K. and Padegimas B. (2012). Mount Elgon Landslide Information needs. Feasibility Study Report. GRID-Arendal. http://worldcoffee.info/MEDIA/docs/UGANDA-elgon/Mt.Elgon_report_ final_LANDSLIDE_Formo-Padegimas-Oct-2012.pdf. Accessed 10 November 2019.

Frank, E., Eakin, H. and López-Carr, D. (2011). Social identity, perception and motivation in adaptation to climate risk in the coffee sector of Chiapas, Mexico. *Global environmental change* 21(1): 66-76.

Greco, G. (2018). Setting the Weights: The Women's Capabilities Index for Malawi. *Social indicators research* 135(2): 457-478.

Headey, B. W. and Wearing, A. J. (1992). Understanding happiness: A theory of subjective well-being. Melbourne: Longman Cheshire.

Hendry, L. B. and Kloep, M. (2002). Lifespan development: Resources, challenges and risks. London: Thomson Learning.

Jassogne L., Läderach P. and van Asten P. (2012). The impact of climate change on coffee in Uganda: Lessons from a case study in the Rwenzori Mountains. Oxfam Research Reports. Nairobi: Oxfam Research Reports.

Joint Research Centre-European Commission (JRCEC) (2008). Handbook on constructing composite indicators: methodology and user guide. OECD publishing. Paris.

Kahneman, D. (1999). Objective happiness: Well-being. *The foundations of hedonic psychology* 3(25): 1-23.

Keyes, C. L., Shmotkin, D. and Ryff, C. D. (2002). Optimizing well-being: the empirical encounter of two traditions. *Journal of personality and social psychology* 82(6): 1007.

Läderach P., Ovalle O., Lau C., Haggar J., Eitzinger A., Baca M., Benedikter A. and Zelaya C. (2012). Climate Change at mesoamerican origins. In Oberthür T., Läderach P.,

Pohlan J. and Cock J.H. (eds), Specialty Coffee: Managing Quality. Penang. Malaysia: International Plant Nutrition Institute..

Liebig, T., Jassogne, L., Rahn, E., Läderach, P., Poehling, H. M., Kucel, P., Van Asten, P. and Avelino, J. (2016). Towards a collaborative research: a case study on linking science to farmers' perceptions and knowledge on Arabica coffee pests and diseases and its management. *PloS one* 11(8): e0159392.

Mosley, P. and Verschoor, A. (2005). The development of trust and social capital in rural Uganda: An experimental approach. Working Papers 2005011. The University of Sheffield.

Mugagga, F. (2011). Land use change, landslide occurrence and livelihood strategies on Mount Elgon slopes, eastern Uganda. PhD dissertation, Faculty of Science at the Nelson Mandela Metropolitan University.

Uganda Bureau of Statistics (UBOS) (2017). Bulambuli District. National Population and Housing Census 2014: Area Specific Profiles. Kampala.

Nicoletti, G., S. Scarpetta and O. Boylaud (2000). Summary Indicators of Product Market Regulation with an Extension to Employment Protection Legislation. Working Paper No. 226. Paris: OECD Publishing.

Ruben, R., and Fort, R. (2012). The impact of fair trade certification for coffee farmers in Peru. *World Development* 40(3): 570-582.

Santeramo, F. G. (2015). On the composite indicators for food security: Decisions matter!. *Food Reviews International* 31(1): 63-73.

Sayer, G. (2002). The impact of falling world prices on livelihoods in Uganda. Coffee futurs, Uganda coffee report for Oxfam. Oxford, UK: Oxfam GB.

Seligman, M. E. (2011). Flourish: A new understanding of happiness and well-being and how to achieve them. Boston: Nicholas Brealey.

Suh, E., Diener, E. and Fujita, F. (1996). Events and subjective well-being: Only recent events matter. *Journal of Personality and Social Psychology* 70(5): 1091–1102.

State of Uganda Population Report (SUPRE) (2018). Good Governance: A prerequisite to harness the demographic dividend for sustainable development. http://npcsec.go.ug/wp-content/uploads/2013/06/SUPRE-2018-.pdf. Accessed 23 November 2019.

Sseguya, H., Mazur, R., Abbott, E. and Matsiko, F. (2012). Information and communication for rural innovation and development: Context, quality and priorities in southeast Uganda. *The Journal of Agricultural Education and Extension* 18(1): 55-70.

Uganda Bureau of Statistics (UBOS) (2010). Uganda census of agriculture 2008/2009, Uganda Bureau of Statistics and Ministry of Agriculture, Animal Industry and Fisheries. Kampala.

United Nations Development Programme (UNDP) and Bureau for Crisis Prevention and Recovery (BCPR) (2012). Climate Risk: Management for Sustainable Crop Pro-duction in Uganda: Rakai and Kapchorwa Districts. New York.

Uganda Coffee Development Authority (UCDA) (2018). UCDA Monthly Report for March 2018. Kampala.

Uganda Coffee Development Authority (UCDA) (2019). UCDA Monthly Report for July 2019. Kampala.

Uganda National Household Survey (UNHS) (2018). Uganda National Household Survey 2016/2017 Report. Uganda Bureau of Statistics (UBOS). Kampala.

List of abbreviations

CI	Composite Indicator
HH	Household
JRCEC	Joint Research Centre, European Commission
KS	Kolmogorov-Smirnov
NARO	National Agricultural Research Organization
PCA	Principal Component Analysis
UBOS	Uganda Bureau of Statistics
UCDA	Uganda Coffee Development Authority
UNHS	Uganda National Household Survey

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Full Research Article

Agricultural Sector Performance, Institutional Framework and Food Security in Nigeria

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Abstract. This study examines how the performance of the agricultural sector can be enhanced in the long-run through institutional framework thereby ensuring food security in Nigeria. It employs the ARDL (Autoregressive Distributed Lag) with data from the Central Bank of Nigeria (CBN) statistical bulletin, Food and Agriculture Organisation (FAO), World Development Indicators (WDI), and World Governance Indicators (WDI). Food security is used as the dependent variable proxied by the number of the people undernourished under the stability dimension; agricultural sector performance and institutional framework as the independent variables, while population is a control variable. Two agricultural variables (agriculture production and agriculture credit) are employed with six variables of institutional framework. The findings show that in the log-run, agriculture production and agriculture credit (agriculture variables) will increase food security by reducing the number of people undernourished by 2% and 18%, respectively. In terms of institutional framework; political stability and absence of violence and rule of law increase food security by reducing undernourishment by approximately 69% and 29%, respectively; control of corruption and voice and accountability tends to reduce food security by increasing the number of the people undernourished by 74%, 51% and 63% respectively. Therefore, the study concludes by recommending, among others, that the Nigerian institutional framework should be improved (especially the control of corruption) in addressing the challenges in the implementation of food security programmes and ensuring timely distribution of food resources.

Keywords. Agriculture, Food Security, Governance, Institutions.

JEL Codes. G38; H1, O43.

1. Introduction

This study explores the nexus between agricultural sector performance, institutional framework and food security in Nigeria. It engages Autoregressive Distributed Lag (ARDL) as the econometric technique in examining the long-run relationship among the selected variables. The results show that in the long-run, agricultural performance con-

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tribute to food security by reducing the number of the people who are undernourished (Ejikeme, Ojiako, and Ezeh, 2017; Ibe, Alozie and, Iwueke, 2017). This is germane as ensuring food security is an important factor for human survival (Babatunde, Omotesho and Sholotan, 2007; Omonona and Agoi, 2007; Dias, Juliana, Giller, and Ittersum, 2017; Waldron 2017). Extant studies have presented the subject of food security from a number of perspectives: government's involvement, climate change and the need for availability of food and related resources for human consumption (Ike, Jacpbs and Kelly, 2017; Osabohien, Osabuohien, and Urhie, 2018; Osabohien, Ufua, Moses and Osabuohien, 2020).

The role of institutional framework in ensuring food security cuts across all tiers of government: federal, state and local (Osabohien *et al.*, 2018). The different mandates in each tier and territories produce a continuous state of change in the expectations and roles of government (Dollery *et al.*, 2003). A great deal of responsibility is of essence at the local level as it interacts directly to the population. At some point the revenue has decreased (Bell, 2007) while local government human service responsibilities have increased, mostly at local government level, the impact of such challenges is often evidenced (Agranoff, 2014). Policy deduction occasionally springs out from the local strata which in turn is been reshaped at the federal level. There exists a strong relationship with specific agricultural policies and the evolution of food security in different regions, which are structured by international relations, changing conditions in urbanized areas and local societal factors (Koning, 2017). The effectiveness and/or economic output are no measuring factors on the multiple level problems but it demands for fitness in the government levels for a comprehensive solution (Batley and Larbi, 2004). Provision of access to food for the population is also not properly eradicated as this challenge is been combated on a regular basis. Combining biophysical, geographical, political and societal factors appears to be a location outcome with respect to food security (Huisman *et al.*, 2016; Sheahan and Barrett, 2014)

The institutionalization of society provides a vital insight in the government proceedings. On a broader view, understanding how innovation, food processing, agricultural development, and access to food get shape is considered as the importance of institutions (Acemoglu *et al.*, 2012; Booth *et al.*, 2015; Frankema, 2014; Rodrik *et al.*, 2004; Ruttan and Hayami, 1984). In general terms, institutions can be defined as "systems of established and prevalent social rules that structure social interactions" (Hodgson, 2006). The interaction of human in its environment might not solely be captured by institution but there exists an agreement that institutions are important determinants of the trajectories of socio-ecological systems (Young, 2002).

Despite the effort of successive government administrations in Nigeria, non-governmental organizations (NGOs), and the international agencies, the challenge of achieving food security has remained a herculean task (Ufua, 2015; Abdulrahman Mani, Oladimeji, Abdulazeez, and Ibrahim, 2017; Osabohien, Osabuohien, and Urhie, 2018; Osabohien et al., 2020). However, while the government has made some efforts through various budgetary allocations, supports from international agencies, and so on (Androsova *et al.*, 2016; Lynam, Beintema, Roseboom and Badiane; Osabohien, Matthew, Aderounmu and Olawande, 2019), the instrumentality of accountability, government effectiveness in equitable distribution and preservation of food resources, which could provide relevant support in ensuring food security tends to have been inadvertently neglected in the literature. Nev-

ertheless, with a stable population growth, the possibility of eradicating hunger by 2050 becomes questionable in Nigeria (FAO, 2017). This forms one of the motivations for this study that focuses on the need for developing agriculture for sufficient food production and institutional framework food even distribution.

The foregoing is essential, as the challenge of distribution along the relevant value chain has resulted in the scarcity of certain food resources. Hence, the poor and lower class of the society are usually excluded through hiked prices occasioned by increased cost along the value chain. This points out the need for strong value chain and distribution of food resources in terms of food management in the interest of citizenry (Ufua *et al.*, 2018). Institutional framework in the context of this study promotes the use of records and data for planning food security issues, with due attention given to all stakeholders who are either involved or affected in the planning and implementation of food security programs (Haddad, Hawkes, Achadi, Ahuja, Bendech, Bhatia and Fanzo 2015; Olurankinse and Oloruntoba, 2017). This could be achieved through the practice of meaningful engagement with the stakeholders at each stage of the implementation of food security programs (Ufua *et al.* 2018). This would result in mutual understanding between the stakeholders and the interveners that may undertake the task of designing the right food distribution strategy and facilitate a conflict free platform to execute the task of accountable food distribution (Womack and Jones, 2003; Ufua *et al.* 2015; Osabohien, Afolabi and Godwin, 2018).

The study is structured as follows: the next session presents the literature review, followed by the adopted methodology, next is the presentation of result and the last session is conclusion, which includes managerial implications, and suggestions for further research.

2. Empirical Literature

It has been predicted that food demand will increase in the coming years, especially Nigeria with high population and to control this food demand, strategies for efficient and effective supply of food to all households in Nigeria needs to be put in place to mitigate food shortage. This can be done through innovation like warehouse and other storage facilities, among others (Osabohien *et al.*, 2018). Populations spread of countries in West African sub-region during the period under review; Nigeria, which is the focus of this study has a high population growth rate. This has not been reflected on food production and security practice in Nigeria. Instead, the growth in national population has resulted in a further complexity in terms of availability of food that meets the demands of the population density, especially in urban areas where food production is minimal and the demand is high (Ojo, 2004; Echebiri and Edaba, 2008; Jhingan, 2003).

It is widely believed in literature that increase in production generates more food capable of reducing food shortage and the exclusion of the poor as a result of hunger as experienced in France and England (Fogel, 2004). The improvement in supply of food for both countries showed efficient production of food systems. In terms of food production, Nigeria as the most populated country in Africa with over 190 million people lags behind other West African countries as its food production observed to be lower (FAO, 2017). In this regard, more attention is needed to boost food production, food preservation and distribution, which could form a notable base for projecting the economy to better performance

in the future. Furthermore, it has been noted in Mali that, food production (especially food crops) has conventionally formed the bedrock for the pursuit of food security agenda (Sidibe *et al.*, 2018). This idea has been a long position of giving main concern of successive governments since Mali's gained political independence in 1960. Structural responses to food insecurity in Mali have mainly consisted of strategic reforms to enable the nation enhance agricultural production for the attainment of food security (Bélières *et al.*, 2008).

In rethinking the strategies for sustainable development in ensuring food security in Nigeria, the potentials of agriculture can be enhanced through institutional frameworks, effective governance, accountability and regulatory quality. From the empirical study of Osabohien, Osabuohien, and Urhie (2018) employing the Autoregressive Distributed Lag (ARDL) technique in examining the role of institutional framework on food security, pointed out that institutional framework in Nigeria exerts a negative effect on food security, due to weak institutional quality in Nigeria. According to Osabohien *et al.*, (2018), the Nigerian agricultural sector remains an important sector of the economy, owning to the fact that the sector employs approximately 75% of the total workforce, especially in the rural communities where most of the farmers earn their livelihood.

The study of Munene, Swartling and Thomalla (2018) employed the adaptive governance approach which pointed out that strategies to achieve sustainable development needs to be redirected. This would be more effective through the implementation of the framework requiring non-traditional management and governance approaches for a substantial reduction of food waste. It was noted that adaptive governance (AG) has been known to be the medium to change the link between development and disaster risk, with potentially far-reaching implications for policy and practice to ensure food security. Similarly, Osabuohien *et al.*, (2018) used the qualitative method with focus group discussion to examine how local institutions contribute to food (rice) production in Ogun State, Nigeria where it was pointed out that local institutions play a key role in food production. In a study conducted by Herbel, Crowley and Ourabah (2012), it was shown that achieving food security and the enhancement of dietary level is at the heart of the Sustainable Development Goals (SDGs). In line with that, Sidibé, Totin, Thompson-Hall, Traoré, Traoré, and Olabisi (2018) noted that achieving food security can be done through the enforcement of rules and laws designed at the national level which remains one of the central institutional mechanisms for efficient multi-scale governance in most countries.

According to Termeera, Drimieb, Ingram, Pereirad, Whitting (2018), policymakers are increasingly enlightened on the food security perspective, which has over the years reflected poorly in terms of institutional framework. Thus, this paper fills this gap by addressing the question as to what forms of institutional framework is more appropriate to govern food systems in a more holistic way to achieve sustainable development goals (SDGs) of the United Nations by the year 2030 and Agenda 2063 of the African Union. In Africa, food security in relatively is high on the policy agenda of governmental authorities all over the globe (Candel, 2014). Food and Agricultural Organization-FAO (2011) report, 'Food security governance' relates to the 'formal and informal' rules and processes through which interests are expressed, and decisions which are germane to food security in a country are prepared, implemented and enforced on behalf of members of society.

From the findings of Rodrik (2010), Osabuohien *et al.*, (2018) and Osabohien *et al.*, (2018), to achieve food security, there is a need for equal opportunity in resource alloca-

tion and the delivery of services; coherent and coordinated policies, institutions, and actions. This means that the challenge for policymakers interested in addressing the key policy issues are to redesign strategies that allow countries to have a stable and affordable food supply that is distributed as household food insecurity continues to be widespread with strong inequities across and within countries governance and strategies. Given the economic situation in some critical parts of the country, for example; the North-east (Scribner, 2017; Ajayi and Adenegan, 2018), where starvation has been prevalent due to insurgency of Boko Haram, the use of the right approach to addressing the national challenge of food insecurity, based on a platform of accountability, have remained a maximum requirement for achieving the right results of this subject area. Thus, from the fallouts in the literature, this study addresses the gaps in knowledge and takes up the debate to a new level with respect to the issues of food security and agriculture and institutional framework in Nigeria.

3. Methodological Approach of the Study

The food system concept is poorly reflected in institutional terms at local, national, and international levels (Osabohien *et al.*, 2018; Fresco, 2009; Kennedy and Liljeblad, 2016; Osabohien *et al.*, 2020). Handling problems associated with food insecurity requires a more holistic approach in terms of institutions to fully address it.

To achieve the objective of the study, the Autoregressive Distribution Lag (ARDL) econometric approach to cointegration is applied in examining the log-run relationship between agricultural sector performance, institutional framework and food security in Nigeria. The study engaged time series data sourced from the Statistical Bulletin of the Central Bank of Nigeria (CBN), World Governance Indicators (WGI), World Development Indicators (WDI) of the World Bank, and Food and Agricultural Organization (FAO). The study adopted the Malthusian theory of population growth model (Malthus, 1798) as recently explained in Agarwal (2019); thus, the implicit function of the model is specified in equation (1).

$$FOODSEC = f(AGRICVAR, INSVAR, POP) \quad (1)$$

In equation (1) *FOODSEC* means food security, used as the dependent variable; *AGRICVAR* means agriculture variables (two agriculture variables; agricultural production and agricultural credit) were employed, *INSVAR* represents institutional variables employed in the study; six major institutional variables were included in the model which are: voice and accountability, political stability and absence of violence, control of corruption, rule of law, government effectiveness and regulatory quality. *POP* means population, which was used as a control variable in the model. The variables are incorporated in a comprehensive model as shown in equation (2).

$$foodsec = f(AGRICVA_2, INSTVAR_6, POP) \quad (2)$$

From the model, 2 represents the tow agricultural variables included, 6 represents the six institutional variables included in the model. The explicit form of the model is specified as shown in equation (3)

$$foodsec = \alpha_0 + \alpha_1\, agricpro + \alpha_2\, agriccredit + \alpha_3\, va + \alpha_4\, psav + \alpha_5\, coc + \alpha_6\, rol + \alpha_7\, ge + \alpha_8\, rq_+ \alpha_9\, pop + \mu \quad (3)$$

Where *foodsec* represents food security (stability component) proxied by the number of people undernourished, *agricpro* represents agricultural production, *agriccredit* represents agricultural credit; *va* represents voice and accountability, *psav* represents political stability and absence of violence, *coc* represents control of corruption, *rol* represents rule of law, *ge* represented government effectiveness, *rq* represents regulatory quality, *pop* represents population and μ represents the stochastic term.

Insight of the ARDL model is drawn from the empirical work of Osabohien et al (2018). The reason for the use of ARDL approach compared to other econometric techniques like the Johansen cointegration approach is built on the assumption that time series data trend in difference order of stationarity. Hence, other approaches to cointegration becomes inefficient in handling this situation. The ARDL model is specified in equation (4)

$$\Delta foodsec_t = \alpha_0 + \sum_{t=0}^{n} \alpha_1 \Delta agricpro_{t-1} + \sum_{t=0}^{n} \alpha_2 \Delta agriccredit_{t-1} + \sum_{t=0}^{n} \alpha_3 \Delta\, va_{t-1} + \sum_{t=0}^{n} \beta_4 \Delta psav + \sum_{t=0}^{n} \alpha_5 \Delta\, coc_{t-1} + \sum_{t=0}^{n} \alpha_6 \Delta\, rol_{t-1} + \sum_{t=0}^{n} \alpha_7 \Delta ge_{t-1} + \sum_{t=0}^{n} \alpha_8 \Delta\, rq_{t-1} + \sum_{t=0}^{n} \alpha_9 \Delta pop_{t-1} + \mu_{t-1}$$

The ARDL model is presented in equation (4), while the error correction model is presented in equation (5) showing the mechanism and the adjustment speed which presents the extent to which the system adjust to equilibrium when disturbed by exogenous shocks.

$$\Delta foodsec_t = \alpha_0 + \sum_{t=0}^{n} \alpha_1 \Delta agricpro_{t-1} + \sum_{t=0}^{n} \alpha_2 \Delta agriccredit_{t-1} + \sum_{t=0}^{n} \alpha_3 \Delta\, va_{t-1} + \sum_{t=0}^{n} \beta_4 \Delta psav + \sum_{t=0}^{n} \alpha_5 \Delta\, coc_{t-1} + \sum_{t=0}^{n} \alpha_6 \Delta\, rol_{t-1} + \sum_{t=0}^{n} \alpha_7 \Delta ge_{t-1} + \sum_{t=0}^{n} \alpha_8 \Delta\, rq_{t-1} + \sum_{t=0}^{n} \alpha_9 \Delta pop_{t-1} + \gamma ECM_{t-1} + \mu_{t-1}$$

From equation (5), Where: Δ is the change in operator and ECM_{t-1} denotes error correction term. γ represents the speed of adjustment from the short-run to the long-run equilibrium (Osabohien *et al.*, 2018). The hypothis is stated that:

H_0: $\alpha_0 = \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = \alpha_7 = \alpha_8 = \alpha_9$ *(there is no long-run relationship)*

H_1: $\alpha_0 \neq \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq \alpha_6 \neq \alpha_7 \neq \alpha_8 \neq \alpha_9$ *(there is a long-run relationship)*

The a priori expectation of the study is that: agricultural performance and institutional framework increase food security by reducing the number of the people undernourished, while population contributes to food insecurity. This can be demonstrated mathematically as: $\alpha_0 > 0$, $\alpha_1 > 0$, $\alpha_2 > 0$, $\alpha_3 > 0$, $\alpha_4 > 0$, $\alpha_5 > 0$, $\alpha_6 > 0$, $\alpha_7 > 0$, $\alpha_8 > 0$, $\alpha_9 < 0$, implying that the coefficient of the explanatory variables are expected to be positively related to food security (negatively related to the number of the people undernourished), except population.

Irrespective of the overall progress in reducing food insecurity across the world, Nigeria remains one of the countries with the highest number of undernourished people (FAO, 2011). Some countries have shown progress in terms of food security in recent years, this progress occurred in most countries in Europe, Eastern and South Eastern Asia, as well as countries in Latin America, while Nigeria showed little progress as the country lags behind even among other African countries. Food security can be referred to the state where all people, at all times, have physical, social, and economic access to adequate, safe and nourishing food which meets their dietary needs and food preferences for an active and healthy life (FAO, 2015).

Basically, there are four major dimensions of food security, which are availability, accessibility, utilisation, and stability; each of the four dimensions has its own unique component as a measure of food security (Pangaribowo, Gerber, and Maximo, 2013; Osabohien *et al.*, 2018). Though, the four dimensions of food security are highly important, in this study, given the peculiarity of the economy of our study, we considered mainly the stability aspect. The main reason for focusing on stability is because it addresses the stability of the other three dimensions over time. Individuals will not be considered food secure until they feel so and they do not feel food secure until there is stability of availability, accessibility and proper utilization condition (Bajagai, 2019).

Another major reason for the use of the number of the people undernourished as proxy for food security is because the world is in a nutrition crisis. Out of 667 million children under the age of five, scholars have shown that approximately159 million are undernourished (Adams, 2017) and household living in poverty suffer to purchase nutritious foods for themselves and other members of the household. Most times, these households of which most of them are farmers are constrained by limited access to sufficient agricultural inputs materials like seeds and fertilizers, making it difficult to cultivate the crops that could feed their families. Moreover, undernourishment and poverty exist in vicious cycle – children who are undernourished face intellectual deficiency, are less likely to do well in school, and therefore less likely to be productive as adults. As a result, they either struggle to earn enough income in adulthood to purchase nutritious foods or they do not have the productive capacity to grow the food needed to feed their households (Adams, 2017).

Instability of market price of staple food and inadequate risk baring capacity of the people in the case of adverse condition (e.g. natural disaster and adverse weather conditions), political instability is the major factor affecting stability of the dimensions of food security, which we have considered in this study. The dependent variable, food stability is proxied by the number of people who are undernourished. Two main independent variables (agricultural performance and institutional framework) with population as the control variable proxied by growth rate of population are engaged in the analysis.

The study builds on the Malthusian theory of population as recently explained in Agarwal (2019). This is because according to Malthus theory, the population grows exponentially while food production grows arithmetically doubling in each generation; in this wise, while food production is likely to increase in arithmetic progression, population is capable of increasing in geometric progression (Agarwal, 2019; Malthus, 1798). This situation of arithmetic food growth with simultaneous geometric human population growth predicts a future when people would have no resources to survive. This means many people will have to chase the few available food, in turn, leading to food insecurity. The data,

Table 1. Data sources, measurement of variables and summary statistics.

Variable	Identifier	Data Source	Measurement	Mean	Standard Deviation	Minimum	Maximum
Food security	Foodsec	FAO	Number of people undernourished (% of total population)	10.8	1.4	8.8	14.3
Agriculture	Agricpro	CBN	Total volume of agriculture production (units)	3707.3	4405.70	38.4	14709.1
	Agriccredit	CBN	Credit to agricultural sector (million naira)	3827678	4325308	80845.8	1.3
Population	Pop	WDI	Total number of people	1.2	3.1	8.4	1.9
Institutional Framework	VA[1]	WGI	Institutional qualities	-0.7	0.3	-1.6	-0.5
	PSAV[2]			-1.92	0.20	-2.19	-1.52
	COC[3]			17.10	10.13	0.70	28.00
	ROL[4]			1.14	0.19	0.72	1.43
	GE[5]			-0.4	0.81	3	7
	RE[6]			-0.8	0.2	0.1	1.5

Note: FAO: Food and Agricultural Organization; CBN: Central Bank of Nigeria; WGI: World Governance Indicators; WDI: World Development Indicators.

[1] Voice and accountability reflects perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media (WGI, 2019).

[2] Political Stability and Absence of Violence/Terrorism measures perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism (WGI, 2019).

[3] Control of corruption reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence (WGI, 2019).

[4] Rule of law Reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests (GWI, 2019).

[5] Government effectiveness reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies (WGI, 2019).

[6] Regulatory quality reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development (WGI, 2019).

sources, and measurement of the variables for the study are presented in Table 1.

4. Results

The results obtained from the ARDL approach is presented in this section.

4.1 Unit Root Test

To conduct the ARDL effectively, the unit root test for stationarity was conducted to determine the integrating order of the selected variables. This is considered as a necessary step in order to validate the assumption that none of the variables should be stationary at second differenced (that is, I [2]). This assumption is aimed at preventing the issue of 'spurious result. Insight of the ARDL methodology was drawn from the empirical work of Osabohien *et al.* (2018) and Ouattara *et al.* (2006). Ouattara *et al.* (2006) has it that F-statistic that Pesaran (2007) presented seems ineffective when differentiated at order two [I (2)], since the method is based on the premise that variables either co-integrated at order zero [I (0)] or co-integrated at order one [I (1)]. Therefore, engaging a unit root tests in the ARDL approach to cointegration is to ensure that none of the variables is integrated of order 2 as presented in Table 2.

In Table 2, variables exhibit different levels of stationarity, regulatory quality, political stability and absence of violence, control of corruption, agricultural credit and population are stationary at first difference, while others are stationary at levels. The result from the ARDL econometric analysis is presented in Table 3

The result obtained from the ARDL for both the short-run and long-run dynamics are shown in Table 3. The short-run result showed that: 1% change in agricultural produc-

Table 2. Unit Root Test for Stationary.

Variables	ADF t-statistic @ Levels	CV @ 5%	ADF t-statistic @ 1st Difference	CV @ 5%	Integration Order	Remark
Number of people undernourished	-1.82	-1.95	-2.75	-1.96	I(1)	Stationary
Agricultural production	-17.10	-1.95	-	-	I(0)	Stationary
Agricultural credit	-2.90	-3.21	-4.67	-3.69	I(1)	Stationary
Population	-1.81	-0.92	-4.83	-1.95	I(1)	Stationary
Voice and accountability	-2.18	-1.95	-	-	I(0)	Stationary
Political stability/Absence of Violence	-2.31	-2.87	-5.31	-3.82	I(1)	Stationary
Control of corruption	-1.52	-1.89	-4.41	-3.67	I(1)	Stationary
Rule of law	-3.91	-3.71	-	-	I(0)	Stationary
Government effectiveness	-3.82	-3.00	-	-	I(0)	Stationary
Regulatory Quality	-0.62	-2.99	-5.79	-2.90	I(1)	Stationary

Note: ADF means Augmented Dickey-Fuller, CV means critical value.
Source: Authors' using STATA 13.

Table 3. ARDL result.

Agricultural production	Agriculture credit	Population	Voice & accountability	Political stability	Control of Corruption	Rule of law	Government Effectiveness	Regulatory Quality
Long-run relationship								
-0.02 (*0.00*) [*0.01*[b]] [***0.01*****]**	*-0.18* (*0.10*) [*0.09*[b]]	*0.74* (*0.19*) [*0.08*[b]]	*0.51* (0.68) [*0.01* [b]]	*-0.69* (*0.40*) [*0.00* [a]]	*0.63* (*0.08*) [*0.468*]	*-0.29* (*0.05*) [*0.05* [c]]	- 0.08 (0.002) [0.001[a]]	- 0.24 (0.06) [0.08 [c]]
Short Run Relationship								
L1D	L2D	L1D	L2D	L1D	L2D	L1D	L2D	L1D	L2D	L1D	L2D	L1D	L2D	L1D	L2D	L1D	L2D
-0.05 (0.00) [0.00[a]] [0.00*]	-0.03 (0.17) [0.01[b]]	-0.06 (0.35) [0.02[b]] [0.02**]	-0.20 (0.80) [0.00[a]]	0.11 (0.49) [0.191]	0.200 (0.63) [0.19]	-0.07 (0.33) [0.55]	-0.06 (0.14) [0.13]	-0.21 (0.40) [0.04[b]]	-0.09 (0.42) [0.02 [b]]	0.03 (0.02) [0.11]	0.03 (0.02) [0.00 [a]]	-0.58 (0.56) [0.0 [b]]	-0.67 (0.81) [0.32]	-0.05 (0.02) [0.00[a]]	-0.08 (0.09) [0.00[a]]	-0.09 (0.85) [0.91]	-0.21 (0.92) [0.62]

Note: The standard error and the probability values are in parenthesis () and [] respectively. a, b, c means that variables are statically significant at 1%, 5% and 10% respectively, while LD shows that variables are lagged and differenced.
Dependent Variable is food security proxied by the number of People undernourished.
Source: Authors' using STATA 13.

tion all things being equal, leads to approximately 2% decrease in the number of people undernourished. This is done by increasing the availability of food as posited in Pangaribowo *et al.* (2013). Similarly, increase credit to agriculture helps to increase production that in turn leads to food security by reducing the number of people undernourished by 18%, similar to the findings of Osabohien *et al.* (2018). Given the weak control in the level of corruption, increase population, voice and accountability, which are positively related to the number of people who are undernourished meaning that change in these variables increase the number of the people undernourished by 63%, 74%, and 51% respectively, which is similar to the findings of Osabohien *et al.* (2018).

The long-run result showed that 1% changed in the first and second lag of agricultural production reduces the number of people who are undernourished by approximately 5% and 3% respectively, meaning that; increase agricultural production contribute to food security by diminishing the number the people who are undernourished. Similarly, 1% change in first and second lag of agricultural credit also contribute to the reduction of the number of the people who are undernourished and contribute to food security by approximately 20% and 11%, respectively. Population both the first and second lag increased the number of the people undernourished this is akin to Malthusian population theory, increase in population increases undernourishment, the reason for this high increase is because of low food production and many people chase little available food produced.

The findings of this study in similar to the study of Sidibé *et al.* (2018). Sidebe *et al.* (2018) argued that enforcement of effective rules and laws contribute to food security. In this study, accountability, government effectiveness, regulatory quality, political stability and absence of violence and rule of law in the long-run increase food security by reducing the number of the people who are undernourished these variables in the long-run these variables increase food security in the first lag 6%, 9% and 58% respectively, while in the second lag 21%, 3% and 67% respectively, but corruption and population reduce food security by 3% and 11% respectively. In summary, the general socio-economic and political conditions affect directly affect food security. The major causes, as outlined in the social, economic, and political context, imply that macroeconomic stability; economic growth and its distribution, public expenditure, and governance as well as quality of institutions are among the crucial factors affecting nutritional level (Pangaribowo *et al.* 2013).

In line with Adams (2017) there is a strong relationship between undernourishment and infection. While undernourishment can cause increased vulnerability to infection, infection also contributes to undernourishment - reinforcing a vicious cycle. The consequences of undernourishment include weight loss, damage to mucus membranes surrounding vital organs, impaired growth and development in children, and lowered immunity. This makes it easier for children to become infected by various pathogens. Once infected, nutritional status is further worsen, which, in turn, causes reduced dietary intake. Chronic exposure to pathogens from living in contaminated conditions can worsen health outcomes and damage the intestine, impairing long-term nutrient absorption. As a result, even if an individual were consuming enough food with the correct nutrients, the body would not be able to use and process those nutrients (Adams, 2017). In a study by Adams (2017) measuring the costs of hunger in Rwanda, it has been estimated that in 2012 there were an additional 280,385 clinical episodes as a result of childhood undernourishment of those, 47,064 were directly resulting from diarrhoea, fever, respiratory

Table 4. Estimates from Error Correction Mechanism.

Regressors	Regressand									
	D_npu	D_ agricpro	D_acgsf	D_ pop	D_va	D_psav	D_cc	D_rlaw	D_ge	D_rq
ECterm	-0.0245 [a]	-0.3137 [a]	-0.0351 [a]	-051087 [b]	-0.0951 [c]	-0.0038	-0.5561 [a]	-0.0481 [a]	-0.1201 [a]	-0.321
	(0.000)	(0.002)	(0.004)	(0.035)	(0.545)	(0.142)	(0.000)	(0.000)	(0.000)	(0.599)
npu(LD)	0.9216 [a]	-586.9926	-0.3541 [a]	-21282.73	0.1709	0.115773	-9.5024 [a]	-0.599 [a]	-0.599 [a]	-0.213
agricpro(LD)	(0.000)	(0.179)	(0.000)	(0.315)	(0.538)	(0.441)	(0.000)	0.000	0.000	(0.200)
	-0.00048	-0.0345	-1117.83 [b]	-9.1983	0.0202 [a]	0.0017 [c]	-0.0116 [a]	-0.003 [a]	2.208	3.108
	(0.034)	(0.856)	(0.0229)	(0.660)	(0.0430)	(0.060)	(0.000)	(0.032)	(0.544)	(0.67)
acgsf (LD)	4.0809 [a]	0.01216 [c]	-0.0551	0.0031	-2.1508	-4.0408 [b]	-2.4909 [a]	2.208	2.208	2.208 [a]
	(0.000)	(0.020)	(0.809)	(0.395)	(0.753)	(0.025)	(0.001)	0.544	0.544	(0.000)
Population (LD)	-2.8007 [a]	0.0924*	1.6065 [c]	1.046 *a**	-1.9407	1.4107	0.0121 [a]	3.421 [a]	4.027 [a]	1.043 [a]
	(0.0000)	(0.000)	(0.068)	(0.000)	(0.456)	(0.113)	(0.000)	(0.001)	(0.001)	(0.001)
Va(LD)	-0.06387 [a]	-36.72332 [a]	-293060.8 [b]	-9665.715	-0.25739*	-0.0464	4.7568	0.6685 [a]	-.180111	-.180111
	(0.000)	(0.000)	(0.0244)	(0.867)	(0.008)	(0.577)	(0.003)	(0.000)	(0.705)	(0.705)
psav (LD)	-0.5867 [b]	231.2085 [a]	32.8656 [b]	25765.93 [b]	-0.1919	-0.6713 [a]	0.44084	0.2047	-.180111	-.180111
	(0.097)	(0.000)	(0.023)	(0.0427)	(0.576)	(0.004)	(0.841)	(0.365)	(0.705)	(0.705)
Cc (LD)	-0.0027 [a]	-45.1274 [a]	24783.82	1397.085	-0.0890	-2.0173	-2.372	0.9265	-.180111	-.180111
	(0.000)	(0.002)	(0.350)	(0.386)	(0.459)	(0.128)	(0.260)	(0.258)	(0.705)	(0.705)
rlaw (LD)	-0.7855[b]	709.4312 [b]	-1571.819 [a]	-6163.004	-.180111	0.0200	6.7578 [a]	1.1067 [a]	-0.2311	-0.111[a]
	(0.047)	(0.031)	(0.000)	(0.865)	(0.705)	(0.938)	(0.000)	(0.000)	(0.705)	(0.005)
Ge(LD)	-0.7855[b]	0.0027 [a]	0.0027 [a]	0.0027 [a]	0.0027 [a]	0.0027 [a]	-0.45211	-2.0167	-0.492 [a]	-0.975
	(0.047)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.405)	(0.705)	(0.000)	(0.405)
rq(LD)	-0.7855[b]	0.0027 [a]	0.0027 [a]	0.0027 [a]	0.0027 [a]	0.0027 [a]	-0.8213	-9.0111	-0.811	-5.0111
	(0.047)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.705)	(0.705)	(0.705)	(0.705)
Adj. R-sq	0.8820	0.9804	0.6062	0.7480	0.831	0.9095	0.7973	0.695	0.750	0.620
AIC: 57.97317				HQIC: 59.21476				SBIC: 62.14865		

Note: a, b, c means that variables are statically significant at 1%, 5% and 10% respectively. D is difference operator, while LD shows that variables were lagged and differenced based on Akaike information criterion (AIC), Hannan-Quinn information criterion (HQIC) and Schwarz's Bayesian information criterion (SBIC)

Source: The Authors'

infection, and anaemia – all conditions correlated with the adverse impact of undernourishment

To ensure the long-run estimates are not spurious and the system adjusted properly to equilibrium, the error correction mechanism as presented in Table 4 was employed because, time series regression model is based on the behavioural assumption that two or more time series exhibit an equilibrium relationship that determines both short-run and long-run behaviour for the correction of error. The error correction relates to the fact that last period deviation from long-run deviation influences the short-run dynamics of the dependent variable. The result (-0.0245) from the error correction mechanism showed that the system adjust by approximately 2.5% to equilibrium. The error correction model is that each variable acts dependent (*regressand*) and independent (*regressor*).

5. Conclusion and Recommendations

The role of institutional framework in ensuring food security is multifaceted, as it is subjective to collective factors operating at diverse tiers of the social-ecological model. These factors comprise the accessibility of a sufficient food supply and access to food from the federal to the state and local government levels. Access to the food supply is in turn mainly influenced by agricultural production; this means that; the higher the production, the more people gain access to food. At the macro-level, food access is driven by factors such as food prices, job opportunities, minimum wages, and social protection policies.

Therefore, this study has made contribution by explores the importance of food security in Nigeria, considering agriculture and institutions as key variables. In other words, the population of Nigeria is not equating with the productivity, which in turn has a high negative significant effect on the state of undernourished people. The study found that it is a worthwhile practice for Nigeria to pursue food stability as this can form a background to channel the national economy to address the challenges of food. Thus, food security can be controlled with a high impact intervention from the government with an indelible intention of reducing corruption at a minimal rate. This could be done through an aggressive support initiative and other pragmatic actions to engage stakeholders to embark on effective food production and distribution that meet household demands. In order to meet households food demand, agricultural incentives should be granted to farmers to increase food production, this is evident from the result obtained in the study which shows that in the long-run increase in agricultural production reduces the number of undernourishment by 5% and 3%, agricultural credit enhances food production base thereby reducing undernourishment by 20% and 11%, respectively.

The need to address the issue of food insecurity in Nigeria demands a strong institutional framework, which could help demarcate the current situation in its entirety, highlighting the key areas affected, and encourage the advancement of relevant methods that can resolve the issue. This would create a platform of food supply resilience aimed at keeping the developed approach on a rapid response to emerging food security challenges. Fresh fruits and vegetables can be made available to the respondent communities without giving lots of dependency on vehicles and increasing the avenue of learning on healthy food options and opportunity to own and grow food (Hobsoons Bay City Council, 2009a: City of Darebin 2010). Under-development of agriculture, among other factors points to

the fact that food security would pose the challenge of low per capita productivity, especially in food production, which is relevant to food security. In Nigeria, uneven distribution of food probably reflects in price instability, which effects vulnerable households' ability to make long-term adjustments to their resource constraints. It is necessary to understand the nature of fluctuations in a food system that can aid researchers and policymakers on the strategies to be employed in enhancing the food systems in Nigeria.

Institutional framework is also required to address gender imbalance because social and economic inequalities between men and women also stand in the way of balanced nutrition. More often than not, undernourishment disproportionality affects women. In households vulnerable to food insecurity, women are shown to be at greater risk of undernourishment than men. Undernourishment in mothers, especially those who are pregnant or breastfeeding can create a cycle of deficiency that increases the likelihood of a low birth weight child and childhood undernourishment additionally, lack of decision-making power around family planning means that women have less ability to harmonize childbirth and breastfeeding schedules, which has direct implications for nutritional status

This menace of food insecurity, especially in Nigeria could also be traceable to the inherent crises by herdsmen and Boko Haram insurgency in the Northern parts of the country as the violence between the Fulani herdsmen and farmers have become one of Nigeria's most constant security challenges and have left thousands of people displaced and dead in recent years (Vanguard, January 11, 2018). Crisis in these locations (especially Benue that is referred to as the 'food basket of the nation' and other high agricultural states) have adversely affected food production and supply, because when there is crisis in these locations, there would be a further challenge on food security which would in turn result to the challenge of food shortage in supply to the various parts of the country like Lagos where demands are high, leading to higher prices and scarcity. There could also be wastage of scarce food resources with the emergence of a crisis that could prevent distribution. Boko Haram insurgency has been an ungodly act that has greatly affected the country's level of food security. Maiduguri, which has been the capital city of Borno State, have had food insecurity treats since the outbreak of Boko Haram conflict. Food items supplied from the North such as beans, yam, carrots, beef, potatoes, groundnuts, and vegetables have been affected by the crises emanating from the Northern part of the country. Utilization of food is of importance for the well been of human development, which is been affected by the crises Northern part of Nigeria.

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7. References

Abdulrahman, S., Mani, J.R., Oladimeji, Y.U., Abdulazeez, R.O. and Ibrahim, L.A. (2017). Analysis of entrepreneural management and food security strategies of small ruminant women farmers in kirikassamma Local Government Area of Jigawa State. *Journal of Animal Production Research* 29(1): 419-429.

Adams, B. (2017). Malnutrition is about more than Food security, Gardens for Health International accessed from: https://www.publichealthpost.org/viewpoints/malnutrition-food-security/

Afolayan, O., Okodua, H., Matthew, O. and Osabohien, R. (2019). Reducing unemployment malaise in Nigeria: The role of electricity consumption and human capital, International Journal of Energy Economics and Policy 9(4): 63-73.

Agarwal, P. (2019). Malthusian Theory of Population, Intelligent Economist, accessed from https://www.intelligenteconomist.com/malthusian-theory/

Agranoff, R. (2014). Local governments in multilevel systems: emergent public administration challenges. *Am. Rev. Public Admin* 44 (44): 47S–62S.

Ajayi, C.O. and Adenegan, K.O. (2018). *Rights-Based Approach to Food and Nutrition Security in Nigeria.* In: Food Systems Sustainability and Environmental Policies in Modern Economies. *IGI Global, pp. 217-234.*

Androsova, I.V., Melnichuk, A.V., Bondaletov, V.V., Vinichenko, M.V. and Duplij, E.V. (2016). On the issue of state support of agriculture: Regional aspect. *International Journal of Economics and Financial Issues* 6(1S).

Ayotamuno, J.M. and Gobo, A.E. (2004). Municipal solid waste management in Port Harcourt, Nigeria: Obstacles and prospects. *Management of Environmental Quality: An International Journal* 15(4): 389-398.

Babatunde, R.O., Omotesho, O.A. and Sholotan, O.S. (2007).Socio-economic characteristics and food security status of farming households in Kwara State, North-Central Nigeria. *Pakistan Journal of Nutrition* 6 (1): 49-58.

Bajagai, Y.S. (2019). Basic Concepts of Food Security: Definition, Dimensions and Integrated Phase Classification, Food and Environment, accessed from https://www.foodandenvironment.com

Batley, R. and Larbi, G., (2004). The Changing Role of Government The Reform of Public Services in Developing Countries. Palgrave Macmillan, Hampshire, UK.

Bélières, J.F, Benoit-Cattin, M., Barret, L., Djouara, H. and Kebe, D. (2008). Producer organizations in the cotton zone in Mali. Conditions of emergence and perspectives. *Rural economy. Agricultures, Foods, Territories* (303-304-305): 22-38.

Bell, P., (2007). How local government can save Australia's Federal System. In: Brown, A., Bellamy, J. (Eds.), Federalism and Regionalism in Australia New Approaches, New Institutions? ANU E Press, Canberra, pp. 171–183

Candel, J.J. (2014). Food security governance: a systematic literature review. *Food Security* 6: 585-601.

City of Darebin (2010). Food Security Policy. City of Darebin, Victoria.

Dias, B.G., Juliana, R.P. Giller, K.E. and Ittersum,M.K. (2017). Agriculture, Food Security and the Sustainable Development Goals: theory and practice in three development contexts. 3rd International Conference on Global Food Security Conference, Cape Town, 2017-12-03/2017-12-06.

Dollery, B., Marshall, N. and Worthington, A. (Eds.) (2003). Reshaping Australian Local Government. UNSW Press, Sydney.

Echebiri, R.N. and Edaba, M.E.I. (2008). Production and utilization of cassava in Nigeria: prospects for food security and infant nutrition. *PAT* 4(1): 38-52.

Ejikeme, J.O., Ojiako,J.C. and Ezeh, F.C. (2017). Enhancing Food Security in Anambra State, Nigeria, Using Remote Sensing Data. *Journal of the Faculty of Environmental Sciences, Nnamdi Azikiwe University Akwa, Nigeria* 6 (9): 27-44

FAO (2009). How to Feed the World in 2050, accessed from http://www.fao.org/fileadmin/templates/wsfs/docs/expertpaper/How_to_Feed_the_World_in_2050.pdf

FAO (2011). Good Food Security Governance: The Crucial Premise to the Twin-Track Approach. Background paper. *ESA Workshop, FAO, Rome*, accessed from http://www.fao.org

Fogel, R.W. (2004). The escape from hunger and premature death, 1700-2100: Europe, America, and the Third World (Vol. 38). Cambridge University Press.

Fresco, L.O. (2009). Challenges for food system adaptation today and tomorrow. *Environmental Science & Policy* 12(4): 378-385.

Haddad, L.J., Hawkes, C., Achadi, E., Ahuja, A., Ag Bendech, M., Bhatia, K. ... and Fanzo, J. (2015). *Global Nutrition Report 2015: Actions and accountability to advance nutrition and sustainable development*. Intl Food Policy Res Inst.

Herbel, D., Crowley, E., Ourabah, H. and Lee, M.(2012). Good Practices in Building Innovative Rural Institutions to Increase Food Security. *Food and Agriculture Organization of the United Nations (FAO).*

Hobsons Bay City Council (2009a). Hobsons Bay City Council Community Consultation Report. Hobsons Bay City Council, Victoria.

Hodgson, G.M. (2006). What Are Institutions? *J. Econ. Issues* 40(1): 1-25.

Huisman, L., Vink, M.J. and Eerdt, M. (2016). Africa in perspective. In: NEAA PBL (Ed.), National-level Land Use Dynamics in 10 African Countries under a Growing Demand for Food. Environmental Assessment agency, The Hague: PBL, Netherlands.

Ibe S.O., Alozie, S. T. and Iwueke O.C. (2017). Food security among households in eastern Nigeria: a descriptive analysis, *International Journal of Gender and Development Issues* 1(6): 1-9.

Ike, C. U., Jacobs, P.T. and Kelly, C. (2017). A multidimensional approach to measuring household food security in Taraba State, Nigeria: comparing key indicators. *Development in Practice* 27(2): 234-246.

Jhingan, M.L. (2003). The Economics of Development and Planning. *36th Revised and Enlarged Edition, Vrinda publications (P) LTD, Delhi, India*

Kennedy, A. and Liljeblad, J. (Eds.). (2016). Food Systems Governance: Challenges for justice, equality and human rights. Routledge.

Koning, N. (2017). Food Security, Agricultural Policies and Economic Growth: Long-term Dynamics in the Past, Present and Future. *Historia Agraria* 76: 253-315.

Lele, U., Masters, W.A., Kinabo, J., Meenakshi, J.V., Ramaswami, B. and Tagwireyi, J. (2016). Measuring Food and Nutrition Security: An Independent Technical Assessment and User's Guide for Existing Indicators. Rome: Food Security Information Network, Measuring Food and Nutrition Security Technical Working Group.

Lynam, J., Beintema, N.M., Roseboom, J. and Badiane, O. (Eds.). (2016). *Agricultural research in Africa: Investing in future harvests*. Intl Food Policy Res Inst.

Malthus, T.R. (1798). An Essay on the Principle of Population. Chapter II, p. 18

Matthew, O., Miebaka-Ogan, T., Popoola, O., Olawande, T., Osabohien, R., Urhie, E., Adediran, O. and Ogunbiy, T. (2019). Electricity consumption, government expenditure and sustainable development in Nigeria: A co-integration approach. *International Journal of Energy Economics and Policy* 9(4): 74-80.

Munene, M.B., Swartling, Å.G. and Thomalla, F. (2018). Adaptive governance as a catalyst for transforming the relationship between development and disaster risk through the Sendai Framework? *International Journal of Disaster Risk Reduction* 28: 653-663.

Ojo, S.O. (2004). Improving labour productivity and technical efficiency in food crop production: A panacea for poverty reduction in Nigeria. *Journal of Food Agriculture and Environment* 2: 227-231.

Omonona, B.T. and Agoi, G.A. (2007).An Analysis of food security situation among Nigerian urban households: evidence from Lagos state, Nigeria.

Osabohien, R. (2018). Contributing to agricultural mix: analysis of the living standard measurement study - Integrated survey on agriculture data set, *Data in Brief* 20: 96 -100

Osabohien, R., Afolabi, A. and Godwin, A. (2018). An Econometric Analysis of Food Security and Agricultural Credit Facilities in Nigeria. *The Open Agriculture Journal* 12(1): 227-239.

Osabohien, R., Matthew, O., Gershon, O., Ogunbiyi, T. and Nwosu, E. (2019). Agriculture Development, Employment Generation and Poverty Reduction in West Africa. *The Open Agriculture Journal* 13: 82-89.

Osabohien, R., Matthew, A.O. Aderounmu, B. and Olawande, T. (2019). Greenhouse Gas Emissions and Crop Production in West Africa: Examining the mitigating potential of social Protection. *International Journal of Energy Economics and Policy* 9(1): 57-66.

Osabohien, R., Osabuohien, E. and Urhie, E (2018). Food Security, Institutional Framework and Technology: Examining the Nexus in Nigeria using ARDL Approach. *Current Nutrition and Food Science* 14(2): 154-163.

Osabohien, R., Ufua, D., Moses, C.L. and Osabuohien, E. (2020). Accountability in agricultural governance and food security in Nigeria. *Brazilian Journal of Food Technology* 23, e2019054. DOI: https://doi.org/10.1590/1981-6723.08919.

Osabuohien, E., Okorie, U. and Osabohien, R. (2018). Rice Production and Processing in Ogun State, Nigeria: Qualitative Insights from Farmers' Association. In Obayelu, E. (Eds).Food Systems Sustainability and Environmental Policies in Modern Economics, Hershey, PA: IGI Global, pp. 188-215.

Pérez-Escamilla, R., Shamah-Levy, T. and Candel, J. (2017). Food security governance in Latin America: Principles and the way forward. *Global Food Security* 14: 68-72.

Pesaran, M.H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics* 22(2): 265-312.

Ouattara, K., Ouattara, B., Assa, A. and Sédogo, P.M. (2006). Long-term effect of ploughing, and organic matter input on soil moisture characteristics of a Ferric Lixisol in Burkina Faso. *Soil and Tillage Research* 88(1-2): 217-224.

Rodrik, D. (2010). Diagnostics before prescription. *Journal of Economic Perspectives* 24(3): 33-44.

Scribner, S. (2017). On The Brink: As famine looms, world leaders must pay up and deliver political solutions to save lives.

Shamah-Levy, T., Mundo-Rosas, V., Flores-De la Vega, M.M. and Luiselli-Fernández, C. (2017). Food security governance in Mexico: How can it be improved? *Global Food Security* 14: 73-78.

Sheahan, M. and Barrett, C.B. (2014). Understanding the agricultural input landscape in sub-Saharan Africa: Recent plot, household, and community-level evidence. *World Bank Policy Research Working Paper*, pp. 7014.

Sidibé, A., Totin, E., Thompson-Hall, M., Traoré, O.T., Traoré, P.C.S. and Olabisi, L.S. (2018). Multi-scale governance in agriculture systems: Interplay between national and local institutions around the production dimension of food security in Mali. NJAS-Wageningen *Journal of Life Sciences* 84: 94-102.

Thi, N.B.D., Kumar, G. and Lin, C.Y. (2015). An overview of food waste management in developing countries: current status and future perspective. *Journal of Environmental Management* 157: 220-229.

Ufua, D.E., Papadopoulos, T. and Midgley, G. (2015). Enhancing Lean Interventions through the use of Systems Thinking in the food production industry: a case in the Niger Delta region of Nigeria. In Proceedings of the 58th Annual Meeting of the ISSS-2014 United States (Vol. 1, No. 1).

Ufua, D.E., Papadopoulos, T. and Midgley, G. (2018). Systemic lean intervention: Enhancing lean with community operational research. *European Journal of Operational Research* 268(3): 1134-1148.

Vanguard News Nigeria (11 January, 2018). Nigerian herdsmen crisis: what's at stake? Accessed from https://www.vanguardngr.com/2018/01/nigerian-herdsmen-crisis-whats-stake

Waldron, A., Garrity, D., Malhi, Y., Girardin, C., Miller, D.C. and Seddon, N. (2017). Agroforestry can enhance food security while meeting other Sustainable Development Goals. *Tropical Conservation Science* 10: 1940082917720667.

Womack, J.P. and Jones, D.T. (2003). Lean Thinking: Banish Waste and Create Wealth in Your Corporation. 2nd edition. Simon and Schuster, London.

Young, O.R. (2002). The Institutional Dimension of Environmental Change: Fit, Interplay, and Scale. MIT Press, Cambridge, Massachusetts, USA, accessed from https://mitpress.mit.edu/books/institutional-dimensions-environmental-change.

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Full Research Article

Innovation adoption and farm profitability: what role for research and information sources?

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Abstract. The paper analyses the determinants of farmers' adoption of innovations and studies the effect of the source of information and the connection with agricultural research on the contribution of innovation to farm performance. The paper uses primary data collected ad hoc in the Province of Bologna (Emilia-Romagna, Italy) and analyses it through an econometric analysis. The results indicate that structural factors and farm specialisation still play a relevant role in innovation adoption. Connection to scientific research triggers significant improvements in terms of value-added and quality of production but does not affect other profitability-related parameters. The results confirm the need for policy to better consider the role of intermediate actors between research and the farmer as well as to better clarify the final performance strategy in order to set the policy instruments right. The paper also highlights the need for further research about farms' proactivity in searching for and selecting information during the process of innovation adoption and competitive advantages in terms of profitability components.

Keywords. Innovation adoption, information sources, research-innovation link, farm profitability.

JEL Codes. D83, O14, O31, O33.

1. Introduction

The interest in studying the process of innovation adoption and impact, both from theoretical and empirical perspectives, is motivated by the key role of innovation in fostering agricultural competitiveness and socio-economic growth (Ramos-Sandoval *et al.*, 2018; Sauer *et al.*, 2019). In fact, a noteworthy share of the literature to date has focused primarily on understanding the patterns of innovation diffusion, rather than adoption. In recent decades, several studies have started to broaden the research perspectives on agricultural innovation by introducing frameworks and models aimed at understanding the process of innovation adoption in agriculture (Gadhim and Pannell, 1999; Diederen *et al.*, 2002). The early approaches can be roughly classified into those mostly focusing on eco-

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nomic interpretations and those taking a more sociological perspective (Marra *et al.*, 2003). Economists have argued that adoption and diffusion of innovation is motivated by changes in economic factors, such as prices, production efficiency, risk attitude and utility, whilst sociologists have, for their part, highlighted the major role of the adopter's characteristics and the social environment in which the adoption process occurs. Although from different perspectives, both approaches have converged in identifying in the learning behaviour of individuals one of the most important factors in the innovation adoption process which, in turn, characterises the diffusion pattern (rate of adoption) (Ruttan, 1996).

Micro-level studies concerning the adoption and diffusion of innovations has progressed over time by testing new models explaining adoption and new patterns of diffusion, characterised by the inclusion of (farm level) information (uncertainty and risk) and time (diffusion as a sequence of adoptions) factors. While new insights have been identified with respect to the theoretical evolution, the empirical results provide an increasingly varied range of explanations for adoption (Ghadim and Pannell, 1999), including the recent attention to the innovation behaviour of farmers (Läpple *et al.*, 2015; Sauer *et al.*, 2019).

At the aggregate level, the evolution of theories and practices concerning the concept of innovation have moved from a linear model of knowledge transfer from public research to the farm (Röling, 1990), to the so-called agricultural knowledge system (AKS), to an even more complex and dynamic innovation process, in which different actors (including public and private stakeholders beyond the research, education and consulting/extension sectors) cooperate in a network, referred to as agricultural knowledge and (information) innovation system (AKIS) (Esposti, 2012; SCAR, 2012; Ramos-Sandoval et al, 2019). The AKIS concept supports the idea that the development and realisation of innovations are not limited to pre-defined and unidirectional processes (path-dependence, demand-pull or technology-push), as in the case of AKS, but rather fed by a multitude of processes characterised by a continuous interaction between stakeholders within a network. Such a paradigm although, on the one hand, makes the study of approaches to innovation adoption more complex, on the other hand it broadens the research perspectives by allowing for the inclusion of latent or hidden elements in modelling innovation adoption in agriculture, such as multiple information channels, for which the contribution of literature is still limited, and the role of research, recently highlighted by several European policy initiatives such as the European Innovation Partnership (EIP) and the (related) Innovation Operation Groups (IOG). An especially relevant gap in the literature concerns the link between upstream connections with research as a source of information and innovation performance on the farm, in a context characterised by the growing role of the farmer in combining information and new technologies in designing farm-level innovations.

This paper seeks to contribute to this literature through a farm-level study on the impacts of scientific research in agriculture (SRA) on the economic performance of farms taking into account the intermediary steps of innovation adoption. The paper relies mainly on primary farm-level data, collected through direct interviews with farmers using an *ad hoc* survey questionnaire, with the broad aim of collecting data suitable for analysing the determinants of farmers' adoption of innovations, the effect of innovation on farm economic outcomes, in terms of different components of profitability of the introduced innovation, and link these back to the role of research in innovation development.

The contribution of the paper is mainly on empirical grounds, using insights and variables from a wide range of literature. However, our study is inspired by concepts mainly derived from two seminal theoretical frameworks, namely *induced technical change* by Hayami and Ruttan (1985) and the *evolutionary model* by Nelson and Winter (1982). We apply a demand-driven approach, as proposed by Walker *et al.* (2010), which, together with the *recall* technique strategy, allows us to set an impact pathway, tracing back the determinants of the effects of successful innovation adoption on economic performance. In this paper, the use of the term *innovation* is intended as *new to the farm/farmer* and not as *new to the market* (Mairesse and Mohnen, 2010).

The main novelty of the paper is the attempt to clarify whether a higher farm performance might be linked to the fact that the adopted innovation is rooted in scientific research. In particular, we investigate the extent to which, and how, the fact that an innovation is known to derive from scientific research affects, beyond the adoption decision, the economic performance of the farm. The origin of innovation from scientific research is identified through collected data about prior-knowledge of farmers. Performance is also measured based on farmers' statements regarding the gains realised from the adoption of the innovation, in terms of reduced costs, increased production, higher value-added and higher product quality.

We investigate the effects of information on the adoption decision processes in two steps. After having presented the survey results in terms of descriptive statistics, we first analyse which factors and processes influence farmers' decisions to adopt, or not to adopt, new technologies; then, as concerns the innovators (the farmers who introduced an innovation), we investigate whether the origin of innovation from scientific research yielded effects on profitability at farm level.

The paper continues with a literature review in section 2. The methodology is outlined in section 3, followed by the presentation of the case study area (Province of Bologna, Emilia-Romagna) in section 4. Section 5 illustrates the results, followed by a discussion in section 6 and concluding remarks in section 7.

2. Literature review

Early studies on innovation adoption at farm level focused mostly on disentangling the innovation adoption process through a micro-economic approach (Cochrane, 1958; Hayami and Ruttan, 1985; Thirtle, 1985), by relying on the basic assumption of profit maximisation as the main economic driver for adoption (Sunding and Zilberman, 2001). On the other side, recent studies on innovation in agriculture, although relying on the same framework, focus more on the variety of different elements determining the adoption, as well as the diffusion processes. Indeed, Hall (2012) sketches how the modern innovation adoption process goes largely beyond the (public) function of introducing technology to farmers, as exogenously intended by Cochrane (1958) and Hayami and Ruttan (1985), conceiving the innovation in agriculture as a system in which partnership, alliance and network actors work together to develop and spread innovation. A fundamental role in this system is acknowledged to be played by *producers* and *users* of knowledge, but the issue of who and how such links are created is still very much under scrutiny. Indeed, the multiplicity of underlying dynamics characterising the links between the actors of the

agricultural innovation system might be at the basis of the discordant findings of studies on innovation adoption. In fact, recent studies on the topic have addressed this issue and are evolving towards the definition and role of knowledge and/or innovation brokers within the AKIS (Klerkx *et al.*, 2009; Ramos-Sandoval et al, 2019).

As regards the adoption of innovation in agriculture, in fact, different studies report varied results with regard to the relative importance of different determinants of adoption (Ghadim and Pannell, 1999), such as education, credit constraints, land size and others (Feder and Umali, 1993). One reason for such discordant results can be attributed to the difficulty in relating empirical information, model hypotheses and the conceptual/theoretical framework in which innovation adoption in agriculture is modelled (Lindner, 1987; Besley and Case, 1993). In fact, the evolution of the theoretical framework progressed towards the inclusion of informational attributes (Koundouri *et al.*, 2006; Walder *et al.*, 2019) and learning behaviour (Ramos-Sandoval *et al.*, 2018) into the models hence making it possible to envisage innovation adoption as a dynamic process. Information has played a major role in modelling the uncertainty concerning adoption decisions as well as farmers' risk attitudes and risk aversion behaviour in the face of uncertainty. Indeed, in a context of incomplete information, the degree of risk perception is assumed to be affected by learning, as learning can reduce the uncertainty concerning the innovation adoption (especially the downside production risk) (Marra *et al.*, 2003; Koundouri *et al.*, 2006). Time, especially in connection to learning, is another important factor characterising the speed and rate of aggregate adoption and, hence, diffusion (Sunding and Zilberman, 2001). Other additional factors beyond profitability, such as environmental and social sustainability concerns, potentially determining innovation adoption have been explored as well (Walder *et al.*, 2019).

In relation to the above, diffusion itself has been subject to different interpretations. In economic terms it can still be interpreted as depending mostly on the perceived short-run profitability of the innovation (Levins and Cochrane, 1996; Diederen *et al.*, 2002). However, from a more sociological perspective, innovation diffusion also depends on the spread of information and is negatively related to the distance from the propagation point (Rogers, 1983). Improvements in human capital through learning affect positively the adoption rate and diffusion of innovation. Based on this concept and starting from the evolutionary model of Nelson and Winter (1982), a stream of research advanced up to the adaptation of the technology acceptance model (TAM), proposed by Davis (1989), to the farming sector (Flett *et al.*, 2004; Folorunso *et al.*, 2008; Rezaei-Moghaddam and Salehi, 2010). Through TAM, innovation adoption is explained as a process that depends on the perceived usefulness and perceived ease of use of the technology which, in turn, affects the acceptance (and the adoption) of the innovation. This theoretical framework belongs mainly to the psychological perspectives of the topic and attributes more importance to the individual beliefs and perceptions underlying the learning behaviour involved in the adoption process.

A noteworthy gap in the literature concerns investigating whether and how the origin of innovation, and in particular research, may be related to the economic performance of innovation adopted by the farms[1]. Two aspects can be distinguished: a) one is the "objec-

[1] This topic has been recently explored by Hockmann et al. (2018) in the food processing sector, evaluating the impact of internal R&D activities on the economic performance of multinational corporations.

tive" origin of innovation; and b) the second is the knowledge of the origin. This distinction and the attribution of innovation to specific events or projects is often difficult due to the fact that multiple players and activities may contribute to its development, including the farmers themselves.

As demonstrated in the literature, knowledge about innovation, improved through learning, plays a central role in the adoption process (Marra *et al.*, 2003). This holds especially in agriculture where the relatively high costs of internal R&D activities do not allow for the easy and affordable development of innovations within the farm (Sunding and Zilberman, 2001; Diederen *et al.*, 2003). For a large part of the literature, the positive role of knowledge by the farmer in the process of innovation adoption is referred to (or limited to) the adoption of available innovations and limited to the features of innovative technologies/solutions, disregarding its origin. In particular, learning (ability) is mostly considered to be a skill that makes the farmer (the innovator) able to reduce the downside risk of the innovation adoption and to improve the performance of the innovation through a process of adaptation to his/her farm's peculiar characteristics.

This approach implicitly assumes that the learning behaviour is considered to be detached from the path leading from research to innovation. Instead, here we assume that knowledge about the innovation development process matters in terms of improved adoption processes and economic performance of the farm. This view is consistent with theoretical frameworks and empirical evidence that highlight how the cognitive elements of the innovator, such as his/her educational background (Lin, 1991; Reimers and Klasen, 2013), attainments and experience (Foster and Rosenzweig, 1995), affect positively both adoption and performance of innovations (Sauer *et al.*, 2019), though (knowledge about) origin is not generally explicitly addressed. Moreover, this hypothesis easily accommodates the theoretical framework pertaining to AKIS, according to which farmers interact with articulated networks of actors in the innovation research, development and adoption processes and may hence be aware of, or participate in, the research stages of innovation development or in the further stages of knowledge dissemination (SCAR, 2012). In this paper, we consider both the knowledge of research generating the innovation and the sources of information about the innovation as potential factors affecting the economic performance of innovation adoption.

3. Methodology

3.1 Overall approach

The analysis proposed in this paper seeks to link information, research and farm-level performance by analysing the declared effects of innovation introduction with respect to farm structural factors, farmers' characteristics and elements related to the process of innovation adoption, such as the sources of information, specifically the origin from research. The main objective of our study (besides explaining innovation adoption) is to evaluate whether the effects of adopted innovation on farm profitability is affected by the origin of the adopted innovation, in particular how innovation originating from research can affect various aspects of farm performance in different ways.

The paper is based on survey data, provided from farmers' responses to questions. This will require some qualifications, which are provided in the discussion section.

As mentioned, the paper does not refer to one specific theoretical framework. However, the set of explanatory variables draws mainly from the analysed literature, which is grounded upon the *induced technical change* theory by Hayami and Ruttan (1985), for which innovation adoption is responsive to both economic conjuncture and technical evolution brought about by R&D, and the *evolutionary model* (Nelson and Winter, 1982), according to which farmers put effort into searching for better techniques and the selection of successful innovations (local searches for innovations, imitation of the practices of others and satisficing economic behaviour). These theoretical frameworks are integrated with insights drawn from the most recent literature on the AKIS framework and innovation adoption, especially considering linkages with non-farm actors, different sources of information and personal attitudes towards adoption. The theoretical development of the topic involves further aspects of the process in order to better qualify innovation adoption and diffusion, such as diffusion in terms of imitation of adoption, timing of adoption, endogenous and exogenous factors affecting adoption, elements characterising heterogeneity of farmers, etc.

In order to address the evolving theoretical framework and to adapt to available data, a variety of methodological approaches have been used in the literature. Sunding and Zilbermann (2001), in reviewing the innovation process in agriculture, argued that the analytical methodologies mostly suited to evaluate the process of technology/innovation adoption are the binary or the limited dependent variable approaches. This opinion hinges upon the fact that innovation adoption is regarded as a discrete choice and, as such, represented by the means of threshold models. Alternative and more articulated approaches have been employed over time, e.g. Ghadim and Pannell (1999) adopted time-series methodologies, Diederen *et al.* (2002, 2003) used nested and ordered logit models, Dimara and Skuras (2003) tested the application of partial observability models, while Koundouri et al (2006) applied a two-stage binary choice model.

Given that the objectives of the present study mainly pertain to the evaluation of the effects of different elements of the innovation adoption process on both the adoption choice itself and the consequences of the adoption in terms of positive economic performance, we use econometric techniques belonging to the class of limited dependent variable models on cross-section data derived from an original survey.

3.2 Methodological approach

A two-stage conceptual framework is employed for modelling the analysis. The first stage concerns farmers' choice to adopt an innovation and the second concerns the profitability of the adopted innovation. The underlying process is composed by a participation stage and an outcome stage, where the outcome depends on the participation: the first stage is about the choice to adopt or not and, conditional on this first decision, the second is about the economic performance of the adopted innovation.

An expected utility maximization framework is used to examine farmers' choice to adopt, including the sequential adoptions as well. Assuming that farmers are profit oriented and that their expected utility depends on the level of profit earned, the objective function of the farmers will be to maximize expected utility through maximizing expected profits (posed that utility is monotonically increasing in expected profit). It follows that a higher profit implies a higher expected utility for farmers.

Thus, for the i_{th} farmer: $U_i=U(\pi_i(I_i,X_i,S_i))$, where U_i is expected utility of farmer i, π_i is expected profit of farmer i, I_i is the innovation adopted (that guaranteed the highest performance) by farmer i, X_i is vector of determinants of adoption of farmer i that impact expected profits of production, and S_i is a vector of other factors affecting the ability of farmer i of generating profit.

According to Lynes *et al.* (2016), the choice of adopting an innovation occurs if the expected utility U_i, expressed in terms of expected profit from the adoption of I_i, is greater than the expected utility of no adoption, namely *no* I_i. Assuming that the choice of I_i depends on X_i and S_i as well, $I_i(X_i,S_i)$ and by simplifying the notation, so that U_i is stated as a function of I_i, the following condition applies: $U_i(I_i)>U_i(no\ I_i)$, such that $U_i(I_i)-U_i(no\ I_i)=\Delta(U_i)>0$.

Expected higher profits, i.e. the *outcome*, is dependent on the choice of adopting, i.e. the *participation*. The outcome stage can be identified according to two different specifications. On one hand, the outcome of adopting an innovation, as suggested by Cochrane (1958) and Levins *et al.* (1996), can be intended as a continuous choice or a sequence of adoptions, namely more than one adoption, in order to guarantee, according to the *technology treadmill*, the competitiveness and the profitability of the farm. On the other hand, the outcome stage can be meant as the profitability consequent to the adoption of a specific innovation, namely the realized economic performance resulting from the introduction of the innovation into the farm.

In both cases, it is assumed that farmers who choose to adopt knows that the outcome is affected by adoption determinants, such as structural factor (farm size, specialization, mechanization, market), subjective characteristics of the farmer (education, experience, off-farm income, business motivation, entrepreneurial attitude), but they also know that, to maximize the profitability, innovations need to be introduced after a learning process has been made and after that other elements have been scrutinized and evaluated accurately, such as the ability of self-developing the innovation, trial and error, the sources of information from others and links with R&D. Expected higher profit can, therefore, be considered as an indirect function of both the determinants, the farmers' subjective characteristics and the learning process leading to the adoption of a specific innovation. The stage two can be represented as follows: $\pi_i[I_i(X_i,S_i)]>0$, for which $\frac{\partial I_i}{\partial S_i}>0$, $\frac{\partial \pi_i}{\partial I_i}>0$ and, in turn, $\frac{\partial \pi_i}{\partial S_i}>0$, while $\frac{\partial I_i}{\partial X_i}$ is ambiguous.

3.3 Econometric modelling strategy

The econometric modelling strategy proceeds in two main steps: first, we provide an analysis of the adoption choice; then we proceed by explaining the performance and connecting it to the source of information. In order to avoid potential confusion across analyses and models, the first group is called *adoption models*, while the second is referred to as *performance models*.

The analytical models chosen to analyse such variables belong to the class of limited dependent variable models. In the general case, the choice to adopt, namely the *adoption model*, is observed as a binary action, representing the underlying outcome of the utility maximization: if $Y_{ai}=1$ means that $\Delta(U_i)>0$, while in the opposite case $Y_{ai}=0$. That is, $Y_{ai}=1$ when farmer i chooses to adopt the innovation, and $Y_{ai}=0$ otherwise. Determinants of (X_i)

and other factors (S_i) are assumed to linearly affect the adoption decision related to the farmers' choice to adopt. Let $Z_{ai}(Z_{a1},\ldots,Z_{ak})$ be the set of both the determinants of (X_i) and the other factors (S_i) affecting the adoption choice, $a_{ai}(a_{a1},\ldots,a_{ak})$ be a vector of parameters and ε_i be a mean zero IID error term.

Then, the adoption choice can be modelled as: $\Delta(U_i) = \alpha_{ai}Z_{ai} + \varepsilon_i, Y_{ai} = \begin{cases} 1 \; if \; \Delta(U_i) > 0 \\ 0 \; otherwise \end{cases}$.

The choice variable is simply the record of the adoptions, recorded as a single choice (in the case of one innovation) and as a sequence of choices (in the case of more than one innovation). This part of the analysis was carried out by evaluating the determinants of both the propensity to innovate and the number of innovations introduced, by employing a *Probit* and a *Poisson* model, respectively. In addition, a *Double-hurdle* model has been used. This type of model has the advantage of making it possible to analyse the number of adoptions (single or repeated) that are conditional on the analysis of the choice to innovate (participation), which potentially follows a different data generating process (or, rather, that may be affected by different explanatory variables). The additional contribution of the *double-hurdle* regression is the capacity to clearly separate the factors mainly affecting the choice from those mostly affecting the adoption. The determinants include the technical and commercial characteristics of the farms and the subjective, socio-demographic characteristics of the farmers. Other factors include the motivations of farmers to innovate, the knowledge of the adopted innovation prior to its adoption, the sources of information that farmers consulted, including the origin of innovation from scientific research, as well as whether farmers developed the innovation by themselves.

Following the same rationale, the profitability induced by the adopted innovation, namely the *performance model*, is observed as a binary outcome as well: if Y_{bi}=1 means that $\frac{\partial \pi_i}{\partial I_i}$>0, while in the opposite case Y_{bi}=0. That is, Y_{bi}=1 when the adopted innovation yielded an improvement in profitability and Y_{bi}=0 otherwise. Even in this case, determinants of (X_i) and other factors (S_i) are assumed to linearly affect the improvement in profitability. Let $Z_{bi}(Z_{b1},\ldots,Z_{bk})$ be the set of both the determinants of (X_i) and the other factors (S_i) affecting the profitability (they do not need to be the same employed in step one), $\alpha_{bi}(\alpha_{b1},\ldots,\alpha_{bk})$ be a vector of parameters and ξ_i be a mean zero IID error term.

Then, the profitability can be modelled as: $\pi_i(I_i) = \alpha_{bi}Z_{bi} + \xi_i, Y_{bi} = \begin{cases} 1 \; if \; \pi_i(I_i) > 0 \\ 0 \; otherwise \end{cases}$.

The determinants are the same as the previous analytical model, while other factors include the motivations of farmers to innovate, the knowledge of the adopted innovation prior to its adoption, the sources of information that farmers consulted, including the origin of innovation from scientific research, as well as whether farmers developed the innovation by themselves.

Profitability is the measure of the realized gains, based on farmers' declarations, resulting from the introduction of the innovation, in terms of *cost reduction*, *production increase, value-added increase* and *quality increase*. The first three have been collected in per cent terms, while the last in ordinal categorical terms (*not at all*, *low*, *high*, *very high*). However, they have been transformed in binary variables in order to evaluate solely the presence (not the magnitude) of the declared (positive) effects of the introduced innovation. However, given the use of the *recall* technique, these variables could suffer from approximation due to difficulties in providing precise estimates of the actual amount (Mairesse and Mohnen, 2010). Such potential measurement errors could lead to biases in estimates and inefficient statistical conclusions and, in turn, render the use of the Tobit

model ineffective. Despite this, these data provide for (i) important quantitative information, when used for explorative descriptive statistics and for comparative exercises, and (ii) qualitative information, when opportunely transformed into binary or categorical variables, to be used in econometric models for inferential purposes. Indeed, the hypothesis of experiencing *better performance* if the innovator knows that the adopted innovation is derived from research could be reformulated in terms of *positive (or non-null) performances*. This implies the cost of losing the magnitude of the effect (marginal effect) but, at the same time, the benefit of at least keeping the presence of the effect (propensity of experiencing a positive outcome).

Such a perspective makes it possible to approach the analysis by considering the measured performance in terms of latent continuous variables and, in turn, by employing a *Probit* and a *Heckit* model, with the aim, respectively, of analysing the propensity of obtaining positive performances, with regard to the innovators, and of accounting for the possible presence of sample selection bias. In fact, the presence of positive performance outcomes due to the research-innovation link might depend upon the self-selection process of those farmers who decided to innovate because of higher expected gains. Each model has been applied separately to each of the four performance variables, using the same set of explanatory variables.

The analysis on economic performance has the same specification of the *probit adoption* regression with the inclusion of the *other factors*, namely the variables accounting for knowledge of the research-innovation link and source of information (hereafter "information variables"). Specifically, the *research-innovation link* is the variable expressing whether the farmer is informed that the innovation originated from research, while *source of information* indicates whether the farmer knew about the innovation from external sources or developed the innovation by himself. *Age of innovation,* for its part, is a measure of time distance between the year of introduction and 2015 (maximum 20 years) and is a proxy of farmers' experience using such innovation (fine-tuning of innovation usage) as well as for the innovation to fully express its effects in terms of economic performance. The dependent variables used in the *probit performance* models are *cost reduction*, *production increase*, *value-added increase* and *quality increment*, all expressed as binary variables.

3.4 Survey: sampling procedure and questionnaire

A survey strategy was adopted because of the absence of datasets on innovation adoption processes and/or the existence of datasets characterised by noteworthy margins of non-representativeness and of collection/transcription errors, such as the ones operated by regional administrations to evaluate measures of the Rural Development Plans (RDP) or the regional level FADN data. The survey strategy represents an appropriate research tool for this work because, like similar research works, this type of approach is preferred for anticipatory/forecast purposes and for studying elements and factors that are much more difficult to identify, such as the innovation adoption process (Besley and Case, 1993).

The sampling plan, aimed at collecting complete information from at least 300 farms in the Province of Bologna, randomly picked from a sequential selection of about 1000 farms, constrained to be representative of both the agricultural specialization (type of farming) and the altitude level.

The data have been collected by the way of an *ad hoc* questionnaire, first checked through direct interviews, further adapted to be used by telephone and finally carried out by telephone interviews (of approximately 15 minutes in length).

The survey was designed to collect information about the farm, information about the farmer, specific elements pertaining to the innovation adoption process realised by the farmer and, in sequence, the relative effects on farms' economic performance from the adopted innovation.

The questionnaire is structured in six sections:

- The introduction presents the aims of the survey and the project it relates to (EU FP7 project IMPRESA);
- The first section includes questions about farm structure: production specialisation and ancillary activities; land, labour, machines, technological plants;
- The second section deals with the adoption process, including the choice of innovating, the number and types of innovations introduced, the motivation for, and for not, innovating;
- The third section concerns one introduced innovation, namely the most important innovation (in terms of profitability), the sources of information and the link with research;
- The fourth section addresses the financial aspects of innovation adoption, in particular whether the innovators benefited from supports from the Common Agricultural Policy (CAP) and the amount of total investments;
- The fifth section deals with the effects of the adopted innovation in terms of economic performance: perceived changes in costs (efficiency gains), in production (output gains), in value-added products and (higher) product quality;
- The sixth section includes questions about future behaviour of the farmers and expectations/sentiments with respect to the CAP;
- The last seventh and final section includes questions about the socio-demographic characteristics of the farm and the farmer's family.

The first and the last sections of the questionnaire aim to collect, respectively, structural (objective) data about the farms and socio-demographic (subjective) data about the farmers, focusing on those elements considered in the literature as "classic" determinants of innovation adoption, such as specialisation, size, mechanization, altitude, farm income, education, and experience. The second section inquiries into the process of innovation adoption by first exploring (eliciting) the opinion of the farmer about the existence of important innovations (in terms of profitability) in his specialisation sector in the last 20 years. The subsequent information regards the types of innovation introduced on the farm in the last 20 years, as well as the choice of not introducing any particular innovation, specifying innovation with regard to products, production factors and process innovations. Crossing these two types of information makes it possible to clearly frame the individual choice context in which the adoption process has been developed. In this section, the farmer indicates which of the introduced innovations is, in his/her view, the most important in terms of profitability. The third section focuses solely on the most important innovation indicated by the farmer and deals mainly with the motivations underlying the adoption. This section has been built on the basis of the *Induced Innovation Adoption* (IIA) by Hayami and Ruttan (1985) and the *evolutionary model* (EM) by Nelson and Win-

ter (1982). With regard to the IIA, farmers were asked whether the choice of innovating was determined, *inter alia*, also by a reaction to changes in products' and factors' prices or by the intention to anticipate the evolution of the markets of both products and production factors. Further, the condition of being early adopters or laggards has been investigated by asking farmers for how long the introduced innovation was already commonly used. As regards the EM, farmers were questioned about the origin of the introduced innovations, with the aim of exploring the connections between the farmer and the other actors involved in the AKIS, including the research sector. In primis, a distinction was made between farmers who stated to have created/developed the innovation by themselves (*self-innovators*) and those who declared to have learned of the innovation from *external sources*. In this way, for the latter, the information channels can be explored in more detail by referring to a menu of possible sources. The external sources are split into three groups: institutional, market and acquaintances. The institutional group includes sources related to the sphere of agricultural research and extension, such as universities, research centres and other private and public entities (i.e. regional administrations, local authorities, R&D from firms, training etc.); the market group refers to the sources of information from producers, retailers and commercial agents; whereas the acquaintances group involves as a source of information the network of people surrounding each farmer, such as relatives, neighbours and others. This section seeks to highlight the role of information and research, namely the elements representing the potential contribution to further understanding the innovation adoption process as well as the relative weight of agricultural research to the farm-level effects of innovation adoption. The key element meant to establish a connection between external sources and effectiveness of the adopted innovation is the investigation of the *research-innovation link* that is whether the farmers know about the research behind the development of the adopted innovation.

The fifth section is dedicated to the declared effects of the introduced innovation in terms of changes in economic performance, combination of inputs and leisure time. Information on the effects on economic performance of the introduced innovation were collected by breaking down the profitability into four elements: *Cost Reduction, Production Increase, Value-Added Increase and Quality Increase.* The importance of these variables within the context of the innovation adoption process is found in their potential to reveal the mechanism allowing the adopted innovation to contribute to the farms' overall economic performance (profit). The sixth section investigates the future intentions of the farmers regarding the continuation of the agricultural activity and the adoption of further innovations in the next five years. Further inquiries are posed in order to record the opinions of farmers about the relationship between innovation and agricultural policy, as well as the role of innovation for the improvement of competitiveness in agriculture. The last section concludes the questionnaire by inquiring into the future of the farm and of the farmers and eliciting opinions about innovation and the CAP. The data collected in this section are used for supporting the evaluation of, and better interpreting, some farmers' choices, such as the motivations for not innovating.

Most of the data collected have been recorded as binary or categorical variables, whilst data related to farm size, labour, introduced innovations and others, have been recorded as continuous variables. Exceptions are represented by the information related to farms' economic performance, which has been surveyed according to four variables,

namely *cost reduction*, *production increase* and *value-added increase*, collected in per cent terms, and *quality increase*, recorded according to an ordinal categorical variable (*not at all*, *low*, *high*, *very high*).

4. Case study area, data collection process and descriptive statistics

4.1 Case study area

The agricultural sector in Emilia-Romagna is one of the most advanced and productive in Italy, due to the favourable geographical and climatic conditions (the southern part of the territory is mountainous, whilst the northern part belongs to the Po valley, which is a very fertile zone), and the presence of highly specialised enterprises. Emilia-Romagna is particularly active in the production of cereals (wheat and maize), fruit and livestock (mainly bovines, pigs and poultry) (Fanfani and Pieri, 2016).

The Province of Bologna is located in the central part of the region, is agriculturally varied and composed of plains, hilly and mountain areas. According to the last agricultural census carried out in 2010 by the Italian Institute of Statistics (ISTAT), the Province of Bologna accounts for about 10,800 agricultural units over an UAA[2] of about 173,000 ha.

As shown in Table 1, the agricultural sector is mainly based on arable crops, involving about 7,000 farms and about 141,000 ha of UAA. Arable crop farming is mainly composed of farms growing cereals (about 4,000) and forage (about 2,000), whose UAA shares are 53% and 27%, respectively. The average size of farms producing cereals and forage crops is 12 and 10 ha, respectively, and more than half of them are located in plain areas. The second major type of farming in the province is livestock and related activities, involving about 800 cattle-holding farms with 33,000 heads as well as 150 swine-breeding farms and 75,000 heads. The largest livestock farms are based in plain areas.

Regarding fruit cultivation, about 2,700 farms grow orchards over an UAA of about 16,000 ha.

Table 1. Agricultural census data per specialization (type of farming) and altitude level.

Specialization	Plain	Hill	Mountain	Total	
Cattle farms (Milk, Beef, ovine-caprine and mixed)	295	454	369	**1118**	10%
Cereal crops (wheat, maize, oats, barley)	3177	633	187	**3997**	37%
Other arable crops (open field, horticultural, mixed and grain pulses crops)	1284	849	608	**2741**	25%
Fruit (orchards, olives and grapes)	1529	1082	90	**2701**	25%
Non-classifiable	65	109	28	**202**	2%
Total	**6350**	**3127**	**1282**	**10759**	
	59%	29%	12%		

Source: our elaboration on ISTAT data.

[2] UAA stands for 'Utilised Agricultural Area'.

4.2 Sample data and selected descriptive statistics

The sample, represented in Table 2, includes 178 farms located in the plains (59%), 87 in hilly (29%) and 35 in mountain (12%) areas. According to the principal specialisation, the sample is composed of 20 livestock farms, 116 cereal farms, 69 'other arable' crop farms, 88 fruit farms (including olives, grapes and 11 nurseries), and 7 non-classifiable farms. Cereal crop results are the most frequent specialisation with about 39% of the total farms, followed by fruit farms (about 26%), arable crop farms (22%) and cattle farms (7%). Given that it is a direct result of the sampling procedure, the sample can be considered to be representative of the Province of Bologna.

Table 2. Sample units per specialisation (type of farming) and altitude level.

Specialisation	Plain	Hill	Mountain	Total	
Cattle farms (Milk, Beef, pork and mixed)	5	7	8	**20**	7%
Cereal crops (wheat, maize, oats, barley)	86	21	9	**116**	39%
Other arable crops (open field, horticultural, mixed and grain pulses crops)	33	21	15	**69**	23%
Fruit (orchards, olives and grapes)	49	36	3	**88**	29%
Non-classifiable	5	2		**7**	2%
Total	**178**	**87**	**35**	**300**	
	59%	29%	12%		

Source: our elaboration of primary data collected.

The sample accounts for about 8,000 ha of UAA, of which about 5,000 in ownership. The larger share of the land is that of cereal crop farms with about 36% of total land, followed by cattle farms (27%), (arable) crop farms (18%) and fruit farms (15%). The descriptive statistics of the collected data are presented in Table 1A (see Annex), while a wider presentation of the statistics of the sections from second to fifth is illustrated in the results section.

5. Results

5.1 Descriptive results

Altogether, 121 out of 300 farmers adopted at least one innovation in the last twenty years (about 40%) (the precise question was "*in the last 20 years, what kind of product or process innovations have been introduced on your farm?*"). This question was posed after asking the farmers about the existence of important innovations in agriculture ("*Do you believe that in the last 20 years there have been very important innovations in your main field of specialisation (measured in terms of income)?*"). Almost 47% (140 out of 300) of respondents replied positively. Table 3 provides an illustration of these results by crossing the answers to these two questions.

Table 3. Cross-tabulation of innovation introduction and consideration of important innovations in the last 20 years.

		Introduction of at least one innovation in the last 20 years		Total
		No	Yes	
Important innovations in the last 20 years	**No**	125	35	**160**
	Yes	54	86	**140**
	Total	**179**	**121**	300

Source: own elaboration on collected data.

The consistent replies on the diagonal combinations (*No-No* and *Yes-Yes*) are somehow intuitive, while a less straightforward reasoning may emerge from an analysis of the off-diagonal cross-answers. We discuss these four options, in turn, by also attaching some descriptive statistics of the farmers/farms belonging to each combination.

The 125 *No-No* answers (roughly 42% of the sample) are composed of 50% cereal, 26% other arable crop and 15% orchard growers. With respect to the total of each specialisation, cereal growers represent 54% (63 out of 116), other arable crop, 49% (33 out of 67) and the orchard growers, 25% (19 out of 77). These 125 respondents are mainly small farms with low agricultural income. In fact, on average, 83% of them operate on less than 20 hectares and 76% of them have an income from agricultural activities that accounts for less than 30% of family income. Such conditions are consistent with the declared reasons for 'no adoption', mainly related to high costs.

The 54 *Yes-No* answers indicate no adoption in spite of the existence of important innovations in the sector of specialisation. These 54 farms are composed of 41% cereal, 24% other arable crops and 30% orchard growers. With respect to the total of each specialisation, cereal growers represent 19% (22 out of 116), other arable crop, 19% (13 out of 67) and the orchard growers, 21% (16 out of 77). This group also is composed of small farms with low agricultural income, but the frequency of these types of farms is slightly lower than in the previous group. In fact, on average, 72% of them operate on less than 20 hectares and 71% receive an income from agricultural activities that is less than 30% of family income. In this case also, such conditions seem to be consistent with the declared reasons for 'no adoption', mainly related to high costs, the expectation of soon retiring from farming (cereal) and maintaining production traditions (orchard).

The 35 *No-Yes* replies indicate adoption despite the declaration that there have been no important innovations in the sector of specialisation. These 35 farms are composed of 17% livestock farms, 43% cereal producers, 9% of other arable crops and 26% of orchard growers. With respect to the total of each specialisation, livestock farms represent 30% (6 out of 22), cereal growers, 13% (15 out of 116), other arable crops, 4% (3 out of 67) and the orchard growers, 12% (9 out of 77). This group of innovators is characterised by the fact that they operate on larger farms with higher agricultural incomes. In fact, on average, only 47% of them operate on less than 20 hectares and 49% receive an income from agricultural activities that is less than 30% of family income. These figures clearly differ from those of the previous two groups and the declared motivations for having introduced

at least one innovation (with positive effects on profitability) mostly refer to reducing costs and increasing production. Both groups, and in particular the first one, are consistent with innovations that are more linked to late adoption of existing solutions motivated by economies of scale, rather than by strong innovation behaviour.

In the last group, the 86 *Yes-Yes* replies consist of 12% of livestock farms, 19% of cereal producers, 21% of other arable crops and 38% of orchard growers. With respect to the total of each specialisation, livestock farms represent 45% (10 out of 22), cereal growers 14% (16 out of 116), other arable crops 28% (18 out of 67) and the orchard growers represent 43% (33 out of 77). This other group of innovators operates on farms with sizes similar to the ones of the previous group, but with higher agricultural income. In fact, on average, 43% of them operate on less than 20 hectares and only 27% of them obtain an income from agricultural activities that is less than 30% of family income. Similarly to the previous group, this last group also indicates as the main motivations for adopting at least one innovation (with positive effects on profitability) cost reduction and production increases, with the addition of other motivations pertaining to the improvement of labour conditions, such as reducing fatigue and improving the safety of workers. This profile, which is particularly consistent with the orchard specialisation, denotes farmers who are focusing on agricultural production on well-structured farms and who are open to an understanding of the outside markets' trends as well as who are highly focused on innovation.

On the other hand, about three-fifths of the interviewees (179 farmers) decided not to innovate due to the economic and managerial hurdles that reduce the capacity of farmers to obtain new technology and adopt innovations[3]. We asked these farmers to motivate their decision not to adopt innovation by choosing among two categories of responses: obstacles and intentional choice. Among the obstacles, we proposed high costs, bureaucracy and risks, while for intentional choice we asked about ethical reasons, the intention to quit the business, negative past experiences and the desire to maintain traditional production processes. Eighty-four (84) out of 179 replies deemed the excessive costs of adopting innovations to be the main hurdle, while 16 and 18 answers indicated their intention to quit the business soon and to keep maintain production traditions, among the intentional choice group, respectively. Therefore, the sample revealed that the main reason for not having adopted innovations in the last 20 years was the excessive cost, highlighting economic barriers and the lack of managerial skills for gaining access to new technology. However, since for 33 out of 51 (65%) other reasons were expressed by cereal farms, we deduce that for about two-thirds of respondents such choice is due to a disinterest in innovation given that they possess less than 20 hectares, no weeding and harvesting machines, and therefore opt for the services of other companies. This is an important point considering the recent structural trends as it points at a dichotomy between larger professional farms, for which innovation remains important, and small farms that keep land tenure but farm via contracts, for which innovation is rather carried out or adopted by contractors themselves, i.e. outside the farm. For the remaining third, we equally deduce that they have not been interested in adopting innovations, but unlike the pre-

[3] Detailed descriptions of such data have been omitted in order to save text. These are, however, available from the authors upon request.

vious farmers, because the technology they possess is considered to still be effective and hence does not need to be replaced or upgraded.

The number of innovations introduced in the last 20 years is more than 200 for 121 innovators (an average rate of about 2 innovations per farmer).

The distribution of adoptions, shown in Table 4, reveals that mechanical innovations are the most frequently adopted ones (32%), followed by energy-water saving (21%), diversification (15%) and biological, agricultural and informatics (about 8% each). The distribution of type of innovations changes if considering the unique (most important) innovation that, according to farmers, yielded the highest impact on profitability. In fact, the shares of mechanical (42%) and energy-water saving (25%) innovations increases, while the others decreased slightly. As for motivations, the adoption of these types of innovations is mainly motivated by the need to reduce costs, to increase production and to face new climatic challenges affecting the availability of natural resources, such as water.

As concerns the timing of introduction, about 65% of the mechanical innovations were introduced during the 2010-2015 period, while about 66% of the energy-water saving technologies were adopted in the 2005-2015 period. The adoption timing of the other types of innovation is smoothly spread across the considered time span (1995-2015).

The main reasons motivating the adoption of the (one) most important innovation are concentrated in cost reduction (66 or 35%) and production increase (56 or 30%) (122

Table 4. Number of innovations introduced in the last 20 years and selection of the most important in terms of profitability.

Type of adopted innovations	All adoptions	Share of adoptions on total	Unique adoption considered most-important in terms of impact on profitability	Share of important innovations on total
Biological-Genetic	18	8.5%	8	7.5%
Diversification or Manufacturing	32	15.0%	15	14.0%
Agricultural-Zootechnic	18	8.5%	7	6.5%
Mechanical-Automation	68	31.9%	45	42.1%
Informatics	17	8.0%	2	1.9%
Energy-Water saving (irrigation plants, solar panels, biogas)	44	20.7%	27	25.2%
Marketing strategies (quality systems, production protocols)	5	2.3%	2	1.9%
Operational (cooperatives, associations, logistics)	2	0.9%		0
Other	9	4.2%	1	0.9%
Total adoptions	**213**	**100%**	**107**	**100%**
Does not know			14	

Source: own elaboration on collected data.

replies out of 187)[4]. However, out of these 122 replies, 31 prove to be jointly chosen by the same farmer, indicating an important synergy between the two aspects in contributing to the increase of profitability[5]. Other motivations, collected in open format, result in general profitability improvement, without any reference to specific motivation, and reduction of worker fatigue. The main motivations for cost reduction and production increases are more frequent for cereals (25%), fruit (19%) and grape farms (16%). In particular, by looking at the (one) most important innovations, mechanical-automation and energy-water saving proves to be the most frequent with 32 and 20 replies out of 66 for cost reduction and 19 and 10 out of 56 for increasing production, respectively.

Beyond the motivations underlying the choice of the selected innovations, the survey investigated the selection and the adoption processes operated by the farmers. Indeed, farmers were asked whether they designed and/or developed the (adopted) innovation by themselves or obtained the information regarding the introduced innovations from external sources (and from whom the farmer was informed about the existence of such innovation).

In this respect, farmers who declare to have designed and/or developed the innovation by themselves are denominated "self-developers" and are considered to be the(ir) *internal source of information* as opposed to the other innovators who declared to have learned about the innovation from an *external source of information*.

The data about the sources of information, shown in Table 5, indicate self-developed innovation in the first column and the list of proposed external sources. Self-development of innovation has been declared by 31% of innovators, with prevalence for cereal, fruit and nursery farms. It follows that the remaining 69% learned about the innovation from external sources and, in particular, mostly from sources other than public institutions and unions/farmer associations. Indeed, 37% of the innovators declared to have acquired information about the innovation they decided to introduce from consultants, courses, local and visits to farms abroad. The second largest share is the 17% represented by the sources of information from people belonging to the sphere of personal relationships of the farmers such as friends, relatives and neighbours.

Unions and sectorial associations cover 10% of the external sources of information and the relative frequency appears to be uniformly distributed across specialisations. Only a residual share of about 2% represents the public institutions devoted to research and development in agriculture as the external sources of information. Such a result highlights the importance of intermediation between research and farmers.

As a follow up question, farmers were asked to declare their knowledge of the maker/producer of the innovation. By excluding self-developers, this inquiry reveals that most innovators (about two-thirds), who learnt about the existence of the introduced innovation from external sources, were also aware of who developed the innovation. This might indicate that farmers engage in a careful decision-making process before adopting the innovation or at least show a good level of awareness about its background. Qualitative

[4] The number of replies is greater than the number of adopters as the inquiry was devised as a multiple-choice question.

[5] The link was not explicitly asked, but, in the explicit list, we included the reduction of risks and the diversification of the activity in order to evaluate the motivations directly related to profitability. Very few replies were collected.

Table 5. Sources of information for innovation adopted per specialization.

Specialization	Self developed	External source of information				No reply	Total
		Institutions (University, Region, Province, Ministry)	Unions, associations	Acquaintances, friends, relatives, neighbours	Other sources (consultants, refresher courses/ trainings, visiting…)		
Milk-beef cattle							
Beef cattle	1			1	2		**4**
Milk cattle	3		2		2	2	**9**
Mixed cattle, mainly pastern	1						**1**
Ovine-caprine and pastern cattle					1		**1**
Cereal crops (wheat, maize, oats, barley)	**12**		3	6	**10**		**31**
Open field crops	2		1	1	4		**7**
Mixed crops							
Horticultural crops	2		2	2	3	1	**10**
High protein crops (grain pulses)				2	1		**3**
Combination of crops and cattle					1		**1**
Fruit	**9**	1	2	4	**9**		**25**
Olives					1		**1**
Grapes	3	1		2	**10**		**16**
Nursery	5		1	2			**8**
Non-classifiable			1		1	1	**3**
Total	**38**	**2**	**12**	**20**	**45**	**4**	121
	31.4%	1.7%	9.9%	16.5%	**37.2%**	3.3%	

Source: own elaboration on collected data.

additions during the interview revealed indeed that farmers rely upon trusted external sources of information and acquaintance with the producers[6,7]. Overall, the sample reveals that the majority of farmers either strictly rely on their own ability to develop an innovation or, on one's own initiative, search for information and cues from others' experience in order to make the best innovation choice and to meet their profit expectations.

In order to explore the connection between innovation adoption at farm level and research, farmers were asked to state whether they knew that the innovation they adopted originated from a specific agricultural research. This question was addressed only to those farmers that previously declared to have learned of the innovation through an external source of information. We excluded self-innovators from this question because we suppose that they engage in a process for introducing innovation that is mainly based on the self-development of their own ideas, which is completely different from the process followed by the other interviewed innovators. Hence, this question was asked to 83 innovators. Fifty-three respondents (about 64%) stated that they knew that the innovation was derived from specific research in agriculture. In particular, 29 out of these 53 (about 55%) concern mechanical innovations, mainly related to cereal, grape and fruit farms.

The stated effects on economic performance are reported in Figure 1. *Cost Reduction, Production Increase, and Value-Added Increase* are measured in per cent increase, while *Quality Increase* is measured through four categorical levels (not at all, low, high and very high) of increase due to the introduction of the innovation.

The number of observations of these variables does not correspond to the numerousness of the innovators' sub-sample (121), because not all respondents provided a reply to each of the four questions. Zero answers correspond to the actual observation of the performance by the farmer, while a missing reply might be justified by the lack of expectation, detection or perception of any impact on that specific component of profitability (in fact many farmers stated to not know the specific performance). Since the answers were not mutually exclusive, respondents had the choice to indicate more than one positive effect and potentially all of the four asked.

Cost Reduction (A), *Production Increase* (B), *Value-Added Increase* (C) show a noteworthy frequency of zeros; this was expected since it is unlikely that one innovation might yield positive profitability outcomes on all of the four considered components at the same time. The effect on *Cost* presents a concentration of positive outcomes within the range of 10-60% cost reduction (with the highest share on the lower boundary of the interval and no case recorded between 40% and 50%), while *Production* and *Value-added* are more frequently within the 10-40% interval of increase. *Production Increase* also shows a fairly high frequency around the 50-60% range. As far as *Quality increase* is concerned, it is observed that about 60% of the replies indicate an improvement in profitability due to high and very high quality increases, while only about 25% show no quality increases at all.

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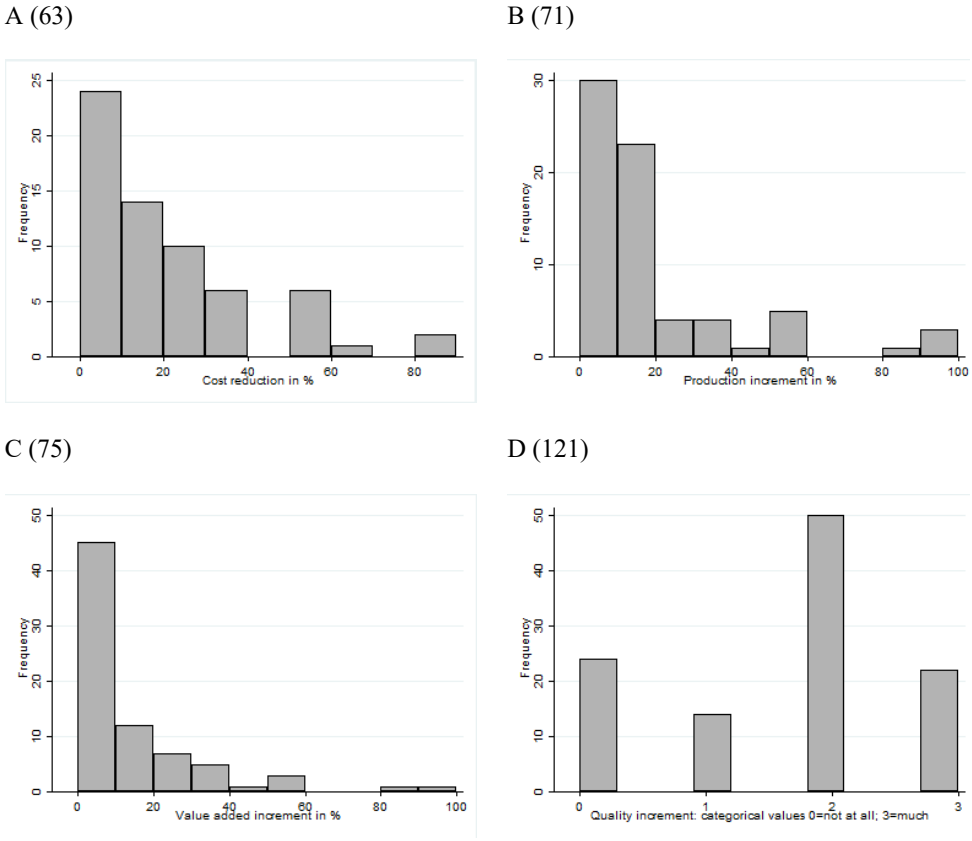
[6] For some types of innovation, such as mechanical ones, farmers have a better knowledge of the major brands/producers because of the presence, in the Emilia-Romagna region, of a large number of mechanical manufacturers that have been operating there since the beginning of the last century. Farmers in the Province of Bologna possess a deep knowledge of the evolution of mechanical technologies and mechanical manufacturing, which provides them with a sufficient ability to develop their own mechanical innovations.

[7] Detailed results are available from the authors upon request.

Figure 1. Frequency distribution of Cost Reduction (A), Production Increase (B), Value-Added Increase (C) and Quality Increase (D).



Source: own elaboration on collected data; number of observations in parentheses.

5.2 Econometric analysis

According with the methodology illustrated in section 3, the results obtained from the econometric analyses are reported in two groups: the first pertains to the adoption of innovation (adoption models) and the second concerns the linkage between adopted innovation and performance (performance models).

The results of the *Poisson* and *Probit adoption* models, shown in Table 6, indicate which factors are most important in determining respectively the number of innovations and the choice of (propensity to) introducing an innovation.

The ability of both models to analyse the survey data is quite good, as indicated by the Wald χ^2 statistics. The results from both models indicate that the propensity to innovate, in particular to adopt more than one innovation, is highly determined by the eco-

Table 6. *Poisson* and *Probit adoption* models.

Characteristics		Number of introduced innovations (Poisson)		Introduction of innovation (0-1) (Probit)	
		Coefficient	Marginal effect	Coefficient	Marginal effect
Innovation	Important innovations (last 20 yrs.)	0.91***	0.66***	0.78***	0.21***
Farm	Share of rented over total land	0.73***	0.53***	1.00***	0.26***
	Number of tractors	0.05***	0.03***	0.03	0.01
	Livestock specialisation	0.22	0.16	0.42	0.11
	Cereal specialisation	-0.54***	-0.39***	-0.59***	-0.16***
Socio-economic	Education > than mid-school	0.64***	0.47***	0.57***	0.15***
	Family income from Agric<30%	-0.58***	-0.42***	-0.53***	-0.14***
	Number of family labour	-0.16**	-0.11**	-0.11	-0.03
	Individual farm	-0.38*	-0.28*	-0.59***	-0.16***
	Constant	-0.70**			
	Observations	244		244	
	Wald χ^2	146***		80***	
	AIC	478.6		248.4	
	BIC	513.6		283.4	

Note: robust standard errors; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

nomic size and other structural characteristics of the farm, as well as by some individual and behavioural characteristics of the respondents. The positive role of the share of rented, over total, land may be connected to both the structural characteristics of the farm, likely qualified by a rent-based expansion, and to the overall size in terms of land area. The number of tractors is positively and significantly correlated to the number of innovations (but not to the decision to innovate) and shows that multiple innovations are more likely on large and capital-intensive farms. The positive and significant coefficient of the share of agricultural income shows a higher propensity to innovate on more professionally farms focused on agricultural activity. On the contrary, a higher number of family labourers and the juridical status of individual farms indicate that small farms are less inclined to adopt innovation (these are also correlated to the specialisation given the remarkable share of small cereal farms). As concerns individual and behavioural features, instead, we can observe that more educated farmers and those declaring that, in the last 20 years, important innovations in terms of profitability have been released show a higher propensity to innovate and, in particular, to adopt more than one innovation.

In order to further support these first results, and to better explain the process, a two-step model has been applied by employing a double-hurdle regression[8]. The results are shown in Table 7.

[8] Thanks to an anonymous referee for the suggestion of including a two-step model.

Table 7. *Double-Hurdle* model.

Characteristics		Number of introduced innovations
	Outcome (quantity) equation	
Farm	Number of tractors	0.09**
	Livestock specialisation	1.15**
	Cereal specialisation	-0.64*
	Fruit specialization, including grape and olives	0.29
Socio-economic	Specialised Ag education	-0.47*
	Family income from Ag <30%	-0.63**
	Family workers per ha	1.00*
	Constant	1.21**
	Choice (participation) equation	
Innovation	Important innovations in last 20 yrs	1.01***
Farm	Location: plain=1; hill=2; mountain=3	-0.22**
	Total Land	0.01***
Socio-economic	Education superior than middle school	0.75***
	Family workers per ha	-0.65**
	σ_Q	1.86***
	$\sigma_Q\sigma_P$	-1.69***
	Observations	245

Note: robust standard errors; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; σ_Q is the estimated value of the standard deviation of the error term of the quantity equation; $\sigma_Q\sigma_P$ is the estimated value of the covariance between the error terms of the quantity equation and the participation equation.

The results obtained through the double-hurdle model confirm those from the *Poisson* and the *Probit* models. In addition, they indicate that the choice of innovating depends highly upon location, especially in the plains and hills. Larger farms and higher education contribute to improve the probability of adoption. The consideration of *important innovations in the last 20 years* notably affects adoption, but it does not contribute to explain the number of adoptions. Moreover, what seems to determine increases in the number (quantity) of adoptions are factors related to the type of farming (and relative physical and economic size of the farm). In fact, larger farms with higher agricultural income, such as livestock farms, or farms with higher family labour and higher mechanisation (number of tractors) are more prone to adopt more than one innovation.

The core part of the analysis concerns the explanation of the economic performance of the adopted innovation, specifically in relation to its origin from research and in connection to the source of information. The results from the *probit performance* model concerning each of the four components of the farm's profitability are shown in Table 8.

Given the application of the *performance* models to each measure of performance, the number of observations for each group of regression is reduced with respect to the entire sample.

Table 8. *Probit performance* models.

Characteristics		Economic performance			
		Cost reduction [yes=1; no=0]	Production increment [yes=1; no=0]	Value added increment [yes=1; no=0]	Quality increment [very high, high=1; otherwise=0]
Innovation	Research-innovation link	0.21	0.77*	0.76*	0.83**
	Source of innovation [external=1; self =0]	-0.93	-1.22*	-1.59**	-0.87**
	Age of innovation	-0.01	0.04	0.06**	0.05*
	Important innovations (Last 20 years)	-0.73	-1.13**	0.05	-0.07
Farm	Cereal specialisation	0.65	0.53	-0.67	-0.05
	Share of rented land over total land	-0.42	-0.27	-0.42	0.18
Socio-economic	Individual farm [yes=1; no=0]	-0.20	0.11	0.67*	0.10
	Family income from Ag <30%	-0.91*	-1.72***	-1.37***	-0.32
	Education > than mid-school	0.34	-0.11	0.52	-0.28
	Constant	1.98**	1.88**	0.25	0.41
	Observations	50	56	62	88
	Pseudo R^2	0.176	0.245	0.317	0.115
	Wald χ^2	12.1	14.9*	30.4***	11.7
	AIC	71.7	76.6	78.7	123.9
	BIC	90.8	96.9	100.0	148.7

Note: robust standard errors; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The *probit performance* models applied on *cost reduction* and *quality improvement* proved to have a scarce capacity to explain the likelihood of obtaining positive performances. In the first model (*cost reduction*) only one regressor out of nine is significant and the sample is relatively small, while in the last model only the group of information variables contributes to explaining the variability in *quality improvement*.

On the contrary, the *probit performance* model proved to perform better when applied on *production* and *value-added increment*. In fact, for the latter models, the results show significant contributions in both groups of variables. From all significant results, a common pattern can be identified in the positive contribution of innovation originating from research, but also in the negative effect of *external information* on the likelihood of obtaining a positive economic performance.

These results indicate that farmers who knew the innovation from external sources have lower chances to obtain positive economic performance, especially in terms of *value-added* and *production*, with respect to *self-innovators*. On the other hand, the positive contribution of *research* on economic performance is more pronounced in terms of *quality*.

However, although the *probit performance* analysis provides interesting results, its specification might be affected, beyond the reduced number of observations, by selection bias in that only farmers who expect higher economic performance, on the basis of the information they possess, might decide to effectively adopt the innovation. In order to evaluate such a hypothesis, a *Heckit* model, specifically a *probit* model with sample selection, is run by formally dividing the variables into two groups, namely the selection (*adoption*) and outcome (*performance*) variables. The *Heckit* models indicate the presence of a self-selection process of innovation introduction related only to positive expected gains in *value-added*, as indicated by the significance of ρ, while the other model specifications indicate that both processes are essentially independent[9] (Table 9).

The results indicate that the *Heckit* models appear to be more appropriate in explaining the effects of the information variables on the economic performance. Indeed, these models, on one hand, confirm the results related to *research* and *source of information* from the previous *probit performance* models, and, on the other hand, report the same results as the *introduction* models, with the exception of the variable *number of tractors*.

6. Discussion

In this paper we investigate the determinants of innovation adoption and the relationship between origin of innovation and economic performance at farm level.

In the sample considered there is a noteworthy share of farmers who are actively innovating, which is partly explained by the long-time horizon taken into account. Most frequent innovations are in the field of mechanical innovations and innovation aimed at water-energy saving. This is consistent with the fact that mechanisation is a widespread need across farm specialisations, on the one hand, and with the current need to save resources in a context characterised by climate change; the latter issue is potentially emphasised by the location of the study area in a Mediterranean region. Multiple innovations are frequent among innovators, which may be explained by both the existence of connections among innovations (innovation packages) and the tendency of most active farm(er)s to innovate continuously (Läpple *et al.*, 2015).

The results from the adoption models, mainly testing the adoption determinants, are largely consistent with the findings in literature in terms of structural characteristics of the farms, such as farm size, mechanization, labour and production type, and subjective characteristics of the farmers, such as farmer education, experience and off-farm income[10]. The main novelty arises from the consideration of the judgement of farmers regarding the existence of important innovations in their field of specialisation, which helps to distinguish between cases in which the innovation choice by the farm results from the need of keeping up with a general technology shifts (i.e. replacing obsolescence), aligned to the *technological treadmill*, from cases in which innovation is more a choice tuned to the specific production and marketing needs of the farm. It also helps to understand the differ-

[9] Indeed, results were verified by running a *probit* regression on the performance variables by solely employing the information variables. The results confirm the ones obtained in the output equation of the *Heckit* model.

[10] The consistency of our results has been compared to the following literature: Feder and Slade, 1984; Lin, 2001; Daberkow *et al.*, 2003; Diederen *et al.*, 2003; Dimara *et al.*, 2003; Kounduri *et al.*, 2006; Cavallo *et al.*, 2014, Läpple *et al.*, 2015; Ramos-Sandoval *et al.*, 2018; Sauer *et al.*, 2019.

Table 9. *Probit performance* model with sample selection.

Characteristics		Economic performance			
		Cost reduction [yes=1; no=0]	Production increment [yes=1; no=0]	Value added increment [yes=1; no=0]	Quality increment [very high, high=1; otherwise=0]
	Outcome equation (O)				
Innovation	Research-innovation link	0.31	0.53	0.58*	0.79**
	Source of innovation [external=1; self =0]	-1.20*	-1.16**	-1.16***	-0.91**
	Age of innovation	-0.01	0.03	0.04	0.05*
	Constant	1.36**	0.98**	0.98**	0.30
	Selection equation (S)				
Innovation	Important innovations (last 20 years)	0.41*	0.48*	0.48**	0.84***
Farm	Breeder specialisation	0.52	-0.11	-0.20	0.56
	Cereal specialisation	-0.47**	-0.32	-0.64***	-0.52**
	Share of rented over total land	1.15***	0.76**	0.99***	1.03***
	Number of tractors	0.04	0.05	0.05	0.02
Socio-economic	Education > than mid-school	0.44*	0.49**	0.53***	0.52**
	Family income from Ag <30%	-0.22	-0.62***	-0.44**	-0.55***
	Family labour	-0.26**	-0.29***	-0.22**	-0.09
	Individual farm [yes=1; no=0]	-1.13***	-0.75***	-0.77***	-0.71***
	arctan(ρ)†	0.05	-0.27	-1.13*	-0.14
	Observations	241	243	240	232
	Uncensored Obs	50	56	62	88
	AIC	272.5	301.6	308.7	344.3
	BIC	321.3	350.5	357.4	392.5
	Wald χ^2 (O)	3.76	4.55	8.42**	10.2**

Note: robust standard errors; *t* statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; † arctan(ρ) indicates the correlation coefficient between output and selection equations.

ent profiles of the non-innovators, namely those for whom no-innovation is linked to the absence of innovation in the sector in contrast to those foregoing innovation for personal or farm reasons, in spite of the progresses of innovations in the sector.

The second group of models, namely the *performance* models, represent, in our knowledge, the first attempt to evaluate the existence of a relationship between research and farm performance, also taking into account farmer intermediation. The first results support the hypothesis of a differential impact of innovations originating from research, which increase profitability by positively affecting value-added and quality improve-

ments. On the contrary innovations originating from research do not appear connected to improvements in productivity or cost reduction.

Although this paper contributes to evidence on the role of research and information sources in improving farms' economic performance, it is also affected by some limitations that may affect the robustness and the generalisation potential of the results. First, the sample is rather small, in particular for the adopters' subsample, in particular considering the heterogeneity brought about by the large coverage of different farm specialisations. This may have contributed to the low significance of some of the models and some difficulty in estimation. This has also made potential additional explanatory variables difficult to use.

Second, the case study relies on a specific province in Italy, which, while benefiting from an internal heterogeneity (in terms of farm specialisation and altitude), still represents a specific context in terms of general ecological and legal conditions (including specific priorities e.g. for investment).

A third limitation concerns the way the data were collected. Due to a lack of better information availability (e.g. from accounting data) and resource limitations, most of the variables are based on statements made by farmers. This is a sensible topic, in particular with respect to the estimation of the impact of innovation on profitability parameters, which also implies a request for a difficult judgement on the part of the farmers, and of the origin of innovation, especially with respect to research, that incorporates a mix of actual information about the origin and level of documentation by the farmers. The origin of innovations and knowledge about it, in turn, relate to each other and are almost impossible to distinguish in the way in which the survey was run. Based on other questions and statements by farmers on their own level of information, we can interpret this information mostly as revealing the true origin of innovation, however there is certainly some level of (unmeasurable) approximation.

Fourth, and connected to the above, using stated information coupled with resource constraints implied the need to collect this information in a simplified way (e.g. using qualitative or dichotomous variables) and, in some cases, to use classes in the data treatment in order to account for "perceptive discontinuities" (such as round numbers in per cent statements). This, however, implies some further difficulty in the estimation and interpretation of the models.

These limitations, associated with the promising results achieved, highlight relevance and provide more precise hypotheses for further investigation on this issue. This would require, however, a larger sample, wider territorial coverage and would benefit from linkages to structural and performance data not available for this study.

An important message arising from the paper, in spite of the limitations, is that the role of farmers is crucial for innovation development and that farmers who are willing to innovate are engaged in a continuous learning process which includes, beyond the practical knowledge of the available innovations, the knowledge and awareness of the process leading from research to the realisation of the innovation as well. This evidence supports the paradigmatic change of the innovation process from AKS towards the AKIS and multi-actor concepts (SCAR, 2012), by providing additional insight into the proactive role of farmers in the management of external information coming from different sources, including research, and of own-knowledge within the innovation adoption pro-

cess (Klerkx *et al.*, 2009; Läpple *et al.*, 2015). Such proactivity might represent a relative competitive advantage for the improvement of farm performance and a key feature of entrepreneurship. However, its 'anatomy' would need to be better analysed in future studies, with the collection of more specific information about on-farm processes leading to innovation adoption or implementation on the farm.

7. Conclusions

The results of this paper show the importance of innovation for a large share of farms, considering a substantial time frame of 20 years. Most frequent innovations are in the field of mechanical innovations and innovation aimed at water-energy saving. Multiple innovations are frequent among innovators.

Classical factors, such as proxies related to farm size, remain the most suited variables to explain the adoption of innovations, while motivations for innovation adoption are largely related to the combination of cost reduction and production increases.

The process of innovation development and adoption follows two main pathways: self-development by farmers and development by mostly private companies. Agricultural research is generally known to be in the background, but rarely seems to lead directly to technology development and even less to adoption. This may also be connected to the prevailing technologies that are considered to be relevant in the area (mechanisation and water/energy saving), which require important steps in terms of 'engineerisation' of knowledge and fine tuning in local conditions (including machinery set-up and feedback from users). In either case, the mediation between research and farmers has an important industry component or, in any case, involves different layers of actors.

The (knowledge of) existence of research activities in developing the innovation seems to be associated to better performance only for the specific but important cases of improving the value-added and of achieving very high-quality production. This suggests that scientific research can have a specific role in terms of different performance-improving strategies, and, in particular, that it can contribute comparatively more to quality, while self-development or industry-led technology adaptation can have a better role in cost reduction.

These results also yield relevant insights in terms of research policy. In particular, when promoting multi-actor approaches, innovation policies should better consider different regional/sector objectives in terms of quality, productivity or cost reduction, and related to this, more explicitly evaluate the potentially different roles of private and public research and innovation players. In addition, while it can be expected that economic incentives linked to factor and product prices mainly affect cost reduction through self-innovation, a stronger role has anyway to be attributed to direct research and innovation incentives if quality objectives are to be pursued.

In spite of its limitations, the study hints at the need to further explore the co-existence and interplay among different innovations, different innovation pathways and different innovation impacts. Moreover, the interaction between awareness of technology development pathways and actual technology performance at farm level is an issue that was only partially untangled in this paper and one that is undoubtedly worthy of further investigation.

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9. References

Besley, T. and Case, A. (1993). Modeling technology adoption in developing countries. *The American Economic Review* 83(2): 396-402.

Cavallo, E., Ferrari, E., Bollani, L. and Coccia, M. (2014). Attitudes and behaviour of adopters of technological innovations in agricultural tractors: A case study in Italian agricultural system. *Agricultural Systems* 130: 44-54.

Cochrane, W.W. (1958). *Farm prices: myth and reality*. U of Minnesota Press.

Daberkow, S.G. and McBride, W.D. (2003). Farm and operator characteristics affecting the awareness and adoption of precision agriculture technologies in the US. *Precision Agriculture* 4(2): 163-177.

Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly* 13(3): 319-340.

Diederen, P., Van Meijl, H., Wolters, A. and Bijak, K. (2002). Innovation adoption in agriculture: innovators, early adopters and laggards. *Cahiers d'Economie et de Sociologie Rurales* 67: 29-50.

Diederen, P., van Meijl, H. and Wolters, A. (2003). Modernisation in agriculture: what makes a farmer adopt an innovation? *International Journal of Agricultural Resources, Governance and Ecology* 2(3-4): 328-342.

Dimara, E. and Skuras, D. (2003). Adoption of agricultural innovations as a two-stage partial observability process. *Agricultural Economics* 28(3): 187-196.

Esposti, R. (2012). Knowledge, technology and innovations for a bio-based economy: lessons from the past, challenges for the future. *Bio-based and Applied Economics* 1(3): 235-268.

Fanfani, R. and Pieri, R. (Eds.) (2016). *Il sistema agro-alimentare dell'Emilia-Romagna*. Osservatorio Agro-Alimentare, Unioncamere e Regione Emilia-Romagna Assessorato Agricoltura, caccia e pesca.

Feder, G. and Slade, R. (1984). The acquisition of information and the adoption of new technology. *American Journal of Agricultural Economics* 66(3): 312-320.

Feder, G. and Umali, D.L. (1993). The adoption of agricultural innovations: a review. *Technological Forecasting and Social Change* 43(3): 215-239.

Flett, R., Alpass, F., Humphries, S., Massey, C., Morriss, S. and Long, N. (2004). The technology acceptance model and use of technology in New Zealand dairy farming. *Agricultural Systems* 80(2): 199-211.

Folorunso, O. and Ogunseye, S.O. (2008). Applying an enhanced technology acceptance model to knowledge management in agricultural extension services. *Data Science Journal* 7: 31-45.

Foster, A.D., and Rosenzweig, M.R. (1995). Learning by doing and learning from others: Human capital and technical change in agriculture. *Journal of Political Economy* 103(6): 1176-1209.

Ghadim, A.K.A. and Pannell, D.J. (1999). A conceptual framework of adoption of an agricultural innovation. *Agricultural Economics* 21(2): 145-154

Hayami, Y. and Ruttan, V. (1985). *Agricultural Development: An International Perspective*. Baltimore: Johns Hopkins University Press.

Hall, A. (2012). Partnerships in agricultural innovation: Who puts them together and are they enough? In OECD (Eds.), *Improving Agricultural Knowledge and Innovation Systems: OECD Conference Proceedings*, OECD Publishing, 219-236.

Hockmann, H., Garzon Delvaux, P.A., Voigt, P., Ciaian, P. and Gomez y Paloma, S. (2018). Corporate R&D and the performance of food-processing firms: Evidence from Europe, Japan and North America. *Bio-based and Applied Economics* 7(3), 233-247.

ISTAT (2014). Symbola, Secondo Rapporto sulla Meccanizzazione Agricola Verde.

Klerkx, L., Hall, A. and Leeuwis, C. (2009). Strengthening agricultural innovation capacity: are innovation brokers the answer? *International Journal of Agricultural Resources, Governance and Ecology* 8(5-6): 409-438.

Koundouri, P., Nauges, C. and Tzouvelekas, V. (2006). Technology adoption under production uncertainty: theory and application to irrigation technology. *American Journal of Agricultural Economics* 88(3): 657-670

Läpple, D., Renwick, A. and Thorne, F. (2015). Measuring and understanding the drivers of agricultural innovation: Evidence from Ireland. *Food Policy* 51: 1-8.

Levins, R.A. and Cochrane, W.W. (1996). The treadmill revisited. *Land Economics 72*(4), 550-553.

Lin, J.Y. (1991). Education and innovation adoption in agriculture: evidence from hybrid rice in China. *American Journal of Agricultural Economics* 73(3): 713-723

Lindner, R.K. (1987). Adoption and diffusion of technology: an overview. In *ACIAR proceedings series*.

Marra, M., Pannell, D.J. and Ghadim, A.A. (2003). The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve? *Agricultural Systems* 75(2): 215-234

Mairesse, J. and Mohnen, P. (2010). Using innovation surveys for econometric analysis. In Hall, B.H., and Rosenberg, N. (Eds.), *Handbook of the Economics of Innovation* (Vol. 2). Elsevier, 1129-1155.

Nelson, R.R. and Winter, G.S. (1982). An evolutionary theory of economic change. Cambridge: Harvard U. Press.

Ramos-Sandoval, R., Más Verdú, F. and García Álvarez-Coque, J.M. (2018). Do research and extension services improve small farmers' perceived performance?. *New Medit* 4: 7-19.

Ramos-Sandoval, R., García Álvarez-Coque, J.M. and Más-Verdú, F. (2019). Innovative capabilities of users of agricultural R&D services. *Regional Science Policy & Practice* 11(2), 295-305.

Reimers, M. and Klasen, S. (2013). Revisiting the role of education for agricultural productivity. *American Journal of Agricultural Economics* 95(1), 131-152.

Rezaei-Moghaddam, K. and Salehi, S. (2010). Agricultural specialists intention toward precision agriculture technologies: integrating innovation characteristics to technology acceptance model. *African Journal of Agricultural Research* 5(11): 1191-1199.

Rogers, E.M. (1983). *Diffusion of innovations*. Simon and Schuster.

Röling, N. (1990). The agricultural research-technology transfer interface: a knowledge systems perspective. In Kaimowitz, D. (Eds.), *Making the link: Agricultural research and technology transfer in developing countries*. Westview Press Boulder, San Francisco & London.

Röling, N.G. (1994). Agricultural knowledge and information systems. In Blackburn, D.J. (Eds.), *Extension handbook: Processes and practices*. Toronto, Canada: Thompson Educational Publ. Inc.

Ruttan, V.W. (1996). What Happened to Technology Adoption-Diffusion Research? *Sociologia Ruralis* 36(1): 51-73

Sauer, J. and Vrolijk, H. (2019). Innovation and performance–evidence at micro level. *Applied Economics* 51(43): 4673-4699.

SCAR, E.U. (2012). *Agricultural knowledge and innovation systems in transition–a reflection paper*. Brussels: European Commission, Standing Committee on Agricultural Research-Collaborative Working Group on Agricultural Knowledge and Innovation System (CWG AKIS).

Sunding, D. and Zilberman, D. (2001). The agricultural innovation process: research and technology adoption in a changing agricultural sector. *Handbook of Agricultural Economics* 1: 207-261

Thirtle, C.G. (1985). Induced Innovation in United States Field Crops, 1939-78. *Journal of Agricultural Economics* 36(1): 1-14.

Walder, P., Sinabell, F., Unterlass, F., Niedermayr, A., Fulgeanu, D., Kapfer, M., Melcher, M.and Kantelhardt, J. (2019). Exploring the Relationship between Farmers' Innovativeness and Their Values and Aims. *Sustainability* 11(20): 5571.

Walker, T., Ryan, J. and Kelley, T. (2010). Impact assessment of policy-oriented international agricultural research: Evidence and insights from case studies. *World Development* 38(10): 1453-1461.

Annex

	Obs	Mean	Std. Dev.	Min	Max
Structural data					
Zootechnics specialisation	300	0.08	0.26	0	1
Fruit specialisation, including grape and olives	300	0.26	0.44	0	1
Cereal specialisation	300	0.40	0.49	0	1
Protein crop specialisation	300	0.06	0.23	0	1
Arable crop specialisation, including horticultural crops	300	0.62	0.49	0	1
Presence of ancillary activity: yes=1; no=0	300	0.26	0.44	0	1

	Obs	Mean	Std. Dev.	Min	Max
Sale contracts	300	0.33	0.47	0	1
Share of rented land over total land	300	0.20	0.30	0	1
Own land	300	17.03	27.82	0	300
Rented land	300	9.72	25.11	0	200
Total Land	300	26.75	45.67	0	500
Number of tractors	300	3.43	2.83	0	20
Number of operational machines	300	3.15	2.32	0	9
Demographic data					
Individual farm: yes=1; no=0	300	0.80	0.40	0	1
Family farm: yes=1; no=0	300	0.96	0.20	0	1
Family labour	285	1.89	1.09	0	7
Family labour Full Time	285	1.35	0.89	0	6
Family labour Part Time	285	0.54	0.86	0	4
Education inferior than medium school =1	300	0.22	0.41	0	1
Education superior than elementary school =1	300	0.73	0.45	0	1
Education superior than high schoo l=1	300	0.09	0.29	0	1
Specialized Ag education =1	300	0.46	0.50	0	1
Family income from Ag <30% =1	142	0.55	0.50	0	1
Family income from Ag <50% =1	176	0.69	0.46	0	1
Considerations					
Important innovations in last 20 years: yes=1; no=0	300	0.47	0.50	0	1
Continue farming in 5 years: yes=3; maybe yes=2; maybe no=1; no=0	277	2.36	0.79	0	3
Introduce innovation in next 5 years: yes=1; no=0	176	0.35	0.48	0	1
Innovation important for competitiveness: not at all=0; little=1; enough=2; much=3	272	2.42	0.72	0	3
CAP help innovation adoption: not at all=0; little=1; enough=2; much=3	248	1.57	1.00	0	3
CAP necessary for supporting agriculture: not at all=0; little=1; enough=2; much=3	267	2.19	0.97	0	3
Description of data for non-innovators (reasons for not innovating)					
No introduction = 1	300	0.60	0.49	0	1
No introduction for high costs = 1	179	0.47	0.50	0	1
No introduction for ethical reasons = 1	179	0.01	0.11	0	1
No introduction for too bureaucracy = 1	179	0.05	0.22	0	1
No introduction for high risks = 1	179	0.06	0.23	0	1
No introduction for quitting activity soon = 1	179	0.09	0.29	0	1
No introduction for negative past experiences = 1	179	0.02	0.13	0	1
No introduction for keeping traditions = 1	179	0.10	0.30	0	1
No introduction for other reasons = 1	179	0.28	0.45	0	1
Description of data for the subsample of innovators					
Number of introduced innovations	300	0.71	1.16	0	8
Introduction of innovation: yes=1; no=0	300	0.40	0.49	0	1

	Obs	Mean	Std. Dev.	Min	Max
Year of introduction of the innovation	109	2007	6.01	1995	2015
Age of innovation wrt to introduction	109	8.03	6.01	0	20
Intro for reducing risks = 1	121	0.11	0.31	0	1
Intro for diversifying ag activity = 1	121	0.14	0.35	0	1
Intro for reducing costs = 1	121	0.55	0.50	0	1
Intro for increasing production = 1	121	0.46	0.50	0	1
Other reasons (most increasing profitability and reducing labour)	121	0.27	0.45	0	1
Reaction to increase in input prices	121	0.49	0.50	0	1
Reaction to reduction in output prices	121	0.52	0.50	0	1
Anticipate inputs markets trend	121	0.36	0.48	0	1
Anticipate outputs markets trend	121	0.37	0.49	0	1
External help from private or seller	120	0.37	0.48	0	1
External help from public institutions	120	0.01	0.09	0	1
No external financial support for introducing innovation	120	0.56	0.50	0	1
Level of self-financing: 0=less than 5.000; 3=more than 50.000	91	1.85	1.10	0	3
Type of innovations					
Biological and Genetic innovations	121	0.07	0.25	0	1
Agronomical and Zoological innovations	121	0.06	0.23	0	1
Mechanical innovations	121	0.37	0.49	0	1
Informatics innovations	121	0.02	0.13	0	1
Energy and water saving innovations	121	0.22	0.42	0	1
Diversification innovation	121	0.12	0.33	0	1
Market strategies innovations	121	0.02	0.13	0	1
Information about origin of innovation					
Source of information about innovation: external=1; self produced=0	121	0.69	0.47	0	1
Knowledge of innovation origin from research	121	0.44	0.50	0	1
Effects of introduced innovation on economic performance					
All effects: presence of (positive) effect=1; otherwise=0	121	0.87	0.34	0	1
Cost reduction in %	63	17.81	20.94	0	90
Cost reduction: yes=1; no=0	63	0.71	0.46	0	1
Production increment in %	71	16.17	24.02	0	100
Production increment: yes=1; no=0	71	0.65	0.48	0	1
Value added increment in %	75	11.20	18.56	0	100
Value added increment: yes=1; no=0	75	0.52	0.50	0	1
Quality increment >0: very high, high and low=1; nothing=0	121	0.80	0.40	0	1
Quality increment >1: very high, high=1; otherwise=0	121	0.60	0.49	0	1
Quality increment: not at all=0; little=1; enough=2; much=3	110	1.64	1.04	0	3

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Full Research Article

Determinants of Farm Households' Willingness to Accept (WTA) Compensation for Conservation Technologies in Northern Ghana

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Abstract. This paper examines the determinants of farmers' willingness-to-accept (WTA) in a hypothetical payment scheme for the adoption of stone and soil bunds in northern Ghana using contingent valuation data from 305 farm households. Bayesian estimation of the interval-data regression model is employed to obtain farmers' WTA and its determinants. Besides farmer and household characteristics, farm characteristics and socioeconomic and institutional variables such as soil fertility and previous participation in conservation projects increase and decrease willingness-to-accept respectively. The results suggest that costs of soil and water conservation payment schemes may be significantly decreased by careful targeting of households more ready to accept compensation.

Keywords. Conservation technology/practice, interval-data regression model, willingness-to-accept, Contingent valuation method, Payment for Environmental Services.

JEL Codes. Q18, Q56, Q57.

1. Introduction

Land degradation is one of the world's environmental concerns today. It can be regarded as a process that includes soil degradation and erosion. The main processes that lead to land degradation are soil erosion by water and wind; chemical changes such as acidification, salinization, and nutrient loss; and physical degradation through pressures such as compaction (Eswaran *et al.*, 2001; UNCCD, 2013). There is no consensus on the exact extent and severity of land degradation in the African region, there is however consensus that it is severe and widespread. Analyses of global land degradation indicate that Africa is especially susceptible to land degradation and is the most severely affected part of the world (Lal, 1995; Obalum *et al.*, 2012). An estimate of two-thirds of Africa's productive land is affected by land degradation and almost all the land area is susceptible to

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soil and environmental degradation (FAO, 2011; Jones *et al.*, 2013; UNCCD, 2013; Vlek *et al.*, 2008). In sub-Saharan Africa (SSA), in excess of 320 million hectares of land have been made unsuitable for agricultural purposes due to soil erosion, deforestation, overgrazing and mismanagement of land resources (Sant, 2001). Nabhan (1997) also reports that 67% of agricultural lands are affected by land degradation, with close to 490 million hectares displaying signs of erosion and declining fertility.

The issue of land degradation is of immense importance in Africa as majority of its population's livelihood is heavily reliant on natural resources. Agricultural productivity in the region is stagnating or declining, largely due to land degradation. Land degradation in Africa has thus been immensely detrimental to agricultural ecosystems and crop production consequently leading to increasing levels of food insecurity, loss of farm incomes, poverty, high mortality rates, other social vulnerabilities, migration and conflict (Gomiero, 2016; Hamdy & Aly, 2014; Hemant & Padmini, 2013; UNCCD, 2013). Land degradation thus has socioeconomic implications for African countries.

Soil and land degradation in Ghana was recognized decades ago, as since the 1930s, it has attracted considerable attention and concern (Agyepong, 1987; Benneh & Agyepong, 1990). Land degradation is affecting all parts of Ghana, however, the northern regions placed within the Guinea and Sudan Savannahs are the most vulnerable zones and the most degraded area of the country (Asiedu *et al.*, 2016; World Bank, 2006). Ghana had 35% of its land threatened by desertification particularly in the northern regions (Upper East, Upper West and Northern Regions) since the 1960s (Adanu *et al.*, 2013; Kenworthy, 1995). Land degradation in the northern regions of Ghana has thus rendered large tracts of croplands which were once fertile currently unproductive as such contributing to depleting farm income and food sources. As a result of land degradation, grasslands, woodlands and forests are being lost while natural water bodies are drying up due to prolonged droughts and deposition of sediments into water courses (Adanu *et al.*, 2013). Land degradation in Ghana, which is mainly as a result of soil erosion and soil nutrient depletion, has negative impact on farm productivity and environmental quality. The human-associated drivers of long-term soil and vegetation degradation in Ghana include unsustainable farming practices, removal of vegetation cover (including deforestation and overgrazing), mining activities, and urbanization and industrial activities caused by increased population growth pressures.

Agriculture remains an important sector in the Ghanaian economy contributing about 22% to the country's gross domestic product (GDP) and providing 44.7% of employment in 2013 (Aryeetey & Baah-Boateng, 2015). Agriculture also remains the main source of livelihood for many subsistence smallholder farmers living in rural Ghana. The agricultural activities of these smallholders is cited to be a key factor in promoting land degradation through the use of environmentally unsustainable cultural practices (Asiedu-Amoako *et al.*, 2016; Boardman *et al.*, 2003; Diao & Sarpong, 2007; Helming *et al.*, 2006; Senayah *et al.*, 1998). As agriculture is the major user of rural land, its relevance is not only in relation to its economic significance, but also its influence over the use of land in rural Ghana and its environmental health in general. With the relationship between land degradation, agricultural productivity and poverty well understood (Dasgupta & Mäler, 1995; Gomiero, 2016; Hamdy & Aly, 2014; Heath & Binswanger, 1996; Hemant & Padmini, 2013; Shetty *et al.*, 1995; World Bank, 1992), it is clear that land

degradation is a threat not only to national and household food security but the overall welfare of many households in Ghana.

In order to maintain agricultural productivity, reduce food insecurity and poverty, and improve environmental conditions, the Government of Ghana (GoG), international donor agencies and Non-Governmental Organizations (NGOs) have promoted soil and water conservation practices and technologies including soil and stone bunds. This has been done for several decades particularly in the Northern, Upper-East and Upper-West regions because they collectively constitute the most degraded part of the country.

Adoption of the promoted technologies has arguably been unsuccessful due among others to weak regulatory institutions which have restricted the 'command and control' interventions (Wunder, 2008). Farmers' inability to adopt soil and water conservation measures is mainly as a result of constraints resulting from market failures which lead to externalities like degradation. When externalities are present, government intervention has the potential to internalise these externalities. One potential intervention is Payment for Environmental Services (PES) in which incentive payments are made to resource managers in return for the adoption of conservation practices/technologies. Such external financial incentives may be crucial in ensuring that socially desirable levels of environmental services/goods (ES) are supplied and maintained since poor smallholder farmers may not be able to afford to maintain healthy environmental quality especially when large opportunity costs occur when conservation technologies/practices are adopted.

Soil and water conservation technologies (e.g., soil and stone bund) are technologies that preserve the integrity of soils and their water content, and they offer a number of on-farm and off-farm ecosystem services of value to society as well as on-farm productivity improvements. Stone and soil bunds are stone or soil walls built across a slope (along a contour) to act as a barrier to prevent run-off, therefore helping in reducing soil erosion and increasing water retention capacity of soil. They are often appropriate for gentle slopes (2-5%) (Diao & Sarpong, 2007). Ecosystem services from stone and soil bunds include: substantial flood and erosion control, substantial reduction in sedimentation of water bodies and its consequent improvement in water quality and aquatic life; reduction in leaching and deposition of fertilizers, herbicides and pesticides, i.e. generally improved landscape quality, etc. (Bingham *et al.*, 1995; Holland, 2004; Webb *et al.*, 2001). The adoption of soil and water conservation (SWC) technologies is aimed at returning a landscape to a condition where it can again provide the ES enumerated above after a period of degradation. Farmers can therefore be paid/compensated for the adoption of such technologies as soil and stone bund per unit area to produce the socially beneficial ES mentioned. Payments can be in the form of money, in kind, and access to resources and markets.

In order to know the optimum rate of public investment, the required level of compensation (WTA) necessary for encouraging agricultural households to adopt a conservation technology which produces ES must be ascertained. In addition, knowledge of the factors determining WTA also informs policy implementation by enabling the direction of payments towards those that are the most predisposed towards adopting the proposed technologies.

The current study therefore uses the contingent valuation (CV) method to estimate farmers' WTA for adopting stone and soil bunds in a hypothetical conservation plan/valuation scenario context. The method of elicitation within the CV employed allows

for uncertain responses so as to maximise respondent's engagement with the survey. It employs an interval regression model to estimate WTA and determines the factors influencing their WTA, having adapted this model to allow for uncertain responses.

Extensive literature exists on PES as an alternative intervention for environmental conservation. However, much of this has focused on parts of the world other than Africa leading to a dearth of knowledge on environmental values and the main factors influencing WTA for PES conservation practice/technologies for Africa and specifically for PES schemes in Ghana. This study fills this gap by building on previous studies, with a specific aim to determine the manner in which various factors influence WTA compensation for stone and soil bunds in northern Ghana. The manner in which various factors influence WTA for conservation technologies may be location and conservation practice specific. This study therefore serves to analyse these factors, so they can be understood in a way that enables better designed interventions and decision-making in Ghana.

The paper proceeds by first reviewing literature on valuation of the welfare impact of adoption of soil and stone bunds and the factors that influence farmers' preferences for or WTA for conservation practices in Section 2. The interval data regression model specification and estimation is presented in Section 3 while Section 4 discusses the field survey, data and variables. The results are presented in Section 5 and Section 6 discusses the results. The conclusions and policy implications is given in Section 7.

2. Literature review

2.1 Valuation of the welfare impact of adoption of soil and stone bunds

The contribution of a resource to human welfare forms the basis of the economic approach to the valuation of resources. An economic value is measured by the variations in welfare related to the variation in the quantity or quality of goods or services. Variations in environmental service flows can influence the welfare of individuals in complex ways and through both marketed or non-marketed activities (Shiferaw *et al.*, 2005). Interventions like adoption of soil and stone bund by farm households that lead, for example, to reduction in soil erosion apparently change the welfare of different members of the society. Welfare economics suggests that welfare values or changes are determined by individual preferences and measured by their personal assessment of changes in well-being (Bockstael *et al.*, 2000) or the extent to which they are willing to make trade-offs between scarce resources to obtain or preserve something.

Investments in soil and stone bund provide multiple economic and environmental benefits to different groups of people beside the adopting smallholder farm households. An impact evaluation of the interventions should therefore take into account any non-marketed ecosystem goods and services along with marketed economic benefits (Baker, 2000; Shiferaw *et al.*, 2005). The welfare gains from investments in soil and stone bund include the direct economic benefits (e.g., yield gains) and environmental benefits (e.g., sustainability benefits and ecosystem services) that have both use and non-use values to people. Indirect welfare benefits obtained from environmental improvements are justifiable components of the welfare changes related to any conservation interventions, and must be measured in impact evaluation (Shiferaw *et al.*, 2005). Total welfare benefit to people, therefore,

is the sum of the direct economic and indirect environmental benefits. Hence, the benefits accruing to soil and stone bund can be assessed as those captured privately by the farm household, which include the value of yield loss averted and/or yield gains which may be felt on-site by the farm household, and those external to the farm household that are captured publicly, whose value include the improvement in ecosystem services.

The valuation of changes in ecosystem services as a result of the adoption of soil and stone bund by farmers "needs to take into account both intended and unintended outcomes as different individuals may attach values for such changes because of the use benefits they derived, or any expected or conceived non-use welfare benefits" (Shiferaw *et al.*, 2005). The concept of total economic value (TEV), the usual and most appropriate framework for aggregating the value of non-market ecosystem goods and services and measuring welfare changes is a vital part of economic valuation (Pearce, 2002; Philcox, 2007). Economic values reflect the services of an ecosystem and not the economic value of that ecosystem (Nijnik & Miller, 2017).

The potential welfare changes or impacts as a result of soil and stone bund on groups of individuals differ, i.e., the farm household's welfare change is different from the welfare impact on the consumers of the ecosystem services accruing from soil and stone bund. Assessing the economic value of soil and stone bund can thus be done in two ways. First, the measurement "of how much better or worse-off a person is due to the variation in the quantity or quality of the service flow" and second, "the addition of the individual welfare variation (gains and losses or WTP/WTA) to assess the value of this variation for the entire society (Shiferaw *et al.*, 2005). The former is the focus of the current paper.

Total welfare gains include the direct economic benefits (e.g., yield gains) and indirect environmental benefits (e.g., ecosystem services) that have both use and non-use values to people (Shiferaw *et al.*, 2005). The benefits accruing to the adoption of soil and stone bunds can be assessed as those captured privately by the farm household, which include the value of yield loss averted and/or yield gains which may be felt on-farm by the farm household, and those external to the farm household (off-farm) that are captured publicly, whose value include improvement in ecosystem services. Direct use values comprise consumptive uses including the potential yield increase that may be associated with the adoption of the conservation technology and indirect use value is improvement in landscape quality. The non-use value of soil and stone bund includes improved and preservation of aquatic life, erosion control, and the reduction of the deposition of soil and agricultural chemicals into water bodies. For this study, the WTP or WTA indicates how the adoption of stone and soil bund impact on the welfare of participating farm households.

The benefits accruing to farmers by adopting soil and stone bunds are often below the total benefits created once public good values have been accounted for, leading to below optimal levels of resource supply. In the presence of high public good values, incentive payments for resource conservation may be necessary. There is dissimilarity between the average gross margin of adoption and non-adoption of conservation technologies/practices that result in conservation opportunity costs for farmers (Krishna *et al.*, 2013). The opportunity costs for farmers adopting soil and stone bunds include: loss of valuable cropping land to bunds (Ludi, 1997; Wyatt, 2002) which for farmers is an important issue when land is scarce and which imposes revenue loss to farmers; additional labour requirements of household for construction and annual maintenance (Shiferaw & Holden,

2001; Stocking & Abel, 1989). PES schemes should pay for the farmers' opportunity costs. The stated preference (SP) of farm households' stated WTA compensation for adopting soil and stone bunds can be employed as an appropriate measure of the opportunity cost of adopting such technologies. The minimum compensation needed to motivate a farm household to accept a PES contract involving the construction of soil or stone bunds on a unit area of land is presumed to indicate the farmer's real opportunity cost per unit area of soil or stone bunds adoption.

2.2 Factors determining farmers' willingness to accept/preferences for conservation practices/ technologies

The factors influencing preferences and WTA compensation for conservation practices and technologies have generally been categorised into: farm characteristics; farmer and household characteristics; socioeconomic; and, institutional factors by previous studies (see, e.g., Ayuba *et al.*, 2011; Cooper & Keim, 1996; Matta *et al.*, 2009; Minten, 2003).

Key farmer and household characteristics have generally been thought to include gender, age, level of education of household head, own labour, labour sufficiency of the household, and wealth status of the household. For example, Thurston (2006) observes that females have higher WTA than males in valuing environmental conservation. Stephen (2015) and Wang *et al.* (2019) also estimate higher WTA for females relative to males. Sangkapitux *et al.* (2009), PRESA/ICRAF (2010), Minten (2003), Stephen (2015), and Wang *et al.* (2019) all find a positive relationship between age and WTA compensation. However, this relationship is found to be significant by Sangkapitux *et al.* (2009), Minten (2003), Stephen (2015), and Wang *et al.* (2019) and insignificant by PRESA/ ICRAF (2010). Feng *et al.* (2018) however observe a negative effect of age on WTA. Education has usually been found to have a positive influence on WTA for conservation/supply of environmental services (Ninan *et al.*, 2007; Wang *et al.*, 2018; Wang *et al.*, 2019; Xu *et al.*, 2015). Minten (2003) explains that more educated households, who have a higher reservation wage, prefer to put more effort in off-farm earnings and hence, prefer to practice agriculture in a more extensive manner. In contrast, Xiong and Kong (2017) and Yu and Cai (2015) observe a negative influence of education on WTA. Household size has been used as an index of the farm household's access to labour in most studies. PRESA/ ICRAF (2010) find a significant negative effect of household size on WTA compensation for watershed services whilst Minten (2003) observes an insignificant positive influence of household size on WTA to give up slash and burn agriculture ('tavy) and an insignificant negative effect of household size on WTA to give up forest use in Madagascar. Stephen (2015), Xiong and Kong (2017), and Wang *et al.* (2019) all find a significant positive effect of household size on WTA. Sangkapitux *et al.* (2009) observe that poorer farmers have a higher willingness to engage in a compensation scheme for providing better ecological services, probably indicating a lower WTA for the supply of environmental services. Farmers who rely on income from farm and aquatic products have higher WTA (Stephen, 2015; Xiong & Kong, 2017).

Key farm characteristics include total farm size, level/severity of erosion on farm/plot, level of soil fertility of farm/plot, slope of plot, and location/region. Sukic (2001), Xiong and Kong (2017) and Wang *et al.* (2019) find statistically significant positive impact of

land size on WTA compensation for conservation practices whilst PRESA/ICRAF (2010) discovers an insignificant influence. Previous findings suggest that the higher the level of erosion and the lower the soil fertility, the higher the willingness to participate in a payment scheme (Sangkapitux *et al.*, 2009). This in turn suggests that farmers with severe farm erosion and low soil fertility are likely to demand less compensation for conservation practices than those with less severe erosion on their fields and more fertile soils. Farm location heavily influences WTA (Minten, 2003; Stephen, 2015; Xiong & Kong, 2017; Yu & Cai, 2015). Minten (2003) reports that households with more lowland (which are more flat) are willing to accept less for compensation, though the estimates are statistically insignificant. By contrast farming in highlands (likely to be steeper) is a significant determinant of WTA compensation.

Monthly income, adoption status, and previous participation of the household in a conservation programme/project are institutional and socio-economic factors that have been associated with WTA compensation. A positive relationship between income and WTA is observed by PRESA/ICRAF (2010) and Sukic (2001), though the effect is statistically significant and insignificant respectively. Xu *et al.* (2015), Yu and Cai (2015), and Wang *et al.* (2018) find the opposite, that is a negative influence of household income on WTA.

For non-market valuation, respondents may be unable to give their true preferences because they have had little prior experience with the item in question and so have trouble establishing their minimum WTA during a single survey (Cummings *et al.*, 1986). Household knowledge of the good being valued can be proxied by identifying households who have previously adopted the conservation practice of interest or taken part in wider conservation programmes or projects. The literature is, however, silent on the direction of influence on WTA of households' prior adoption of a practice/technology and participation in previous conservation projects. However, various studies have found farmers' environmental awareness and knowledge affect WTA positively (Feng *et al.*, 2018; Wang *et al.*, 2018; Xu *et al.*, 2015; Yu & Cai, 2015).

3. Estimation methodology

CV studies require questions as to whether respondents are prepared to pay or accept specified monetary amounts in the light of changes that will impact upon them (e.g. the adoption of a technology). Valuation studies often assume that respondents know their preferences with certainty, i.e. they know how much they would be willing to accept for ES provision. However, empirical evidence in the SP literature indicates that respondents are uncertain about their responses (Akter & Bennett, 2013; Akter *et al.*, 2008; Alberini *et al.*, 2003; Champ *et al.*, 1997; Ready *et al.*, 1995). This is mainly because respondents use a heuristic mode while processing information provided in any of several CV formats which tends to dominate over more systematic ways of information processing for decision-making (Bateman *et al.*, 2004). Unsurprisingly, the CV literature has spawned multiple forms of elicitation which are aimed at minimising or mitigating biases. One factor that leads to potential bias is that respondents may not know or be able to state with certainty their underlying preferences and forcing them to do so can induce bias (Akter & Bennett, 2013; Ariely *et al.*, 2003; Poe, 2016; Ready *et al.*, 2010). Uncertainty is an important aspect of many public goods, especially environmental goods (Mitchell & Carson, 1989) such

as produced by SWC technologies like stone and soil bunds. Preference uncertainty is a stochastic error term which comes about in hypothetical valuation scenarios as individuals do not know their true values of a good with certainty (Li & Mattsson, 1995). In the current study, the LB and UB are obtained based on the expansion approach of Broberg and Brännlund (2008), which takes uncertainty into consideration. This method can be termed the 'multiple-bounded uncertainty choice' (MBUC) approach. It has been argued that this approach is more intuitive, better fits the data, estimates mean and median WTP with better precision, is less sensitive to distributional assumptions, and it is better suited for policy analysis than other approaches (Broberg & Brännlund, 2008). The elicitation method employed here (and outlined in Section 4) is to give respondents a 'payment card' (a series of possible ranges) but allowing them to indicate whether they would pay for that amount with certainty or with some level of uncertainty. However, this approach also requires an adaptation to the standard methods used to model WTA/WTP.

A standard model for dealing with the case where the dependent variable is only known within a range is the interval data model (Stewart, 1983). Hanemann *et al.* (1991) observed that the interval-data model improves the statistical efficiency of WTP estimates by reducing the variance and point estimates of WTP models relative to single-bound models. Alberini (1995) explored the efficiency and biases of the estimates obtained from the bivariate probit and interval-data models and observed robust estimates for mean/median WTP and concludes that in the absence of perfect correlation as is the case in many CV studies, the interval-data model might be appropriate. However, the interval-data model assumes that answers provided by respondents reflect WTP/WTA which are known with certainty (Alberini, 1995). However, as discussed above, the elicitation approach outlined in Section 4 is more general in that it allows for uncertain responses. Because MBUC responses do not translate directly into the statistical models conventionally employed to model stated-preference responses, assumptions about the interpretation of the responses by the researcher are necessary. The literature provides a number of empirical ways to convert MBUC CV data to easily estimable forms. Intervals are obtained by assigning, $LB<y_i^*<UB$ given the responses, where LB and UB are the lower and upper bounds respectively.

The notation used in this section are adapted from Balcombe *et al.* (2009). If utility is unobserved and indicated by the latent variable y_i^*, and WTA_i is the WTA of the th individual, then the utility can be expressed as:

$$WTA_i = y_i^* = \beta' x_i + \varepsilon_i \quad \varepsilon_i \sim N(0,h) \tag{1}$$

where x_i is a vector of explanatory variables determining respondents' WTA, β' is the parameter vector related to x_i and ε_i is the error term assumed to be normally distributed with zero mean and variance h.

Consequently for WTA, the highest "definitely no" and lowest "definitely yes" responses form the LB and UB respectively. Uncertainties are accommodated in the model resulting in the uncertainty interval model which is employed in this study. The rule used to create the WTA interval for the th individual is a function of his responses with the LB and UB constructed based on the following assumptions:

1. A 'Y': bid forms WTA_{upper}

2. A 'N': bid forms WTA_{lower}
3. A 'PY': bid forms WTA_{upper}, with a fixed probability, τ
4. A 'PN': bid forms WTA_{lower}, with a fixed probability, τ

where τ, a probability value of truncation, is between 0 and 1 and set by the authors at 0.75; Y is definitely yes, PY is probably yes, DK is don't know, PN is probably no, and N is definitely no.

The latent variable y_i^* therefore has the clear interpretation of a person's WTA, and equation (1) would give a direct estimate of the mean WTA.

For a Bayesian estimation and inference, priors for the β and h parameters are specified normal $N(.,.)$ and inverse gamma $IG(.,.)$ respectively:

$$\begin{aligned} \beta &\sim N(\underline{b}, \underline{V}) \\ h &\sim IG(n, s) \end{aligned} \tag{2}$$

The likelihood of the latent variable y^* is

$$p(y^*|x, \beta, h) = (2\pi)^{-\frac{n}{2}} h^{\frac{n}{2}} e^{-\frac{1}{2}h(y^*-x\beta)'(y^*-x\beta)} \tag{3}$$

The posterior distribution is obtained by combining equations (2) and (3). The posterior distribution of model (1) is simulated using the Gibbs sampler (see for example Koop, 2003).

Two models were estimated using the model above. The first one contains an estimate of the WTA which can be interpreted as describing the unconditional distribution of the WTA in the population (Verbeek, 2004). The second model includes the explanatory variables shown in Table 2 below.

The models were estimated using Markov Chain Monte Carlo (MCMC), setting the burn-in phase to 2000 iterations which is followed by another 200,000 iterations in which every 20th observation was sampled in order to lessen the dependence in the sequence, resulting eventually in 10,000 observations for analysis. Convergence diagnosis was done using visual plots of the sequences of values produced by the sampler and by modified t-tests for the hypothesis of 'no-difference' between the first and second halves of the sampled values for each of the parameters. Observations without either an upper or lower bound were not included in the analysis; hence none of the models was estimated with the total of 350 observations.[1]

4. Field survey, data and variables

In a hypothetical conservation plan context, data were collected from 305 households in the three northern regions of Ghana through a survey conducted from January – March, 2010. The questionnaire used included a description of the technologies with pictures as well as pictures of the possible environmental consequences (i.e., landscape quality improvement/maintenance) of the technologies. A multi-stage sampling approach was adopted in which a district was first selected from each region. From a purposively

[1] Gauss code for estimation of the models written by Kelvin Balcombe.

Table 1. An example of an answered CV question.

Example: Which of the values would you be willing to accept for constructing **STONE BUNDS** on an acre of your own field? Please tick only one option for each value.

Amount in Cedis/acre	Definitely No	Probably No	Don't Know	Probably Yes	Definitely Yes
200	√				
300	√	√			
350		√			
400		√			
450			√		
500				√	
550					√
600					√

selected group of communities in each district where physical evidence of the SWC structures of interest to the research are present, ten communities from two of the districts and five from the remaining district were then randomly chosen.[2] Finally, ten or five respondents were randomly selected from the 25 communities.

For the estimation of WTA, a CV of four polychotomous-choice multiple-bounded elicitation format with variations of yes/no answers to indicate respondent uncertainty (FAO, 2000; Mitchell & Carson, 1989). The dichotomous choice format with follow-up questions reasonably mimics the bargaining process common in developing countries (FAO, 2000) and hence familiar to respondents.

The CV consisted of a question format of eight bid amounts ranging from a minimum of GH¢200 to a maximum of GH¢600 for each of the technologies of interest, namely, stone bund and soil bund.[3] These amounts were obtained from focus groups sessions and discussions with experts. Face-to-face interviews with respondents were conducted during the CV survey. Table 1 shows an example of a CV question format and how it should be answered and Table 2 presents a description of variables.

5. Results

5.1 Description of respondents

Descriptive and summary statistics of selected socio-economic and demographic characteristics of respondents, physical characteristics of farm/fields, and institutional characteristics are presented in Table 3. Out of the total of 305 survey respondents, approximately 78% are males. The dominance of male-headed households in the survey

[2] Physical evidence is important because for stated preference studies, knowledge and familiarity of the good being valued is useful.

[3] The average exchange rate in 2009 was GH¢2.2024 and GH¢1.4132 to GB £1 and US$1 respectively (BoG, 2010: p.51).

Table 2. Description and statistics of variables used to explain WTA.

Variable	Description
Farmer and household characteristics	
Gender	Gender of household head (Dummy, 1 if male, 0 if female)
Age	Age group of household head (1 = 20 – 30 years)
Education	Level of education (1 = no formal education)
Own labour	Number of household members working on farm
Labour sufficiency	Whether farm household has enough labour (Dummy, 1 if yes, 0 otherwise)
Wealth status	Index of household perception of wealth status (1 = rich)
Farm characteristics	
Farm size	Total farm size in hectares
Severity of erosion	Average index for perception of erosion on plots (1 = not severe)
Soil fertility	Average index for soil fertility level on plots (1 = very fertile)
Slope of farm	Average index of type of slope of plots (1 = flat)
North[1]	Location is northern region (Dummy, 1 if northern region, 0 otherwise)
UWest	Location is upper-west region (Dummy, 1 if upper-west, 0 otherwise)
Socio-economic and institutional variables	
Income	Index for monthly income (1 = below GH¢21.00)
Adoption	Adoption of SWC by household (Dummy, 1 if adopter, 0 otherwise)
Participation	Participation in previous conservation project (Dummy 1 if yes, 0 otherwise)
Member	Membership in farmer association (Dummy, 1 if member, 0 otherwise)

[1] To avoid the dummy variable trap (Greene, 2003), the Upper East region is used as reference location and therefore dropped from the models.

sample conforms to GLSS5 (2008), which reports that the proportion of male-headed households in the rural savannah areas (study area fall within this category) is 85%. The highest proportions of more than 36% of respondents are over 50 years of age, whilst 33% are under 41 years, and about 67% are over 40 years. It can be concluded that households involved in agriculture are headed more by older heads than by young ones. This could be the reason why the adoption of SWC technologies by farm households in the study area is low. Respondents have low levels of education. About 77% and only 15% of respondents have had no formal education and primary education respectively. Only 8% of farm household heads have had either secondary or higher level of education. With an average family size of nine (9) persons, households in the study area generally reflect the large household sizes typical of African villages and farm households. On average, 4 persons per household provide on-farm labour. Most households (71%) do not have enough own/household labour to perform farm production activities. This has important implications for the adoption of labour intensive soil and water conservation technologies like stone and soil bunds. This lack of adequate household labour is probably one of the reasons why adoption of these technologies is low in the study area. In terms of land holdings, the study area is generally characterized by small holdings. The average total farm size is 2 hectares, with minimum and maximum values of 0.40 and 6.20 hectares respectively. Only 31% of households have total land sizes greater than the mean value. The small farm sizes

may also indicate that households will have low willingness to adopt SWC technologies that take up too much of cropland.

In terms of the adoption of either one or both SWC technologies under consideration, 55% of the responding households are adopters. This distribution provides enough data to make comparisons between adopting and non-adopting households. An adopter household in this study is one that has already adopted any one or both of the technologies

Table 3. Sample descriptive and summary statistics.

Sample characteristic	District		Total sample	
	Lawra (%) (n=103)	T-Nabdam (%) (n=100)	W-Mamprusi (%) (n=102)	Freq. (%) (n=305)
Gender of household head				
Male	74 (71.84)	84 (84.00)	79 (77.45)	237 (77.70)
Female	29 (28.16)	16 (16.00)	23 (22.55)	68 (22.30)
Age group (years)				
20 – 30	11 (10.68)	16 (16.00)	12 (11.76)	39 (12.79)
31 – 40	18 (17.48)	25 (25.00)	20 (31.37)	63 (20.66)
41 – 50	22 (21.36)	30 (30.00)	42 (72.55)	94 (30.82)
Over 50	52 (50.49)	29 (29.00)	28 (72.55)	109 (35.74)
Level of education of household head				
No formal education	83 (80.58)	64 (64.00)	89 (85.29)	234 (76.72)
Primary	13 (2.62)	21 (21.00)	12 (11.76)	46 (15.08)
Secondary	3 (2.91)	13 (13.00)	3 (2.94)	19 (6.23)
Tertiary	1 (0.97)	2 (2.00)	0	3 (0.98)
Other	3 (2.91)	0	0	3 (0.98)
Adoption of conservation technology				
Adopter	51 (49.51)	37 (37.00)	48 (47.06)	168 (55.08)
Non-adopter	52 (50.49)	63 (63.00)	54 (52.94)	137 (44.92)
Participation in previous conservation programme/project				
Participant	54(52.43)	41 (41.00)	78 (76.47)	173 (56.72)
Non-participant	49 (47.57)	59 (100.00)	24 (23.53)	132 (43.28)
Membership of a group				
Member	55 (53.40)	41 (41.00)	59 (57.84)	155 (50.82)
Non-member	48 (46.60)	59 (59.00)	43(42.16)	150 (49.18)
Labour sufficiency				
Yes	54 (52.43)	21 (21.00)	12 (11.76)	87 (28.52)
No	49 (47.57)	79 (79.00)	90 (88.24)	218 (71.48)
Wealth status				
Rich	18 (17.48)	5 (5.00)	20 (19.61)	43 (14.10)
Average	54 (52.43)	74 (74.00)	72 (70.59)	200 (65.57)
Poor	31 (30.10)	21 (21.00)	10 (9.80)	62 (20.33)

Sample characteristic	District			Total sample
	Lawra (%) (n=103)	T-Nabdam (%) (n=100)	W-Mamprusi (%) (n=102)	Freq. (%) (n=305)
Household monthly income group (GH¢)				
Below 10	47 (45.63)	31 (31.00)	9 (8.82)	87 (28.52)
10 – 20	47 (45.63)	29 (29.00)	35 (34.31)	111 (36.39)
21 – 30	3 (2.91)	4 (4.00)	13 (12.75)	20 (6.56)
31– 40	0 (0.00)	4 (4.00)	10 (9.80)	14 (4.59)
41 – 50	2 (1.94)	9 (9.00)	11 (10.78)	22 (7.21)
Above 50	4 (3.88)	23 (23.00)	24 (23.53)	51 (16.72)
Degradation problem in locality				
Yes	101 (98.06)	90 (90.00)	102 (100.00)	293 (96.07)
No	2 (1.94)	10 (10.00)	0 (0.00)	12 (3.93)
Severity of erosion				
Not severe	29 (28.16)	22 (22.00)	18 (17.65)	69 (22.62)
Fairly severe	17 (16.50)	36 (36.00)	23(22.55)	76 (24.92)
Severe	38 (36.89)	13 (13.000	29 (27.45)	79 (25.90)
Very severe	19 (18.45)	29 (29.00)	33 (32.35)	81 (26.56)
Soil fertility				
Very fertile	0 (0.00)	13 (13.00)	9 (8.82)	22 (7.21)
Fertile	51 (49.51)	54 (54.00)	63 (61.76)	168 (55.08)
Not fertile	52 (50.49)	33 (33.00)	30 (29.41)	115 (37.70)
Slope of farm				
Flat	11 (10.68)	2 (2.00)	10 (9.80)	23 (7.54)
Fairly steep	72 (69.90)	68 (68.00)	39 (38.24)	179 (58.69)
Steep	14(13.59)	25 (25.00)	50 (49.02)	89 (29.18)
Very steep	6 (5.83)	5 (5.00)	3 (2.94)	14 (4.59)
District	Mean	Stdv	Min	Max
Own labour				
Lawra	4.18	2.16	1	10
Talensi-Naddam	3.85	2.29	1	13
West-Mamprusi	3.49	1.58	1	9
Total sample	3.84	2.05	1	13
Household size				
Lawra-Nandom	8.36	2.98	2	16
Talensi-Naddam	8.75	3.56	2	18
West-Mamprusi	9.93	3.39	2	16
Total sample	9.01	3.38	2	18
Total farm size (acres)				
Lawra-Nandom	1.18	0.68	0.40	4.80
Talensi-Naddam	1.98	1.21	0.60	6.00
West-Mamprusi	2.84	1.53	0.60	6.20
Total sample	2.00	1.36	0.40	6.20

under consideration. Almost equal proportions of respondents belong to an organized farmer association/group. An important feature of these associations is labour sharing. A proportion of about 65% of households earn a monthly income (from all sources, both on and off-farm) below GH¢21.00 ($14.87) and are categorised as poor based on the Ghana Living Standard Survey (GLSS5, 2008). However, from the farmers' own perspective, only 20% of them consider themselves as poor. Ninety-six percent (96%) of respondents think that land degradation is a problem in their area. Most households, 95%, report that erosion is a problem on their own farms/fields, whilst about 77% perceive the level of erosion as being fairly severe to very severe. However, only about 38% of respondents view their farms as infertile.

5.2 Upper and lower bounds of WTA

The distribution of lower and upper bounds of WTA are reported in Table 4. The lower and upper bounds represent amounts that respondents are not willing and willing to accept respectively. For stone bund, whilst the range GH¢500-875 ($353.85-619.24)

Table 4. Distribution of lower and upper bounds of WTA for stone bund and soil bund.

WTA (GH¢/ hectare)	Lower bound No. of responses (%)		Upper bound No. of responses (%)	
Stone bunds				
250	31	(10.20)	0	(0.00)
500	104	(34.21)	1	(0.33)
750	88	(28.95)	13	(4.28)
875	49	(16.12)	23	(7.57)
1000	22	(7.24)	54	(17.76)
1125	6	(1.97)	62	(20.39)
1250	1	(0.33)	84	(27.63)
1375	3	(0.99)	48	(15.79)
1500	0	(0.00)	19	(6.25)
Total	304	100.00)	304	(100.00)
Soil bunds				
250	90	(30.00)	0	(0.00)
500	141	(47.00)	27	(8.91)
750	47	(15.67)	52	(17.16)
875	18	(6.00)	66	(21.78)
1000	4	(1.33)	64	(21.12)
1125	0	(0.00)	52	(17.16)
1250	0	(0.00)	38	(12.54)
1375	0	(0.00)	4	(1.32)
1500	0	(0.00)	0	(0.00)
Total	300	(100.00)	303	100.00)

Figures in parentheses are percentages.

form the most important range in terms of numbers reporting for the lower bound, it is GH¢1000-1375 ($707.71-973.10) for the upper bound.

Amounts ranging from GH¢250-750 ($176.92-530.78) and GH¢750-1250 ($530.78-884.64) form the most important lower and upper ranges respectively for soil bund. The total numbers reporting are different for the two technologies because, in some cases, respondents do not have either an upper or lower bound and therefore the percentages are in respect of the numbers reporting for the bounds and not of the total sample of 305.

5.3 WTA estimates

Mean WTA/hectare for stone bunds and soil bunds are shown in Table 5. These estimates are the unconditional WTA in the population. Respondents are willing to accept GH¢922.08/hectare (US$652.56) and GH¢714.92/hectare (US$505.95) for stone bunds and soil bunds respectively. WTA for stone bund is GH¢207.16/hectare (US$146.61) more than for soil bund because the construction of stone bunds is labour intensive.

Table 5. Interval data model estimates on farmers' WTA for stone bund and soil bund.

Technology	WTA(**GH**¢/hectare)	S.D
Stone bund	922.08	12.808
Soil bund	714.92	12.807

5.4 Determinants of WTA

The results of the estimation of the determinants of WTA for stone bunds and soil bunds are shown in Table 6. Irrespective of the conservation technology, farmer and household characteristics which have significant effect on WTA are gender, the number of household members working on farm, whether household has enough farm labour, and the households' perception of its wealth status, with their direction of influence being the same for stone and soil bunds. Soil fertility and the farm location of Northern region are the two farm characteristics variables that are significant determinants for both stone and soil bunds. For stone bunds, severity of erosion and the location of Upper-West region are significant determinants as well. Among the three socio-economic and institutional variables considered, only previous participation is found to be significant for both stone bunds while all three variables are important for soil bunds.

6. Discussion

Resource managers' WTA is important in the implementation of any PES aimed at restoring ES. Influencing factors of preferences and WTA compensation for conservation have been grouped into: farm characteristics; farmer and household characteris-

Table 6. Interval data model estimates on determinants of WTA/hectare for stone bund and soil bund.

Variable	Stone bund		Soil bund	
	Coefficient	S.D	Coefficient	S.D
Constant	789.22*	71.09	546.78*	67.33
Farmer and household characteristics				
Gender	52.61*	29.88	61.55*	30.16
Age	-4.53	12.35	00.93	12.05
Education	24.75*	17.59	17.47	17.87
Own labour	-5.81*	04.01	-9.55*	03.92
Labour sufficiency	55.48*	27.81	51.52*	28.30
Wealth status	52.60*	20.66	80.92*	19.96
Farm characteristics				
Farm size	-2.20	08.55	-9.64*	07.99
Severity of erosion	12.65*	11.22	09.85	10.03
Soil fertility	76.16*	20.54	82.93*	18.53
Slope of farm	09.82	17.66	11.71	16.42
Northern region	-36.62*	31.77	-185.43*	29.51
Upper-West region	93.51*	32.17	-11.74	29.36
Socio-economic and institutional variables				
Income	-3.83	11.14	-27.05*	10.59
Adoption	24.78	30.11	53.57*	27.98
Previous participation	-84.21*	30.25	-104.30*	28.29

Note: * pseudo t-value significant at 5%; Within Bayesian inference, the coefficient's confidence/credible interval excludes zero if the ratio of the estimate of the mean to the standard deviation exceeds 2.

tics; socioeconomic; and, institutional factors by previous studies (see, e.g., Ayuba *et al.*, 2011; Cooper & Keim, 1996; Matta *et al.*, 2009; Minten, 2003). In the current study, as is shown in Table 6, gender, the number of household members working on farm, whether household has enough farm labour, and the households' perception of its wealth status are the farmer and household characteristics significantly influencing WTA. The direction of influence of these factors on WTA for both stone and soil bunds is the same. The observed differences in all the coefficient estimates for stone and soil bunds, i.e., higher positive and lower negative for stone bunds and lower positive and higher negative for soil bunds is because it costs more to adopt stone bunds than soil bunds.

Households headed by females are willing to accept less than male household heads. Female are willing to accept GH¢52.22/hectare ($36.98/hectare) and GH¢61.55/hectare ($43.59/hectare) less than males for stone and soil bunds respectively. This result is contrary to Thurston (2006), Stephen (2015), and Wang *et al.* (2019) who found female respondents have higher WTA than male respondents in valuing environmental conservation. The dissimilarity between the genders may be due to a number of reasons. First, wage disparity between genders and weak negotiation skills of females; second, females

may not be fully aware of the effort required as construction of bunds is done by males in the study area; third, women consider conserving the environment as a personal benefit unlike men who focus on financial rewards; and finally, women see current levels of PES funding as more helpful and useful than do men (Schwartz, 2017). Households with higher number of members providing farm labour are willing to accept less for adoption. This could be because the higher the household members providing on-farm labour, the less that household would require hired labour. The WTA for own labour for stone and soil bunds are GH¢5.75/hectare ($4.07/hectare) and GH¢9.55/hectare ($6.76/hectare) respectively implying that an additional household member working on the farm leads to a reduction in the WTA/hectare accepted by these amounts. There is no plausible explanation for the positive influence of labour sufficiency on WTA. Households who perceive themselves as poor demand GH¢52.50/hectare ($37.18/hectare) and GH¢80.92/hectare ($57.31/hectare) less for stone and soil bunds respectively than those who perceive themselves of average wealth. This result is consistent with that of Sangkapitux *et al.* (2009) that poorer farmers have a higher willingness to engage in a compensation scheme for providing better ecological services, indicating a lower WTA for the supply of environmental services. Education is a significant determinant of WTA for only stone bunds. Consistent with Ninan *et al.* (2007), Wang *et al.* (2019), Wang *et al.* (2018), and Xu *et al.* (2015), the more educated the household head, the more the WTA and this is explained by Minten (2003) that more educated households have a higher reservation wage and thus prefer to put more effort in off-farm earnings. This is particularly true as stone bunds require much more effort than soil bunds. For example, farmers who have had primary education will accept GH¢24.75/hectare ($17.53/hectare) more than farmers with no formal education. In contrast, Xiong and Kong (2017) and Yu and Cai (2015) observe a negative influence of education on WTA.

Two farm characteristics, soil fertility and the farm location of Northern Region are the significant determinants for both stone and soil bunds. For stone bunds, severity of erosion and the location of Upper-West region are significant determinants as well. As the fertility of soil becomes poorer, farmers demand more compensation. Farmers will accept GH¢76.16/hectare ($53.94/hectare) more for stone bunds on fertile than on very fertile soil. Also the higher the severity of erosion, the more WTA wanted. More infertile soils and highly eroded lands require more resources to construct closer bunds which also mean that more productive land is lost to conservation structures. The severity of erosion is significant for stone bund but not soil bund because stone bunds are comparatively better at controlling erosion. This result does not agree with Sangkapitux *et al.* (2009) whose results on peoples' willingness to participate in payment schemes posits that the lower the soil fertility and severe the erosion, the lower the WTA demanded is likely to be.

For soil bund, farm size is a significant variable showing that the bigger the households' farm size, the less WTA those households are willing to accept. Farm size negatively influences WTA probably because the opportunity cost of committing land is less for large landholders than for small landholders. This result conforms to that of Minten (2003) but contradicts that of Sukic (2001), Xiong and Kong (2017), and Wang *et al.* (2019). Willingness-to-accept of farmers in Northern and Upper-West regions are less and more compared to Upper-East region respectively for stone bunds. Farmers in Northern Region are willing to accept GH¢36.62/hectare ($25.93/hectare) less than their counter-

parts in the Upper East Region, whereas those in Upper-West Region demand higher, a mean of GH¢93.51/hectare ($66.22/hectare) more than those in Upper East. Willingness-to-accept is more in the Upper-West because stones are more readily available on farms in Upper-East than in Upper-West where stones will need to be transported from elsewhere. In the case of Northern region, it is perhaps because though stones are not abundant here, lands are much more flatter here compared to those in Upper-West and Upper-East and therefore will require less labour and materials for construction. This result does show that location influences WTA as is found by Minten (2003), Stephen (2015), Yu and Cai (2015), and Xiong and Kong (2017).

Previous participation is found to be the only socio-economic and institutional variable significant for both stone bunds and soil bunds. Households that have participated in previous soil and water conservation projects are willing to accept GH¢84.21/hectare ($59.64/hectare) less than households that have not. This result is also observed by PRESA/ICRAF(2010). Such result, Cummings *et al.*(1986) explained as respondents probably being unable to provide their true preferences because they have had little prior experience with the item being valued and thus have difficulty establishing their minimum WTA during a single survey. This explanation does not however tell us the direction of influence on WTA. However, various studies have found farmers' environmental awareness and knowledge affect WTA positively (Feng *et al.*, 2018; Wang *et al.*, 2018; Xu *et al.*, 2015; Yu & Cai, 2015).

For soil bunds, income and adoption affect WTA in a negative and positive way respectively. For instance, farmers in the monthly income range of GH¢21-30 ($14.87-21.25) will accept GH¢27.05/hectare ($19.16/hectare) than those earning GH¢31-40 ($21.95-28.33) per month. The higher the income of the household, the less WTA they are willing to accept agrees with Xu *et al.* (2015), Yu and Cai (2015), and Wang *et al.* (2018) but is inconsistent with PRESA/ICRAF (2010). This result is however contradictory to the influence observed for the wealth status variable probably because wealth status is a variable measuring perception than actual wealth. The adoption variable has positive effect, indicating, for example, that adopter households demand GH¢53.57/hectare ($66.22/hectare) more than non-adopter households. Adopter households have previous knowledge of the technology thus it is logical to assume that their WTA represent their true preferences. This result contradicts that of the participation variable in that previous experience leads to positive effect on WTA (i.e., adoption) and negative influence on WTA (i.e., previous participation) at the same time. The only explanation that can be given for this inconsistency is that adopters perhaps have better and more experience with the technology because they have actually adopted on their own fields than previous participants of projects who may not have adopted.

7. Conclusions

Factors like gender, the number of household members working on farm, whether household has enough farm labour, the households' perception of its wealth status, soil fertility, farm location and participation in previous conservation project are significant determinants of WTA for both soil and water conservation technologies/practices. However, other factors like education, farm size, severity of erosion and income also show that

the determinants of WTA may vary with technology and location and therefore results from one location and for one technology should be employed in another location and on another technology with care.

The fact that location effects are observed in the average amount of compensation that smallholders in northern Ghana are prepared to accept indicates that location specific approaches might be employed, and that the amounts paid for the promotion of payment schemes should also be location specific. Particularly, smallholders in the Northern Region are willing to accept less for soil and stone bund than those in Upper East region and should be targeted.

A widely held argument in the literature is that poor smallholders are concerned about short-term but not long-term economic interests, and are, therefore, not willing to adopt sustainable management services. The fact that in the current study, households who perceived themselves as poor are willing to accept less than those who perceived themselves as rich suggests that the poorer groups among the farm households in northern Ghana are more willing to engage in conservation compensation schemes. Therefore, the evidence provided in the current study supports the proposition that compensation schemes can, in addition to their environmental objectives, address poverty.

To ensure effectiveness and efficiency of PES, policies should be designed to consider important factors. Factors such as gender, age, education, location, farm size, income, and previous participation in conservation programmes are important. Any category of household prepared to accept less compensation is more likely to participate in the PES scheme. Therefore, if a PES scheme will be implemented in the study, groups that need to be consciously targeted include: less educated and female headed households and households headed by older individuals. Compensation schemes should also concentrate more on poorer households than richer ones since this achieves both efficiency and equity objectives. Monetary compensation can be an avenue for improving livelihoods, alleviating poverty and diminish reliance of such groups on natural resources.

We briefly mention some limitations of our study. First, the high illiteracy rates of smallholder farmers impose some difficulties when conducting stated preference surveys in developing countries. Even after considerable training, enumerators may still make considerable mistakes. We tried to address this by reviewing each administered questionnaire at the end of each interview to highlight incorrect responses, and make sure that responses are corrected before leaving the respondents. Second, all valuation methods involve some uncertainty. The very complex nature of ES themselves limits how precisely they can be valued. The complexity limits the ability of respondents to understand and appreciate nature of ES or the reasoning behind the choices they make. We employed the MBUC CV format and the interval-data model to try and address the issue of uncertainty. Finally, the values attached to benefits from ES are subjective and variable over time, space and issue. These values differ substantially with people's attitudes, awareness of background issues, cultural norms, preferences and status. Additionally, it is extensively known that valuation of ES is very context specific and should be informed by the viewpoints and needs of the beneficiaries within these contexts. Thus the results obtained are space and time specific and apply only to a particular location. We reason that the results may well be extended to other parts of Ghana and perhaps SSA where conditions are similar, however, this should be done with care.

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9. References

Adanu, S.K., Mensah, F.K. and Adanu, S.K. (2013). Enhancing Environmental Integrity in the Northern Savanna Zone of Ghana: A Remote Sensing and GIS Approach. *Journal of Environment and Earth Science 3*(5): 67-77.

Agyepong, G.T. (1987). *Perspectives on Land Resource Planningfor Conservafion in Ghana*. Environmental Protection Council (EPA), Accra.

Akter, S. and Bennett, J. (2013). Preference uncertainty in stated preference studies: facts and artefacts. *Applied Economics 45*(15): 2107-2115.

Akter, S., Bennett, J. and Akhter, S. (2008). Preference uncertainty in contingent valuation. *Ecological Economics 67*(3): 345-351.

Alberini, A. (1995). Efficiency vs Bias of Willingness-to-Pay Estimates: Bivariate and Interval-Data Models. *Journal of Environmental Economics and Management 29*(2): 169-180.

Alberini, A., Boyle, K. and Welsh, M. (2003). Analysis of contingent valuation data with multiple bids and response options allowing respondents to express uncertainty. *Journal of Environmental Economics and Management 45*(1): 40-62.

Ariely, D., Loewenstein, G. and Prelec, D. (2003). "Coherent arbitrariness": Stable demand curves without stable preferences. *Quarterly Journal of Economics 118*(1): 73-105.

Aryeetey, E. and Baah-Boateng, W. (2015). Understanding Ghana's growth success story and job creation challenges. Helsinki, Finland: UNU-WIDER.

Asiedu-Amoako, S., Ntiamoah, M.K. and Gedzi, V.S. (2016). Environmental Degradation: A Challenge to Traditional Leadership at Akyem Abuakwa in the Eastern Region of Ghana. *American Journal of Indigenous Studies 1*(1): 1-13.

Ayuya, O.I., Lagat, J.K. and Mironga, J.M. (2011). Factors influencing potential acceptance and adoption of clean development mechanism projects: Case of carbon trade project among small scale farmers in Njoro District, Kenya. *Research Journal of Environmental and Earth Sciences 3*(3): 275-285.

Baker, J. (2000). *Evaluating the Impact of Development Projects on Poverty: A Handbook for Practitionersb*. Washington, DC: World Bank.

Balcombe, K., Chalak, A. and Fraser, I. (2009). Model selection for the mixed logit with Bayesian estimation. *Journal of Environmental Economics and Management 57*(2): 226-237.

Bateman, I., Burgess, D., Hutchinson, W.G. and Matthews, D. (2004). Learning Effects in Repeated Dichotomous Choice Contingent Valuation Questions. *Paper presented at the Royal Economic Society Annual Conference*. Swansea.

Benneh, G. and Agyepong, G.T. (1990). *Land Degradation in Ghana*. Commonwealth Secretariat, London; University of Ghana, Legon, Ghana.

Bingham, G., Bishop, R., Brody, M., Bromley, D., Clark, E., Cooper, W., *et al.* (1995). Issues in ecosystem valuation: improving information for decision making. *Ecological Economics 14*(2): 73-90.

Boardman, J., Poesen, J. and Evans, R. (2003). Socio-economic factors in soil erosion and conservation. *Environmental Science & Policy 6*(1): 1-6.

Bockstael, N.E., Freeman, A.M., Kopp, R.J., Portney, P.R. and Smith, V.K. (2000). On Measuring Economic Values for Nature. *Environmental Science & Technology 34*(8): 1384-1389.

BoG. (2010). Bank of Ghana Annual Report. Accra: Bank of Ghana.

Broberg, T. and Brännlund, R. (2008). An alternative interpretation of multiple bounded WTP data--Certainty dependent payment card intervals. *Resource and Energy Economics 30*(4): 555-567.

Champ, P.A., Bishop, R.C., Brown, T.C. and McCollum, D.W. (1997). Using Donation Mechanisms to Value Nonuse Benefits from Public Goods. *Journal of Environmental Economics and Management 33*(2): 151-162.

Cooper, J.C. and Keim, R.W. (1996). Incentive Payments to Encourage Farmer Adoption of Water Quality Protection Practices. *American Journal of Agricultural Economics 78*(1): 54-64.

Cummings, R.G., Brookshire, D.S., Schulze, W.D., Bishop, R.C. and Arrow, K.J. (1986). *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method*. Totowa, NJ: Rowman & Allanheld.

Dasgupta, P. and Mäler, K.-G. (1995). Chapter 39 Poverty, institutions, and the environmental resource-base. In Jere, B. and Srinivasan, T.N. (Eds.), *Handbook of Development Economics*, Elsevier, pp. 2371-2463.

Diao, X. and Sarpong, D.B. (2007). *Cost implications of agricultural land degradation in Ghana: An economywide, multimarket model assessment*. Washington, DC: International Food Policy Research Institute (IFPRI).

Eswaran, H., Lal, R. and Reich, P.F. (2001). Land Degradation: an Overview. *Conference Proceedings of the 2nd International Conference on Land Degradation and Desertification*. Khon Kaen, Thailand: Oxford Press.

FAO. (2000). *Applications of the contingent valuation method in developing countries: A survey* (Vol. 146). Rome: United Nations Food and Agriculture Organization.

FAO. (2011). Assessing forest degradation. Towards the development of globally applicable guidelines. *Forest Resources Assessment Working Paper 177*. Rome.

Feng, D., Liang, L., Wu, W., Li, C., Wang, L., Li, L., *et al.* (2018). Factors influencing willingness to accept in the paddy land-to-dry land program based on contingent value method. *Journal of Cleaner Production 183*: 392-402.

GLSS5. (2008). *Ghana Living Standards Survey Report of the Fifth Round*. Accra: Ghana Statistical Service.

Gomiero, T. (2016). Soil Degradation, Land Scarcity and Food Security: Reviewing a Complex Challenge. *Sustainability 8*(3): 1-41.

Greene, W.H. (2003). *Econometric Analysis* (5th ed.). New Jersey: Prentice Hall.

Hamdy, A. and Aly, A. (2014). Land degradation, agriculture productivity and food security. *Fifth International Scientific Agricultural Symposium. Agrosym 2014. (October 2014)*.

Hanemann, W.M., Loomis, J. and Kanninen, B. (1991). Statistical Efficiency of Double-Bounded Dichotomous Choice Contingent Valuation. *American Journal of Agricultural Economics 73*(4): 1255-1263.

Heath, J. and Binswanger, H. (1996). Natural resource degradation effects of poverty and population growth are largely policy-induced: the case of Colombia. *Environment and Development Economics 1*(01): 65-84.

Helming, K., Rubio, J. and Boardman, J. (2006). Soil erosion across Europe: research approaches and perspectives. *Catena 68*(2-3).

Hemant, K. and Padmini, P. (2013). Effects of soil erosion on agricultural productivity in semi-arid regions: the case of Lower Chambal Valley. *Journal of Rural Development (Hyderabad) 32*(2): 165-180.

Holland, J.M. (2004). The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. *Agriculture, Ecosystems & Environment 103*(1): 1-25.

Jones, A., Breuning-Madsen, H., Brossard, M., Dampha, A., Deckers, J., Dewitte, O., *et al.* (2013). *Soil Atlas of Africa*. Luxembourg: Publications Office of the European Union.

Kenworthy, J.M. (1995). Environmental degradation and desertification in Ghana: a study of the Upper Western Region. *African Affairs 94*(374): 120-121.

Koop, G. (2003). *Bayesian Econometrics*. Chichester, West Sussex: John Wiley & Sons Ltd.

Krishna, V.V., Drucker, A.G., Pascual, U., Raghu, P.T. and King, E.D.I.O. (2013). Estimating compensation payments for on-farm conservation of agricultural biodiversity in developing countries. *Ecological Economics 87*: 110-123.

Lal, R. (1995). Erosion-Crop Productivity Relationships for Soils of Africa. *Soil Science Society of America Journal 59*(3): 661-667.

Li, C.-Z. and Mattsson, L. (1995). Discrete Choice under Preference Uncertainty: An Improved Structural Model for Contingent Valuation. *Journal of Environmental Economics and Management 28*(2): 256-269.

Ludi, E. (1997). *Household and communal strategies: small-scale farming families and their options for self-improvement: A case study in Anjeni, Ethiopia.* Addis Abeba and Bern: Soil Conservation Research Programme, Research Report 30.

Matta, J.R., Alavalapati, J.R.R. and Mercer, D.E. (2009). Incentives for Biodiversity Conservation Beyond the Best Management Practices: Are Forestland Owners Interested? *Land Economics 85*(1): 132-143.

Minten, B. (2003). Compensation and Cost of Conservation Payments for Biodiversity. *Cornell Food and Nutrition Policy Program Working Paper, 142*.

Mitchell, R.C. and Carson, R.T. (1989). *Using surveys to value public goods: The contingent valuation method*: Resources for the Future, Washington DC

Nabhan, H. (1997). Integrated soil management for sustainable agriculture and food security in southern and east Africa (pp. 8-12). Harare, Zimbabwe: Proceedings of FAO/ ISCW Expert Consultation on Management of Degraded Soils in Southern and East Africa (MADS – SEA).

Nijnik, M. and Miller, D. (2017). Valuation of ecosystem services: paradox or Pandora's box for decision-makers? *One Ecosystem 2:e14808*: 1-33.

Ninan, K.N., Jyothis, S., Babu, P. and Ramakrishnappa, V. (2007). *The Economics of Biodiversity Conservation: Valuation in Tropical Forest Ecosystems*. London: Earthscan.

Obalum, S.E., Buri, M.M., Nwite, J.C., Hermansah, Watanabe, Y., Igwe, C.A., *et al.* (2012). Soil Degradation-Induced Decline in Productivity of Sub-Saharan African Soils: The Prospects of Looking Downwards the Lowlands with the Sawah Ecotechnology. *Applied and Environmental Soil Science 2012*: 10.

Pearce, D. (2002). *The Role of 'Property Rights' in Determining Economic Values for Environmental Costs and Benefits*. Bristol: The Environment Agency.

Philcox, N. (2007). Literature review and framework analysis of non-market goods and services provided by British Columbia's Ocean and Marine Coastal Resources: Canada/British Columbia Oceans Coordinating Committee.

Poe, G.L. (2016). Behavioral Anomalies in Contingent Values and Actual Choices. *Agricultural and Resource Economics Review 45*(2): 246-269.

PRESA/ICRAF (2010). Assessing landholder preferences for alternative land management schemes and willingness to accept rewards for watershed services provision: the case of Kapingazi River basin, Mt. Kenya East. Nairobi: Pro-poor Reward for Environmental Services in Africa (PRESA/ICRAF).

Ready, R.C., Champ, P.A. and Lawton, J.L. (2010). Using Respondent Uncertainty to Mitigate Hypothetical Bias in a Stated Choice Experiment. *Land Economics 86*(2): 363-381.

Ready, R.C., Whitehead, J.C. and Blomquist, G.C. (1995). Contingent Valuation When Respondents Are Ambivalent. *Journal of Environmental Economics and Management 29*(2): 181-196.

Sangkapitux, C., Neef, A., Polkongkaew, W., Pramoon, N., Nonkiti, S. and Nanthasen, K. (2009). Willingness of upstream and downstream resource managers to engage in compensation schemes for environmental services. *International Journal of the Commons 3*(1): 41-63.

Sant, R.A. (2001). Soil degradation and crop production in arid regions of Africa, *The 4th Session of the Inter-African Experts Committee on African Soils Conference* (pp. 6–8.). Accra, Ghana.

Schwartz, G.J. (2017). The role of women in payment for environmental services programs in Osa, Costa Rica. *Gender, Place & Culture 24*(6): 890-910.

Senayah, J.K., Adjei-Gyapong, T. and Asiamah, R.D. (1998). *Soils of the Busa agricultural station of the Upper West Region*. Kumasi, Ghana: Soil Research Institute (SRI) of The Council for Scientific and Industrial Research (CSIR).

Shetty, S.V.R., Debrah, S.K. and Renard, C. (1995). Technology development, testing and transfer: An overview of ICRISAT's experience in semi-arid Africa, *Proceedings of Workshop on Moist Savannas of Africa: Potentials and constraints for crop production*. Cotonou, Benin.

Shiferaw, B., Freeman, H.A. and Navrud, S. (2005). Valuation Methods and Approaches for Assessing Natural Assessment: Management Impacts. In Shiferaw, B., Freeman, H.A. and Swinton, S.M. (Eds.), *Natural Resource Management in Agriculture: Methods for Assessing Economic and Environmental Impacts*. Wallingford: CABI Publishing, pp. 19-51.

Shiferaw, B. and Holden, S.T. (2001). Farm-level benefits to investments for mitigating land degradation: empirical evidence from Ethiopia. *Environment and Development Economics 6*: 335-358.

Stephen, C. (2015). *Willingness to accept payment for conservation of ecosystem services in Mount Kilimanjaro, Tanzania and Taita Hills, Kenya*. Unpublished MSc. dissertation, Department of Agricultural Economics and Agribusiness, Sokoine University of Agriculture, Morogoro, Tanzania.

Stocking, M. and Abel, N. (1989). Labour Costs: A Critical Element in Soil Conservation. *6th International Soil Conservation Conference*. Addis Ababa, Ethiopia.

Sukic, A.D.M. (2001). *Landowners' willingness to accept compensation for selling saltwater marshes to a conservation program: a multiple bounded discrete choice approach*: McGill University.

Thurston, H.W. (2006). Non-market valuation on the internet. In Alberini, A. and Kahn, J. (Eds.), *Handbook on Contingent Valuation*. Edward Elgar: Edward Elgar, pp. 265-291.

UNCCD. (2013). *The Economics of Desertification, Land Degradation and Drought: Methodologies and Analysis for Decision-Making*. Bonn: United Nations Convention to Combat Desertification.

Verbeek, M. (2004). *A Guide to Modern Econometrics*. Chichester: John Wiley & Sons, Ltd.

Vlek, P.L.G., Le, B.Q. and Tamene, L. (2008). *Land decline in Land-Rich Africa: A creeping disaster in the making*. Rome: CGIAR Science Council Secretariat.

Wang, J., Moucheng, L., Yang, L. and Min, Q. (2018). Factors Affecting the Willingness of Farmers to Accept Eco-Compensation in the Qianxi Chestnut Agroforestry System, Hebei. *Journal of Resources and Ecology 9*(4): 407-415.

Wang, X., Adamowski, J.F., Wang, G., Cao, J., Zhu, G., Zhou, J., *et al.* (2019). Farmers' Willingness to Accept Compensation to Maintain the Benefits of Urban Forests. *Forests 10*(8): 691.

Webb, J., Loveland, P.J., Chambers, B.J., Mitchell, R. and Garwood, T. (2001). The impact of modern farming practices on soil fertility and quality in England and Wales. *The Journal of Agricultural Science 137*(02): 127-138.

World Bank (1992). *Ghana 2000 and beyond: setting the stage for accelerated growth and poverty reduction*: Report No. 11486-GH, Western Africa Department, The World Bank, Washington, D.C.

World Bank (2006). *Ghana Country Environmental Analysis*: Report No: 36985-GH, Environmentally and Socially Sustainable Development Department (AFTSD), African Region, World Bank.

Wunder, S. (2008). Necessary conditions for ecosystem service payments, *Paper presented at the Economics and Conservation in the Tropics: A Strategic Dialogue*. San Francisco: Conservation Strategy Fund/ Moore Foundation /Resources for the Future.

Wyatt, T.J. (2002). Liquidity and Soil Management: Evidence from Madagascar and Niger. In Barrett, C.B., Place, F. and Aboud, A.A. (Eds.), *Natural Resources Management in African Agriculture: Understanding and Improving Current Practices*. Oxon and New York: CABI Publishing, pp. 129-142.

Xiong, K. and Kong, F. (2017). The Analysis of Farmers' Willingness to Accept and Its Influencing Factors for Ecological Compensation of Poyang Lake Wetland. *Procedia Engineering 174*: 835-842.

Xu, L., Yu, B. and Li, Y. (2015). Ecological compensation based on willingness to accept for conservation of drinking water sources. *Frontiers of Environmental Science & Engineering 9*(1): 58-65.

Yu, L.l. and Cai, Y.Y. (2015). Ecological compensation based on farmers' willingness: A case study of Jingsan County in Hubei Province, China. *The Journal of Applied Ecology 26*(1): 215-223.

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