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Are there Trade-offs in Valuation with Respect to Greenhouse Gas Emissions, Origin and Food Miles Attributes?[1]

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Abstract

This study measures consumers' willingness to pay for the attributes Greenhouse Gas (GHG) emissions during production, food miles, and origin (local/non-local) of rice products and assesses the interaction effects (complementarities and substitutions) between these food attributes, using a non-hypothetical experimental auction. Results typically show that consumers are willing to pay a price premium for rice that has lower GHG emissions and/or lower food miles and/or is local. Most importantly, consumers were found to trade off these three food attributes. The results also show that consumers do not perceive the attributes food miles and origin as perfect substitutes.

Keywords: willingness to pay, GHG emissions; food miles; local; trade-offs.

JEL Classifications: D12, Q13.

1. Introduction

There is a consensus among most climate scientists that greenhouse gases (GHG) generated by human activities are the main drivers of climate change today. Agriculture alone releases between 10% and 12% of the global quantity of GHG emissions; this share is expected to increase in the future due to the escalating demand for foods (Smith *et al.*, 2007). Consequently, many climate

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change experts recommend the implementation of improved management practices in agriculture, particularly the increase of the production of foods with lower GHG emissions. Furthermore, row crop producers are aware of the benefits and potential mandates to reduce emissions in crop production because of increased consumer demand for environmentally-friendly agricultural products, as well as pressure from the government, food processors and retailers.

Rice production has been identified as a significant source of atmospheric methane emissions because it is a labour, water, and energy-intensive crop (McFadden *et al.*, 2013). Rice is also an important commodity since it is one of the most-produced and most-consumed agricultural products in the world. According to the Food and Agriculture Organization of the United Nations (FAO), rice is the main staple food for over half of the world's population. In developing countries, rice provides 27% and 20% of dietary energy and protein intake, respectively (FAO, 2004). Interestingly, countries listed among the top producers and exporters of rice like China, India, USA, and Japan are also among the top GHG emitters in the world (WRI, 2010). This observation is noteworthy given that a reduction in GHG emissions in rice production[2] (e.g. through the adoption of rice varieties with lower GHG emissions such as hybrid rice[3] varieties) could significantly decrease the global emissions of GHG from agriculture.

Furthermore, a disparity can occur in GHG emissions per acre and per bushel for different rice varieties (Hybrid and conventional rice) since those rice varieties have distinct input requirements and outputs. Given the recent introduction and adoption of hybrid rice, producers may expedite the use of embedded seed technology as its yield premiums create input use efficiencies, which lead to greater environmental benefits by reducing GHG emissions. To demonstrate, hybrid

[2] In this paper, we only considered the GHG emitted during the life cycle of the rice (up to the farm gate). Therefore, the emissions from the transport and processing (packaging etc.) of the rice are excluded.

[3] Hybrid rice is any genealogy of rice produced by crossbreeding different varieties of rice. As with other types of hybrids, hybrid rice typically displays heterosis (hybrid vigor); in that, when it is grown under the same conditions as comparable high-yielding inbred rice varieties, it can produce up to 20% more rice. High-yield crops, like hybrid rice, are one of the most important tools for combatting world food crises (FAO, 2004).

rice can yield 15-20% more than a conventional variety under the same growing conditions with roughly the same input requirements (McFadden *et al*., 2013)[4].

Nonetheless, consumers may not be able to differentiate between rice varieties solely based on appearance. Hence, producers may not have the financial incentive to adopt varieties with embedded environmental benefits. However, if consumers have a preference and are willing to pay a price premium for rice varieties labelled as having lower GHG emissions, then rice producers could possibly profit from adopting varieties that possess environmental benefits. For this reason, the first objective of this study is to measure and assess, among others, consumer's willingness to bear, whether partially or totally, the additional costs that are required to decrease GHG emissions from rice production.

In retail stores, rice varieties labelled as having lower GHG emissions (i.e. hybrid rice) could be displayed and sold along with conventional rice varieties that are certified as local food and/or have lower food miles[5]. In this case, the price premium consumers might be willing to pay for rice varieties with lower GHG emissions may be adversely affected by the fact that rice varieties that have higher GHG emissions (i.e. conventional rice) are locally produced and/or more sustainable in terms of carbon emissions released during transport. Thus, it is possible that consumers might be indifferent in choosing between a rice variety that has lower GHG emissions from production, but contributes to more carbon dioxide emissions during transport to retail stores, i.e. higher food miles; and a rice variety that has higher GHG emissions from production, but contributes less to carbon dioxide emissions during transportation, i.e. lower food miles.

Despite its importance, this issue has not been directly examined in the literature. Therefore, the second main objective of this paper is to assess the trade-offs that consumers make when they are presented with different levels of the three rice attributes (GHG emissions, origin, and food miles). Of particular interest is the case where consumers are asked to choose between a rice variety

[4] It is important to mention that not all hybrid rice varieties emitted lower GHG emissions as compared to the conventional inbred rice varieties.

[5] Food miles indicate how far food products have travelled from farm to store. A food product labelled as having lower food miles implies that it was transported for a shorter distance resulting in lower emissions of carbon dioxide during its transport.

that has lower GHG emissions from production but is not local and has higher food miles and another rice variety that is labelled as local with lower food miles but emits significantly higher GHG emissions during its life cycle.

The remaining of this article is organized as follows. It proceeds with a review of the relevant literature that motivates our study and the contributions of the paper to this literature. This section is followed by a description of the underlying methodology employed to collect (sample, product and experimental auction) and analyze (statistical tests and econometric models) the data. The results of the study are then presented in a subsequent section. The last section of the article provides a summary of the results and discusses implications with regard to the findings. Limitations and directions of future research are also described.

2. Background: literature and contributions

There is a wealth of literature on consumer WTP for the attributes GHG emissions (e.g. Wiser, 2007; Bollino, 2009; Onozaka and McFadden, 2011), origin (e.g. Brown, 2003; Tropp, 2008; Darby *et al*., 2008; Toler *et al*., 2009; Akaichi *et al*., 2012; Kallas and Gil, 2012; Moser *et al*., 2014), and food miles (e.g. Kemp *et al*., 2010; Caputo *et al*., 2013; Grebitus *et al*., 2013). Nonetheless, very little research has been conducted on the trade-offs that consumers make when they are provided with information on these three attributes at the same time.

One exception to this shortage in literature is the work of Onozaka and McFadden (2011), who conducted a hypothetical choice experiment to assess the differential and interactive effects of information on GHG emissions from production and location claims. Ultimately, they found that consumers were willing to pay a price premium for reducing their carbon footprint. They also discovered that consumers gave the highest price premium to locally-grown food products. Surprisingly, however, they found that consumers discounted more severely the carbon-intensive local products than those brought from other locations. While their findings informed our research, our experiment varies with Onozaka and McFadden's study in four key ways.

First, in contrast to Onozaka and McFadden (2011), we used a non-hypothetical experimental auction to rule out the effect of hypothetical bias that significantly influences the validity of WTP in hypothetical settings. To demonstrate, a meta-analysis of 29 experimental studies conducted by List and Gallet (2001) revealed that subjects on average overstate their preferences by a factor of 3 in hypothetical settings. Little and Berrens (2004) reconfirmed these results using an expanded sample of studies. Although we recognize the merit of the work carried out by Onozaka and McFadden (2011), the hypothetical nature of their choice experiment poses some unanswered questions regarding the validity of their results and the implications that follow suit.

Second, Onozaka and McFadden (2011) used a choice experiment that does not directly measure participants' WTP since it is computed based on the estimated partworths. In fact, in choice experiments, the WTP is inferred from a statistical model by dividing the estimated partworth associated with the attribute's level by the estimated partworth of the price attribute (with a negative sign) or by estimating the choice model in WTP space. The estimated WTP is also conditional on the price levels considered in the design of the choice sets; thus, a significant change in the levels of the attribute price could make the validity of the estimated WTP questionable. Additionally, the estimated WTP in choice experiments is sensitive to the choice model and its corresponding modeling assumptions. To rule out these problems, we used a non-hypothetical experimental auction that provides a direct measure of participants' WTP by asking them to report what they are actually willing to pay for the auctioned product (Lusk and Shogren, 2007).

Third, previous empirical studies that assessed consumer preferences and WTP for local food products (e.g., Zepeda and Leviten-Reid, 2004; Adams and Salois, 2010; Grebitus *et al*., 2013) found that consumers bought local foods because of their environmental sustainability through shorter distances in transportation, i.e. lower food miles. In difference with Onozaka and McFadden (2011), this paper assesses whether consumers perceive low food miles as: (1) a characteristic of local foods, (2) a perfect substitute for the attribute, "local", i.e., both attributes are used to describe exactly the same thing, or (3) different from the attribute "local". In the first two cases, it is expected that labelling local rice as having low food miles will not increase consumers' WTP because it does not add any new information to consumers. In the third case, it is expected that labelling local rice as having lower food miles will, however, increase consumers' WTP. This increase is possible, especially, if consumers are unaware of the link between the attributes "food miles" and "origin"[6]; or they may think a food produced locally could have been transported to a non-local plant to be processed and then brought back to be sold in the local market, which can cause a significant increase in the amount of food miles.

Assessing how consumers perceive the relation between the attributes "origin" and "food miles" is important for two reasons. First, if labelling local rice as having lower food miles does not significantly increase consumers' WTP[7], then using both labels on the same product should be avoided. If both labels are used, it is likely to increase the cost of labelling without improving the demand for the product. Nonetheless, if consumers' WTP increases when both labels are used, it may be recommended to label the locally-produced rice as local with lower food miles without the fear of a counterproductive effect (i.e. overlapping effect) when both labels are used simultaneously. Secondly, if consumers are found to perceive the attributes "origin" and "food miles" as substitutes, i.e. cases (1) and (2), then it would be inappropriate, in research studies, to consider these two attributes as different when assessing consumers' preferences and WTP for food product attributes (e.g. using choice experiments etc.).

Fourth, in contrast to Onozaka and McFadden's (2011) work, our experimental design allowed us to measure participants' WTP before and after receiving information on GHG emissions, food miles and origin. Therefore, the effect of providing additional information to consumers in our study can be assessed using between- and within-subjects analyses.

To the best of our knowledge, this work is a first attempt to use non-hypothetical experimental auctions to: (1) assess whether consumers are willing to pay a price premium for rice varieties with lower GHG emissions and, hence, a positive economic signal can be passed on to rice

[6] In particular, food products with low (high) food miles are seen by consumers as local (non-local).
[7]In contrast, consumers may see them as overlapping attributes and this may decrease their WTP.

producers who can economically benefit and significantly participate in the reduction of GHG emissions by producing more sustainable rice varieties; (2) assess whether US consumers' WTPs for food products with different level of GHG emissions are negatively or positively affected by the presence of other sustainable claims (i.e. higher vs. lower food miles) and location claims (i.e. local vs. non-local), and (3) assess whether consumers perceive local (non-local) and low (high) food miles as similar or different food attributes.

3. Methods

3.1. Products used in the experimental auction

In our experiment, two long grain rice varieties were considered that are popular in the Mid-South of the U.S.: the conventionally inbred, Wells, and the hybrid, XL723. Wells is the most popularly grown conventional rice variety in Arkansas, and was released by the Division of Agriculture at the University of Arkansas. Conversely, XL723 is a high-yielding popular hybrid variety in Arkansas released by the private company "Ricetec". Each rice variety was produced and milled prior to the experiment in two different locations: Stuttgart (Arkansas) and New Madrid (Missouri). They were then brought in from the corresponding locations two weeks before the experiment and were appropriately stored in the university's rice lab to avoid any change in appearance or organoleptic properties. Moreover, the food miles for the rice varieties from Stuttgart, AR and New Madrid, MO to the experimental location in Fayetteville, Arkansas[8] are 250 miles and 422 miles, respectively. Hence, in this experiment, the rice from Stuttgart (AR) is expressed as local rice and the rice from New Madrid (MO) is expressed as non-local rice.

There are several definitions of local food in the US. For this study, we used the definition that defines local food as food that is grown and distributed within the state for the following reasons. First, Congress in the 2008 Food, Conservation, and Energy Act defined local foods as follows: *"The term locally or regionally produced agricultural food product means any*

[8] We think our location choice (Arkansas) is the most appropriate place since Arkansas is the largest producer of rice in the U.S. (40% of the U.S.'s rice production). Furthermore, our results show that all participants are consumers of rice and 74% of them reported to be habitual buyers of non-fragrant rice (e.g. the rice used in this study).

agricultural food product that is raised, produced, and distributed in: (1) the locality or region in which the final product is marketed so that the total distance that the product is transported is less than 400 miles from the origin of the product; or (2) the State in which the product is produced." Therefore, according to the second definition, the rice grown and distributed in Arkansas is considered local. Second, several consumer studies (Eastwood *et al*., 1987; Loureiro and Hine, 2002; Giraud *et al*., 2005; Schneider and Francis, 2006; Darby *et al*., 2008; Carpio and Isengildina-Massa, 2009) showed that the state of origin may be a natural geographic definition of "local" for consumers, and that most consumers are willing to pay a premium for state-grown foods.

The estimated amount of GHG emissions, which was presented to participants in the form of CO_2 equivalent (CO_2e), as estimated in McFadden *et al* (2013), were 9.97oz (CO_2e) per pound for Wells and 8.21oz per pound for XL723. The differences between the CO_2 equivalents per pound are attributable to two distinct factors: (1) the hybrid variety yields more rice; and (2) the hybrid variety requires less inputs and thus less trips across the field, which in turn reduces CO_2 emissions per acre and per pound of rice produced. Subsequently, four one-pound rice samples labelled as "rice A", "rice B", "rice C", and "rice D" were auctioned: (1) rice A was the Wells variety from Stuttgart, AR with 9.97oz of CO_2e and 250 in food miles; (2) rice B was the hybrid variety, XL723, from Stuttgart, AR with 8.21oz of CO_2e and with 250 food miles; (3) rice C was the Wells variety from New Madrid, MO with 9.97oz of CO_{2e} and 422 food miles; and (4) rice D was the hybrid variety, XL723 from New Madrid, MO with 8.21oz of CO_2e and 422 food miles (see Table 1).

Table 1. Attributes of the rice samples

Rice sample	Rice variety	Attributes		
		GHG emissions	Food miles	Origin
Rice A	Wells	9.97oz of CO_{2e}	250 miles	Stuttgart, Arkansas
Rice B	XL723	8.21oz of CO_2e	250 miles	Stuttgart, Arkansas
Rice C	Wells	9.97oz of CO_2e	422 miles	New Madrid, Missouri
Rice D	XL723	8.21oz of CO_2e	422 miles	New Madrid, Missouri

3.2. Sample of consumers

A total of 350 consumers were recruited from a panel of 3,000 consumers maintained by the University of Arkansas from their experimental lab for sensory studies. The panel was set up to be a representative sample of the population of U.S. food shoppers. Due to our interest in estimating consumers' WTP for a private good, the population of interest is the population of people, not the general population, who actually purchases the product. Otherwise, the sample is likely to include consumers who consume what other people buy for them, and would therefore produce biased results. Table 2 summarizes the socio-demographic characteristics of the 350 participants in the experiment.

Table 2. Participants' socio-demographic characteristics

Variable	Categories	Values in %
Gender	Female	78
	Male	22
Age	18-29	28
	30-64	71
	65 and older	1
Education	Primary studies	1
	Secondary studies	42
	University studies	57
Annual Household income ($)	Less than 10.000	6
	10.000 - 24.999	20
	25.000 – 44.999	28
	45.000 - 74.999	23
	75.000 – 149.999	19
	More than 150.000	3

3.3. Becker, DeGroot and Marschak (BDM) Mechanism

To assess the effect of information on GHG emissions, food miles, origin, and their effects on US consumers' WTP, a non-hypothetical experimental auction was designed and conducted. An experimental auction was chosen given that it is now an established method in product valuation research. A large part of its popularity is due to its ability to simulate a real market situation where a consumer can make the decision to buy and actually pay for the product; thus offering to participants real products and allowing for exchange of real money. Hence, experimental auctions tend to provide more accurate WTP values than hypothetical value-elicitation methods (Lusk and Shogren, 2007).

The experimental auction mechanism used in this study is the Becker, DeGroot and Marschak (BDM) method (Becker *et al*., 1964; List, 2004; Kanter *et al*., 2009; Bougherra and Combris, 2009; Norwood and Lusk, 2011; Bazoche *et al*., 2013). In the BDM mechanism, participants are asked to report their WTP for a unit of a specific product. Then, the experimenter randomly chooses one of the participants to randomly draw a single price from a price distribution. All participants with a higher bid than the randomly-drawn price are declared winners. Each winner obtains one unit of the auctioned product and pays a price equal to the randomly-drawn price. BDM is a demand-revealing mechanism, which implies that participant's best bidding strategy is to bid exactly at his/her true WTP. In fact, if a participant bids more than the auctioned product is worth to him/her, he/she may end up buying the product for more than he/she really wants to pay. Conversely, if participant bids less than the product is really worth to him/her, he/she may end up not winning the auction even though he/she could have bought the product at a price he/she was actually willing to pay (Krishna, 2010).

Compared with other incentive-compatible auctions, e.g. second price auction and random nth price auction, BDM has the advantage of not requiring an equal number of participants across sessions. In BDM, any participant who reports a bid higher than the price, randomly drawn from a distribution of prices gets a unit of the auctioned product and pays a price equal to the randomly drawn price. Therefore, participants are not competing for the auctioned products; hence, the experimenter is not required to maintain the same number of participants across sessions. In practice, the number of participants who do not show up on the day of the experiment is unpredictable, which reduces the likelihood of running experimental sessions with the same number of participants, i.e., in nth price auctions. For this reason, the incentive compatibility of the BDM mechanism and its flexibility in terms of participants' number, led us to opt for the use of this auction mechanism.

Notably, the BDM like other auction mechanisms has its limitations. It has been criticized for two main reasons: first, the exogeneity of the price distribution based on the market prices is unrelated to the valuations of participants; and second, it has been shown that the type of distribution from which the market price is obtained influences the bidding behavior of participants (Mazar *et al*., 2009; Lusk *et al*., 2004). To get around this problem, a large distribution of prices was specified to include the range of retail prices for rice from \$0.50 to \$4.00, with a small increment of 10 cents, i.e. 36 different prices.

3.4. Implementation of the experimental auction

Recruited subjects were randomly assigned to seven treatments[9]. Sessions were conducted in groups of 10 subjects with each treatment consisting of five sessions. Each participant was allowed to participate in only one session of approximately one hour and was paid a \$25 participation fee. In each treatment, subjects participated in an experimental auction (BDM) consisting of five bidding rounds. Participants in all treatments (except in treatment one) received the same information in rounds one and five, but received different information, in varying order, in the second, third and fourth rounds (see Table 3). Specifically, in round one, participants in each of the seven treatments were invited to visually inspect the four rice samples and then report their WTP for a one pound bag of each rice sample. In rounds two, three, and four, participants in the different treatments (except treatment one) received three different information sets: (1) GHG emissions per one pound bag, (2) food miles and (3) origin of production in varying order (see Table 3). In the fifth round of each treatment, participants tasted each sample before reporting their WTP for each one of them. Participants in treatment one (the control treatment), did not receive any type of information in each

[9] The first treatment is the control treatment. Participant assigned to this treatment did not receive information about the rice's attributes. In the other six treatment participants received information on rice's attributes (GHG emissions, Locality and food miles) in varying order.

of the five rounds and were asked to report their WTP based on the appearance of each of the four rice products.

The experimental auction was performed in five steps. In step one, each participant received a unique identification number and was told that he/she would receive a $25 participation fee at the end of the experiment. One of the main determinants of success in experimental auctions is a thorough understanding by participants of the incentive compatibility of the auction mechanism. To achieve this goal, in step two, participants were given a detailed oral explanation about the operating procedures in a BDM auction. During the explanation, participants were free to ask questions to dissipate any doubts about the process. The next step began only after being sure that all participants fully understood how the auction mechanism worked and why it was in their best interest to reveal their true WTP. Before conducting the actual auction, a training session was carried out, auctioning four brands of a candy bar to mimic the rice auctions.

In step three, participants were invited to physically examine the four samples of rice. Once all participants finished inspecting the product, each participant was asked to indicate how much he or she would be willing-to-pay for each of the four rice samples based on looks alone. To minimize wealth effects, participants were told that at the end of the auction, one of the four rice samples would be randomly chosen as the "binding product" that would be sold in the experiment. In step four, three additional rounds were performed. As previously mentioned, depending on the treatment, participants received a different information set in each round (GHG emissions, food miles, or location of origin of the rice sample)[10] before they were asked to report their WTP for each rice sample. Because treatment one was the control treatment, participants in this treatment did not receive any information in any of these rounds.

[10] The information was written on a placard that was then placed close to the corresponding rice sample (see Appendix 1).

Table 3. Experimental treatments

Rounds	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6	Treatment 7
1	No information	No information	No information	No information	No information	No information	No information
2	No information	GHG Emissions[(1)]	GHG Emissions	Food Miles[(2)]	Food Miles	Origin[(3)]	Origin
3	No information	Food Miles	Origin	GHG Emissions	Origin	GHG Emissions	Food Miles
4	No information	Origin	Food Miles	Origin	GHG Emissions	Food Miles	GHG Emissions
5	No information	Taste	Taste	Taste	Taste	Taste	Taste
Number of participants	50	50	50	50	50	50	50

(1) GHG emissions: two levels of GHG emissions were used 9.97oz per pound for the conventional rice and 8.21oz per pound the hybrid rice.
(2) Origin: Each rice variety was produced and milled in two different locations: Stuttgart (Arkansas) and New Madrid (Missouri).
(3) Food miles: the corresponding food miles are 250 miles for the rice from Stuttgart and 422 miles for the rice from New Madrid to the experimental location in Fayetteville.

In step five, participants in all treatments were asked to taste the different rice samples to determine if taste could affect consumers' WTP after receiving information on the three attributes of interest: GHG emissions, food miles, and the origin of the rice varieties[11]. All the rice products were uniformly cooked in the same type of rice cooker at the same time. Both rice varieties were non-fragrant American long grains with comparable amounts of chalk and broken. Once the participants finished tasting each of the samples, they were told to report their WTP for a one pound bag of each of the four samples.

At the conclusion of the auction (round 5), one of the participants was randomly chosen to randomly draw the binding rice sample and the binding round. The same participant was again asked to randomly draw a single price from a price distribution that ranged from \$0.50 to \$4.00[12], with an increment of 10 cents. The winner(s) were the participants whose bids were greater than the randomly drawn price. Only the winner(s) in the binding round bought the binding product at the randomly drawn price. At the end of each auction session, participants were asked to complete a questionnaire on their attitudes toward environmentally-friendly foods, as well as socio-demographic and economic information. Each participant received \$25 for his/her participation, and the experiment ended by handing the products to the winner(s) who had to pay the corresponding auction price.

3.5. Data analysis

To answer the research questions of this paper, the following analyses were carried out. First, the effect of providing the different types of information on consumer' price premiums were assessed for hybrid rice using within- and between-subjects analyses. Next, consumer perceptions of food miles and origin of rice as similar or different food attributes were analyzed. Finally, random-effects generalized least-square regression models were estimated to analyze whether participants' price premiums were affected by their attitudes and socio-demographic traits.

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[11] The results corresponding to the effect of taste on consumers' WTP are neither reported nor discussed in this paper.
[12] The price distribution was not revealed to participants.

3.5.1. Information effect on consumers' price premiums

In the experimental auction, participants were asked to report their WTP for the four rice samples before and after receiving information. As a result, it is likely that after receiving the information, participants made a comparison between the rice samples and may have made a decision that affected several rice samples at the same time. For example, after receiving information on GHG emissions, a participant could have increased his/her WTP for the hybrid rice samples and decreased it for the conventional rice samples. Therefore, the whole effect is better measured by the difference between the WTP for the hybrid rice and the WTP for the conventional rice, which represents the price premium participants are willing to pay for the hybrid rice.

Since participants were asked to report their WTP for two different hybrid rice samples and two different conventional rice samples; subsequently, four different price premiums were computed: WTP_{LH}-WTP_{NC}, WTP_{LH}-WTP_{LC}, WTP_{NH}-WTP_{NC}, and WTP_{NH}-WTP_{LC}[13]. "WTP_{LH}-WTP_{NC}" is the difference between the local hybrid rice that has lower food miles (LH), and the conventional rice that is non-local and has higher food miles (NC). "WTP_{LH}-WTP_{LC}" is the difference between the hybrid and the conventional rice samples that are both local and have the same lower number of food miles. "WTP_{NH}-WTP_{NC}" is the difference between the hybrid and the conventional rice samples that are not local and have the same higher amount of food miles. Finally, "WTP_{NH}-WTP_{LC}" is the difference between the hybrid rice that is not local and has higher food miles, and the conventional rice sample that is local and has lower food miles.

For the assessment of effect of the information provided during the experiment on consumers' price premiums, the variation of participants' price premiums was analyzed for hybrid rice when provided with only one type of information (GHG emissions, food miles, or origin). Then, the effect of providing two types of information on consumers' price premiums was analyzed (GHG emissions and food miles, GHG emissions and origin, food miles and origin). Finally, the variation

[13] The abbreviations LH, LC, NH and NC stand local hybrid rice, local conventional rice, non-local hybrid rice and non-local conventional rice, respectively.

of consumers' price premiums for the hybrid rice when they were provided with the three types of information (GHG emissions, food miles, and origin) was analyzed.

For the effect of each type of information, a within-subjects analysis was carried out to compare consumers' price premiums before (round 1) and after (round 2) the provision of the corresponding information. To test the effect of information on GHG emissions, food miles and origin on consumers' price premiums, the data obtained in treatments 2 and 3, 4 and 5, and 6 and 7 were used, respectively.

To determine which of the three types of information has the highest effect on participants' price premiums, a between-subjects analysis was conducted. The difference between participants' price premium in round 2 and round 1 was calculated to obtain the net effect of the provided information. Then, we calculated the net effect of the provided information obtained in treatments 2 and 3 to that obtained in treatments 4 and 5 to assess the comparability of the effect of the information on GHG emissions and the information on food miles. To compare the effect of the information on GHG emissions (food miles) and the information on origin, the net effect of the provided information obtained in treatments 2 and 3 (4 and 5) was compared to that obtained in treatments 6 and 7.

Additionally, for the effect of the combination of two different types of information on consumers' price premiums for hybrid rice, within- and between-subjects analyses were conducted. The within-subjects analysis was conducted to compare consumers' price premiums before (round 1) and after the provision of the two types of information (round 3). To test the effect of GHG emissions and food miles, GHG emissions and origin, and food miles and origin on consumers' price premiums, the data obtained in treatments 2 and 4, treatments 3 and 6, and treatments 5 and 7 were used, respectively.

Subsequently, a between-subjects analysis was used to determine which of the combinations of the two types of information had the highest effect on participants' price premiums. First, the difference between participants' price premium in round 3 and round 1 was calculated to obtain the net effects of the provided information (i.e. GHG emissions and food miles in treatments 2 and 4, GHG emissions and origin in treatments 3 and 6, and food miles and origin in treatments 5 and 7). The computed net effects were then compared.

Finally, to analyze the effect of providing the three types of information a within-subjects analysis was conducted. Specifically, consumers' price premiums before (round 1) and after the provision of the three types of information (round 4) were compared using the data obtained in treatments 2 to 7.

To test the statistical significance of the price premiums in the within-subjects analysis (between-subjects analysis), the two-tailed t-test for paired (independent) samples was used. Furthermore, to check the robustness of the two-tailed t-test to the possible non-normality of the price premiums' distributions, the non-parametric version of two-tailed t-test, referred to as the Fisher-Pitman permutation test for paired (independent) samples was used (Fisher, 1935; Pitman 1937; Siegel and Castellan, 1988; Kaiser, 2007). The p-values obtained from the Fisher-Pitman permutation test are reported in parenthesis to differentiate them from the p-values obtained from the two-tailed t-test.

3.5.2. Substitutability of the attributes food miles and origin

To test whether participants in the experiment perceived origin and food miles as independent or related attributes, i.e. perfect substitutes or having something in common, the effect of providing information on food miles (or origin) and the effect of providing information on both food miles and origin of the rice on participants' price premiums for the hybrid rice was compared. The comparison between these two effects was carried out using within- and between-subjects analyses. To control for the order of the provision of information, the within- and between-subjects analyses were carried out for the cases where: (1) the information on food miles was provided before the information on origin; and (2) the information on origin was provided before the information on food miles for each rice sample.

The within-subjects analysis for the first (second) case was carried out as follows. First, the effect of information on consumers' price premiums was computed as the difference between consumers' price premiums in round 3 and 2 in treatment 2 (3), and between consumers' price premiums in round 2 and 1 in treatment 5 (7). Then, the total effect (after providing information on food miles and origin) is determined by computing the difference between consumers' price premiums in round 4 and 2 in treatment 2 (3), and between consumers' price premiums in round 3 and 1 in treatment 5 (7). Finally, the effect of information on food miles (origin) and the effect of information on both food miles and origin were compared. To carry out the within-subjects analysis, the two-tailed t-test for paired samples and the Fisher-Pitman permutation test for paired samples were used.

For the between-subjects analysis, the effects of providing participants with information on food miles, origin, and food miles and origin were computed. Next, the effect of the information on food miles (or origin) and the effect of the information on food miles and origin were compared. The effect on participants' price premiums of the information on food miles (origin) was calculated as the difference between their price premiums in round 2 and 1 in treatments 4 and 5 (6 and 7). The effect of providing both types of information was computed as the difference between participants' price premiums in round 3 and 1 in treatments 5 and 7. To carry out the between-subjects analysis, the two-tailed t-test for independent samples and the Fisher-Pitman permutation test for independent samples were used.

3.5.3. Determinants of consumers' price premiums

In addition to assessing the effect of information on participants' price premium for hybrid rice, the information collected in the questionnaire was used to analyze whether participants' price premium is affected by their attitudes and socio-demographic traits. To identify the appropriate econometric model, we tested for normality, heteroskedasticity and autocorrelation. The results are reported in Appendices 2 to 5. The results of the tests show that the errors are not normally distributed and the error variances are not constant, i.e. presence of heteroskedasticity. The results also show that autocorrelation is not a significant issue in the data. Since the dataset is a balanced panel, a Hausman test was performed, showing that a random-effect framework is more appropriate to use than a fixed-effect framework. As a result, four random-effects generalized least-square regression models, i.e. one model for each of the four price premiums, were estimated with correction for heteroskedasticity[14].

The dataset used in the estimation is a balanced panel where the time dimension is represented by the auction rounds 1 and 4. The dependent variables are the price premiums, WTP_{LH}-WTP_{NC}, WTP_{LH}-WTP_{LC}, WTP_{NH}-WTP_{NC}, and WTP_{NH}-WTP_{LC}, which were computed based on participants' WTP obtained in the first and fourth rounds of the auction. Heuristically, the price premium a consumer is willing to pay is the amount of money that makes her/him indifferent between buying hybrid rice with improved quality, e.g. lower GHG emissions, and keeping the conventional rice with the status quo quality, e.g. higher GHG emissions.

More formally, consider the case of a consumer trying to minimize the expenditure E = XP on rice subject to the constraint level of U = (X, q), where X is the demanded quantity of rice, P is the unit price and q is the level of quality of the rice, e.g. amount of GHG emissions. The result of this dual expenditure minimization problem is the Hicksian or compensated demand function, $X_h(P, U, q)$. Plugging this back into the expenditure function gives the indirect expenditure function, e(P, U, q). Suppose that when the amount of GHG emissions decreases, the quality of rice increases from q_0 to q_1. Then, the estimated value of the price premium that a consumer places on the change in the rice quality from q_0 to q_1 is:

$$\text{Price Premium} = e(P, U_0, q_0) - e(P, U_0, q_1)$$

The independent variables were constructed mainly based on participants' responses in the questionnaire. To avoid the bias of omitting key variables such as the effect of the information

[14] The estimation was carried out using STATA. We used the panel command "***xtgls***" that fits panel-data linear models by using feasible generalized least squares. To allow estimation in the presence of heteroskedasticity across panels, we used the optional commands "***panels(heteroskedastic)***" that specifies heteroskedastic error structure with no cross-sectional correlation.

provided to participants, a dummy variable (INFORMATION) was used that takes the value of 0 in round 1, where participants did not receive any information, and the value of 1 in round 4, where participants were provided with information on GHG emissions, food miles and origin.

Since participants' attitudes were measured using binary scales ("Agree" vs. "Disagree"), an Item Response Theory (IRT)[15] model was used to estimate continuous latent variables from observed binary responses (Kamakura and Balarubramian, 1989; Ewing *et al*., 2005; De Jong *et al*., 2008; Schultz *et al*., 2013; Raykov and Calantone, 2014). IRT considers a class of latent variable models that link mainly dichotomous and polytomous manifest (i.e. response) variables to a single latent variable. For our purpose, the two-parameter logistic model[16] was used to estimate the exact individual position on the three latent traits (the participant's concern about the environment, the participant's interest in the origin of food products, and the participant's sensitivity to the price of food products).

For each trait, at least four binary items were considered. For example, to estimate participant's score for the trait "ENVIRONMENT", participants' responses (Agree/Disagree) to the following binary items were considered: "The most important factor I consider when deciding which product to buy is the product's impact on the environment", "I am concerned or very concerned for the environment", "I think that mankind is playing role in climate change", "I am fully aware of the environmental impact of the foods I buy", "I habitually buy environmentally-friendly foods", and "I buy environmentally-friendly foods mainly because they are better for the environment". The descriptions of the independent variables are displayed in Appendix 9. Taking into account all the variables considered in the estimation, the equation of the price premium can be written as follows:

[15] The authors thank an anonymous reviewer for suggesting the use of IRT.

[16] We also used the constrained (the discrimination parameter is fixed at one) and the non-constrained one-parameter logistic model (Rasch model) and found that the two-parameter logistic model fits the data better.

$$(WTP_{hybrid} - WTP_{conventional})_{ijr}$$
$$= \beta_{0i} + \beta_{1i}INFORMATION_{jr} + \beta_{2i}ENVIRONMENT_j + \beta_{3i}ORIGIN_j + \beta_{4i}PRICE_j$$
$$+ \beta_{5i}LABEL_j + \beta_{6i}GENDER_j + \beta_{7i}AGE_j + \beta_{8i}LOWEDU_j + \beta_{9i}HIGHEDU_j$$
$$+ \beta_{10i}LOWINC_j + \beta_{11i}HIGHINC_j + \mu_{ij} + \varepsilon_{ijr}$$

where: i indexes the price premium for the hybrid rice such that i = 1, 2, 3, 4; j indexes cross-section units such that j = 1, 2, . . . , N (N is the number of participants); and r indexes the number of rounds (time series units) such that r = 1, 2. INFORMATION, ENVIRONMENT, ORIGIN, PRICE, LABEL, GENDER, AGE, LOWEDU, HIGHEDU, LOWINC, HIGHINC are the observable explanatory variables of the model for the price premium j. $(WTP_{hybrid} – WTP_{conventional})_{ijr}$ is the price premium i for participant j in round r. β_{0i} to β_{11i} are vectors of parameters to estimate. The effects of relevant unobservable variables and time-invariant factors are captured by the vector u_{ij}. The stochastic disturbances of the model for the four price premiums are captured by the vector ε_{ijr}.

4. Results

4.1. Consumers' WTP based on rice appearance

In the first round, participants were asked to report their WTP for each one of the four unlabelled rice samples based only on the appearance of the rice. Results, displayed in Table 4, show that participants preferred the appearance of the hybrid rice, since they reported a significantly higher WTP for the hybrid rice than the conventional rice. This is interesting because it shows that consumers are willing to pay a price premium of 11%, on average for the hybrid rice, based on its appearance and in the absence of a label indicating that it is environmentally friendlier than conventional rice. However, the appearance is directly affected by some natural factors, such as weather, that are out of the producers' control. Therefore, the difference in terms of appearance between the hybrid and the conventional rice is not always guaranteed. As a result, it could be risky for rice producers to only rely on the rice's appearance to obtain a premium for the hybrid rice.

Table 4. Willingness to pay ($/lb.) for the four rice samples based only on their appearance

Rice product	**WTP based on appearance**
Local hybrid (LH)	1.01
Non-local hybrid (NH)	1.05
p-value	*.07 (.07)*
Local conventional (LC)	.90
Non-local conventional (NC)	.96
p-value	*.08 (.08)*
Local hybrid (LH)	1.01
Local conventional (LC)	.90
p-value	*.00 (.00)*
Non-local hybrid (NH)	1.05
Non-local conventional (NC)	.96
p-value	*.00 (.00)*
Local hybrid (LH)	1.01
Non-local conventional (NC)	.96
p-value	*.05 (.05)*
Non-local hybrid (NH)	1.05
Local conventional (LC)	.90
p-value	*.00 (.00)*
Number of observations	300

4.2. Information effect on consumers' price premiums

The effect of each of the three types of information on consumers' price premiums for hybrid rice is presented in Table 5. The results on the effect of information on HG emissions (columns 2-4) show that participants significantly increased their price premium when they were informed that the hybrid rice had lower GHG emissions compared to the conventional rice. This result shows that labelling the rice as having lower GHG emissions can incentivize consumers to pay a price premium that might increase the sales, and hence the production, of hybrid rice which in turn could contribute to the reduction of GHG emissions. However, this is expected to happen in contexts where consumers are only aware, via labelling, of the quantity of GHG emitted by the hybrid and the conventional rice.

The results on the effect of information on food miles (Table 5, columns 5 to 7) and information on origin (Table 5, columns 8 to 10) show that in absence of information on GHG emissions, participants significantly increased their price premium when they found out that the hybrid rice was local and the conventional rice was not local (WTP_{LH}-WTP_{NC}). However, they significantly decreased their price premium when they were informed that the hybrid rice had higher food miles or was not local and the conventional rice had lower food miles or was local (WTP_{NH}-WTP_{LC}). These results show that relying only on the appearance of the hybrid rice to attract consumers is not a viable strategy particularly in the absence of information on GHG emissions and in the presence of information that could reflect the superiority of the conventional rice in terms of food miles and location of production.

We compared the effects of the three types of information using a between-subject analysis and the results are presented in Appendix 6. The results show that the effect of information on GHG emissions is significantly higher than the effect of information on food miles or origin. Conversely, the effect of information on origin and the effect of the information on food miles on consumers' price premium for hybrid rice are not significantly different from each other. Assuming that the rice is carrying information on only one of the three attributes, these results imply that consumers are more likely to value a hybrid rice labelled as having lower GHG emissions than a conventional rice labelled as local or having lower food miles.

Table 5. Effect of a single type of information on participants' price premium for hybrid rice (Within-subjects analysis)

	Effect of information on **GHG emissions**			Effect of information on **Food miles**			Effect of information on **Origin**		
Price premiums	Round 1	Round 2	p-value	Round 1	Round 2	p-value	Round 1	Round 2	p-value
$WTP_{LH} - WTP_{NC}$	.12	.38	.00 (.00)	.00	.09	.10 (.10)	.03	.17	.00 (.00)
$WTP_{LH} - WTP_{LC}$	.18	.43	.00 (.00)	.08	.05	.16(.017)	.05	.04	.70 (.71)
$WTP_{NH} - WTP_{NC}$	.11	.37	.00 (.00)	.07	.01	.07 (.06)	.09	.07	.23 (.23)
$WTP_{NH} - WTP_{LC}$	.18	.42	.00 (.00)	.15	-.02	.00 (.00)	.12	-.06	.00 (.00)
Number of observations	100	100		100	100		100	100	

In tables 5 to 10 the following terms stands for: "WTP_{LH}-WTP_{NC}" is the difference between the local hybrid rice that has lower food miles (i.e. LH) and the conventional rice that is not local and hence has higher food miles (i.e. NC). "WTP_{LH}-WTP_{LC}" is the difference between the hybrid and the conventional rice samples that are both local and have the same lower number of food miles. "WTP_{NH}-WTP_{NC}" is the difference between the hybrid and the conventional rice samples that are not local and have the same higher amount of food miles. "WTP_{NH}-WTP_{LC}" is the difference between the hybrid rice that is not local and has higher food miles and the conventional rice sample that is local and has lower food miles.

Results on the variation of participants' price premiums for the hybrid rice when provided with two types of information are presented in Table 6. The results on the effect of information on GHG emissions and food miles (Table 6, columns 2 to 4) and information on GHG emissions and origin (Table 6, columns 5 to 7) show that when participants were informed about the amount of GHG emissions and food miles, or GHG emissions and origin, they significantly increased their price premiums for hybrid rice. In the first case (WTP_{LH}-WTP_{NC}), the effects of both types of information complement each other, i.e. the hybrid rice has lower GHG emission and is local or has lower food miles and the conventional rice has higher GHG emissions and is not local or has higher food miles. In the fourth case (WTP_{NH}-WTP_{LC}), however, the negative effect of the information on food miles or origin, i.e. the conventional rice is local or has lower food miles compared with the hybrid rice, was not large enough to offset the positive effect of the information on GHG emissions, i.e. the hybrid rice has lower GHG emissions compared with the conventional rice. In the second and the third cases (WTP_{LH}-WTP_{LC} and WTP_{NH}-WTP_{NC}), the resulting significant increase in the price premiums can be attributed to the superiority of the hybrid rice samples in terms of GHG emissions which iis the only attribute that differentiates the hybrid rice from the conventional rice, i.e. both the hybrid and the conventional rice have the same origin and amount of food miles.

Table 6. Effect of each combination of two types of information on participants' price premiums for hybrid rice (Within-subjects analysis)

	Effect of information on **GHG & Food miles**			Effect of information on **GHG & Origin**			Effect of information on **Food miles & Origin**		
Price premiums	Round 1	Round 3	p-value	Round 1	Round 3	p-value	Round 1	Round 3	p-value
$WTP_{LH} - WTP_{NC}$	.03	.44	.00 (.00)	.06	.38	.00(.00)	.06	.30	.00 (.00)
$WTP_{LH} - WTP_{LC}$	.07	.38	.00 (.00)	.07	.36	.00 (.00)	.17	.11	.07 (.07)
$WTP_{NH} - WTP_{NC}$	.08	.27	.00 (.00)	.10	.26	.00 (.00)	.10	.05	.15 (.16)
$WTP_{NH} - WTP_{LC}$	.12	.21	.09 (.09)	.11	.23	.00 (.00)	.21	-.14	.00 (.00)
Number of observations	100	100		100	100		100	100	

Finally, the results on the effect of information food miles and origin (Table 6, columns 8 to 10) show that in the absence of information on GHG emissions, the effect of the information on food miles and origin strengthens the superiority of hybrid rice in terms of appearance in case the hybrid rice is local and has lower food miles and the conventional rice is not local and has higher food miles (WTP_{LH}-WTP_{NC}). However, the price premium that participants are willing to pay because of better appearance of the hybrid rice is offset by the negative effect of the information on food miles and origin when participants are informed that the hybrid rice is not local and has higher food miles and the conventional rice is local and has lower food miles (WTP_{NH}-WTP_{LC}). Even more, participants show that they are willing to pay a higher price premium for the conventional rice than for the hybrid rice. This result confirms our previous finding that relying on the superiority of hybrid rice in terms of appearance to attract consumers is a strategy that can fail in circumstances where the conventional rice is labelled as being superior in terms of other food attributes such as food miles and origin.

Additionally, the results from the between-subjects analysis, that was carried out to identify which combination of two types of information has the highest effect on participants' price premiums, are presented in Appendix 7. The results show that there are no significant differences between the price premiums of participants who received information of GHG emissions and food miles and the price premiums of participants who were provided with information on GHG emissions and origin of the rice. Nonetheless, we found that participants' price premiums are significantly higher when they are provided with information on GHG emissions and food miles or information on GHG emissions and origin, as compared to when they are given information on food miles and origin. Therefore, assuming each rice sample carries information on only two of the three attributes, consumers are more likely to value a non-local/higher food miles hybrid rice more than a local/lower food miles conventional rice due to the lower GHG emissions of the hybrid rice.

Subsequently, the results concerning the variation of participants' price premiums when they are provided with information about all three attributes are displayed in Table 7. The data has been pooled from treatment 2 to 7 (300 observations) because at round 4, all participants were already provided with the three types of information. Results show that when participants are told the hybrid rice is local and has lower GHG emissions and food miles compared with the conventional rice that is not local and has higher GHG emissions and food miles (WTP_{LH}-WTP_{NC}), the effects of the three types of information complement each other, resulting in a significant increase of the price premium from $0.05 to $0.46.

Table 7: Effect of information on GHG emissions, food miles and origin on participants' price premium for hybrid rice

	Effect of information on **GHG** & **Food miles** & **Origin**		
Price premiums	Round 1	Round 4	p-value
$WTP_{LH} - WTP_{NC}$	.05	.46	.00 (.00)
$WTP_{LH} - WTP_{LC}$	.11	.34	.00 (.00)
$WTP_{NH} - WTP_{NC}$	.09	.21	.00 (.00)
$WTP_{NH} - WTP_{LC}$	.15	.08	.04 (.04)
Number of observations	300	300	

However, in the case where the hybrid rice has lower GHG emissions, higher food miles and is non-local, while the conventional rice has higher GHG emissions, is local and has lower food miles, the positive effect on the price premium (WTP_{NH}-WTP_{LC}) of the information on GHG emissions seems to compete with the negative effect of the information on food miles and origin, resulting in a significant decrease in the price premium from $0.15 to $0.08. Interestingly, the final price premium of $0.08[17] is still significantly different from zero. Furthermore, the results show that participants significantly increased their price premiums for the hybrid rice when they were informed that the hybrid rice had lower GHG emissions over the conventional rice, but both rice varieties had the same amount of food miles and the same origin (WTP_{LH}-WTP_{LC} and WTP_{NH}-WTP_{NC}).

[17] However, it is important to find out whether this price premium is large enough to offset the additional cost that rice producers are going to bear if they decide to adopt the production of the hybrid rice.

4.3. Substitutability of the attributes food miles and origin

The results displayed in Table 8 and Appendix 8, are obtained from the within- and between-subjects analyses, respectively. The results show that the two attributes are not perceived by consumers as perfect substitutes. In fact, we found that informing participants that the hybrid rice is local and the conventional is not, after being told that the hybrid rice has lower food miles compared with the conventional rice (WTP_{LH}-WTP_{NC}), significantly increased their price premium from \$0.15 to \$0.27 (from \$0.09 to \$0.25 in the between-subjects analysis). We also found that when participants were told that the hybrid rice is not local and the conventional rice is local, after being informed that the hybrid rice has higher food miles compared with the conventional rice (WTP_{NH}-WTP_{LC}), they significantly decreased their price premium from \$-0.21 to \$-0.37 (from \$-0.18 to \$-0.35 in the between-subjects analysis). As expected, in the cases of WTP_{LH}-WTP_{LC} and WTP_{NH}-WTP_{NC}, the differences were not statistically significant because the hybrid and the conventional rice have the same origin and the same amount of food miles.

Table 8. Results from the analysis of the relationship between the attributes food miles and origin (within-subjects analysis)

Price premiums	**Food miles**	**Food miles** & **Origin**	p-value	**Origin**	**Origin** & **Food miles**	p-value
$WTP_{LH} - WTP_{NC}$	.15	.27	.00 (.00)	.13	.20	.09 (.08)
$WTP_{LH} - WTP_{LC}$	-.02	-.02	.81 (.82)	.01	.02	.81 (.82)
$WTP_{NH} - WTP_{NC}$	-.04	-.09	.16 (.17)	-.03	-.08	.12 (.12)
$WTP_{NH} - WTP_{LC}$	-.21	-.37	.00 (.00)	-.15	-.26	.00 (.00)
Number of observations	100	100		100	100	

Since the results showed that food miles and the origin are not perfect substitutes, it remains to be seen whether they are perceived as independent attributes, or whether the attribute food miles is seen as one of the characteristics of the attribute origin. If the attribute, food miles, is perceived by participants as a characteristic of the attribute origin, then consumers should be given information only on the origin (local/non-local), and they should be able to deduce whether the rice has low or high food miles. If this is true, then the results would show that giving participants information about the amount of food miles, after informing them about the origin of the rice would not significantly affect their price premiums for the hybrid rice. The results reported in Table 8 and Appendix 8 show that in three out of four cases ("WTP_{LH}-WTP_{NC}" and "WTP_{NH}-WTP_{LC}" in the within- and the between-subject analysis), informing participants about the amount of food miles of the rice after giving them information on the origin of the rice significantly affected their price premiums.

To sum up, in our experiment, participants neither perceived the attributes, origin and food miles, as similar attributes; nor did they clearly consider food miles as a characteristic of the attribute, origin. Nonetheless, more studies should be conducted with different products and in different countries to obtain more evidence on how consumers perceive the substitutability of the attributes food miles and origin.

4.4. Determinants of consumers' price premiums

Overall, the results from the estimation of the four models (see Appendix 10) show that the price premium participants are willing to pay for hybrid rice is not only affected by the information about the rice attributes but also by the consumers' attitudes and socio-demographic traits. Particularly, we found that participants who are more concerned about the environment are willing to pay a higher price premium for the hybrid rice. As expected, we found that participants who are interested in the origin of food products increased their price premium in the case of local hybrid and non-local conventional rice ($WTP_{LH} - WTP_{NC}$), and significantly decreased their price premium in the case of non-local hybrid rice and local conventional rice ($WTP_{NH} - WTP_{LC}$).

The non-significant effect of the trait "ORIGIN" in the second and the third models can be explained by the fact that both the hybrid and the conventional rice have the same origin. Furthermore, the results show that participants who are more sensitive to food prices are willing to pay a significantly lower price premium for the hybrid rice in the case of the first, third and fourth models. We also found that participants who said that "a label indicating the carbon emissions of a product should not be mandatory, but it should be done on a voluntary basis" ("LABEL") reported a lower price premium for the hybrid rice when it was labelled as having lower GHG emissions, but is not local and has higher food miles.

Regarding the effect of participants' socio-demographic characteristics, we found that compared to male participants, female participants are willing to pay a lower price premium when the hybrid rice is local and the conventional rice is not local ($WTP_{LH} - WTP_{NC}$), as well as a higher price premium when the hybrid rice is not local and the conventional rice is local ($WTP_{NH} - WTP_{LC}$). The results show that the higher the participant's age, the lower his/her price premium is for a hybrid rice that is labelled as having lower GHG emissions, food miles and is local, when compared with the conventional rice that has higher GHG emissions, food miles and is not local ($WTP_{LH} - WTP_{NC}$). Additionally, we found that the higher the participant's age, the lower his/her price premium is for a hybrid rice that is labelled as having lower GHG emissions, higher food miles, and is not local, when compared to the conventional rice that has higher GHG emissions, lower food miles and is local ($WTP_{NH} - WTP_{LC}$). The age effect is not significant in the case of model 2.

Furthermore, we found that highly educated participants were willing to pay a higher price premium than less educated participants for the hybrid rice. Nonetheless, participants with a low education level reported a lower price premium for the hybrid rice that is labelled as having lower GHG emissions, higher food miles, and is not local, when compared to a conventional rice that has higher GHG emissions, lower food miles, and is local ($WTP_{NH} - WTP_{LC}$). Conversely, the results show that low-income participants were willing to pay a higher premium for the hybrid rice; however, the effect is significant only in the first model. Participants with a high income level were willing to pay a lower price premium in the fourth model. This occurrence may exist because, based on responses in the questionnaire, participants with low incomes consume rice more frequently than participants with high incomes.

Overall, the results show that, consumers' attitudes and socio-demographic characteristics matter. Nevertheless, we think that more data and a deeper analysis are needed to fully understand and explain the heterogeneity among consumers in regards to their willingness to pay for environmentally-friendly foods.

5. Discussion and conclusions

Given consumers' increasing concerns about the state of the environment and climate change, the market for sustainable products is expected to expand significantly in the future. Consequently, it is no longer just environmentalists and policy-makers who are concerned about GHG emissions and food miles, but also consumers, food producers and retailers. In addition, there is an increasing interest for local foods for perceived environmental, health and social reasons. Little is known however about the interactions between these attributes in relation to consumers' valuation for food products. For example, no other known study has determined, through non-hypothetical value elicitation methods, if consumers value a "high GHG emissions/local/low food miles" product more or less than a "low GHG emissions/non-local/high food miles" product. This is an interesting question given the rise of farmers' markets across many developed countries that advertise their produce as "local" and having lower food miles. In reality, these farmers may have a comparative disadvantage in production (both yield and GHG use efficiency) by producing a product locally.

In this study, we found that consumers are willing to pay a price premium for hybrid rice based only on its appearance. The results suggest that this price premium increases significantly if the hybrid rice is labelled as having lower GHG emissions. The results also suggest that this price premium could be increased if rice producers inform consumers in their local market that the hybrid rice is local and has lower food miles. On the other hand, the results also show that when the hybrid rice is sold in non-local markets, along with a local conventional rice the positive effect of the information about GHG emissions seems to compete with the negative effect of the information on food miles and origin. This occurrence results in a significant decrease in the price premium for the hybrid rice. Nevertheless, we found that, given the lower GHG emissions of the hybrid rice, consumers are more likely to value a non-local hybrid rice with higher food miles, over a local conventional rice with lower food miles.

These results imply that producing and labelling food products as environmentally friendly could be an effective way to differentiate food products and support more sustainable farming. Our results could also incentivize retailers to offer and label more environmentally-friendly foods as having lower GHG emissions on their shelves. Nonetheless, we think that the retail sector's concerns toward this type of foods is legitimate especially in relation to issues such as the best way of communicating information on GHG emissions to consumers (e.g. "quantity of carbon dioxide equivalent" vs. "equals to X miles in a medium-sized car" etc.) and the ability and willingness of food producers and processors to provide information on GHG emissions of their food products. For instance, in January 2012, Tesco, the major UK retailer, decided to stop using carbon footprint labels on their products, blaming the amount of work and time to calculate the footprint of each product and other supermarkets for failing to follow its lead. More work is certainly needed to determine the best way to get around these specific retailers' concerns

Furthermore, our results imply that stakeholders should also be aware of the positive and negative interactions of the GHG emissions attribute and other food attributes such as food miles and origin. In fact, our findings imply that consumers generally consider food miles as a non-trivial measure of the food's environmental impact, given the trade-offs in valuation between this attribute and GHG emissions attribute. In reality, transportation accounts for a very small percentage of total GHG emissions associated with the production; however, it appears that consumers do not wholly view this in such a manner. Hence, a natural extension of this study would be to test the robustness of our findings by conducting the same experiment in this study, but with information about the relative contributions of food miles and GHG emissions from production to the overall food system's GHG emissions. In other words, would we still see the same type of valuation trade-offs that we have seen in this study if consumers are given objective information about the relative shares of food miles and GHG emissions from production on the overall food system's GHG emissions?

The results also show that consumers do not perceive the local (non-local) rice and rice with low (high) food miles labels as communicating the same information. This implies that producers and marketers could use the two labels simultaneously to increase consumer demand for local rice with lower food miles. However, it is important to highlight the necessity for more studies (i.e. using different products and consumers with different background (e.g. consumers living in developing countries)) on this issue to confirm our results.

Finally, stakeholders who are interested in marketing environmentally-friendly rice need to keep in mind that consumers' price premium for hybrid rice is also affected by their attitudes and socio-demographic characteristics. For instance, increasing the awareness of consumers about the damaging environmental effect of excessive levels of GHG emissions is likely to increase consumer preferences and WTP for environmentally-friendly rice. .

As in any other empirical study, our work has some limitations. Due to the non-hypothetical nature of our economic experiment, only a few specific levels of GHG emissions and food miles were considered, given that it was not possible to obtain and use rice from other U.S. states with similar quality and of the same variety. Admittedly, it is possible that the use of significantly different levels of GHG emissions and food miles in our study may lead to different results. Therefore, another natural extension of this study is to test the robustness of our findings by conducting the same experiment, but use other levels of GHG emissions and food miles. Furthermore, it would be interesting to check the robustness of our results for other food products, or in other locations like developing countries where rice is a major part of consumer's diet.

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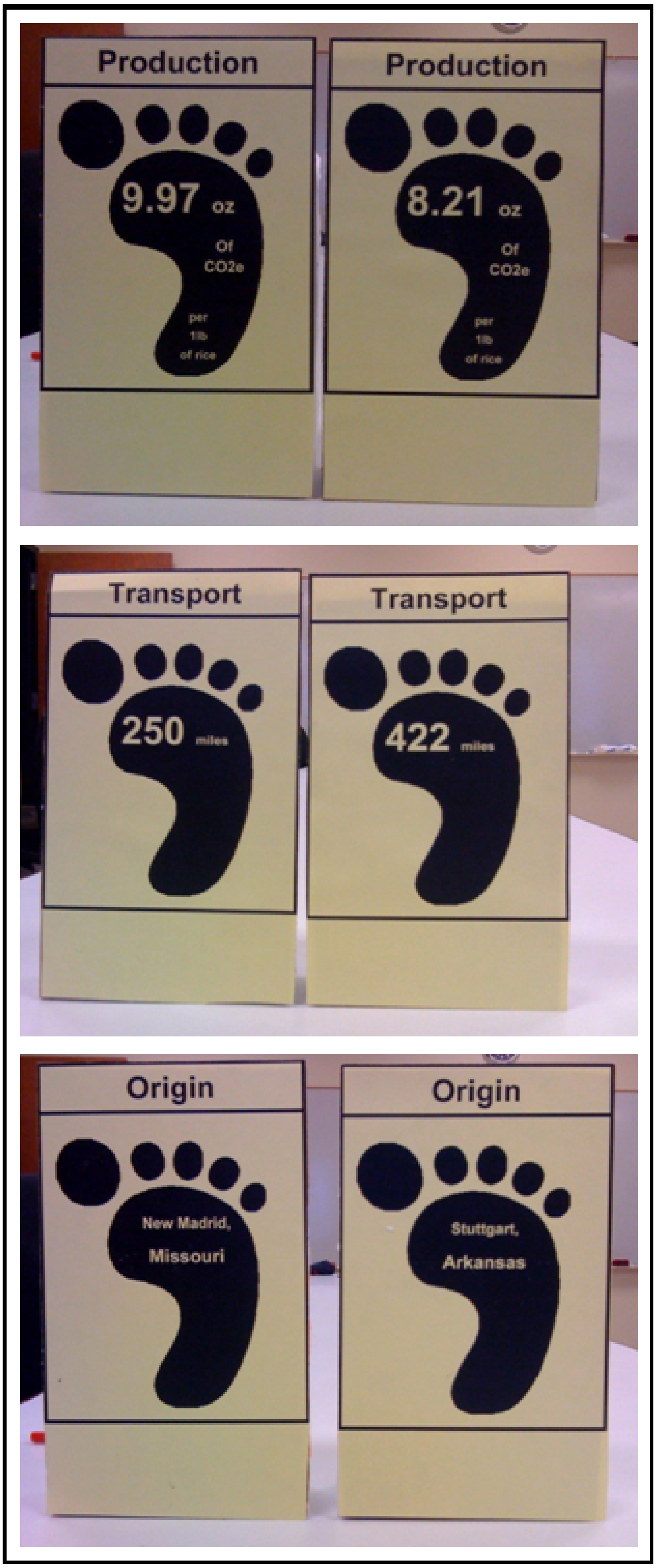
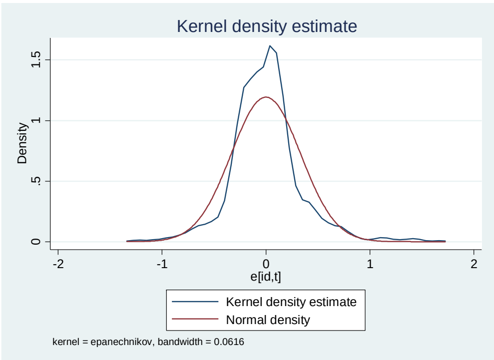
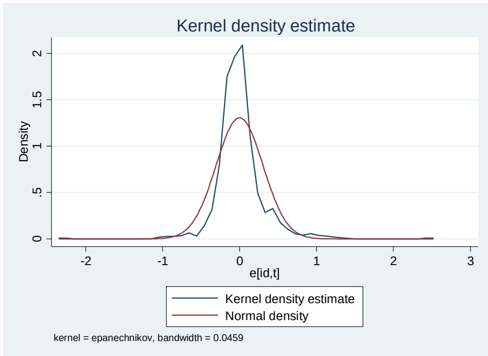
Appendix 1. The placards used to display the information

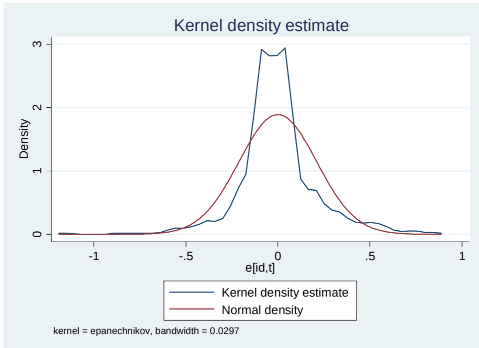


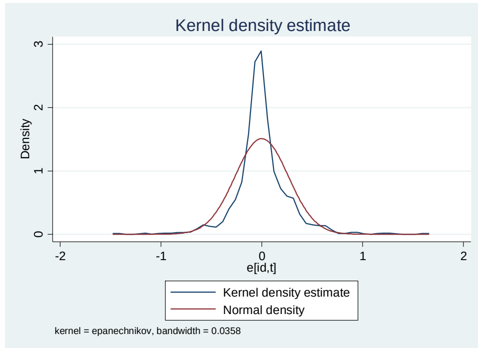
Appendix 2. Test for normality: Shapiro-Wilk (SW) test & Kernel density estimates

$WTP_{LH} - WTP_{NC}$			$WTP_{LH} - WTP_{LC}$			$WTP_{NH} - WTP_{NC}$			$WTP_{NH} - WTP_{LC}$		
SW-value	Z-value	P-value	SW-value	Z-value	P-value	SW-value	Z-value	P-value	SW-value	Z-value	P value
.939	7.698	.000	.841	10.030	.000	.924	8.243	.000	.899	8.941	.000









Appendix 3. Test for autocorrelation: Breusch-Godfrey/Wooldridge test

$WTP_{LH} - WTP_{NC}$			$WTP_{LH} - WTP_{LC}$			$WTP_{NH} - WTP_{NC}$			$WTP_{NH} - WTP_{LC}$		
Chi2	df	P-value	Chi2	df	P-value	Chi2	df	P-value	Chi2	df	P value
3.105	2	.211	1.187	2	.552	.823	2	.662	1.877	2	.391

Appendix 4. Test for heteroscedasticity: Breusch-Pagan test (BP)

$WTP_{LH} - WTP_{NC}$			$WTP_{LH} - WTP_{LC}$			$WTP_{NH} - WTP_{NC}$			$WTP_{NH} - WTP_{LC}$		
BP test	df	P-value	BP test	df	P-value	BP test	df	P-value	BP test	df	P value
1552.82	310	.00	7263.47	310	.00	1822.60	310	.00	3094.74	310	.00

Appendix 5. Hausman test

$WTP_{LH} - WTP_{NC}$			$WTP_{LH} - WTP_{LC}$			$WTP_{NH} - WTP_{NC}$			$WTP_{NH} - WTP_{LC}$		
Chi2	df	P-value	Chi2	df	P-value	Chi2	df	P-value	Chi2	df	P-value
.00	1	1.00	.00	1	1.00	.00	1	1.00	.00	1	1.00

Appendix 6. Comparison of the effects the different types of information on participants' price premiums for hybrid rice (Between-subjects analysis)

Price premiums	GHG emissions	Food miles	P-value	GHG emissions	Origin	P-value	Food miles	Origin	P-value
$WTP_{LH} - WTP_{NC}$	.27	.09	.01(.01)	.27	.13	.04(.04)	.09	.13	.50(.51)
$WTP_{LH} - WTP_{LC}$	.25	-.04	.00(.00)	.25	-.01	.00(.00)	-.04	-.01	.57(.58)
$WTP_{NH} - WTP_{NC}$	.27	-.05	.00(.00)	.27	-.03	.00(.00)	-.05	-.03	.50(.51)
$WTP_{NH} - WTP_{LC}$	.24	.18	.00(.00)	.24	-.18	.00(.00)	-.18	-.18	1.00(1.00)
Number of observations	100	100		100	100		100	100	

In Appendices 5 to 7 the following terms stands for: "WTP_{LH}-WTP_{NC}" is the difference between the local hybrid rice that has lower food miles (i.e. LH) and the conventional rice that is not local and hence has higher food miles (i.e. NC). "WTP_{LH}-WTP_{LC}" is the difference between the hybrid and the conventional rice samples that are both local and have the same lower number of food miles. "WTP_{NH}-WTP_{NC}" is the difference between the hybrid and the conventional rice samples that are not local and have the same higher amount of food miles. "WTP_{NH}-WTP_{LC}" is the difference between the hybrid rice that is not local and has higher food miles and the conventional rice sample that is local and has lower food miles.

Appendix 7. Comparison of the effects of different binary combinations of information on participants' price premiums for hybrid rice (Between-subjects analysis)

Price premiums	**GHG emissions & Food miles**	**GHG emissions & origin**	P-value	**GHG emissions & Food miles**	**Food miles & origin**	P-value	**GHG emissions & origin**	**Food miles & origin**	P-value
$WTP_{LH} - WTP_{NC}$	.41	.32	.22(.22)	.41	.25	.06(.06)	.32	.25	.34(.35)
$WTP_{LH} - WTP_{LC}$	.30	.29	.81(.82)	.30	-.06	.00(.00)	.29	-.06	.00(.00)
$WTP_{NH} - WTP_{NC}$	.20	.16	.55(.55)	.20	-.05	.00(.00)	.16	-.05	.00(.00)
$WTP_{NH} - WTP_{LC}$	.09	.12	.65(.65)	.09	-.35	.00(.00)	.12	-.35	.00(.00)
Number of observations	100	100		100	100		100	100	

Appendix 8. Results from the analysis of the relationship between the attributes food miles and origin (between-subjects analysis)

Price premiums	**Food miles**	**Food miles & Origin**	p-value	**Origin**	**Origin & Food miles**	p-value
$WTP_{LH} - WTP_{NC}$	.09	.25	.05 (.05)	.13	.25	.15 (.15)
$WTP_{LH} - WTP_{LC}$	-.04	-.06	.59 (.59)	-.01	-.06	.32(.32)
$WTP_{NH} - WTP_{NC}$	-.05	-.05	.90(.90)	-.03	-.05	.63(.65)
$WTP_{NH} - WTP_{LC}$	-.18	-.35	.02 (.02)	-.18	-.35	.01 (.01)
Number of observations	100	100		100	100	

Appendix 9. The independent variables used in the estimations

Name of the variable	Description
INFORMATION	Dummy variable that takes the value 1 if the participant received information on GHG emissions, origin and food miles and tasted the rice (Round 5); and 0 if participant neither received information nor tasted the product (Round 1).
ENVIRONMENT	Continuous variable that represents participant's concern about the environment (the higher is the value of the variable the more concerned is the participant for the environment).
ORIGIN	Continuous variable that represents participant's interest in the origin of the food product (the higher is the value of the variable the more interested is participant in the origin of the food product).
PRICE	Continuous variable that represents participant's sensitivity to the price of food products (the higher is the value of the variable the more sensitive is the participant to the price of food products).
LABEL	Dummy variable that takes the value 1 if the participant agreed with the statement "a label indicating the carbon emissions of a product should not be mandatory but it should be done on a voluntary basis"; and 0 otherwise.
GENDER	Dummy variable that takes the value 1 if the participant's gender is female; and 0 if he is male.
AGE	Continuous variable expressed in number of years.
LOWEDU	Dummy variable that takes the value 1 if the participant has a relatively low level of education (at most some secondary studies); and 0 otherwise.
HIGHEDU	Dummy variable that takes the value 1 if the participant has a relatively high level of education (at least participant has a Bachelor degree); and 0 otherwise.
LOWINC	Dummy variable that takes the value 1 if the household's annual income is less than $25,000; and 0 otherwise.
HIGHINC	Dummy variable that takes the value 1 if the household's annual income is greater than $75,000; and 0 otherwise.

MEDEDU is the base category for the education variable and include all participants who revealed to have at least a high school diploma or/and some university studies.

MEDINC is the base category for the income variable and include all participants who revealed that the household's annual income is between $25,000 and $75,000

Appendix 10. Results from estimation of the four random-effects generalized least square models

Variables	Model 1 $WTP_{LH} – WTP_{NC}$		Model 2 $WTP_{LH} – WTP_{LC}$		Model 3 $WTP_{NH} – WTP_{NC}$		Model 4 $WTP_{NH} – WTP_{LC}$	
CONSTANT	.110	***	.006		-.002		-.018	
INFORMATION	.392	***	.216	***	.093	***	-.012	
ENVIRONMENT	.036	***	.075	***	.052	***	.057	***
ORIGIN	.084	***	-.004		.006		-.048	***
PRICE	-.044	**	-.023		-.069	***	-.049	***
LABEL	-.020		.003		-.053	***	-.033	***
GENDER	-.042	**	-.020		.002		.032	**
AGE	-.002	***	.000		.001	**	.002	***
LOWEDU	.000		.030		-.031		-.038	**
HIGHEDU	.026	*	.040	**	.040	***	.042	***
LOWINC	-.021		.055	***	.050	***	.045	***
HIGHINC	.006		.017		-.001		-.024	**
Number of observations	600		600		600		600	
Number of groups	300		300		300		300	
Time periods (Rounds)	2		2		2		2	
Wald chi2(9)	1351.33		406.63		274.19		116.58	
Prob > chi2	.00		.00		.00		.00	

*** (**) (*) denote statistical significance at 1% (5%) (10%) level