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Social Network Effects on Consumer Willingness to Pay for Biofortified Crops

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Social Network Effects on Consumer Willingness to Pay for Biofortified Crops

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Abstract

Micronutrient deficiency, also known as hidden hunger, affects about two billion people globally. Adoption and consumption of micronutrient-enriched—that is, biofortified—staple crops, is a potential solution to alleviating hidden hunger. When creating demand for biofortified crops (seeds or food), social networks may complement "traditional" advertising channels, such as mass media. Ex-ante studies investigating the effects of nutrition information on acceptance of biofortified crops rarely assess explicitly the role of social networks.

This study investigated the effects of social networks on consumer willingness to pay (WTP) for two high-iron bean (HIB) varieties (HIB-A and HIB-B) using data collected from 572 farmers in rural Rwanda. The study used the Becker-DeGroot-Marshak mechanism to elicit consumer WTP in the absence and presence of radio messages providing positive and negative frames of information on nutritional benefits of HIB varieties at different frequencies. Instrumental variable and random effects models were used to assess the determinants of WTP.

Results show that consumers were willing to pay more for the preferred HIB variety (HIB-A). The effect of social network size on demand could be positive or negative, depending on consumer perception of the product quality. Negative information about less preferred products can easily be spread within social networks, especially by men, who have larger networks than women, making it harder for media advertising alone to create sufficient demand for an inferior product. Media advertising positively influenced WTP only for the more preferred variety, but has a potential to increase WTP for the less preferred variety, if conducted more intensively and by using negative-framed information that emphasizes desirable product features.

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1 INTRODUCTION

Micronutrient deficiency is a public health problem that affects about two billion people around the world, most of whom reside in low-income countries (Tulchinsky 2010). Iron deficiency, one of the major contributors to anemia, is highly prevalent in preschool children and women of reproductive age (Camaschella 2015). The common bean (*Phaseolus vulgaris*) is an important source of iron in parts of Africa south of the Sahara where it is consumed, but many people living in these areas still suffer from iron deficiency (Petry et al. 2015). One approach that is deemed effective in alleviating micronutrient deficiency is the development of micronutrient-dense staple crops through biofortification (Hefferon 2015; Petry et al. 2015). Among the biofortified staple crops being developed are biofortified beans, which contain higher levels of iron than existing bean varieties (Brigide, Canniatti-Brazaca, and Silva 2014).

Widespread acceptance and adoption of biofortified beans by farmers and purchase by consumers are critical if the benefits of enhanced micronutrient content are to be realized (Nestel et al. 2006; Bouis et al. 2013). Biofortified crops have only been recently introduced in a number of developing countries, and information on their attributes and benefits is a key determinant of their demand by both farmers and consumers (Tumuhimbise et al. 2013). In Rwanda, where this study was carried out, the Rwanda Agriculture Board (RAB) in collaboration with HarvestPlus officially released 10 conventionally bred, biofortified high-iron bean (HIB) varieties that are about 40 percent richer in iron content than local varieties. The introduction of HIB varieties in Rwanda is strategic, because on one hand Rwandans have one of the highest average daily per capita consumption of beans in the world, while on the other hand, micronutrient deficiency is prevalent in the country, where the prevalence of anemia among children 6–59 months old is about 37 percent overall (NISR 2016). To achieve impact, the HIB varieties must be adopted widely by farmers and consumed by the population. Preliminary results of a nationally representative impact assessment study conducted in 2015 jointly by RAB, HarvestPlus, and the International Center for Tropical Agriculture (Centro Internacional de Agricultura Tropical, or CIAT) reveal that since the official release of four HIB varieties in 2010 and an additional six in 2012, about 29 percent of the rural bean-growing households have grown at least one HIB variety in at least one season (Asare-Marfo et al. 2016).

Contrary to the case for many nonbiofortified improved varieties, delivery of information on products of biofortified crops needs careful consideration to achieve impact. This is largely because biofortification, especially biofortification with provitamin A, tends to change some physical and organoleptic traits of the varieties, such as grain color, taste, and smell (Nuss and Tanumihardjo 2011; De Groote et al. 2014), which may in turn limit the demand for biofortified crops. Hence, farmers need information that assures them of the nutritional superiority of the biofortified crops, notwithstanding the perceived differences in physical or organoleptic characteristics (compared with local varieties) that may have resulted from the breeding process.

Information about such new products normally flows from product developers and marketers through formal channels, such as the print and electronic media, and informal mechanisms, such as word of mouth (Perks 2000). But product developers and marketers are not the only primary channels of information to consumers: consumer-to-consumer communication, which occurs through social networks, has long been recognized as an informal mechanism by which product information may reach consumers (Iacobucci and Hoeffler 2016). It has often been argued that social networks complement other “traditional” marketing information channels, such as mass media, and have in some cases proven more influential on consumer perceptions and purchase decisions (Allstop, Bassett, and Hoskins 2007; Trusov, Bucklin, and Pauwels 2009). However, studies that investigate the complementarity of formal information channels and informal communication through social networks in marketing of agricultural products are rare.

Recent studies on biofortified crops around the world address the questions of consumer acceptance and the best way to provide farmers and consumers with information to stimulate demand (Bouis et al. 2013; Birol et al. 2015). For instance, Pillay et al. (2011) assessed the acceptance of both popular maize food products prepared with a popular white maize variety and yellow, provitamin-A biofortified maize varieties among schoolchildren and adults in South Africa, with no nutritional information provided to the participants. Their results suggest that while primary schoolchildren had no significant preference for the white or yellow maize varieties, high school students and adults preferred the white to biofortified maize. Chowdhury et al. (2011) assessed the role of nutritional information provision on willingness to pay (WTP) for provitamin-A biofortified orange sweet potatoes in Uganda. They found that without nutritional information, consumer WTP values for biofortified and traditional white varieties were not significantly different. However, providing nutritional information increased the WTP for biofortified varieties compared with the traditional variety.

The above studies show that information provision can play a role in the demand for biofortified crops. However, the explicit effects of social networks on demand for biofortified crops by farmers or consumers have not been analyzed. While social networks have been shown to influence flows of information on and choice of consumer products and new agricultural technologies (Matuschke and Qaim 2009; Janakiraman 2011; Tatlonghari et al. 2012), such studies rarely control for the potential effects of product advertising, for instance, through media campaigns. Yet, contrary to formal information channels which disseminate only positive messages about a product, informal information that flows through social networks conveys even the perceived negative aspects of the product or its developers (Edison and Geissler 2011). Social networks, therefore, can enhance or limit the demand for a product, depending on the strength of information and influence flowing through them. A clearer understanding of the role of social networks can provide policymakers with insights on how to incorporate network effects when designing programs for deployment of biofortified crops, in order to enhance their demand.

This study, therefore, aimed to investigate the effects of social networks on consumer WTP for biofortified crops, focusing on HIBs. Using data collected from 572 farmers in Rwanda, the study sought to specifically characterize the social networks for bean production and marketing, determine consumer WTP for biofortified beans, determine the effects of social networks on consumer WTP for biofortified beans and compare them with those of media advertising, and assess the determinants of social networks in rural Rwanda.

A quasi-experiment was designed and implemented in the Northern Province of Rwanda to elicit consumer valuation for three (two iron-biofortified and one popular) local bean varieties using the Becker-DeGroot-Marschak (BDM) incentive-compatible, auction-like mechanism (Becker, De Groot, and Marschak 1964). Before the participants stated their bids in the auction, we used a hedonic rating method to examine their evaluation of the sensory attributes of the bean varieties, thus having product experience before stating their WTP. In understanding the effect of media advertising (and its frequency) on WTP, our sample comprises five experimental groups: (1) a control group (T1) without any information about iron beans and the importance of iron in diets and (2) four treatment groups (T2–T5) provided with nutrition information on the iron beans and the importance of iron in diets at different frequencies through simulated radio messages. To examine the effect of social networks on WTP, the experiment was implemented in a home-use test setting, where participants tested the three varieties over a period of seven days. Each participant was visited at home four times by the research team. We assumed that during this period, participants were likely to discuss the experiment and the varieties within their social networks.

The rest of the paper is organized as follows: we first discuss the methodology used in the study in Section 2, then discuss the results in Section 3, and finally conclude in Section 4.

2 METHODOLOGY

Theoretical Framework

Social networks

From a sociological perspective, farmers can be thought of as being intricately embedded in dense webs of social ties and interactions (called social structures or social networks) that define the context and way they express themselves (Borgatti et al. 2009). A social network refers to a set of actors who have links or ties with one another. Over the years, the social network theory has been used by social scientists to provide explanations on flows of influence, ideas, and economic behavior among people (Granovetter 2005). Effects of social networks on consumer WTP for biofortified crops (termed as *endogenous social effects*) can be hypothesized to occur through two main mechanisms: *social learning* and *social influence* (Hogset and Barrett 2010).

Social learning occurs when consumers actively search for information and use it to update their beliefs, leading to purchase decisions, such as the product to buy or amount to pay for it. Learning about a new product is facilitated by interactive sessions through which actors discuss and reflect on their knowledge, views, and experiences about a product (Vinke-de Kruijf, Bressers, and Augustijn 2014). On the other hand, social influence results from the need to conform to the behavior of significant others in a consumer's network. Consumers may imitate or mimic the product choice decisions of their social network members, even when they do not have complete information about the product's attributes or the motivation behind their network members' decisions on the product. This may happen as a result of the trust within social networks—such imitators believe that some attributes of the product are superior enough to warrant its purchase by their network members. It could also be the case that a consumer admires the network member who has purchased the product, or would enjoy some benefits from the social network if he or she conforms to the behavior adopted by members of the network (Hedström, Sandell, and Stern 2000; Borgatti et al. 2009; Easley and Kleinberg 2010).

Social learning and influence may also be explained from the *market mavens* concept commonly applied in advertising literature. Market mavens are the type of consumers who are well versed with current happenings in the marketplace, such as new products, prices, and sales, and initiate word-of-mouth campaigns that greatly influence information flows, opinions, and consumer decisions about certain market products (Fitzmaurice 2011). Their willingness to share market information with other customers is motivated by their perceived obligation and pleasure in sharing information, and the desire to help others (Walsh, Gwinner, and Swanson 2004). Mavens may also be motivated to spread information to members of their social network about a product with which they had a negative experience, in order to warn them, reduce anxiety through airing their grievances, seek advice on a course of action, or mete out vengeance on the product manufacturers (Edison and Geissler 2011). Hence, information that flows through social networks about a product could be positive or negative.

Based on the theoretical underpinnings above, we hypothesized that some of the farmers who participated in this study may have shared information on their experiences with the HIBs with their social network members, since they mostly reside in the same villages where the study was conducted. HIBs are new in Rwanda, and as Berger and Schwartz (2011) argue, people initiate discussions about products that are considered interesting, because they are new, exciting, unusual, outrageous, or surprising. Following the same argument, it is reasonable to hypothesize that some farmers have exchanged information on new bean varieties within their social networks, which may influence their opinions on and attitudes toward any new varieties, including the HIBs.

Behavior and outcomes in a social network are influenced by *centrality* measures, which describe the *structure* of the network (Borgatti et al. 2009). Allstop, Bassett, and Hoskins (2007) argue that the spread of information in word-of-mouth communication, such as social networks, is influenced by the number of people involved. Hence, in this study we used the centrality measure known as the *network degree*, which refers to the number of other actors to whom a network member is directly connected (Newman 2010). Network degree has been widely used as a proxy measure for network size (McCormick, Salganik, and Zheng 2010). Our hypothesis was that farmers with a larger network were exposed to more verbal discussions and information about HIBs in particular, or improved varieties in general. Consequently, the influence of social networks on the WTP for biofortified beans was expected to be greater for farmers with larger networks.

The BDM mechanism

Analysis of ex-ante evaluation of consumer preferences involves eliciting consumer values for a private or public good. Various valuation techniques (such as experimental auctions and stated-choice experiments) have been applied in the consumer acceptance literature to elicit consumer values, especially for food products (Harrison, Harstad, and Ruström 2004; Lusk and Shogren 2007; Corrigan et al. 2009; De Groote, Kimenju, and Morawetz 2011). Unlike in stated-choice experiments, where values are indirectly inferred from participants' choices among multiple options, bids submitted in experimental auctions provide a direct measure of consumer WTP for the good on offer for sale. In experimental auctions, an active exchange environment is simulated, where real goods are offered for sale and participants spend real money to purchase them. Either publicly in English auctions or privately in sealed auctions, participants are asked to submit the highest price they will be willing to pay for a fixed quantity of good.

BDM is an auction-like mechanism that has been widely applied in developing countries (Banerji et al. 2013). While individual bidders compete against one another in many of the experimental auction techniques, such as the second-price auction, individuals compete against market price in the BDM mechanism. In a BDM mechanism, participants submit the highest price they are willing to pay—that is, their bids (y) for a product being auctioned. Each participant has a chance to "win"[3] a quantity of the auctioned product if the bid submitted is greater than or equal to a randomly drawn price (p) from an established price distribution. On the other hand, individuals do not "win" in the BDM experiment when $y < p$. As an outcome, individual A, with $y \geq p$, pays the market price, p, to acquire the product auctioned, while individual B, with $y < p$, neither pays a price nor acquires the product. The BDM mechanism is incentive compatible because the individual's true WTP for a unit of the product is defined as the price that induces indifference between "winning" [$U_i(y_i - p)$] and "not winning" [($U(0) = 0$)] the unit, where U is an income-dependent utility function and p is random. That is, $u(1, w - WTP) = u(0, w)$, where w is the individual's resources at the beginning of the experiment. Rational behavior under this mechanism is to place a bid equal to WTP (Lusk and Shogren 2007).

Thus, the optimal bid is when

$$y^* - y_A | y^* - y_B = 0. \quad (1)$$

Study Area and Sampling Design

The study was conducted in the last quarter of 2013, which is out of the bean-harvesting season. Gakenke district in Rwanda's Northern Province was chosen for the study's implementation because (1) it is one of the main bean-producing areas where iron bean varieties are targeted for introduction in the country, and (2) no delivery or marketing activities on iron beans had taken place in the district at the time of the study. The district has 19 sectors, and we applied a multistage cluster sampling procedure to select participating households. Four sectors were selected based on population density: Coko, Muyongwe, Karambo, and Mugunga. Given logistical considerations, one-fifth of all villages in each sector were

[3] This is quoted because no one is worse off in the end, and it does not mean that an individual lost.

randomly selected, and all households within the selected villages were listed. From the village household lists, participating households were randomly selected.

The total sample size was determined by the average treatment effect. Based on the results of previous studies on consumer acceptance of biofortified foods in Africa (for example, Chowdhury et al. 2011; Meenakshi et al. 2012), we assumed (1) an effect size of 6 percent (or 18 Rwandan francs (RWF))[4] as the minimum observable, (2) a lower or safe effect size of 5 percent (or RWF 15), and (3) that the effect size is normally distributed with RWF 60 as a maximum expected standard deviation. Treatments were randomized at the individual level. The result of power calculations (using a significance level of 5 percent and a power of 0.8) shows that with the assumed difference in the mean response of matched pairs and one-tailed test, a minimum of 89 participants per treatment was required for a 5 percent effect size assumption, while a minimum of 128 participants was required for a 6 percent effect size assumption. While a lower effect size assumption was applied in most cases, the 6 percent effect size assumption was applied in some cases, given the budget and logistical considerations (Table 1). The sampling consisted of 562 (plus an additional 10 for replacement)[5] farming households that were randomly drawn proportionate to size from the household list.

Table 1: Sample size by experimental group

Sample sizes	T1: Control	T2: Treatment	T4: Treatment	Total
	No information	"Gain frame" or positive information + listen *once*	"Loss frame" or negative information + listen *once*	
Sample size 1	128	128	128	384
		T3: Treatment	**T5: Treatment**	
		"Gain frame" or positive information + listen *three times*	"Loss frame" or negative information + listen *three times*	
Sample size 2		89	89	178

Empirical Strategy

Experimental design

To control for the effects of media advertising, we designed an experiment that would deliver product information using two different approaches. The first was message *frame*, whereby product information would be delivered in a "loss" or negative or "gain" or positive frame, and the second was advertising *frequency*, whereby consumers would listen to product information more or less frequently. The loss

[4] See Oparinde et al. (2016) for a detailed explanation of the power calculation.

[5] More households (a total of 583) were initially invited to participate, but 572 ended up participating in the study.

frame information is assumed to be "negative," because it emphasizes the negative consequences of not having enough iron in diets, while the gain frame information is assumed to be "positive," because it emphasizes the opposite. To examine the effects of the media advertising, participants were randomly allocated into a control group (T1) and four treatment groups (T2–T5). Group T2 listened *once* (on day 1) to a one-minute "gain frame" radio message about the *health benefits* of consuming iron bean varieties and of having *enough iron* in their diets, while T3 participants listened to the same "gain frame" message *three times* (once per visit on day 1, day 3, and day 5). In contrast, T4 participants listened *once* (on day 1) to the "loss frame" message about the iron bean varieties and the *consequences* of having *insufficient iron* in their diets, while T5 participants listened to the same message three times (once per visit on day 1, day 3, and day 5). The radio messages were in the widely spoken local language (Kinyarwanda), and were conveyed through MP3 players (see Appendix A for the English texts of the messages used). Participants in group T1 did not receive any information about the health benefits of consuming iron bean varieties or having enough iron in their diets.

Sensory evaluation of the three bean varieties (red mottled local, red HIB (HIB-A), and white HIB (HIB-B)) and the BDM experiment were conducted during four visits in seven consecutive days. Sensory evaluation protocols from food science literature were followed (Tomlins et al. 2007; Talsma et al. 2013). Raw grains for each bean variety were packed in 1-kilogram (kg) paper bags, and the order in which they were distributed was randomized across participants and across visits. While control group participants were not told which of the varieties is local and which is new, treatment group participants were given this information.

Estimates of WTP for the treatment groups were expected to suffer from information spillovers resulting from social interactions among participants. One way to potentially minimize such effects would be to use a cluster-randomized design, where randomization is done at the village level. However, since we aim to examine the effects of social interactions among participants within their village, we randomized at the household level in order to observe the endogenous social network effect. Even when this would allow us to estimate the social network effect, spillover of information from treatment group to control group is inevitable and will make the information effect difficult to estimate. Therefore, the study followed the option of randomizing at the household level, with a small time lag between control and treatment group interviews within each selected village.

The control group interviews were conducted in the first week, and treatment group interviews were randomized across four subsequent weeks. While this strategy assists in removing information spillover from treatment to control, there is still potential contamination as a result of experience sharing from control to treatment. However, since the control group was not given any varietal or nutritional information prior to the experiment, we expected any information flowing from the control to treatment groups to have an insignificant impact on the effect of media advertising. Meanwhile, the spillover of experience sharing from control to treatment would constitute a part of the social network effects. Subsequent to the random allocation of participants into experimental groups, the following procedure was followed in eliciting participant WTP for the bean varieties:

Day 1 (Collection of socioeconomic information and delivery of first variety): Participants were the household members older than 18 years of age who are mainly responsible for deciding which bean variety to purchase or cook for home consumption. Participants were informed ex ante that they would be asked to test three bean varieties and participate in a game to purchase one of the bean varieties. They were also informed that if they agreed to participate, they might "win" 1 kg of bean grains and must pay out of pocket to acquire it. Once the study was introduced with no information about improved varieties and participants agreed to participate in the study, their households were visited the next day (day 1—that is, the first visit). Participant- and household-level social and economic data were collected first. On the first visit (day 1), all participants were given 1 kg of raw grains of the first bean variety and were told that they would be revisited in 2 days (day 3). The one-day interval would give the participants sufficient time to cook, consume, and test the overnight keeping quality of the variety with other household members. Those participants allocated to the treatment groups were given information on an MP3 player.

Day 3 (Sensory evaluation and delivery of second variety): On day 3 (the second visit), participants were given 1 kg of raw grains of the second variety. Following this, each participant was asked to evaluate the sensory attributes (that is, color, raw and cooked bean sizes, taste, cooking time, overnight keeping quality, and ease of breaking) of the first bean variety on a seven-point Likert scale (that is, 7—like very much ... 1—dislike very much).[6] Participants allocated to the T3 and T5 groups were given information on an MP3 player.

[6] The sensory evaluation procedure and data are discussed in detail in an earlier paper.

Day 5 (Sensory evaluation and delivery of third variety): Similar to day 3, participants were asked to evaluate the sensory attributes of the second variety and were also given the third variety on day 5 (third visit). Participants allocated to the T3 and T5 groups were given information on an MP3 player.

Day 7 (Sensory evaluation of third variety and BDM experiment): On the final visit (day 7), participants were first asked to evaluate the sensory attributes of the third variety. Subsequently, the BDM experiment was conducted to elicit participant WTP for each of the three varieties. Before participants were asked to state their WTP for each variety, they were introduced to the experiment. The instructions emphasized the possibility of a participant buying one of the varieties evaluated and paying out of pocket. Enumerators explained to the participants that their optimal strategy was to state a bid equal to their true WTP for each of the three varieties. Using numerical examples, they demonstrated to the participants that stating a bid higher than their true WTP could result in having to buy the beans at a price higher than what they were willing to pay, whereas stating a bid lower than their true WTP could result in losing a profitable opportunity to buy. Participants were then told about the distribution of prices from which the random (competing) price was to be drawn, after which they were taken through a practice round with biscuits, to familiarize them with the instructions. As the answers to the follow-up questions in the practice rounds suggested that the participants understood the game instructions, there was no reason for us to suggest that the BDM experiment might have been limited by game form recognition failures (Cason and Plott 2014).

Next, the participants were asked to state separate bids (their WTP) for 1 kg of each variety evaluated. They were then asked to randomly draw a chip corresponding to the "binding" variety. For this binding variety, each participant was asked to draw a sale price by randomly selecting a price strip from a bag that contained 16 price strips with a uniform distribution (RWF 250, 300, 350, 450, …, 1,050) around the prevailing market price of the local variety. If the participant's stated WTP for this binding variety exceeded or matched the sale price drawn, the variety was sold (that is, the participant would "win" 1 kg of bean grain of this variety), and the participant would pay a price equal to the sale price out of pocket; if the sale price was higher than the stated WTP, the variety was not sold.

Apart from immediate payment out of pocket, participants were also given the option of purchasing on credit at a zero percent interest rate. These participants were asked to specify a payment date, and were instructed to pay the amount owed to the farmers' leader in their community, who would remit the money to the study team via mobile money transfer. A payment contract agreement was signed between the participant and the enumerator. All credits were effectively collected. Participants only became aware of the credit option after the BDM experiment was completed, and once they declared their inability to pay out of pocket.

Measurement of social networks

Two main approaches could be used in measuring social networks in this study: full network or sampled network (Hanneman and Riddle 2005). The first approach, which would be ideal, involves collecting data about all the farmers and other people to whom each participant is linked. Despite its theoretical appeal, this approach posed serious challenges for our study, such as the difficulty in tracing all of a participant's possible network links (Handcock and Gile 2010) and the resources needed (time and funds) to carry out such an exercise (Bramoullé, Djebbari, and Fortin 2009). The second approach, which is much more common in empirical studies, involves studying only part of the network and using data gathered to make generalizations about the real network. Santos and Barrett (2008) discuss sampling methods in detail.

In this study, we followed the sampling approach used by Tatlonghari et al. (2012) and Cai, De Janvry, and Sadoulet (2015). We asked each participant (*ego*) to name a maximum of 10 people who are important to him or her in bean farming and marketing (known as *alters*). These were people who provide the ego with information regarding such issues as planting beans, choosing the variety to plant, using pesticides, working on the farm, selling beans, and any other challenges in bean farming and marketing. The advantage of this approach is that participants were most likely to mention network members to whom they are strongly linked—hence, those with significant impact in terms of social learning and influence (Bandiera and Rasul 2006).

Using the information provided by participants, we constructed a measure of social network size for exchange of information on bean farming (network degree), equal to the number of mentioned individuals. There were no restrictions regarding the people mentioned as network members, and it was possible for a respondent to belong to several social networks. Further, the participants were asked some questions about the characteristics of the named alters, such as age, education level, social status, landholding, and where they reside. These were deemed necessary for characterizing the networks. To assess exchange of bean information through their social networks, participants were asked to state if they discussed the HIB experiment with other farmers, the number of farmers they discussed it with, and where discussions took place.

Econometric Framework

To determine the effect of social networks effects on farmer WTP for biofortified HIBs, we controlled for a number of variables hypothesized to influence farmer access to product information or purchase decisions. This was accomplished by running the following regression:

$$D_i = \alpha + \beta' S_i + \varphi' T_i + \gamma' X_i + e_i \quad (2)$$

where for each participant *i*, *D* is the WTP measured in RWF; S is the social network size represented by network degree—the number of farmers with whom the participant discusses bean farming and marketing issues; *T* is a vector of experimental variables defined as treatment groups (T1—T5) in Section 2.3; *X* is a vector of participant characteristics, such as age, sex, education level, and demographic and other household characteristics; α, β, φ, and γ are parameters to be estimated; and *e* represents a normally distributed error term.

Since sensory evaluations were conducted on three occasions for each participant, it is reasonable to expect some correlation among the three WTP values; hence, estimating WTP separately for each bean variety would be biased. To circumvent this, we used two approaches. First, we estimated equation (2) using a panel data model (random effects). The second approach involved defining the WTP for HIBs in terms of a premium above the local bean variety—by differencing the WTP values. While a participant's WTP for HIBs may be correlated with that for the local variety, differenced WTP is free of unobserved factors that may jointly influence the two WTP measures. The variables used in the empirical model together with their descriptive statistics are shown in Table 2.[7]

Table 2: Definition and descriptive statistics of variables used in econometric models

Variable	Definition	Mean (N=524)	Std. dev.	Min.	Max.
Treated	Received radio message on iron and high iron beans (1=yes, 0=no)	0.78	0.41	0.0	1.0
T1	Control group (1 if in this group, 0 otherwise)	0.22	0.41	0.0	1.0
T2	Gain frame information, listen once (1 if in this group, 0 otherwise)	0.23	0.42	0.0	1.0
T3	Gain frame information, listen thrice (1 if in this group, 0 otherwise)	0.17	0.38	0.0	1.0
T4	Loss frame information, listen once (1 if in this group, 0 otherwise)	0.23	0.42	0.0	1.0
T5	Loss frame information, listen thrice (1 if in this group, 0 otherwise)	0.15	0.36	0.0	1.0
hiba_early	HIB-A was evaluated earlier than local variety (1=yes, 0=no)	0.52	0.50	0.0	1.0
hibb_early	HIB-B was evaluated earlier than local variety (1=yes, 0=no)	0.38	0.49	0.0	1.0
beannet	Bean network size (no. of members)	3.31	1.79	0.0	10.0
beanvill1	Intravillage bean network size (no. of members)	2.44	1.70	0.0	10.0

[7] The sample size used here and in successive analyses excludes participants with some missing data.

beanvill0	Intervillage bean network size (no. of members)	0.85	1.14	0.0	7.0
visitsmkt	Number of visits to the nearest market in the last one week	0.80	1.13	0.0	7.0
sectpop	Population of respondent's sector (thousands)	16.2	2.63	12.2	19.3
agevill	Mean age of participants in respondent's village (years)	44.1	3.64	38.1	51.0
gendrespo	Gender of respondent (0=female, 1=male)	0.46	0.50	0.0	1.0
agerespo	Age of respondent (years)	44.1	15.8	17.0	94.0
yrseduresp	Respondent's years of formal education	3.52	3.14	0.0	15.0
Hhsize	Size of respondent's household (no. of members)	4.52	1.80	1.0	12.0
Nopay	Participant's bid won but participant did not pay, or lost but participant would not have paid even if the bid won	0.11	0.31	0.0	1.0
beanhmkg	Quantity of beans respondent has at home during interview (kg)	3.32	10.6	0.0	100.0
ownland	Land owned by household (acres)	1.71	12.1	0.0	253.0
incsources	Number of respondent's sources of income	2.29	0.71	0.0	4.0
radio	Household has at least one radio (1=yes, 0=no)	0.62	0.49	0.0	1.0
celphon	Household owns a cell phone (1=yes, 0=no)	0.45	0.50	0.0	1.0

Potential endogeneity in social networks

Endogeneity is a common concern in social network analysis (Fafchamps and Minten 2002). Since participants' social networks are self-reported, the variable S in equation (2) is likely to be endogenous, because social network size and WTP may be determined by the same or correlated unobserved factors. For example, while some very sociable farmers may attract more social network ties, they may also have a higher proclivity for new technologies and, hence, a higher WTP for HIBs. Another challenge when identifying peer effects is the uncertainty as to whether the average behavior of a social network affects the behavior of an individual network member, or whether the reverse is also true—a phenomenon Manski (1993) terms a "reflection problem." For instance, it could be argued that while bean network characteristics may influence a farmer's demand for beans, an individual farmer's demand for beans may in turn shape the characteristics of the bean network of which the farmer is a member. This is a typical case of simultaneity, a well-known cause of endogeneity.

Granted that S in equation (2) is endogenous, the effects estimated will be biased and difficult to interpret (Antonakis et al. 2014). We tested for possible endogeneity using an instrumental variables (IV) approach, which we discuss more in the results section. Assuming that endogeneity was present, it can be hypothesized that the social network size in equation (2) is determined by the following equation:

$$S_i = \delta + \pi' Z_i + \theta' T_i + \rho' X_i + \mu_i \quad (3)$$

where, Z is a vector of instruments—variables that are significantly correlated with S when the effects of T and X are netted out, but not correlated with the error term (e_i) in the WTP model shown in equation (2) (Wooldridge 2010). The term μ is a normally distributed error, while the rest of the variables are as defined in equation (2).

In our search for suitable instruments, we identified the population of the respondent's sector, the number of visits to local markets in the experimental week, and the mean age of participants in the respondent's village, as potential instruments, Z. It was hypothesized that the sector population was unlikely to be directly correlated with WTP for bean varieties, but could determine network formation. Similarly, visiting the local markets may be correlated with the number of other farmers a participant meets and contacts made—hence, social network formation; but this should not be directly correlated with WTP. Moreover, the mean age of farmers in a village is indicative of the duration they have lived in the village, which could determine the characteristics of the networks formed, but it is reasonable to assume that it does not directly affect one's WTP.

3. RESULTS

Characteristics of Social Networks in Gakenke

Characteristics of the network size are shown in Table 3. On average, each farmer discusses bean farming and marketing with about four people (network size of 3.4), but a small proportion (11.2 percent) of the farmers did not have any social network for bean farming (social isolates). The bean network size did not differ significantly across the treatment groups, indicating a random distribution of the network size among the experimental groups. About 2.4 social network members (73 percent of the network) were found within the respondent's village, implying that most discussions about bean farming and marketing occur within rather than across villages.

Table 3: Distribution of network size across treatments (mean values)

Treatment	Total network size	Intravillage network size	Intervillage network size
T1	3.5	2.4	1.0
T2	3.2	2.3	0.9
T3	3.1	2.4	0.7
T4	3.2	2.4	0.8
T5	3.5	2.7	0.8
Sample	**3.3**	**2.4**	**0.9**

Further network characteristics are shown in Table 4. We find that the network size did not differ much by education status. On average, 1.7 members (about 50 percent of the network size) had the same education level as the respondent. However, the network composition differed with respect to social status and wealth. An average social network consisted of 2.2 members (65 percent of the network) with a higher social status than the respondent and 1.8 members (60 percent of the network) possessing more land (a proxy for farmers' wealth) than the respondent. This shows that farmers in Gakenke tend to seek bean-farming and marketing information from other farmers whom they consider to be of higher social status or wealthier than they are. This may be so because members of the society who are wealthier have more access to new farming information (Koskei et al. 2013), apply better farming methods, and command more respect within the communities than the "average" members. The social network consists of a higher number of members who are younger or older than the respondent. Similarly, a respondent's network has more members with smaller or larger households than those with the same household size. These results imply that farmers are more likely to form bean-farming networks with older or younger counterparts, and those with smaller or larger households than theirs. Moreover, the number of relatives and members of the same farmers' group in a respondent's network does not exceed one-third, implying that farmers form networks mostly outside their kinship and group circles.

Table 4: Characteristics of social networks

Variable	Comparison with respondent	Mean number of network members
Education level	Same	1.6
	Different	1.7
Social status	Same	0.6
	Lower	0.6
	Higher	2.2
Land size	Same	0.3
	Less	0.9
	More	1.8
Age	Same	0.4
	Younger	1.4
	Older	1.4
Household size	Same	0.3
	Smaller	1.3
	Larger	1.6
Relationship	Relative	1.2
Group membership	Same	0.3

Information Flows through Social Networks

Participants were asked whether they discussed the study with anyone, and the setting in which the discussions occurred. These results are shown in Table 5. Over the one-week experimentation period, 53 percent of the participants had discussed the study with other members of the community. This shows the high speed with which social networks can disseminate information about new products in a rural community. The proportion of farmers who discussed the experiment with others was significantly higher in the treatment than control groups, except for treatment group T4. However, among the treatment groups, the proportion of participants who discussed the experiment did not differ significantly. That the least discussion occurred in the control group is not surprising, because the group was the first to participate in the experiment and did not receive any nutritional information about the bean varieties they evaluated. This result shows some evidence to support market maven behavioral tendencies among farmers—the perceived obligation and pleasure in sharing information, and the desire to inform others (Walsh, Gwinner, and Swanson 2004). Discussions about the experiment were mostly face to face, rather than over the phone, and seemed to have happened at a more personal level than in public settings. At the sample level, the most important settings for discussions were along the way when farmers met (39 percent of respondents) and at farmers' homes (38 percent of respondents). The least-used discussion forums were ceremonies, places of work, and farmers' group or cooperative meetings. The findings on discussion settings are plausible: people are likely to be busy with other agenda at public forums.

Table 5: Levels and settings of discussions about the HIB experiment (% of respondents)

Variable	**Sample**	**Treatment group**				
		T1	T2	T3	T4	T5
Respondent discussed the study with someone	53.4	42.6	59.8***	56.2**	50.8	60.0***
Setting for the discussion						
Along the way	39.3	42.9	32.9	48.0	45.0	29.2
At home	38.2	28.6	47.9	34.0	35.0	41.7
Village/community meeting	8.2	4.1	9.6	8.0	11.7	6.3
At the village, sector or town market	7.9	6.1	6.8	8.0	5.0	14.6
At the church	6.4	12.2	8.2	4.0	3.3	4.2
At a farm or field (while gathering animal fodder)	3.9	6.1	1.4	4.0	5.0	4.2
Over a the phone	3.6	8.2	2.7	4.0	1.7	2.1
At a cooperative or farmer's group meeting	2.1	2.0	2.7	0.0	3.3	2.1
At the place of work	1.8	2.0	2.7	0.0	3.3	0.0
At a ceremony	1.4	0.0	0.0	6.0	1.7	0.0

Note: ** and *** = significantly higher than control at 5% and 1% levels, respectively, following a t-test.

Characteristics of Participant WTP for Beans

The descriptive characteristics of WTP for bean varieties are shown in Table 6. Participants were willing to pay between RWF 150 and RWF 1,000 for 1 kg of bean varieties tested. The mean WTP of RWF 433 was less than the market prevailing price of beans (mean: RWF 540; range: RWF 240–750) by about RWF 107 (19.8 percent). In addition, the mean WTP was lower by 8–12 percent for the treatment groups compared with the control group. Pairwise comparisons using t-tests show that the differences were significant at a 1 percent level. A possible explanation for this rather surprising result is that the treatment group participants were informed by those in the control group that, if their bids won, they would have to pay for the beans, prompting them to lower their bids. This points to the potentially significant impact of social networks on consumer valuation of HIBs. Analysis of variance showed that the differences in WTP among the treatment groups were insignificant, suggesting that information frame and frequency may not significantly affect WTP. Further, sensory evaluation data on participants' preferences for the beans' attributes reveal that participants in the treatment and control groups rated all the sensory attributes of the HIB-A variety the highest, followed by the local variety, while HIB-B was liked the least (Oparinde et al. 2016, 16).

Table 6: Descriptive statistics for willingness to pay

Variable	Willingness to pay (RWF)			
	Mean	Standard deviation	Min.	Max.
Sample	432.9	124.7	150	1,000
Treatment				
T1	470.3	134.5	200	1,000
T2	430.8 (–8.4)***	119.0	200	1,000
T3	416.1 (–11.5)***	125.8	150	1,000
T4	414.4 (–11.9)***	113.4	150	1,000
T5	428.2 (–9.0)***	122.5	200	1,000
Variety				
Local	425.4	112.3	150	900
HIB-A	488.5 (14.8)***	116.8	250	1,000
BHI-B	384.8 (–9.5)***	122.3	150	800
Sensory evaluation round				
Round 1	442.3	125.9	150	1,000
Round 2	438.2 (–0.9)	128.4	200	1,000
Round 3	418.1 (–5.5)***	118.3	150	800

Note: Figures in parentheses are the percentage difference between this mean value and that of the first category (T1, local variety, or round1).

Sensory evaluation round refers to the time participants evaluated the bean varieties, whereby round1 is the first time (experiment day 3), round2 is the second time (day 5), and round3 is the third time (day 7).

*** = difference is significant at a 1% level, following a t-test.

WTP differed significantly by bean variety. Participants were willing to pay about RWF 63 more (15 percent) for HIB-A, but about RWF 41 less (10 percent) for HIB-B, compared with the local variety. If the WTP reflects participants' valuation of bean biofortification, then it implies that consumers would not perceive all improvements in grain nutritional content to add value. These results support Pillay et al. (2011), who showed in a sensory evaluation study in South Africa that high school students and adults preferred a popular non-biofortified commercial maize variety to the three pro-vitamin A-biofortified maize varieties tested. Interestingly, we find that WTP decreased over time. The mean WTP values for bean varieties evaluated on the second and third visits (days 5 and 7) were less by about RWF 4 (1 percent) and RWF 24 (5.5 percent), respectively, compared with that of varieties evaluated on the first visit (day 3). This implies that regression analyses ought to incorporate a dummy to control for time trend.

Next, we examine WTP as a premium—that is, the extra amount (RWF) participants were willing to pay for each of the HIBs above the cost of the local bean variety. The results are shown in Table 7. On average, the consumer WTP premiums compared with the local variety were RWF 63 for HIB-A and RWF –41 for HIB-B. Pairwise comparisons show significant differences in WTP premiums for HIB-A among all groups provided with nutritional information and the control group. For HIB-B, however, only the groups provided with more frequent information (three times) reported a significantly higher WTP premium than the control group, irrespective of the information framing. These results indicate that provision of information about the benefits of HIBs increased the WTP premium, more so for the HIB-A variety. Another interesting observation is that if the HIB varieties were evaluated before the local variety, then the mean WTP premium was significantly higher; hence, we control for this order in regression analyses.

Table 7: Descriptive statistics for willingness to pay premium

Variable	WTP premium for HIB-A (RWF)				WTP premium for HIB-B (RWF)			
	Mean	Standard deviation	Min.	Max.	Mean	Standard deviation	Min.	Max.
Sample	63.1	91.1	–400	500	–40.6	104.5	–350	300
Treatment								
T1	30.9	98.1	–400	200	–49.8	114.5	–350	300
T2	65.2***	87.1	–200	300	–45.7	95.8	–300	200
T3	79.6***	87.5	–200	400	–30.6*	92.9	–200	200
T4	61.8***	88.4	–100	500	–46.9	110.5	–300	300
T5	89.9***	82.2	–150	500	–21.5**	104.5	–250	300
Variety evaluated first								
Local	54.8	92.8	–400	500	–47.0	100.6	–300	300
HIB	70.7**	88.9	–200	500	–30.1**	110.2	–350	300

Note: *, **, and *** = difference between this value and that of the first category (T1 or Local variety) is significant at 10%, 5%, and 1% levels, respectively, following a t-test.

Results of Endogeneity Tests

Equations (2) and (3) were estimated in a two-stage least-squares (2SLS) framework. Using the WTP premium as the dependent variable, the endogeneity of the bean information network size was tested in the models for HIB-A and HIB-B varieties. (More details are provided later in Table 10.) Robust standard errors were used to correct for possible heteroscedasticity; hence, the Wooldridge (1995) score tests were applied (StataCorp 2013, 948). The results in Table 8 show that, in both models, the test score was above 6.5 and the p-value was about 0.01. Hence, the test rejected the null hypothesis that bean network size was exogenous. We then tested the three instruments used for suitability as stated in equation (2). Staiger and Stock (1997) recommend that for one endogenous variable, instruments are strong if the F-value of the first-stage regression is 10 or greater. Our results show first-stage F-values greater than 60, which are highly significant, implying that the instruments were strong. In addition, the correlation of each instrument with the social network size was significant. Since we use more than one instrument, we tested for overidentifying restrictions, which is whether excluded instruments are valid (uncorrelated with the error term and correctly excluded from the estimated equation). The Wooldridge (1995) statistics were insignificant, implying that the instruments were uncorrelated with the error term and, thus, were valid. These results show that our endogeneity tests were valid. Full results are shown in Table 10, models (4) and (8).

Table 8: Endogeneity test results

Null hypothesis	WTP Premium (HIB-A)			WTP Premium (HIB-B)		
	Test statistic	P-value	Decision	Test statistic	P-value	Decision
H_0: Bean network size is exogenous	6.37	0.012	Null rejected	6.71	0.010	Null rejected
H_0: Instruments are weak (first stage F<10)	57.48	0.000	Null rejected	56.22	0.000	Null rejected
H_0: Excluded instruments are uncorrelated with error term	2.38	0.305	Null not rejected	4.59	0.101	Null not rejected

Determinants of WTP for HIBs

Following the conclusion that bean network size is endogenous, assessing the determinants of WTP as shown in equation (2) requires a special estimation procedure. Bramoullé, Djebbari, and Fortin (2009) suggest three methods than can be used to address the endogeneity of social networks when investigating social effects: randomized lab experiments, use of panel data methods that track the dynamics of social networks, and use of instrumental variables (IV) methods. In this study, we used the 2SLS IV method, based on available data. Two approaches were then used: (1) estimating absolute WTP via random effects IV models by linear methods, and (2) using linear IV models with a WTP premium as the dependent variable. The results of this analysis are shown in Tables 9 and 10. For comparison, we present the results of non-IV linear regressions (random effects and ordinary least squares models) in Appendix B as Tables B1 and B2.

We first discuss the results of the random effects models shown in Table 9. In the first set of results (models 1 and 2), the radio message was modeled as a binary variable, while the second set of results (models 3 and 4) presents the full set of radio message dummies described in the experimental design (Section 2.2). The results show that social networks negatively and significantly affected farmer WTP. However, interactions between bean network and bean varieties reveal that the social network effect depended on the bean variety. Having an additional member with whom to discuss bean-farming issues increased WTP for HIB-A by about RWF 19 (4.5 percent), but decreased WTP for HIB-B by about RWF 27 (6.4 percent), compared with the local variety. This effect remained fairly constant, even after controlling for the socioeconomic characteristics of respondents.

Models 1 and 2 of Table 9 show that participants provided with radio messages containing nutritional and variety information (treatment group) reported generally lower WTP than those not provided such information (control group). As stated earlier, we hypothesize that the treatment group participants may have lowered their WTP after learning from the experiences of the control group participants. While the provision of a radio message had an overall positive effect on WTP for both HIB varieties compared with the local variety, this effect was significant only in the case of HIB-A, for which participants were willing to pay RWF 45 (10.6 percent) more. Generally, the WTP for HIB-B did not differ from that for the local bean variety after media advertising was provided. This result is consistent with that of Birol et al. (2015), who reported insignificant difference in WTP for a biofortified and local bean variety in Guatemala, even after providing consumers with information on the nutritional superiority of the biofortified variety tested.

Table 9: Random effects IV regression results for determinants of willingness to pay

Variable	Bean network + radio message dummy		Bean network + radio message in different frames & frequencies	
	Model (1)	Model (2)	Model (3)	Model (4)
Beannet	–43.86***	–35.87**	–18.36***	–14.50**
	(15.99)	(15.45)	(6.76)	(7.11)
Beannet X HIB-A	18.90**	18.91**	18.73**	18.72**
	(8.21)	(8.20)	(8.25)	(8.25)
Beannet X HIB-B	–26.95***	–26.94***	–27.27***	–27.28***
	(8.21)	(8.21)	(8.25)	(8.25)
Treated	–185.54***	–154.25**		
	(64.77)	(62.12)		
Treated X HIB-A	45.15***	45.15***		
	(12.22)	(12.22)		
Treated X HIB-B	4.71	4.72		
	(12.23)	(12.23)		
Beannet X Treated	33.85*	28.69		
	(18.46)	(17.56)		
T2 X HIB-A			38.75**	38.75**
			(15.10)	(15.09)
T2 X HIB-B			–5.45	–5.45
			(15.12)	(15.12)
T3 X HIB-A			55.99***	55.99***
			(16.45)	(16.45)
T3 X HIB-B			9.25	9.25
			(16.47)	(16.47)
T4 X HIB-A			35.20**	35.20**
			(15.15)	(15.15)
T4 X HIB-B			–5.52	–5.52
			(15.17)	(15.16)
T5 X HIB-A			57.22***	57.22***
			(16.70)	(16.70)
T5 X HIB-B			29.16*	29.16*
			(16.68)	(16.68)
T2 (Gain-frame, once)			–56.70***	–44.51***
			(15.64)	(15.53)
T3 (Gain-frame, thrice)			–83.88***	–68.26***
			(17.03)	(16.93)
T4 (Loss-frame, once)			–71.31***	–56.42***
			(15.73)	(15.80)
T5 (Loss-frame, thrice)			–69.84***	–54.98***
			(17.38)	(17.33)
HIB-A	–34.14	–34.20	–33.59	–33.57
	(30.42)	(30.42)	(30.57)	(30.57)
HIB-B	45.75	45.69	47.09	47.12
	(30.42)	(30.42)	(30.56)	(30.56)
Round2	–6.36	–6.37	–6.42	–6.42
	(5.11)	(5.11)	(5.13)	(5.13)
Round3	–6.49	–6.49	–7.40	–7.40
	(5.15)	(5.15)	(5.18)	(5.18)
Nopay		68.04***		71.42***
		(15.21)		(14.47)

Gendrespo		5.24		6.28
		(9.02)		(8.73)
Hhsize		2.08		2.03
		(2.47)		(2.40)
Agerespo		0.06		–0.01
		(0.31)		(0.29)
Yrseduresp		3.19**		3.02**
		(1.59)		(1.53)
Beanhmkg		–0.33		–0.30
		(0.44)		(0.42)
Maxprice		0.02		0.02
		(0.03)		(0.03)
Ownland		0.69*		0.66*
		(0.36)		(0.35)
Incsources		5.10		7.14
		(7.16)		(7.01)
Radio		3.88		4.59
		(9.75)		(9.45)
Celphon		3.45		0.73
		(10.24)		(9.78)
Constant	633.00***	534.93***	544.36***	458.23***
	(57.07)	(60.18)	(26.38)	(38.15)
N	1572	1572	1572	1572

Note: Figures in parentheses are standard errors. * = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$.

These results imply that media advertising may not always increase demand for a product: customer experience with the product may play a much bigger role. About 86 percent of treatment participants mentioned HIB-A as their favorite HIB variety, compared with 14 percent who reported HIB-B as their favorite variety. The results for social networks show that interpersonal communication can be used to influence the demand for a new product that farmers perceive to be superior. Similarly, media advertising significantly increases new product demand only if consumers deem the product as superior to others. This supports the argument by Kotler and Armstrong (2012) that product advertising will cause a change in consumer behavior only if consumers believe they will benefit, for instance, from better quality or features, by switching to the advertised product. On the other hand, for a product perceived to be of lower quality, social networks influence the demand negatively. Given that one-time radio messaging did not affect WTP for HIB-B but more frequent “negative-frame” messaging did, we argue that intensive advertising may help to boost the demand for a less popular product. Moreover, intensive advertising may cushion product demand from the effects of the negative word-of-mouth messages emanating from social networks, but this requires further investigation.

The effect of the radio message provision on WTP for HIB varieties becomes clearer when the treatment group is disaggregated in models 3 and 4 (Table 9). We find that each of the treatments had positive effect on WTP for HIB-A compared with the local variety, but no significant effect on WTP for HIB-B, except for treatment T5, which was only weakly significant. The differences in coefficients on interacted variables were not significant, implying that, generally, neither information frame nor frequency had a significant effect on WTP. However, this is slightly different when the WTP premium is investigated further in Table 10.

To corroborate the above results, we estimated the effect of social networks and radio messages on each of the two HIB varieties separately (Table 10). Since the WTP for the two varieties may be correlated, the dependent variable used was a differenced measure—the WTP premium. For each HIB variety, the WTP premium was computed by subtracting participants' WTP for the local variety from their WTP for the HIB variety. Linear IV methods were used in this analysis, and the first-stage results are also presented for comparison. The results in models (1) and (5) show that network size has significant effects on WTP. As shown in models (3) and (7), the significance of these effects did not diminish when other control variables were added.[8] In particular, social network size positively influenced the WTP premium for HIB-A, but was negatively correlated with the WTP premium for HIB-B. Having an extra bean network member increased a participant's WTP premium for HIB-A by about RWF 11–15, but decreased the WTP premium for HIB-B by about the same amount (RWF 15–16). This means that an additional bean network member increased WTP by 2.6–3.6 percent for HIB-A, but decreased WTP for HIB-B by 3.5–3.9 percent, compared with the local variety. These coefficients are smaller those than of the random effects model above, but the qualitative results are similar. This finding supports our earlier proposition that since the literature on product marketing argues that word-of-mouth messages conveyed through social networks can be both positive and negative, the effects of social networks on purchase decisions could also be positive or negative. It further resonates with earlier studies showing negative social network effects for products deemed inferior, as consumers express their dissatisfaction with the products (Kremer and Miguel 2007; Edison and Geissler 2011).

[8] Non-IV methods yield smaller and insignificant coefficients, as shown in Tables A1 and A2. The qualitative conclusions also differ, implying that by assuming the exogeneity of social networks, we would fail to detect the effect of network degree on WTP.

Table 10: Linear IV regression results for determinants of WTP premium

Variable	HIB-A				HIB-B			
	Bean network + radio messages	First-stage regression	Bean network, radio messages, + controls	First-stage regression	Bean network + radio messages	First-stage regression	Bean network, radio messages, + controls	First-stage regression
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Beannet	11.06**		15.20***		–16.41***		–14.80**	
	(4.33)		(5.10)		(5.02)		(5.77)	
T2	37.50***	–0.31	36.69***	-0.27	–0.59	–0.31	0.33	–0.26
	(12.33)	(0.20)	(12.17)	(0.19)	(14.18)	(0.20)	(14.33)	(0.20)
T3	52.82***	–0.29	59.77***	–0.28	13.12	–0.29	16.15	–0.28
	(13.22)	(0.21)	(13.31)	(0.21)	(15.15)	(0.21)	(15.09)	(0.21)
T4	33.76***	–0.22	38.94***	–0.29	–1.36	–0.22	–1.41	–0.29
	(12.61)	(0.22)	(13.44)	(0.21)	(15.05)	(0.22)	(15.55)	(0.22)
T5	58.45***	–0.04	60.62***	–0.03	29.16*	–0.04	31.17*	–0.02
	(13.28)	(0.25)	(13.08)	(0.26)	(16.20)	(0.25)	(16.53)	(0.26)
riba_early			15.77**	0.06				
			(8.02)	(0.13)				
ribb_early							15.60	–0.02
							(9.80)	(0.14)
Nopay			25.57	–0.54**			3.90	–0.53**
			(17.99)	(0.25)			(18.61)	(0.22)
Gendrespo			–23.32***	0.31**			2.50	0.32**
			(8.32)	(0.13)			(9.32)	(0.13)
Hhsize			4.25*	0.03			2.04	0.03
			(2.26)	(0.04)			(2.42)	(0.04)
Agerespo			–0.35	0.00			0.26	0.00
			(0.26)	(0.00)			(0.31)	(0.00)
Yrseduresp			0.46	0.05**			3.52**	0.05**
			(1.37)	(0.03)			(1.75)	(0.03)
Beanhmkg			–0.05	0.00			0.33	0.00
			(0.22)	(0.00)			(0.40)	(0.00)
Ownland			0.32*	–0.0			–0.12	–0.00
			(0.19)	(0.00)			(0.10)	(0.00)
Incsources			–10.26	0.37***			3.97	0.37***
			(6.79)	(0.10)			(7.53)	(0.10)
Radio			–16.87*	0.19			1.25	0.19
			(8.71)	(0.14)			(10.08)	(0.14)
Celphon			–6.56	0.12***			–9.79	0.12
			(8.93)	(0.15)			(10.40)	(0.15)
Sectpop		–0.33***		–0.31***		–0.33***		–0.31***
		(0.02)		(0.02)		(0.02)		(0.02)
Visitsmkt		0.18***		0.10*		0.18***		0.10*
		(0.05)		(0.06)		(0.05)		(0.06)
Agevill		0.09***		0.08***		0.09***		0.08***
		(0.02)		(0.02)		(0.02)		(0.02)
_cons	–7.68	4.66***	7.14	3.45***	7.39	4.66***	–45.66	3.49***
	(17.25)	(0.89)	(25.55)	(1.00)	(21.24)	(0.89)	(31.34)	(1.01)
N	524	524	524	524	524	524	524	524
First-stage F		65.01		57.48		65.01		56.22
		(p=0.00)		(p=0.000)		(p=0.00)		(p=0.00)
Over-identification test score (Chi2)		4.02 (p=0.13)		2.37 (p=0.30)		4.26 (p=0.12)		4.59 (p=0.10)
Wooldridge (1995) test score (Chi2)		4.92 (p=0.03)		6.37 (p=0.01)		10.46 (p=0.00)		6.71(p=0. 01

Note: The dependent variable for models (1), (2), (4), and (5) is the WTP premium. For first-stage regressions, the dependent variable is the bean network size. Figures in parentheses are standard errors. * = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$.

The effects of treatments T2–T5 are very close to those estimated by the random effects IV method. For the HIB-A models (1 and 3), Wald tests failed to reject the hypothesis that coefficients on all treatment coefficients are equal. However, pairwise tests on the coefficients showed weakly significant differences between the T2 and T3 and the T4 and T5 coefficients, but not on those of T2 versus T4 and T3 versus T5, implying that information frequency may have a larger effect on the WTP premium than the information frame. For the perceived inferior product (HIB-B), only T5 has a significant effect on the WTP premium (models 5 and 7). Wald tests rejected the hypothesis that all coefficients are equal at the 10 percent level of significance, meaning that information framing or frequency, or both, significantly affected the WTP premium. Tests on coefficient pairs revealed a significant difference only between T4 and T5, meaning that the frequency of information positively influenced the WTP premium when the information frame was negative.

Findings from the WTP premium estimations corroborate those from the random effects estimation of the absolute WTP. The results support the argument that media channels and social networks complement each other to produce positive marketing outcomes (Keller and Fay 2012; Iacobucci and Hoeffler 2016). However, the results also demonstrate that this complementarity holds only for products that customers perceive to be of superior quality. Hence, media advertising cannot be a substitute for a good-quality product because its effect on the demand for the inferior product can be suppressed by social networks. Meanwhile, the results suggest that an intensive campaign using negatively framed information has a potential to increase the demand for an inferior product.

Other determinants of WTP

Several experimental and socioeconomic characteristics of respondents also influenced WTP, but these were more significant for HIB-A than HIB-B (Table 10). The order in which varieties were tested mattered for HIB-A. Participants' WTP was about RWF 16 (25 percent of the WTP premium for HIB-A) more if they tested HIB-A before the local variety. The WTP premium of female participants for the HIB-A was about RWF 23 (44 percent) higher than that of men, perhaps because of women's understanding of the importance of iron in their diets and the diets of young children. However, WTP did not differ significantly by gender for HIB-B. Household size also influenced WTP, but this was significant only for the HIB-A variety. This may be associated with the higher nutritious food requirements for larger households. The number of years of formal education influenced WTP for HIB-B. This may be related to the cognitive ability of the more educated farmers, which enabled them to understand the benefits of iron in their diets and of HIB technology, notwithstanding its other attributes that may have been perceived as inferior. Finally, the size of land owned by a participant positively influenced WTP for the HIB-A variety. Farmers owning larger areas of land are considered to be wealthier and, hence, may be willing to pay more for the preferred bean variety.

Determinants of Social Network Size

The results of this analysis are presented as first-stage regressions of all models in Table 10 above. Since social network data were collected only once, we discuss the determinants of network size from the linear IV models, rather than from panel data models shown in Table 9. The results show that social network size did not vary by treatment, implying that allocation of participants to treatments was fairly random with regard to the social networks.

As expected, social network size was significantly correlated with the three variables used as instruments: the population of respondent's sector, the respondent's number of visits to local markets, and the mean age of farmers in the respondent's village. While the negative correlation between sector population and social network may be surprising, we hypothesize that sectors with a high population may be more urbanized, in which case their social ties may be weaker than those of the less urbanized sectors (Hofferth and Iceland 1998; Beaudoin and Thorson 2004). Gender played a role in determining the size of social networks. Male farmers had significantly larger networks that their female counterparts. This finding is consistent with that of Tatlonghari et al. (2012), who report larger social networks for men in Indonesia. Another finding is that social network size was positively correlated with the respondent's years of formal education. The result is consistent with the finding by Fafchamps and Minten (2002) that the network size of traders in Madagascar increased with their years of education. This may be a result of the number of contacts established while schooling, which is expected to grow with the number of years spent in school. Farmers' wealth also seems to determine their network size. Participants who were unable to pay for their bids (which can largely be attributed to low purchasing power) also reported smaller bean networks. Such participants may be unable to afford resources for establishing or sustaining large social networks. Last, farmers who owned mobile phones had larger social networks. This seems plausible, as the farmers can communicate with more people than those without a cell phone.

4. CONCLUSIONS AND IMPLICATIONS OF THE STUDY

Micronutrient deficiency, including iron deficiency, is a major public health problem that affects about two billion people around the world. Biofortified HIBs containing higher levels of iron than existing bean varieties have been developed to alleviate iron deficiency among bean-consuming populations. Information on the attributes and benefits of biofortified beans is a key determinant of their acceptance and consumption by farmers and consumers. Social networks may complement "traditional" marketing information channels, such as mass media, and have in some cases proven to be more influential on consumer perceptions and purchase decisions. However, studies that investigate the complementarity of these informal information channels with formal channels in marketing of agricultural products are rare. This study investigated the effects of social networks on consumer demand for biofortified crops, focusing on two HIB varieties (red-molted HIB-A and white-colored HIB-B) using data collected from 572 farmers in Rwanda through a quasi-experiment.

The average WTP for the varieties tested was RWF 433 per kg. Participants were willing to pay about RWF 63 more (15 percent) for HIB-A, but about RWF 41 less (10 percent) for HIB-B, than for the local variety, implying that improvement in grain nutritional content is not the only attribute valued by the consumers. About 86 percent of the participants preferred HIB-A to HIB-B. Hence, the relative WTP measures revealed customer preferences among the varieties.

Overall, the effect of social networks on WTP depended on the variety. Having an additional member with whom to discuss bean-farming issues increased the WTP for HIB-A by about RWF 19 (4.5 percent), but decreased the WTP for HIB-B by about RWF 27 (6.4 percent), compared with the local variety. This supports our hypothesis that the effects of social networks on purchase decisions could be positive or negative. Positive effects are observed if the new product is preferred to the existing one, but for the less preferred product, the effects are negative. This implies that interpersonal communication can be used to increase demand for a new product only if farmers perceive the product to be superior to existing ones. Quite often, agricultural technology developers employ participatory product development and dissemination approaches that work through social networks. However, our findings imply that these approaches will only be effective if the new product attribute is embedded within a package of other desirable features. Moreover, given that men have larger networks than women, they have a higher likelihood of spreading negative information about the less preferred variety (HIB-B) through their networks than women. Hence, targeted behavioral change communication differentiated by gender may be important for maximizing the effect of media advertising in creating demand for biofortified crops.

Regarding the role of nutritional and varietal information, we find that radio messages had an overall positive effect on WTP for both HIB varieties compared with the local variety. However, this effect was significant only in the case of HIB-A, for which participants were willing to pay a RWF 45 (10.6 percent) premium. Moreover, there was weak evidence that information frequency may be more effective than information framing. Given that radio messaging did not increase WTP for HIB-B, except when the information is framed negatively and provided more frequently, we conclude that media advertising does not always increase demand for a product. Customer experience with the product may play a much bigger role; hence, advertising cannot substitute for good product quality. This finding has two implications.

First, media advertising may be used to increase demand for a new product only if consumers deem the product as being superior to others in terms of the product's attributes. For the case of Rwanda, extensive media campaigns for the more preferred variety (HIB-A) may be scaled up across the bean-growing regions to stimulate demand and encourage adoption by farmers. The results for the less preferred variety (HIB-B) imply that the developers of biofortified bean varieties should pay more attention to specific bean attributes that influence demand for the beans in Rwanda. Oparinde et al. 2016 highlight some of these attributes. Such research should involve the target farmers as much and as early in the variety development as possible.

Second, advertising may help to maintain the demand for a less popular product and cushion it from the negative word-of-mouth effects of social networks. However, this would require an intensive advertising campaign with appropriate information framing that emphasizes the important attributes of the new product. One strategy for the HIB-B variety in this regard would be to promote it first through networks of farmers who prefer it to the local variety, combining this with frequent negatively framed nutritional messages. However, further research is required on the most effective way to do this.

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APPENDIXES

Appendix A: Radio Messages

<u>Radio Message (Gain Frame)</u>

[Mother = Karine]

[Karine's neighbor = Female farmer = Marie]

Mother: Good evening, my neighbor Marie, welcome!

Farmer Neighbor: Hello, Madam Karine. I have news for you. Do you know that when you have enough iron in your diet you will have physical strength and endurance and therefore will become tired less rapidly? [**EMPASIS ON THIS ASPECT OF THE MESSAGE**]

This means you will have optimal strength to undertake heavy physical activities (such as working in the field). When your children have enough iron in their diets they will perform better in school because their minds or brains will be able to focus better and pay more attention to school work.

You should be giving high-iron beans to your children. This bean type has about 40 to 70 percent more iron than the local variety. It also grows well like any other popular variety. My family is already growing and consuming high-iron beans.

Farmer Neighbor: I am leaving for market now to buy some high-iron beans for my family. Bye-bye, Madam Karine.

Radio Message (Loss Frame)

[Mother = Karine]

[Karine's neighbor = Female farmer = Marie]

Mother: Good evening, my neighbor Marie, welcome!

Farmer Neighbor: Hello, Madam Karine. I have news for you. Do you know that when you do not have enough iron in your diet, your body is also low in iron and you will feel tired and weak and you will not be able to withstand physical labor or exercise for as long as a healthy person can? **[EMPHASIS ON THIS ASPECT OF THE MESSAGE]**

{All other texts are the same as for the "gain frame" message above.}

Appendix B: Linear Regression Results

Table B1: Random effects linear regression results for determinants of WTP

Variable	Model without additional controls (1)	Model with additional controls (2)	Variable	Model without additional controls (1 cont'd)	Model with additional controls (2 cont'd)
Beannet	–7.37	–7.30	T5		–49.24*
	(5.94)	(5.95)			(29.36)
Beannet X HIB-A	2.61	2.38	HIB-A	22.72**	23.50**
	(1.98)	(1.98)		(10.99)	(11.00)
Beannet X HIB-B	–2.49	–2.71	HIB-B	–38.41***	–37.40***
	(2.46)	(2.44)		(13.23)	(13.23)
Treated	–48.68*		Round2	–7.86*	–7.86*
	(26.92)			(4.32)	(4.34)
Treated X HIB-A	41.18***		Round3	–11.04**	–11.86***
	(10.03)			(4.57)	(4.58)
Treated X HIB-B	9.75		Nopay	79.21***	78.72***
	(11.75)			(16.85)	(16.95)
Beantreat	–1.12	–1.37	gendrespo	3.57	3.94
	(6.29)	(6.33)		(8.31)	(8.32)
T2 X HIB-A		33.37***	Hhsize	1.55	1.58
		(12.00)		(2.29)	(2.29)
T2 X HIB-B		0.45	Agerespo	–0.07	–0.05
		(13.74)		(0.30)	(0.30)
T3 X HIB-A		50.25***	yrseduresp	2.95*	2.95*
		(13.06)		(1.52)	(1.52)
T3 X HIB-B		18.40	beanhmkg	–0.33	–0.34
		(14.54)		(0.41)	(0.42)
T4 X HIB-A		30.77**	Maxprice	0.03	0.03
		(12.25)		(0.03)	(0.03)
T4 X HIB-B		0.02	Ownland	0.69***	0.67***
		(14.67)		(0.17)	(0.17)
T5 X HIB-A		58.02***	incsources	0.82	1.43
		(13.08)		(6.64)	(6.74)
T5 X HIB-B		27.73*	Radio	1.28	1.78
		(15.88)		(9.10)	(9.12)
T2		–36.96	Celphon	0.37	0.29
		(28.06)		(10.36)	(10.36)
T3		–61.03**	Constant	450.71***	446.93***
		(28.63)		(40.16)	(40.38)
T4		–47.66*			
		(27.87)	*N*	1572	1572

Note: Standard errors are in parentheses; * = $p < .1$, ** = $p < .05$, *** = $p < .01$.

Table B2: Linear regression results for determinants of WTP premium

Variable	WTP premium – HIB-A without controls (1)	WTP premium – HIB-A with controls (2)	WTP premium – HIB-B without controls (3)	WTP premium – HIB-B with controls (4)
Beannet	2.38	3.77*	–3.07	–1.91
	(1.98)	(2.03)	(2.44)	(2.62)
T2	34.98***	33.64***	3.28	3.11
	(12.11)	(11.81)	(13.74)	(14.18)
T3	49.57***	56.02***	18.11	20.36
	(13.00)	(12.93)	(14.52)	(14.72)
T4	31.52**	34.25***	2.08	3.37
	(12.27)	(12.73)	(14.65)	(15.23)
T5	58.89***	61.09***	28.48*	30.50*
	(13.01)	(12.81)	(15.82)	(16.43)
hiba_early		16.49**		
		(7.96)		
hibb_early				18.88*
				(9.65)
nopay		16.60		13.66
		(17.01)		(17.69)
gendrespo		–20.22**		–1.12
		(7.99)		(9.23)
Hhsize		4.77**		1.47
		(2.28)		(2.39)
Agerespo		–0.31		0.21
		(0.26)		(0.31)
yrseduresp		0.48		3.51**
		(1.35)		(1.73)
beanhmkg		0.05		0.22
		(0.22)		(0.39)
Ownland		0.32		–0.12
		(0.21)		(0.10)
incsources		–2.62		–4.65
		(5.51)		(6.65)
Radio		–13.21		–3.05
		(8.59)		(10.01)
Celphon		–6.00		-10.61
		(8.97)		(10.37)
_cons	22.58**	21.69	–39.12***	–63.58**
	(11.05)	(24.16)	(13.18)	(29.28)
N	524	524	524	524

Note: Standard errors are in parentheses; * = $p < .1$, ** = $p < .05$, *** = $p < .01$.