Innovations, nudging interventions and food and nutrition security:

Evidence from Experimental and Quasi-Experimental Studies in Ethiopia

Kaleb Shiferaw Jada

Propositions

1. Leveraging people's behavioural tendencies leads to effective behaviour change communications.
   (this thesis)

2. Women's empowerment is more than reducing women's labour at home.
   (this thesis)

3. The most effective way to ensure successful collaborations is to ensure that the consequences of failure are distributed equally among partners.

4. Concentration and focus are like a rare commodity–with limited supply but ever-increasing demand.

5. The most consequential studies in developing countries confirm the obvious.

6. Let x be your interest, y be your professor/supervisor's interest and expertise, z is the amount of guidance you might receive. Let's define $d= |x-y|$. Then $z=f(d)$ with $z'<0$ and $z''>0$.

Propositions belonging to the thesis, entitled

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Thesis

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To my families

Content

Chapter 1
General Introduction

1.1 Problem statement

Malnutrition is a persistent problem for most developing countries, and Ethiopia is no exception. Globally, one in ten people are considered to be undernourished and though the problem exists in every country, not surprisingly, the extent is more severe in low-income countries where the figure is one in four people (World Bank 2017). Notwithstanding an impressive economic growth in the past decades, Ethiopia still struggles to ensure food security for its people. Undernourishment is highly prevalent in the country, particularly among children and women (CSA Ethiopia and ICF, 2017). Macronutrient intake, such as protein, is far below the recommended level (EPHI, 2013). The situation with micronutrient intake is no different. For example, vitamin A deficiency poses a serious public health problem (CSA Ethiopia and ICF, 2017). Both availability and utilization are shown to be the main culprits here. Cognizant of this, food and nutrition security has been given high priority and is included in the Sustainable Development Goals–which among others aims to end all forms of malnutrition by 2030.

Tackling malnutrition is invariably linked with the other key challenge that humanity faces to an unprecedented degree: namely climate change. According to a recent study, food production and consumption account for more than a quarter of all global greenhouse gas (GHG) emissions (Crippa et al., 2021). At the same time, the problem of malnutrition is expected to become worse in the face of climate change (Niles et al., 2021). The implication is that solutions that aim to address the problem of malnutrition should take into account this potential linkage with climate change. A recent report that came out of a three-year project led by 26 experts from 14 countries concluded that these issues should not be tackled separately and there is a need for synergistic actions to bring about long-lasting changes (Swinburn et al., 2019).

Efforts that aim to address the problem of malnutrition should also be based on an understanding of the food system of the global south where malnutrition is most severe. In the global south, smallholder farmers (defined as operating less than 2 ha) play a significant

role in the production and consumption of diverse foods. Globally smallholders produce a third of the food supply using only a quarter of the gross agricultural area (Ricciardi et al., 2018). A strategy to counter malnutrition in the global south should take into account the important role of smallholders in food production and consumption. Smallholders are well placed to address malnutrition and food security problems in the global south as they produce diverse and culturally appropriate food.

The multidimensional nature of the cause of malnutrition creates challenges in finding viable solutions. Key sectors that have a direct bearing on malnutrition are agriculture, health, environment, water and sanitation, infrastructure, gender, and education (Reinhardt and Fanzo, 2014). Due to its multidimensional nature, tackling malnutrition requires mobilization of huge resources and efficient multi-sectoral collaboration. For example, to achieve the goal of ending malnutrition in all its forms by the year 2030, globally $70 billion is needed for the next 8 years (World Bank, 2016a). Thus, identifying cost-effective interventions is an important step toward improving the lives of the rural poor who disproportionately bear the burden associated with malnutrition. This is particularly imperative in the face of the slowly decreasing trend of development aid in real terms to the poorest (OECD, 2019).

The question is thus how to tackle malnutrition in the global south with limited and decreasing development aid, without putting more pressure on the planet and without failing to protect smallholders. The solutions should conserve agricultural biodiversity and should be affordable as well as feasible to scale up effectively.

The thesis looks at innovations (fortification, biofortification and improved cook stoves) that can be leveraged to tackle malnutrition. In terms of the food system innovation typology of de Brauw et al. (2019), the first two fall under technological innovations that take place within the food value chain element of the food system, while the last one falls under the consumer behaviour element of the system as it has an empowerment effect on women by reducing home labour. These technological innovations do not have significant negative environmental impacts and are cost-effective (Bouis and Saltzman, 2017). Moreover, they do not require radical changes in people's eating habits. This is important, at least in the short run, as these habits are deeply entrenched aspects of many cultures (Mead, 1943) and cannot be easily changed. Finally, the innovation examined in this thesis addresses key bottlenecks in the food

system. Fortification and biofortification provide safe and affordable solutions to the micronutrient gap among vulnerable populations.

The studies in this thesis also explore the role of certification–innovation within the food environment– and information interventions that are informed by insights from the field of psychology and targeted at consumers. Thus, innovations examined in this thesis focus on the three primary elements of the food system namely, the food value chain, the food environment and consumer behaviour.

Fortification and biofortification of staple food both are effective and cost-efficient in delivering nutrients to both urban and rural populations. These innovations do not require radical changes in both production and consumption patterns as the target foods are already being consumed widely by the target population. The environmental footprint of these innovations is also minimal as the strategy does not require the target population to eat more of these targeted foods rather it encourages them to switch to a more nutritious variety. Given that the significant majority of those in the global south cannot afford or are unable to access healthy and diverse diets, delivering important nutrients through familiar staple foods ensures that people receive the required nutrients adequately. However, studies that identify effective strategies to promote these innovations are lacking.

The improved cookstove may seem a rather odd technology in the fight against malnutrition. This technology is usually promoted primarily to address the problems of indoor pollution and deforestation. However, these technologies have also the potential to contribute positively to addressing malnutrition. Improved cookstoves can achieve multiple development goals which directly and indirectly have a bearing on household food and nutrition security status. This technology does not require a radical change in the consumption pattern of the target populations, positively contributes to the environment and due to its multiple development outcomes can be a cost-effective way of improving food and nutrition security, particularly in rural areas. However, spillover effects of this pro-poor intervention as a cost-effective entry point to improve household food security have not been explored in the empirical literature.

1.2. Promoting healthy diets

Fortification of foods and biofortification of staple crops are recognized as effective public health interventions to reduce micronutrient deficiencies in poor countries. The core chapters of this thesis contribute to the efforts of promoting these innovations.

The role of food fortification in ensuring a healthy diet has been widely recognized throughout the world. The success of fortified foods essentially relies on whether they are accepted and consumed by the target population. To ensure adequate consumption, there is a need to design effective behaviour change communication interventions. Designing such interventions requires a deeper understanding of the food choice motives of the target consumers. In this regard, nutrition knowledge gaps have long been identified as a major bottleneck (Spronk et al., 2014a), and information interventions have been implemented as key entry points to assist individuals in making optimal food choices (Miller and Cassady, 2015). However, despite the rising concerns regarding food fraud, adulteration, and toxic residues from pesticides and feed additives in developing countries (Ortega and Tschirley, 2017), the effects of food safety on consumer food choice as well as its moderating effect on information interventions have not been explored well. In addition, there is a dearth of evidence that shows how fortification interacts with food safety concerns.

Biofortification–the process of creating micronutrient-dense staple crops– is an important intervention to overcome micronutrient deficiency among a population that may have limited access to diverse diets (Bouis and Saltzman, 2017). For this intervention to achieve its intended goal –reduction of micronutrient deficiencies– the target population (rural population) needs to consume food prepared from biofortified crops. Encouraging consumption of biofortified crops in rural areas usually involves working with smallholder farmers and persuading them to adopt these crops. This is because most staples are produced by smallholders and smallholders form an important group of people with nutrient deficiencies. One of the strategies that have been used to encourage adoption of these crops is provision of nutrition information. However, the impact of such intervention on the adoption rate is found to be negligible (De Brauw et al., 2018). Insights from psychology such as normative messaging and messaging framing have been successfully used to increase the effectiveness of information intervention in the health domain(Binder et al., 2020; Drouin et al., 2018; Godinho et al., 2016;

Ye et al., 2021). However, little has been done to leverage these insights in the domain of agriculture.

Winning the battle against malnutrition requires understanding the multidimensional nature of the problem and devising an equally multidimensional approach. In this regard, empowering women is receiving ever-increasing attention as a way to improve food and nutrition outcomes. It has long been noted that innovations that reduce home labour disproportionately improve the lives of women. These innovations free up women's time and contribute to women's economic empowerment. One of those innovations that are increasingly promoted in the global South is improved cook stoves (ICSs). What makes this innovation attractive is that it has the potential to achieve multiple development goals apart from its women empowerment effect. ICSs reduce indoor air pollution (Grieshop et al., 2011; Grimsby et al., 2016; Pant, 2013), mitigate forest degradation (Chan et al., 2015; Jeuland and Pattanayak, 2012) and reduce greenhouse gas emissions (Agurto Adrianzén, 2013; Bensch and Peters, 2011; Grieshop et al., 2011; Mehetre et al., 2017; Pennise et al., 2009). These effects are well documented. What is not studied and documented as much is the potential contribution of these technologies to food and nutrition security. There are multiple pathways, direct and indirect, from ICSs to nutrition outcomes. However, this effect of ICSs has not been studied and documented well.

1.3. Objective and research questions

This thesis addresses the gaps identified above. It also contributes to the effort of addressing malnutrition by identifying effective interventions to promote innovations that have limited environmental impacts and do not require radical rearrangement of the way of life and food choices of the target populations, which enhances the likelihood of their success. It also aims to identify the potential role of innovations that reduce home labour in the fight against food insecurity. The thesis has four stand-alone chapters with distinct theoretical frameworks and empirical strategies.

The next three chapters focus on fortification and biofortification of widely and regularly consumed foods, incorporate insights from psychology into information intervention, and employ field experiments to identify ways that help to unleash the potential of (bio) fortification in Ethiopia by focusing on maize in rural areas and on cooking oil in urban areas.

The fifth chapter seeks to examine how ownership of improved-cook stoves, which have the potential to economically empower women, affect food and nutrition outcomes. It uses observational data and leverages the availability of instrument variables to study the link between improved cook-stoves and food and nutrition outcomes. Formally, the research questions break down to:

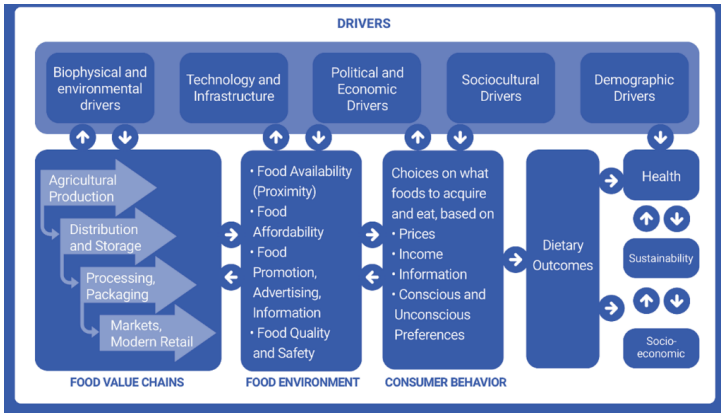
1. To what extent can information provision affect consumers' willingness to pay for fortified cooking oil, and how does information intervention interact with food safety certification and consumers' interest in nutritious and safe foods?
2. How does a social norm intervention coupled with health messaging affect farmers' willingness to pay for biofortified maize seeds?
3. What is the most effective framing technique in behaviour change communication for healthy diets, and how does it interact with motivational orientation and risk perception?
4. How does empowering women economically through improved cook stoves affect household food and nutrition security outcomes?

1.4. Research framework

Feeding the ever-expanding world population requires sustainable solutions that consider the access, availability, utilization and stability dimensions of food and nutrition security. On top of that, different sectors such as agriculture, health, education, water, and sanitation interact with each other and their effects on food security and nutrition would be compounded through the food system. Thus, a system approach is required to incorporate technical, economic, social, and environmental processes and actors of food production, processing, transport, and consumption. There is a realization among the global community that a system approach is the way to create sustainable food systems that facilitate healthy and sustainable food choices which in turn is key to ensuring food and nutrition security. Conceptualization of the food system draws from the HLPE framework (HLPE, 2017). The framework clearly demonstrates how individuals' or collective decisions and choices regarding production and consumption influence food systems and how efficient food systems improve their ability to deliver healthy and sustainable diets. The other advantage of the framework is that since it identifies the key elements of the food system–food supply chains, food environment and consumer behaviour– and how they interact, it allows policymakers to identify key

bottlenecks and design effective policies and programmes that have the potential to shape food systems, contributing to improved food and nutrition security.

Figure 1. Food system framework



Source: (from de Brauw et al., 2019; adapted from HLPE, 2017)

The chapters in the thesis focus on the different aspects of food systems. The chapters explore aspects of food value chains, the food environment and consumer behaviour.

At the food value chain level, chapter two touches up on the issue of seed quality and how it would affect adoption of nutritionally enhanced food crops. Access to quality input is one of the interventions identified across food supply chains (HLPE, 2017) and the results of chapter 2 would provide empirical evidence on the importance of quality inputs in the food supply chain. At the marketing end, the effect of the selling price of biofortified crops as it pertains to farmers' crop choice is also assessed in chapter 2.

Regarding food environment aspects, the chapters in the thesis study effective communication and messaging approaches to disseminate nutrition information, such as nutrition information regarding fortified cooking oil (chapter 2), bundling nutrition information with normative messages (chapter 3), and message framing (chapter 4). Still focusing on the food environment, the thesis examines how food safety and certification issues can be leveraged to promote nutritionally enhanced food and explore the role of government and the private sector in the areas of food certification (chapter 2). Chapter 3 also investigates seed quality, which falls within the food environment– and how it affects farmers' adoption decisions.

Regarding consumer behaviour, how product-intrinsic sensory cues (colour) factor into people's food choices is examined as it relates to biofortified maize (chapter 2). Food colour is shown to exert a huge impact on expectations which in turn affect consumers' food choices (Spence, 2015). Since improving the nutritional quality of food crops might also lead to a change in colour, examining how the colour of a crop interacts with adoption decisions would provide invaluable input in promoting these crops.

Apart from the key elements of the food system, within the sociocultural driver, the role of technologies that reduce women's home labour (improved cookstove) and its effect on nutritional outcomes is examined in chapter 4. This chapter directly responds to the priority as identified by HLPE (2017) in orienting consumer behaviour toward healthier diets.

Overall, chapters in the thesis are interlinked as they relate to the food system and explore its key elements– food value chains, food environments and consumer behaviours and fill some of the evidence gaps in the food system.

1.5. Methodology

All the chapters in this thesis aim to establish a cause-and-effect relationship and estimate the average treatment effect. For three of the four chapters, the main outcome of interest is participants' willingness to pay. Willingness-to-pay is the maximum price a customer is willing to pay for a product or service (Wertenbroch and Skiera, 2002). In the economic literature, this corresponds to a reservation price at or below which a consumer will demand a unit of the good or services (Varian, 1992). Willingness-to-pay reveals individual preferences and can be used to study the demand for a product or service. Discrete choice experiments and the Becker-DeGroot-Marschak mechanism (BDM) are commonly used bidding methods for eliciting this willingness to pay (Becker et al., 1964). A discrete choice experiment is a quantitative method that is used to estimate willingness to pay indirectly based on participants' choices among several alternatives (Mangham et al., 2009). When they are incentive compatible, bidding methods are also effective in eliciting true willingness to pay because they tie the act of revealing one's preference for a product or service to the probability of obtaining it.

I used both Experimental (chapter 2-4) and non-experimental designs (chapter 5). For the experimental design, I conducted three separate experiments where treatments were assigned randomly, and outcome variables were measured for both treatment and control groups. I conducted discrete choice experiments combined with treatment in urban (chapter 2) and rural settings (chapter 3) and estimated participants' willingness to pay using a mixed logit model (Revelt and Train, 1998; K. E. Train, 2009). The treatments were provision of nutrition information (chapter 2) and nutrition and normative messaging (chapter 3).

For chapter 4, I conducted a field experiment where participants were assigned to two treatment groups and a control group. The treatment involved providing gain and loss-framed messages for treatment groups 1 and 2, respectively. To solicit participants' willingness to pay I use a BDM mechanism. The mechanism is an incentive-compatible procedure both theoretically (Becker et al., 1964) and behaviourally (Bohm et al., 1997) and is widely used in economic experiments to measure willingness to pay.

Participants for these experiments were selected randomly and they were assigned to different treatment groups randomly. Since the treatment assignment was random on a randomly drawn participant the effect of the treatment is calculated as the difference in the outcomes with and without treatment (Wooldridge, 2010).

For the non-experimental design (Chapter 5), I used a huge cross-sectional household dataset collected by the International Livestock Research Institute (ILRI). The aim was to study the effect of improved cook stove ownership on household food and nutrition security status. Since ownership of improved cook stoves might be endogenous, the existence of instrumental variables was leveraged, and the instrument variable estimator was used to establish the causal relationship. Since the proposed instrument variables fulfilled the identification assumptions–exclusion restriction (tested indirectly using overidentification test) and the rank condition for identification–the treatment effects are identified and can be estimated by the method of instrumental variables (Wooldridge, 2010).

1.6. Thesis Outline

The rest of the thesis is organized as follows. Chapter 2 presents the results of the choice experiment in urban settings that aim to quantify the extent to which information provision

affects consumers' willingness to pay for fortified cooking oil and how that interacts with certification and consumers' interest in nutritious and safe foods. Chapter 3 examines how bundling the provision of a health message with normative messaging affects smallholder farmers' preference regarding biofortified maize. Chapter 4, still focusing on nutrition-sensitive agricultural technologies, looks at how messaging framing can be leveraged to encourage the production and consumption of foods prepared from nutritionally enhanced maize and its interaction with motivational orientation and risk perception of the target population. Chapter 5 shifts away from nutrition-focused innovations and examines if improved cookstoves, which are expected to lead to women empowerment in rural areas, can be leveraged to improve food and nutrition security. Finally, chapter 6 synthesizes the results. The chapter briefly presents answers to the research questions, discusses the contribution to the broad scientific debates, identifies the limitations and offers some recommendations for future research.

Chapter 2

The effects of safety certification and nutrition messaging on the demand for nutritionally enhanced food in urban Ethiopia

Abstract

Micronutrient deficiency is among the most significant public health problems in Ethiopia. In this setting, food fortification has been identified as a cost-effective and sustainable strategy to deliver essential micronutrients. Safety certification and nutrition education messages can be used to nudge people to choose fortified foods. However, there is little evidence as to the effectiveness of such interventions in this context. This paper aims to fill this gap. We focus on cooking oil, as it has been identified as an ideal candidate for vitamin A fortification in Ethiopia. To study consumers' willingness to pay (WTP) for safety certification and vitamin A fortification, we implemented a stated choice experiment on 996 randomly selected urban consumers to reveal preferences required to calculate WTP. To estimate the causal effect of messages on consumers' WTP for fortification, a nutrition message on the benefits of vitamin A was provided to 518 randomly selected participants. We found that consumers valued safety certification. This finding holds for certification issued by both government and private parties, with a higher value ascribed to the former. We also found that urban consumers were willing to pay a premium for vitamin A fortification. The nutrition message increased WTP for fortification, albeit only slightly. Finally, we found that the effect of safety certification on consumers' WTP for fortified cooking oil was higher than its effect on WTP for non-fortified oil, indicating that urban consumers value certification, even more, when fortification is involved.

Key words: Fortification, food safety, choice experiment, consumer, nutrition message

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2.1. Introduction

In recent years, considerable efforts have been made to reduce micronutrient malnutrition, which contributes substantially to the global burden of disease (Tulchinsky, 2010). While adequately tackling multiple burdens of micronutrient deficiency could require several complementary approaches, food fortification is arguably the most effective, economical and practically feasible method to enhance the availability of the most limiting micronutrients: vitamin A, iron, and zinc (Das et al., 2013; WHO, 2006). Food fortification involves improving the nutritional value of processed staple foods, mostly flours and edible oils, by adding essential vitamins and minerals. It often targets urban people, who are most likely to consume processed foods. While fortification has been a well-established strategy to prevent vitamin and mineral deficiencies in industrialised countries for many decades (Bishai and Nalubola, 2002; WHO, 2006), large-scale fortification has only recently been applied in developing countries (Miller and Welch, 2013; Osendarp et al., 2018).

The success of fortified foods essentially relies on whether they are accepted and consumed by the target population. Fortification programs can be mandatory, whereby producers of specific fortifiable products must comply with national standards, or voluntary, whereby producers may choose whether they fortify or not. When fortification is voluntary, it is important to establish whether there is a demand for fortified food. It is also important to have evidence-based interventions to encourage healthier food choices.

Several studies have shown that African consumers are willing to pay a premium for nutritionally enhanced foods and that the provision of nutrition information is an important lever (Birol et al., 2015; Chege et al., 2019; De Groote et al., 2017; Mabaya et al., 2010; Oni, 2012). Most of these studies focus on rural consumers, while evidence is limited for the urban setting. In addition, these studies do not explicitly examine food safety issues and the role of safety certification. The implicit assumption is that food safety issues are not of great concern. This seems an unrealistic assumption, given the rising concerns in developing countries regarding food fraud, adulteration, and toxic residues from pesticides and feed additives (Ortega and Tschirley, 2017).

One country in which the above-mentioned problems are prevalent is Ethiopia. Diets in Ethiopia are often dominated by starchy staple foods and do not provide the required amounts of important micronutrients (EPHI, 2013; Gebru et al., 2018), making micronutrient deficiencies a widespread public health problem (EPHI, 2016). Nor is the country free of food safety incidents. In mid-2008, there was a major incident of poisonous edible oil in Addis Ababa with 12 confirmed deaths (Alebachew et al., 2013; Assefa et al., 2013), and more recently local media has contained reports of unsafe cooking oil. As a result of such incidents, urban consumers in Ethiopia are more concerned about the safety of their food than about its nutritional content (Melese et al., 2019). Food fortification has been identified as an important strategy in nutrition programme documents (EPHI, 2016; Head et al., 2014), but it may be a difficult goal to achieve. Given the visibility and acuteness of food safety problems, people might be prepared to pay only a smaller premium for fortified food than for food that is certified safe. More importantly, poor people may be willing or able to pay only one premium and prioritise safety at the cost of fortification. However, the interaction between food safety concerns and fortification in Ethiopia has not received empirical scrutiny.

This study aims to fill this knowledge gap. We implemented a stated-choice experiment on 996 randomly selected consumers in the city of Addis Ababa in Ethiopia to study consumers' WTP for biofortification and the impacts of food safety certification and nutrition messaging. We focused specifically on WTP for cooking oil because it has been identified as an ideal candidate for vitamin A fortification. The consumption of cooking oil is widespread and consistent throughout the year (EPHI, 2013; Head et al., 2014). Vitamin A is found to be more stable in oils than in any other food, and oil aids vitamin A absorption (Diósady and Venkatesh-Mannar, 2013). Besides, the fortification process does not change the appearance, taste, texture, flavour, or shelf life of edible oils (Chaudhry, 2018). Finally, the risk of excessive intake of micronutrients by young children is lower for cooking oil than for the alternative option wheat flour (EPHI, 2013).

Our study yielded the following findings. First, the urban consumers were willing to pay a premium for food that is certified to be safe for human consumption. Second, they were willing to pay a premium for vitamin A fortification, yet this premium was lower than for safety certification. Third, nutrition messaging increased WTP for fortification, albeit slightly. Finally,

we found that the effect of safety certification on WTP was higher for fortified cooking oil than for non-fortified oil, indicating that urban consumers value certification, even more, when fortification is involved. Taken together, these results suggest that, to support increased consumption of fortified foods, certification and provision of health messages are feasible behavioural change intervention strategies.

The rest of the paper is structured as follows. Section 2 outlines the design of the choice experiment, the sampling strategy and the methods used to analyse the data. Section 3 presents and discusses the results of the paper. Section 4 draws policy implications and Section 5 concludes the paper.

2.2. Material and methods

2.2.1. Design of the choice experiment and selection of attributes

We used discrete choice experiments to elicit the preferences of consumers for edible oil with different characteristics. Discrete choice experiments are based on Lancasterian consumer theory, which postulates that goods and services are essentially bundles of various attributes and that the value of particular goods or services to a consumer is determined by the relative importance of these attributes (Lancaster, 1966). In choice experiments, choice sets are typically framed in a way that closely reflects the actual purchase decisions of consumers. As a result, choice experiments allow the investigation of the valuation of a new product with one or more new attributes for which there is no revealed preference history. This is the case for our experimental study. In our experiment, participants are asked to choose between hypothetical alternatives, and there are no real consequences associated with the choice. Such responses to hypothetical choices may differ from real-world behaviour (Hensher et al., 2015). Nevertheless, discrete choice experiments have successfully tested theoretical links with real behaviour, and they allow researchers to gain an understanding of how people actually make choices (Louviere et al., 2010).

Our two core attributes are ‘fortification’ and ‘certification’. The ‘fortification’ attribute refers to whether the cooking oil is fortified with vitamin A or not and therefore has two levels. While certification could in theory reflect fortification status, in the study context, it reflects food safety. More specifically, we are referring to a third-party verification that the food is free of contaminants and has met accepted food safety standards that are set to lower the incidence

of foodborne illness. We included three levels: public certification, private certification, and no certification. In Ethiopia, a government agency, namely the Food, Medicine and Health Care Administration and Control Authority, is responsible for ensuring the safety and quality of food manufactured, imported, exported, distributed or made available for human consumption (FDRE, 2014). As a response to current contamination and adulteration problems, the Quality and Standards Authority of Ethiopia (QSAE) has started an initiative for testing and certification of edible oil together with development partners (MDG Achievement Fund, 2011), but this has yet to reach the implementation stage. Currently, the involvement of the private sector in food safety inspection and certification is limited. However, as the food chain becomes more complex and the pressure to enhance food safety increases, it is expected that public efforts will need to be supported by engaging the private sector in certification activities. We included private certification as one of the levels of the certification attribute to assess the preference for this approach by consumers.

We included two additional attributes: 'price' and 'origin'. We limited the attributes to four so as to reduce the cognitive burden on respondents and thereby increase the quality of our data. The 'price' attribute is the price of cooking oil per litre in Ethiopian Birr (ETB). This attribute is relevant in the estimation of the utility derived from the other attributes of the product. Based on a realistic average price in the oil market, three levels were proposed: 38, 51, and 64 ETB/litre.[1] The 'origin' attribute describes the place where the cooking oil was produced. The origin attribute has two levels: the oil is either produced domestically, or it is imported. The inclusion of this attribute results from the findings of a relevant study (Sertse et al., 2011) and our understanding of the cooking oil market.

We conducted a pre-test to see whether the attributes included were relevant and whether the levels for each attribute were plausible and understandable. The test results show that respondents paid attention to the proposed attributes and the attribute levels made sense from their perspective. However, we had to revise the levels for the price attribute, as the initial price range was found to be too narrow to trigger relevant trade-offs. Table 1 shows the final set of attributes and their respective levels.

[1] During the survey period, 1 USD was about 26.81 ETB.

Table 1: Attributes and attribute levels for the choice experiment.

Attributes	Description	Levels considered
Price	The market price of one litre of oil in Ethiopian birr	3 levels (38, 51 and 64 ETB/litre)
Origin	Whether or not the cooking oil is produced domestically	2 levels (Yes and No: reference point)
Fortification status	Whether or not the cooking oil is fortified with Vitamin A	2 levels (fortified and not fortified: reference point)
Certification status	Whether or not the oil is deemed safe for human consumption and who certified it	3 Levels (certified by a government entity, certified by a private entity, and not certified: reference point)

We used the D-optimal approach of fractional factorial to design the experiment with the help of SAS software (Kuhfeld, 2010). This design approach generates choice sets that allow the estimation of all main and key interaction effects. The other advantage of this approach is that it reduces the predicted standard errors of parameter estimates and gives unbiased estimates (Carlsson and Martinsson, 2003; Hoyos, 2010; Rose et al., 2008). Using a D-optimal design, we generated 24 choice sets using random selection without replacement. To promote response efficiency and reduce the cognitive burden on respondents, the choice sets were optimally divided into four equal blocks using SAS macros to ensure orthogonality between the blocking factor and all of the attributes of all alternatives (Kuhfeld, 2010). Each choice set consisted of two cooking oil alternatives (Options 1 and 2) and a no-buy option (Option 3). The design has a maximum between-attributes covariance of 0.04, suggesting a highly optimal and balanced orthogonal design.

2.2. Sampling strategy and data collection

Data collection took place in Addis Ababa in the fall of 2017 using a computer-assisted personal interview (CAPI) method. We used a multi-stage sampling procedure to select respondents. In the first stage, we purposively grouped the ten sub-cities of Addis Ababa into six strata based on location and on food expenditure per capita and total calorie (gross) intake per individual per day (CSA, 2008). Four of the strata consisted of two similar and in most cases neighbouring sub-cities. The remaining two strata consisted of one sub-city each, Bole sub-

city and Akaki-Kaliti sub-city. We then randomly selected one sub-city from each of the four strata and included the two other sub-cities, giving us six sub-cities in total.

In the second stage, all the woredas (districts) in each of the study sub-cities were clustered into three development strata, high, medium, and low, based on a qualitative assessment by local experts. From four sub-cities we randomly selected three woredas, one from each stratum. From two sub-cities with a relatively large number of woredas (Bole and Yeka), we randomly selected four woredas: one woreda from each stratum, and one additional woreda from the stratum that had the highest number of woredas. This process resulted in a total of 20 woredas. In the third stage, two ketanas , or further sub-divisions of the woredas, were randomly chosen from each woreda, giving us in total 40 ketanas or clusters as primary sampling units. We then randomly selected 25 households from a list of residents in each of the ketanas.

Since the number of districts to be sampled was chosen with probability proportional to size, our sample is said to be self-weighting. This simplified the analysis and allowed us to draw precise conclusions about consumers in Addis Ababa by ensuring that sub-groups were properly represented in the sample.

We visited all selected households at their home and conducted a face-to-face interview in the local language. From each household, we interviewed the person who was mainly responsible for household food choice decisions (food purchase and/or preparation). Replacements were randomly drawn from the same list.

Respondents received a short description of the experiment, clear definitions of the product attributes, an explanation of how to respond to questions, and assurance of the confidentiality of their responses. We especially paid attention to the careful explanation of fortification. Fortification is not uncommon in the study area. The government of Ethiopia introduced a mandatory iodised salt programme in 2011 and there has been an intensive campaign to increase awareness about the benefits of consuming salts fortified with iodine. We, therefore, feel confident in our assumption that our urban research participants were familiar with fortification. We explained the attribute of fortification as the addition of vitamin A into the cooking oil, drawing parallels with the iodine in salt when necessary.

Participation was completely voluntary. Moreover, respondents were informed that they could opt out of the experiment at any time with no penalty. They were informed that the cooking oils presented to them differed only in terms of the four attributes described and that all other attributes were identical. In total, responses to 5,976 choice sets were obtained from 996 surveyed household representatives, with each consumer providing responses to six trinary choice sets.

In each choice set, participants were asked to choose their preferred alternative between two cooking oil profiles and a 'no-buy' option. The no-buy option intends to capture consumers' preferences for edible oil alternatives with other attributes in the choice set as well as for a decision not to buy oil altogether. The inclusion of the no-buy option has been recommended by previous literature (Hoefkens et al., 2012; Louviere et al., 2000). This also reflects real market choices, where consumers can decide not to purchase, to purchase something else, or to purchase elsewhere (e.g., Enneking, 2004). Figure 2 presents a sample choice set.

Block 1 Question 1	**Option 1**	**Option 2**	**Option 3**
Price (ETB/litter)	64	51	Neither option 1 nor option two is preferred
Certification Status (Food safety inspected)	Government	Government	
Origin	Imported	Imported	
Vitamin A fortification status	Fortified	Fortified	
I would like to choose: (please mark only one box)	☐	☐	☐

Figure 2. Example choice set

To encourage participants to provide their realistic evaluations of the choices, we informed them prior to the experiment that it was important that they evaluate each alternative as if they were actually facing these exact choices at a shop or supermarket. In addition, we included a consequentiality clause to attenuate the hypothetical bias (the script is provided in Appendix A). The consequentiality clause indicates that the results of the study may be used by policymakers. Finally, to increase the likelihood that participants understood each attribute, we conducted the experiment in the local language.

To examine the effect of nutrition messaging on participants' WTP for fortified cooking oil, participants (996) were randomly assigned to the treatment (n=518) and control (n=478) groups. The treatment group listened to a recorded message about the benefits of vitamin A before being asked to evaluate the choice sets. The control group did not hear the message.

The message highlighted the benefits of vitamin A for eyesight, the skin, and the immune system. The full script of the nutrition message is provided in Appendix B. The message was translated into the local language and an audio recording was made by a native speaker. Participants were assigned randomly to the treatment group so that any differences between the treatment and control groups as to their WTP for fortified cooking oil could be attributed to the nutrition message.

Finally, ethical approval for research protocols, process, data management and risks related to participation in the research was obtained from the Social Sciences Ethics Committee at Wageningen University. Addis Ababa sub-city administrations granted permission to conduct the study. All participants provided written informed consent before participation.

2.3. Specification and estimation

The theoretical foundation of discrete choice models is provided by Hendler's (1975) and Lancaster's (1966) consumer theory, and McFadden's (1974) random utility theory. Lancaster argues that utilities are derived not only from the goods as a whole but also from their characteristics or attributes. Technically, consumers are supposed to make choices based not on the simple marginal rate of substitution between goods but on preferences for attributes of the goods. Random utility theory assumes that individuals select the alternative that yields the highest utility given their information set, and that any variation can be treated as random.

Since our interest was to estimate consumers' WTP for individual attributes, we specified utility in the WTP space. This re-parametrisation is convenient (Hess and Train, 2017) and provides more reasonable distributions of WTP than the conventional specification of utility, which is defined on the preference space (Train and Weeks, 2005). Indexing an individual consumer by *n*, cooking oil type (alternatives) by *j*, and a choice occasion by *t*, the utility can be written as:

$$U_{njt} = -\lambda_n p_{njt} + \lambda_n wtp_n' x_{njt} + \varepsilon_{njt}\,, \qquad (1)$$

where λ_n is a price-scale coefficient, p_{njt} is price, $wtp_n$is a vector of WTP for each of the non-price attributes, x_{njt} are non-price attributes, and ε_{njt} is an i.i.d type-one extreme value, with constant variance $\frac{\pi^2}{6}$. WTP can vary randomly among consumers. Consumer n chooses

alternative j in the choice set J in choice occasion t if $U_{njt} > U_{nit}\ \forall j \neq i$. The probability of this occurring conditional on the price-scale coefficients and WTP is given by the following specification:

$$Prob_{njt}|\,\lambda_{nt} \text{ and } \text{WTP}_{nt} = \frac{e^{-\lambda_n p_{njt} + \lambda_n wtp_n' x_{njt}}}{\sum_{j\in J} e^{-\lambda_n p_{njt} + \lambda_n wtp_n' x_{njt}}} \ . \qquad (2)$$

However, we do not observe the price coefficients and WTP for the individual attributes. Instead, the cumulative distribution function of these coefficients in the population is given by $F(\beta)$. Let F be discrete with a finite support set S and let the probability mass at any $\lambda_r \ and \ wtp_r \ \epsilon \ S$ be expressed as a logit formula. Using a logit formula as a representation of the mixing distribution allows for easy and flexible specification of relative probabilities (Train, 2016). The unconditional probability of consumer *n* choosing *j* is then given by:

$$Prob_{njt} = \sum_{r\epsilon S} \left(\frac{e^{\alpha' Z\,(\lambda_r, wtp_r)}}{\sum_{s\in S} e^{\alpha' Z\,(\lambda_s, wtp_s)}} \right) . \left(\frac{e^{-\lambda_r p_{njt} + \lambda_r wtp_r' x_{njt}}}{\sum_{j\in J} e^{-\lambda_r p_{njt} + \lambda_r wtp_r' x_{njt}}} \right), \qquad (3)$$

where $Z(\lambda_r,\ wtp_r)$ is a vector-valued function of $\lambda_r \ and \ wtp_r$, and α is a corresponding vector of coefficients. The *Z* variables are used to specify the shape of the probability distributions of the coefficients. In this paper, we specified the *Z* variables as orthogonal polynomials and compared the goodness-of-fit of this model with models estimated under the assumption that the coefficients are distributed normally and are uncorrelated.

2.3. Results and discussion

2.3.1. Descriptive statistics

Table 2 shows the descriptive statistics for the sample. Most of the respondents (82%) were female and about one in four had not had formal education. By age group, 37% of the sample were between 18 and 35 years, 47% were between 35 and 60 years and 25% were over 60 years of age. The data set only characterises household members who were largely responsible for food shopping and/or food preparation for the household. Table 2 also reports that 848 respondents out of 996 stated the per capita income of their household to be greater

than 600 birr per month[2]. The implication is that about 15% of the households earned an income under the national poverty line. This is close to the urban poverty headcount ratio (14.8%) based on the national poverty line reported for urban areas in Ethiopia in 2016 (PDC, 2016). Of the 996 respondents, 406 (41%) reported that they trusted health claims on food packages, and for 285 (29%), the nutritional value was an important food choice motive.

Table 2. Summary statistics of the study sample (N = 996)

Variable		**Freq.**	**Percent**
Gender	Female	815	82
	Male	181	18
Age	Between 18 and 35 years	372	37
	Between 35 and 60 years	471	47
	Above 60 years	153	15
Education	No formal education	255	26
	Primary or secondary	610	61
	Above secondary	131	13
Per capita income	Less than 600 birr per month	148	15
	between 600 and 1455[3] birr per month	458	46
	More than 1455 birr per month	390	39
Trust in health claims on food packages	Yes	406	41
	No	590	59
Nutrient value is one of food choice motives	Yes	285	29
	No	711	71

[2] Ethiopia's national poverty line was 7,184 birr per capita per year in 2016

[3] Upper Middle Income Class Poverty Line or 48.5 birr per day per capita in 2015

2.3.2. Main results

The estimates for the different models in the WTP space are reported in Table 3. We first estimated the model using the maximum simulated likelihood (MSL) estimation method by applying the command “mixlogitWTP” in Stata. The WTPs are specified to be jointly normal and the price or scale coefficient is lognormal. Following the procedure in Train (2016), we then estimated logit-mixed logit (LML) models. The first column reports the MSL estimates with uncorrelated coefficients. For LML models, two models were estimated by specifying a second- and sixth-order polynomial, respectively. The LML models were estimated in MATLAB using the code made available by Train (2016). The respective LML estimates are presented in the second and third columns.

Table 3. Statistics of wtps (birr per liter) and standard errors (in parenthesis).

	Model 1	Model 2	Model 3
Mean			
Origin (1=produced nationally)	1.63***	1.60***	1.59***
	(0.08)	(0.12)	(0.06)
Certified safe by government entity (1=Yes)	7.17***	7.03***	7.34***
	(0.13)	(0.18)	(0.20)
Certified safe by private entity (1=Yes)	3.26***	3.23***	3.71***
	(0.29)	(0.15)	(0.10)
Fortification with vitamin A (1=Yes)	4.53***	4.51***	4.64***
	(0.26)	(0.17)	(0.41)
Interaction: Fortification x certified by government	4.76***	4.75***	4.89***
	(0.15)	(0.11)	(0.18)
Interaction: Fortification x certified by private sector	4.38***	4.27***	4.21***
	(0.11)	(0.13)	(0.31)
Interaction: Fortification x health messaging	0.72***	0.68***	0.56***
	(0.14)	(0.13)	(0.17)
No purchase	0.08	-0.14	0.19
	(0.05)	(0.14)	(0.13)
Price/scale	0.28***	0.29***	0.26***
	(0.01)	(0.01)	(0.01)
SD			
Origin (1=produced nationally)	0.30***	0.21***	0.32***

	(0.03)	(0.04)	(0.03)
Certified safe by government entity (1=Yes)	1.07***	1.11***	1.16***
	(0.20)	(0.15)	(0.13)
Certified safe by private entity (1=Yes)	0.37**	0.54***	0.73***
	(0.18)	(0.13)	(0.13)
Fortification with vitamin A (1=Yes)	0.64***	0.69***	0.76***
	(0.06)	(0.18)	(0.14)
Interaction: Fortification x government certification	0.27***	0.24	0.59**
	(0.09)	(0.16)	(0.27)
Interaction: Fortification x private certification	0.23	0.31***	0.57***
	(0.18)	(0.11)	(0.18)
Interaction: Fortification x health messaging	0.64***	0.58***	0.61***
	(0.04)	(0.04)	(0.05)
No purchase	0.88***	0.80***	0.92***
	(0.08)	(0.03)	(0.08)
Price/scale	0.13***	0.13***	0.12***
	(0.01)	(0.01)	(0.02)
Number of respondents	996	996	996
Log-likelihood value at convergence	-4420.43	-4367.34	-4297.83
Akaike information criterion (AIC)	8822.86	8716.68	8577.65
Bayesian information criterion (BIC)	8762.6	8656.42	8517.39
Correlation among parameters	NO	YES	YES

The order of mixing polynomial	2	2	6

Note: *, ** and *** denote significance at 10%, 5% and 1% level respectively.

Allowing for full correlation among coefficients increases the simulated log-likelihood (SLL) at convergence from -4420.43 to -4367.34. Specifying a more general LML model further improves the model's fit, as this model attained even higher SLL at convergence (-4297.83, compared to -4367.34 for the model with a second-ordered polynomial). The likelihood ratio test suggests that the hypothesis that the extra parameters in our more general model are zero can be rejected at the 99% confidence level (χ^2 (36) = 139.02, p = 0.000). In addition, our general model attained lower BIC (8517.39 compared to 8656.42) and AIC (8577.65 compared to 8716.68). Thus, our general specification (Model 3) fits the data better than the alternatives.

The WTP estimates are the premium of the corresponding attribute as compared with the reference point stated in Table 1. Looking at the results of the three specifications (Model 1-Model 3), the estimated means have the same signs and orders of magnitude across models. Overall, the signs are plausible and as expected. In addition, though the stated preferences seem to overestimate WTP, the relative orders are in line with expectations given the context of the study areas.

Focusing on the results of the model that fits our data well (Model 3) the estimated coefficients for the attributes are statistically very significant ($p<0.01$) indicating that respondents had considered each attribute carefully when choosing among the alternatives. The estimated coefficient for the 'origin' attribute was 1.59 and is statistically significant, indicating that consumers are willing to pay 1.59 more for domestically produced cooking oil than for imported oils. The implication is that respondents preferred domestically produced oil to imported oil, supposedly due to its perceived quality. The safety and quality of imported oils are frequently discussed in the food market by consumers. Most imported oils are palm oils that are often partially solid, an attribute viewed as highly negative by consumers. That may partly explain why consumers preferred domestically produced oils, which are mainly produced from niger seeds (FBPIDI and GAIN, 2018) and are in liquid form, even though they are relatively expensive and in limited supply. These preferences may partly explain

consumers' WTP for nationally produced cooking oils is higher than their WTP for imported oils, despite the availability of quality imported cooking oils.

Consumers were willing to pay a significant premium for safety certification. The estimated WTP for certification was 7.33 birr per litre if certification was issued by a government entity, but 3.70 birr per litre for a private entity. Because we interact certification with fortification in our model, the WTP for certification depends on the fortification status and the WTPs stated above are for certification of cooking oil that is not fortified with vitamin A. The results suggest that consumers worry about food safety and seek assurance that the food they purchase is safe. This is not surprising as adulteration of cooking oil with an inferior substance is not uncommon in Ethiopia (Gobena et al., 2018), and this has been reported in the media. The results also show that consumers' WTP for government certification is higher than their WTP for private certification and the difference is found to be statistically significant ($p < 0.01$). This is probably because respondents considered government agencies as more trustworthy and capable of assessing the safety of food products than the private sector. At the same time, the results also suggest that respondents recognise the role of the private sector in food certification programs, which is encouraging as this indicates the feasibility of engaging the private sector in addressing the ever-increasing demand for safe foods. Furthermore, food safety issues such as food adulteration were the focus of media attention prior to the experiment, which partly explains the high willingness to pay for certification. Studies have shown that extensive media coverage of food-related risks can lead to a heightened perception of risk that affects consumer perceptions of products and can consequently influence demand for safer services and products (Frewer et al., 2002; McCluskey and Swinnen, 2011).

The results indicate that urban consumers are willing to pay 4.64 birr per litre on average for vitamin A fortification of cooking oil. Again, because of the interaction term, this refers to an estimated WTP for vitamin A fortification of cooking oil that has not been certified. The results may suggest that the majority of the respondents are aware of the benefits of vitamin A.

Comparing the WTP for certification with the WTP for fortification shows that respondents are more concerned about the safety of the cooking oil than its nutritional value. The

difference in WTP for the two attributes is found to be statistically significant ($p<0.01$), and this holds for both private and government certification.

The interaction between fortification and certification captures the effect of certification on the WTP for vitamin A fortification of cooking oil. The estimated WTPs for certification of fortified cooking oils are positive (4.9 for government and 4.2 for private certification) and statistically significant (p-value <0.01), suggesting that the effect of safety certification on consumers' WTP for fortified cooking oil is higher than its effect on WTP for non-fortified oil. This indicates that urban consumers value certification, even more, when fortification is involved.

To calculate the effect of nutrition messaging on WTP for fortified cooking oil, we interacted the treatment status with fortification status so that the coefficient of the interaction term is interpreted as the treatment effect on a participant's WTP. The results show that informing respondents about the nutritional benefit of vitamin A increased the WTP for fortification, albeit slightly, and the effect is found to be statistically significant (p-value <0.01). On average, the information treatment increased WTP by 0.55 birr per litre. Providing nutrition information about vitamin A presumably increased the consumers' awareness level of the product, and awareness plays a crucial role in the decision process. In the field of public health, a number of studies in developing countries have shown that provision of nutrition information is effective in stimulating consumers to make healthier food choices (Barreiro-Hurlé et al., 2010; Bonaccio et al., 2013; Drichoutis et al., 2005; Miller and Cassady, 2015).

The fact that urban consumers are willing to pay a premium for fortification indicates that there may be a market-mediated solution for malnutrition. For such a solution to work, supplying fortified cooking oil should be profitable for the private sector. However, a detailed cost-benefit analysis of supplying fortified cooking oil by the private sector is not available. Such an analysis would help to identify potential constraints which can be acted upon to encourage the participation of the private sector. As fortification is highly cost-effective from a public health perspective (Horton, 2006), both price and non-price incentives should be considered to facilitate private sector action.

2.3.3. Heterogeneity analysis

The estimated standard deviations of the attributes are statistically different from zero, indicating that there are identifiable differences across respondents in the extent to which they valued each attribute. To further investigate variability in the direction and magnitude of the effect of certification and nutrition messaging on consumers' WTP for vitamin A fortification, we plot the respective distributions. Figure 2 presents the distribution of the relevant WTPs. The first and the second moments of the distribution under Model 3 are similar to those obtained under Model 2, where normal distribution is assumed for random parameters. However, the shape of the distributions of the parameters of interest is different from normal.

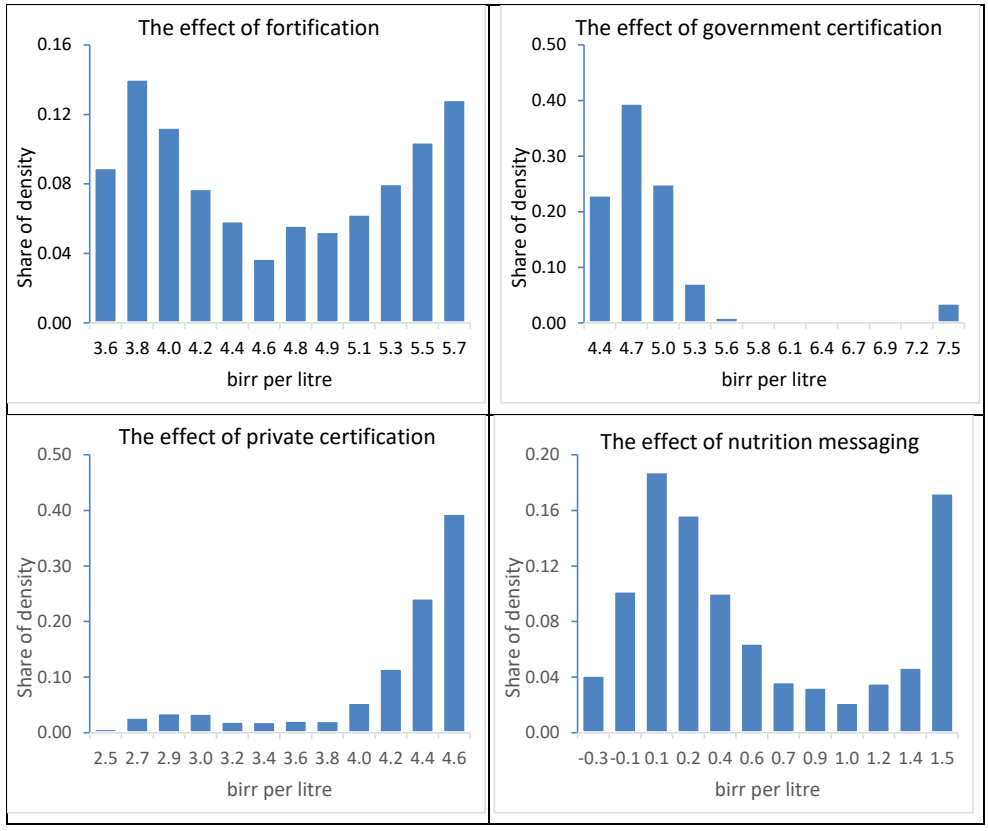

Figure 3. Distribution of selected wtp parameters

The distribution for WTP for fortification as shown in the top left corner of Figure 2 is bimodal and U-shaped, indicating that people either are willing to pay a considerable amount for fortified cooking oil or are only willing to pay a relatively small amount.

The shape of the distributions of the joint effects of fortification and certification either by a government entity (Figure 2, top right) or by a private entity (Figure 2, bottom left) also suggests heterogeneity among respondents. Similarly, the graph in Figure 2 bottom right suggests that most people are slightly more willing to pay for fortification after having received information about the benefits of consuming fortified cooking oil than they would have without the information treatment. However, for a small group of respondents (14%), the information treatment decreased the premium they were willing to pay for fortified cooking oil. This is an unintended effect of the nutrition messaging which is not uncommon in health communication (Hornik, 2002). Persuasion attempts can pose a threat to people's autonomy and self-determination, triggering a negative reaction, which is termed as psychological reactance (Brehm and Brehm, 1981). This phenomenon can undermine the effectiveness of nutrition messaging (Dillard and Shen, 2007; Quick et al., 2013; Steindl et al., 2015).

Factors that may drive this observed heterogeneity are presented in Table 4. For example, government certification combined with fortification had the highest effect on older people (>60 years of age) as compared to the other age groups. This is probably because older people have a more favourable view of government institutions than the other age groups.

The information treatment, however, was less effective for older people. This may not be surprising because communication is shown to be hindered by the normal ageing process, which may involve a decline in memory and slower processing of information (Halter, 1999). As a result, the older people get, the less likely they may be to incorporate new information in their decision process. This explanation is speculative, as we did not collect information on the cognitive processing speed of our participants. There may be other explanations for the results, such as a lack of trust in information.

Fortification has a higher effect on WTP for females than for males. The effect of information on WTP for fortification is twice as strong in females. This is consistent with the growing literature that shows that increasing women's human capital (by filling the nutrition

knowledge gap, for example) improves the nutritional outcomes of their household (Kurz and Johnson-Welch, 2016; Madzorera and Fawzi, 2020; Malapit and Quisumbing, 2015).

Table 4. Heterogeneity analysis of certification and information treatments on respondents' wtp (in birr per litre of cooking oil)

Respondent characteristics		Vitamin A fortification	Fortified cooking oil combined with		
			Government certification	Private certification	Nutrition messaging
Respondent age					
Between 18 and 35[a]		2.2 (0.7)	4.7 (0.6)	4.5 (0.5)	0.6(0.4)
Between 35 and 60[b]		5.6 (0.8)	5.0 (0.5)	4.3 (0.6)	0.7 (0.6)
Greater than 60[c]		2.0 (1.2)	5.4 (1.1)	3.8(1.3)	-0.1 (1.3)
Mean differences	b-a	3.4***	0.3	-0.2*	0.1
	c-b	-3.6***	0.4**	-0.5*	-0.8*
	c-a	-0.2*	0.7**	-0.7**	-0.7*
Respondent Sex					
Male		4.1 (1.3)	5.2 (0.4)	4.3 (0.5)	0.3 (1.2)
Female		4.6 (0.8)	4.9 (0.6)	4.2 (0.6)	0.6 (0.6)
Mean differences		-0.5*	0.3	0.1	-0.4**
Respondent education level					
No education[d]		3.9 (2.6)	4.6 (0.6)	4.2 (0.6)	0.4 (0.9)
Primary and secondary[e]		4.5 (2.7)	4.8 (0.6)	4.1 (0.6)	0.5 (0.9)
More than secondary[f]		4.7 (2.6)	5.3 (0.7)	4.4 (1.4)	0.8 (1.2)
Mean differences	e-d	0.6*	0.2	-0.1	0.1
	f-e	0.2	0.5*	0.3*	0.3*
	f-d	0.8*	0.7*	0.2**	0.4**
Monthly per capita income					
Below 600 birr[g]		3.8 (1.3)	4.3 (1.1)	4.1 (0.3)	0.3 (0.1)
Between 600 and 1,455 birr[h]		4.1 (0.8)	5.1 (0.6)	4.4 (0.7)	0.7 (0.7)
Above 1,455 birr[i]		4.7 (1.1)	5.3 (0.6)	4.0 (0.9)	0.6 (0.5)
Mean differences	h-g	0.3*	0.8*	0.3	0.4*
	i-h	0.6*	0.2	-0.4	-0.1
	i-g	0.9	1.0**	-0.1	0.3*
Respondent trusts health claims					
Yes		4.8 (0.6)	4.8 (0.5)	4.4 (0.5)	0.9 (0.5)
No		4.3 (0.8)	5.1 (0.6)	4.1 (0.3)	0.3 (0.7)
Mean difference		0.5**	-0.3	0.3	0.6**
Nutrient value is one of food choice motives					
Yes		6.1 (0.5)	5.3 (0.2)	4.1 (0.4)	0.8 (0.4)
No		4.5 (0.8)	4.8 (0.2)	4.2 (0.6)	0.4 (0.6)
Mean difference		1.6**	0.5*	-0.1	0.4**

Note: This table reports mean (standard deviation) wtp for product attribute stated in the respective column heading. ***, ** and * represents statistical significance at 1%, 5% and 10% level.

The certification and the nutrition messaging seem to have the highest effect for those respondents with more than secondary education, presumably because they are more likely to understand the content of the message than those with less than secondary education.

Wealthy respondents–per capita income greater than 1,455 birr –are less likely to increase their WTP for fortified cooking oil and respond weakly to the nutrition messaging. Perhaps this is because they do not necessarily need to consume fortified cooking oil to meet their nutritional requirements, as they may get the necessary nutrients from other food sources to which the poorer respondents may not have access. However, this wealthy group responds more strongly to certification, but only if it is issued by a government entity. Those with per capita income slightly above the national poverty line respond strongly to fortification as well as to certification. Compared to those with per capita income less than the national poverty line, those who earn between 600 and 1,455 birr per capita per month respond more positively to nutrition information.

Apart from the above socioeconomic characteristics of respondents, respondents' trust in nutrients and health claims and their food choice motives also moderates the effect of the information treatment. Those respondents who indicated high trust in nutrient and health claims also expressed a higher WTP for fortified cooking oil. This group also responded positively to the nutrition messaging: their WTP for fortification increased after they received the information treatment. The implication is that, apart from providing information, it is also important to pay attention to the credibility of the information.

Individuals whose food choices are motivated by the nutritional values of food are more willing to pay for fortification. They will also pay more for certification if the certificate is issued by the government. This is probably because if individuals take nutritional values in their food choices into account, then they are more likely to take heed of other health considerations in their food choices as well. The information treatment is found to be more effective to those for whom nutrient value was one of the main motives underlying their food choices. These results are consistent with food choice literature that documents the link between food choice motive and food choice behaviour (Konttinen et al., 2013; Naughton et al., 2015). These results highlight the importance of conducting general nutrition campaigns in addition to providing specific nutrition information on fortified foods.

2.4. Policy implications

Malnutrition is a complex issue, and winning the battle requires multiple interventions within the food system. The specific policy implications of this study are summarised as follows. First, nutrition awareness creation campaigns that aim at raising people's awareness of the nutritive value of foods and their benefits are effective in encouraging healthy food choices. This statement is in line with previous studies which show that making nutritional information accessible helps consumers to make better food choices (Berning et al., 2010; Miller and Welch, 2013). In the case of fortified cooking oil, campaigns should encourage the substitution of regular oil for fortified oil and be cautious not to inadvertently encourage overconsumption, especially in a country like Ethiopia where the dominant cooking oil is palm oil, which is high in saturated fat and thus associated with risk of heart disease (Brouwer, 2016). In addition, increased consumption of refined oils has been associated with the nutrition transition toward diets rich in sweeteners, fats and highly processed foods (Popkin, 2015).

Second, introducing a safety certification mechanism can be used effectively to promote a healthy diet. Certification allows consumers to easily identify foods that are deemed safe and thereby facilitates the shift to healthy diets. Sanogo and Masters (2002) reported similar findings for Mali, where people showed increased willingness to pay for quality certification.

Third, nutritional messaging and certification have heterogeneous effects depending on the education level, trust in institutions and people's food choice motives. Liu et al (2019) reported similar results, where consumers' degree of trust in food safety inspection and certificate authority affects their willingness to pay for food certified to be safe. Policymakers who wish to encourage healthy food choice behaviour among the community should be aware of the following points: information interventions need to be tailored to the audience's level of education, attention should be given to building consumer trust in institutions, and interventions need to be informed by the targeted population's food choice motives.

2.5. Conclusion

This study investigated the acceptability of vitamin A fortified cooking oil among urban consumers in Ethiopia and estimated the effect of certification and nutrition messaging on customers' willingness to pay for fortified oil. We conducted a stated choice experiment augmented by nutrition messaging. The experiment was conducted in an urban setting and

996 subjects selected randomly participated. We estimated WTP distributions for key attributes of cooking oil using flexible models parameterised in WTP space. The estimation resulted from the more general LML model in WTP space with correlated terms, which fits the data best.

We found that the average consumer preferred domestically produced cooking oil and was willing to pay for safety certification as well as for fortification. Even though consumers were willing to pay more for nationally produced oil, the magnitude of the WTP for certified and fortified cooking oil indicates that consumers would pay a significant premium for certified and fortified cooking oil even if it were imported. We also find that provision of information about the benefit of vitamin A increased consumers' WTP for fortified cooking oil, albeit slightly. Providing nutrition information is expected to increase the consumers' nutrition knowledge, which in turn allows them to make an informed decision. Finally, we found that the effect of safety certification on consumers' WTP for fortified cooking oil was higher than its effect on WTP for non-fortified oil, indicating that urban consumers value certification, even more, when fortification is involved. Among the product attributes studied, consumers attached higher importance to safety certification, followed by fortification. This is consistent with the study of Addis Ababa consumers by Melesse et al (2019), which reported that food safety issues loom larger in people's decisions than nutrition in the study area

The fact that consumers value fortification and safety certification is encouraging. From a public health perspective, this supports the government's effort to reduce micronutrient deficiency through food fortification. However, in a country like Ethiopia, where market competition and institutional regulations are limited, policymakers need to be aware that producers and traders may use consumer willingness to pay a premium to extract additional surplus from poor consumers. Thus, the distributional aspect is expected to be critical. There could be potential for public-private partnerships to work jointly to mitigate this concern, particularly during the early stage of introducing fortified cooking oil in the market. In addition, there may be a need to establish a regulatory mechanism to prevent the private sector from exploiting consumers' need for safe and nutritious options. This is particularly important given

the recent trend in the Ethiopian cooking oil market, whereby market and non-market shocks seem to give the private sector an excuse to charge an exorbitant price[4].

Heterogeneity analysis revealed that the effects of certification and nutrition messaging on consumers' willingness to pay for fortified cooking oil are moderated by socioeconomic characteristics, people's level of trust in institutions and their food choice motives.

[4] https://addisfortune.news/edible-oil-oily-prices-no-respite-for-consumers/. Accessed on 12th April 2022.

Appendix 2.1: Consequentiality clause

Your responses will be used to assist policymakers to determine whether fortified cooking oil is acceptable for consumers like you. Based on your preferences, policymakers could also determine whether foreign oil should be able to enter Ethiopia. Your preferences could also help the policymakers design an effective certification/food safety inspection mechanism that is acceptable to urban consumers like you.

Appendix 2.2: The script of the nutrition message

Vitamin A is an essential nutrient for humans. It helps people to stay healthy. It is needed for good eyesight, maintaining healthy skin, producing red blood cells and supporting the immune system. Therefore, we all need vitamin A, but young children especially need it because their bodies are at their developmental stage. Pregnant and nursing mothers should have diets rich in vitamin A because they are providing food for growing babies. A study showed that vitamin A deficiency affects 94% of the people in Addis Ababa.

Though vitamin A deficiency may not always have clinical symptoms, inadequate intake of vitamin A can cause blindness, infection, reduced growth and development of our bodies, less healthy skin and even lead to death, particularly in children.

Good sources of vitamin A in the diet include fruits and vegetables, especially those that are deep orange or dark green in colour. Vitamin A can also be found in dairy products, liver and egg yolks. Vitamin A-fortified cooking oil can also be an excellent source for getting the amount of vitamin A that our bodies need.

Chapter 3

Social norm, nutrition messaging demand for biofortified staple crops: Evidence from a discrete choice experiment in Ethiopia

Abstract

Social norms play an important role in any society. They influence how people behave in a given situation. Since the tendency to follow a norm is strong, useful social norms can be used to encourage behaviour change. We examine this possibility in the context of stimulating demand for nutritionally enhanced (biofortified) crops among smallholder farmers. Biofortification of staple crops is recognized as an effective public health intervention to prevent micronutrient deficiencies among smallholder farm households. Though biofortified maize has been introduced in Ethiopia, the adoption rate is low and empirical evidence as to how to effectively encourage the consumption of food prepared from these crops is limited. In this chapter, we explored the extent to which information interventions can be used to stimulate demand for biofortified maize. We examine the effect of a nutrition message – information on the benefits of biofortified maize and a social norm intervention-–information on the acceptability of biofortified maize by other farmers– on farmers' willingness to pay (wtp) for biofortified maize. The experiment is conducted on 2022 smallholder households, selected randomly from high maize-producing highland regions of Ethiopia. Our results indicate that the nutrition message alone is found to be effective in stimulating demand for biofortified maize while the social norm intervention alone does not seem to be effective in that regard. However, combining the two treatments is found to be even more effective in stimulating demand for biofortified maize, indicating the existence of synergistic effects of the two treatments.

Keywords: Social norm; nutrition; health messaging, willingness to pay; choice experiment; biofortified maize

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3.1-Introduction

Overcoming all forms of malnutrition worldwide is one of the most pressing challenges of our time. Malnutrition in children is especially harmful as it has long-term and substantial negative impacts on the child's future. Globally it is estimated that childhood stunting, wasting, and underweight, which all are manifestation of nutrient deficiencies, causes over 1 million deaths (GBD 2016 Risk Factors Collaborators, 2017). Malnutrition is also associated with lower cognitive ability in children (Grantham-McGregor and Ani, 2001; Kar et al., 2008; Liu et al., 2003). This in turn hampers future productivity (Siddiqui et al., 2020) restricting income-earning potential. The problem is especially acute for countries in the global south. For lower- and middle-income countries, the prevalence of stunting, wasting and underweight is reported to be 29.1%, 6.3% and 13.7%, respectively (Ssentongo et al., 2021).

In Ethiopia, a country with a population of 112 million, there are around 15.2 million children under the age of 5. For this age group, malnutrition is a persistent problem with stunting rate and underweight rate reported to be 36.8% (2019 estimate)[5] and 21.1% (2016 estimate)[6], respectively.

Malnutrition arises from insufficient or excess intake of nutrients. In developing countries, however, inadequate food intake is observed most frequently (Bain et al., 2013). In these settings, biofortification has been recognized as an effective and cost-efficient intervention to deliver essential nutrients (Nuss and Tanumihardjo, 2011; Ruel and Alderman, 2013). For biofortification to be effective, the biofortified crops need to be consumed by the target population at scale. Cereals (maize, sorghum, teff) form the bulk of the Ethiopian diet and are therefore good biofortification candidates. While these grains provide cheap energy, they lack key micronutrients and essential amino acids such as lysine and tryptophan (Hafebo et al., 2015; Nuss and Tanumihardjo, 2011). By enriching cereals with micronutrients, it is possible to improve nutrition without significantly disrupting the food system and diets.

The majority (79%, 2019 estimate) of the Ethiopian population lives in rural areas and a large share of these people depends on agriculture for their livelihood. One of the salient challenges

[5] UNICEF/WHO/World Bank Joint Child Malnutrition Estimate. URL: https://data.unicef.org/resources/dataset/malnutrition-data.

[6] UNICEF, WHO, World Bank: Joint child malnutrition estimates (JME)

agrarian households in Sub-Saharan Africa (SSA) face is failure of factor markets (Sheahan and Barrett, 2017). As a consequence, household production and consumption decisions are non-separable and own consumption of agricultural produce is salient (Allen, 2018; Dillon and Barrett, 2017). Hence strategies that support the consumption of biofortified crops should also support their production. Effectively promoting improved crop varieties requires a clear understanding of crop characteristics or attributes that are considered by the target population in their decision process. This is even more so for biofortified crops as the process of biofortification changes the characteristics of a crop. Moreover, since the key selling point of biofortification is its nutritional value, there is a need to understand how much the target population values the nutritional contents of a crop relative to other crop attributes and how one can increase this value.

The study focuses on maize. In Ethiopia, maize is the single most important cereal crop with 74.4 percent of produce used for own consumption in 2014/15 (CSA, 2020a). It is also the most important and cheapest source of calorie intake in the country, providing 23% of per capita calorie intake (Berhane et al., 2012). Recognizing its potential, maize has been an ideal candidate for biofortification interventions in Ethiopia. It has been successfully biofortified with proteins (Asare-Marfo et al., 2013), and the resulting varieties have been promoted in Ethiopia since 2012 (Teklewold et al., 2015). There is strong interest by the government of Ethiopia to cover 10% of the total maize growing area with biofortified maize, which is more than 227 thousand hectares by the latest estimate (CSA, 2020b). However, adoption is disappointingly low (Tessema et al., 2016).

We conducted a behavioural choice experiment among 2022 smallholder households from 184 rural *kebeles* in the maize-producing highlands of Ethiopia to assess their willingness to pay (wtp) for biofortified maize. This large and rich dataset allows us to estimate the effect sizes precisely and to make valid generalizations. We also study the impact of two interventions: nutrition and normative messaging. Provision of nutrition information can effectively stimulate healthy consumption by altering the information set on which people base their decision, though the evidence is relatively sparse for low and middle-income countries (Bonaccio et al., 2013; Chege et al., 2019; Donato et al., 2020; Miller and Cassady, 2015; Shimokawa, 2013). Similarly, social norm treatments have been effectively used to nudge consumers towards healthier choices (Bucher et al., 2016; Higgs et al., 2019; Lehner et

al., 2015; Lycett et al., 2017). Social norms have long been recognized to influence individual behaviour (Fehr and Falk, 2002; Lindbeck et al., 1999; Moffitt, 1983). Pointing people at social norms can motivate conformity (Cialdini, 2008) due to the two psychological phenomena of "herd behaviour" and the "bandwagon effect" (Corneo and Jeanne, 1997). People tend to make social comparisons and evaluate their own performance, possessions, and well-being, not in absolute terms, but relative to others (Smith et al., 2012). In addition, descriptive norms often function as shortcuts (i.e., heuristic cues) in the decision-making process and thereby influence behaviour (Cialdini, 2008).

We contribute to this literature in two main ways. First, we explicitly place nutrition in the context of own consumption of farm produce. The effect of information on food choice is generally limited to the consumption aspects of this choice, even when it involves poor rural populations (e.g., Chege et al. 2019). The notable exceptions are (Hotz et al., 2012), Donato et al. 2020, and De Groote et al (2016) who include the agricultural production process. Hotz et al (2020) compare different training intensities in an intervention to introduce biofortified sweet potatoes among smallholder farmers in Mozambique. Closely related to our study, Donato et al (2020) study the effect of information and storage tools on the feeding of own-produced biofortified maize to young children in Ethiopia. Yet, while we focus on willingness to pay for the biofortified seeds, they focus on the use of the produce after the seeds have been provided. Like us, De Groote et al (2016) study the impact of information on the adoption of biofortified maize in Ethiopia. However, their study is observational, considering the association between participation in extension activities and adoption.

Second, this is one of the first papers to look at shifting social norms in the domain of agriculture. The impact of social norms in affecting people's behaviour has long been recognized in the economics literature (Bagwell and Bernheim, 1996; Bernheim, 1994; Leibenstein, 1950) and continues to be a topic of study in recent years (Acemoglu and Jackson, 2017; Bursztyn et al., 2020). This growing literature has found that the willingness to conform to social norms has strong effects on a range of behaviours (Bursztyn and Jensen, 2017). However, in the agricultural domain, people's tendency to follow norms has not been exploited in encouraging the adoption of technologies. We explore to what extent normative messaging is effective in stimulating demand for agricultural technology. In addition, we assess if there is a complementarity between normative messaging and information

interventions in encouraging adoption of new crops. Since the two interventions can be combined cost-effectively, our result would be useful in designing messaging campaigns.

The results indicate that farmers are willing to pay a premium for biofortification. However, without messaging treatments, this premium is not enough to compensate for their dislike of the colour of biofortified maize, which is yellow whereas commonly consumed maize is white. Both treatments had a statistically significant positive effect on the wtp for biofortification, though the effect of the social norm treatment was too small to compensate for the negative effect of the yellow colour of the maize. The two treatments are found to be complementary and have synergistic effects indicating that combining the health message with a social norm treatment is more effective in stimulating demand for biofortification.

The rest of the paper is structured as follows. Section 2 briefly describes the conceptual framework of the study and how it fits into the food system. Section 2 describes the experimental design, the treatment, the data source, and the methods used to analyse the data. Section 3 presents the theoretical foundation of the experiment and describes the empirical strategy. Section 4 presents the results of the experiment. Section 5 discusses the results and section 6 concludes the paper with policy implications.

3.2. Research design and data collection

3.2.1. Experimental design

We conducted a discrete choice experiment (DCE) to answer the research questions. Choice experiments are based on Lancasterian consumer theory that goods and services are essentially bundles of various attributes, and the value of a good or service to a consumer is determined by the relative importance of these attributes (Lancaster, 1966). In the experiment, participants were asked to choose between hypothetical alternatives and there were no real consequences associated with the choice. As such, responses may differ from real-world behaviour (Hensher et al., 2015). To reduce the potential bias, choice sets were framed in a way that closely reflects the actual purchase decisions of farmers and an opt-out option was included. In this set-up, participants are informed that if they do not prefer either of the two alternatives, they have the option of choosing neither. Thus, though the results should be used with caution, DCEs are still useful and they allow researchers to gain an understanding of people's preferences (Louviere et al., 2010).

Based on the pilot survey and objective of the paper, we considered five attributes—seed price, producers' price, nutritional value, source of seed, and colour. Though there are other interesting crop attributes, we limited the attributes to five so as to reduce the cognitive burden on respondents and thereby increase the quality of our data. The choice of these attributes was guided by an extensive literature review, experts' opinions, and the results of a pilot testing the experimental design. Each attribute has various levels, which we selected to reflect actual situations respondents experience in the market. However, not all combinations of attributes are feasible in practice: as indicated before white biofortified maize is not yet available. We conducted a pilot test to see whether the attributes included were relevant and whether the levels for each attribute were plausible and understandable. The test results showed that respondents pay attention to the proposed attributes and that the attribute levels make sense from their perspective. Table 5 shows the final set of attributes and their respective levels.

Table 5. Attributes and attribute levels for the choice experiment.

Attributes	Description	Levels considered
Seed price	Price of one kg of maize seed in Ethiopian birr.	3 levels (24, 35, 47)
Product price	The selling price of one kg of maize in Ethiopian birr.	3 levels (7.00, 8.25, 9.50)
Origin of the seed	Source of the seed	4 levels (Other farmers, private traders, government, NGOs)
Bio-fortification status	Whether or not the maize is bio-fortified	2 level (bio-fortified, not bio-fortified)
Colour of the grain	The colour of the maize grain.	2 levels (yellow, and white)

The D–optimal approach of fractional factorial was used to design the experiment with the help of SAS software (Kuhfeld, 2010). This design approach generates choice sets that allow the estimation of all main and key interaction effects. It reduces the predicted standard errors of parameter estimates and gives unbiased estimates (Carlsson and Martinsson, 2003; Hoyos, 2010; Rose et al., 2008). Using D-optimal design, we generated 48 choice sets using random selection without replacement. To promote response efficiency and reduce the cognitive effort for respondents, the choice sets were optimally divided into 6 equal blocks of 8 choice sets using SAS macros to ensure orthogonality between the blocking factor and all of the attributes of all alternatives (Kuhfeld, 2010). Each choice set consisted of two maize seed types

(Options 1 and 2) and a no-buy option (Option 3). Inclusion of the no-buy option has been recommended by previous literature (Hoefkens et al., 2012; Louviere et al., 2000), as it reflects real market choices, where consumers can decide not to purchase maize seed. Figure 4 presents a sample choice set. The design has a maximum between attributes covariance of 0.04, suggesting a highly optimal and balanced orthogonal design.

Block 1 Question 1	Option 1	Option 2	Option 3
Seed price (ETB/kg)	35.00	47.00	Neither of the two
Product price (ETB/kg)	9.50	8.25	
Biofortification Status	Biofortified	Non-biofortified	
Source of the seed	Government	Other farmers	
Colour of the maize grain	White	Yellow	
I would like to choose: (please mark only one box)	☐	☐	☐

Figure 4. Example choice set

3.2.2. The treatments

Before the choice experiment, study participants were randomly divided into four groups. Group one was provided with nutrition information; Group two with a social norm treatment. Group three was provided with both nutrition information and the social norm treatment. The last group served as a control.

The nutrition information treatment involved informing participants of the benefits of consuming food produced from nutritionally enhanced maize. The information included in the nutrition message is adapted from a guide prepared by the International Maize and Wheat Improvement Center (CIMMYT) (Teklewold et al., 2015) to promote nutritionally enhanced maize in Ethiopia and incorporated inputs from Nutritionist from Ethiopia Public Health Institute[7]. The exact text of the message is:

> *"Consumption of nutritionally enhanced maize leads to better growth in children for whom maize is the major food staple. This is because nutritionally enhanced maize provides more high-quality protein for the human body than conventional maize."*

The social norm treatment involved informing participants that consumption of foods prepared from nutritionally enhanced maize is both common and socially desirable among their peers. Studies have demonstrated that behaviourally informed interventions induce

[7] Personal communication

substantial behaviour change in rural settings with regard to adopting pro-poor technologies (Benhassine et al., 2015; Donato et al., 2020; Hummel and Maedche, 2019) and influencing people's food choices (Bucher et al., 2016; Lehner et al., 2015; Lycett et al., 2017). More importantly, studies show that knowledge about what others who are close to the target population are doing can be leveraged to promote new technologies (Bandiera and Rasul, 2006; BenYishay and Mobarak, 2019; Krishnan and Patnam, 2014). In the economics literature, the tendency to follow norms has been used to explain a wide range of phenomena ranging from prosocial behaviour (Bénabou and Tirole, 2006; Tabellini, 2008) to the development and evolution of culture (Bernheim, 1994; Bisin and Verdier, 2001) to conspicuous consumption (Bagwell and Bernheim, 1996) to educational effort (Bursztyn et al., 2019). Social pressure or social image concern has also been exploited to design effective rule and punishment structures (Acemoglu and Jackson, 2017). In economics, social image concern or status is studied under the utility maximization framework. It is usually introduced into the utility function and assumed that apart from deriving utility directly from consumption, individuals also derive utility from their public image, which itself depends on their behaviour or actions (Bernheim, 1994; Bursztyn and Jensen, 2017). The literature also highlights that the need to conform to social norms is so strong that people are willing to incur costs or forgo benefits to not depart from social norms (Bursztyn and Jensen, 2017).

Close to our paper is a recent study by Bursztyn et al. (2020) about misperceived norms and women's labour market participation. The authors show that misperceived social norms negatively affect women's participation in labour markets and that correcting these beliefs increased women's labour participation. We bring these insights into a technology adoption context in the domain of agriculture and investigate if carefully crafted normative messages stimulate demand for a new crop variety.

Though the biofortified seed is not widely available in Ethiopia, the social norm treatment is based on the findings of studies conducted in places where the seeds were available. In these studies, subjects were asked to evaluate foods prepared from biofortified maize and conventional maize and most of them preferred foods prepared from biofortified maize (De Groote et al., 2014; Gunaratna et al., 2016; Teklewold et al., 2015). The text used for the social norm treatment was:

> *"A lot of people aren't aware that farmers prefer food prepared from nutritionally enhanced maize. When asked to choose between foods prepared from nutritionally enhanced and conventional maize, most farmers chose foods prepared from nutritionally enhanced maize variety"*

Farmers who are provided with these two types of information are expected to update their beliefs about the benefits of consuming biofortified maize, and this in turn is expected to be reflected in a higher wtp. More formally, farmers make decisions based on their information set. Their posterior belief or perception about bio-fortified maize is assumed to be a function of their prior belief and how they incorporate the information they received. Farmers adjust their choices if their posterior assessment is sufficiently different from their prior. The implication is that even if farmers incorporated the new information they received and update their belief on biofortified maize, they are not expected to change their actions if their posterior belief is not sufficiently different from their prior. Farmers may incorporate the information differently depending on their capacity to process information (age, education level), the level of trust in the information and information sources, and the relevance of the information for their choices (interest in nutrition, the importance of own produced maize in their diets). In addition, people may respond differently to the type of information provided: information about nutrition or social norms.

3.2.3. Data collection

The experiment was carried out as part of the nationally representative survey of the International Livestock Research Institute (ILRI-Ethiopia) conducted for its LIVES project[8]. Data collection took place in March – May 2018, using a Computer Aided Survey Instrument (CAPI) by a trained survey team. The choice experiment was added to the survey for 2022 smallholder households, selected randomly from 184 rural *kebeles*[9] in the six high maize producing zones of the three highland regions of Ethiopia (Amhara; Oromia; and Southern Nations, Nationalities and Peoples (SNNP) regions). Each respondent was randomly assigned

[8] For details, please see the project website https://cgspace.cgiar.org/handle/10568/25098

[9] In rural areas, kebele is the lowest administrative unit in Ethiopia and comprises of 4-5 villages and is a primary sampling unit.

to a treatment arm and to one of the six blocks. In total, we obtained responses to 16,176 choice sets, eight for each of the 2022 household representatives.

Respondents first received the treatment and then were asked to state their choices. The treatments involved audio recordings of messages prepared in a professional studio. The messages were translated into four local languages (Amharic, Oromifa, Gamo-Gofa-Dawro and Sidamo) and the respective audio recordings were prepared using native speakers. Before they were presented with the choice sets, respondents received a short description of the experiment, clear definitions of the product attributes, an explanation of how to respond to questions, and assurance of the confidentiality of their responses. Participation was completely voluntarily. Moreover, participants were informed that they could opt out of the experiment at any time with no penalty. During the experiment, participants were asked to evaluate very carefully the attributes of the maize seed before deciding which option they choose to buy. They were reminded repeatedly that the two maize seeds were identical in terms of agronomical properties such as productivity, diseases, and drought resistance, but different in terms of the five attributes. This information was highlighted to minimize the likelihood of participants evaluating the two maize seeds in terms of attributes not included in the choice experiments. They were also instructed that if they did not prefer any of the two options, they could choose none.

The study protocols, process, data management and risks related to participation in the experimental study are as per ILRI Policy and Guidelines of Research Ethics. The Ministry of Agriculture and Natural Resources and the relevant Regional Bureaus of Agriculture granted permission to conduct the survey. All participants provided written informed consent before participation.

3.3. Empirical approach

3.3.1. Theoretical foundations

The theoretical foundation of discrete choice models is provided by Hendler's (1975) and Lancaster's (1966) consumer theory, and McFadden's (1974) random utility theory. A decision maker faces a choice among j alternatives. Indexing an individual consumer by n, maize seed type (alternatives) by j and in choice situation *t*, the utility can be written as:

$$U_{njt} = -\alpha_n\, p_{njt} + \beta'_n\, x_{njt} + \varepsilon_{njt} \quad (1)$$

Where p_{njt} is price and x_{nj} are non-price attributes, α_n and β_n is a vector of coefficients of these variables for person n representing that person's tastes, and ε_{nj} is a random term that is iid type-one extreme value. The variance of ε_{nj} can be different for different decision makers: $\mathrm{Var}(\varepsilon_{njt}) = k_n^2\left(\frac{\pi^2}{6}\right)$, where k_n is the scale parameter for decisionmaker n. The coefficients are expected to vary over decision-makers in the population with density $f(\beta)$. Consumer n chooses alternative j if and only if $U_{njt} > U_{nit}\ \forall\, j \neq i$. Since a person's tastes (β_n) are not observed by the researcher, the unconditional choice probability will be used to extract the estimates, and this is given as.

$$P_{ni} = \int \prod_{t=1}^{T} \frac{e^{\beta'_n x_{nit}}}{\sum_j e^{\beta'_n x_{njt}}}\ f(\beta)d\beta \quad (2)$$

To estimate the parameters, an assumption was made about the specific functional form $f(\beta)$ would take.

To show how willingness to pay will be extracted, equation 1 can be specified utility as separable in price, p, and non-price attributes, x* and divided by the scale parameter k_n.

$$U_{njt} = -\lambda_n\, p_{njt} + c'_n\, x_{njt} + \eta_{njt} \quad (3)$$

where η_{njt} is iid type-one extreme value, with constant variance $\frac{\pi^2}{6}$. The utility coefficients are defined as $\lambda_n = \left(\frac{\alpha_n}{k_n}\right)$ and $\lambda_n = \left(\frac{\beta_n}{k_n}\right)$. Then, willingness to pay for an attribute is the ratio of the attribute's coefficient to the price coefficient: $\mathrm{wtp}_n = c_n/\lambda_n$.

Let $y_n = (y_{n1}, \ldots, y_{nT})$ denote the person's sequence of chosen alternatives and θ denote the parameters of the distribution, such as the mean and variance. Following (Train, 2009), individual level estimates are given by;

$$\bar{\beta}_n = \frac{\int \beta * P(y_n|x_n,\beta)\ f(\beta|\theta)d\beta}{\int P(y_n|x_n,\beta)\ f(\beta|\theta)d\beta} \quad (4)$$

3.3.2. Empirical analysis

Different econometric models are available to estimate the parameters in equation 2. We used a mixed logit (MXL) model. MXL models provide several advantages to most choice models. The MXL model provides an extended framework to better capture the true behavioural variability in choice making and is more consistent with the reality of making choices than most other discrete choice models (Hensher and Greene, 2002). MXL also allows greater flexibility in model specification and can handle correlation among parameters and choice situations (Hess and Train, 2017). MXL does not require any restrictions on the choice model or distribution of preferences. Finally, the MXL model relaxes the key assumption of independence from irrelevant alternatives (IIA), which is important for the most commonly used multinomial logit (MNL) regression models (Cheng and Long, 2007). We used different specifications to check the robustness of the results. Likelihood ratio test and information criteria such as Akaike information criterion (AIC) and Bayesian information criterion (BIC) were used to discriminate between alternative models.

The empirical analysis also involves estimating the average effects of the two treatments on respondents' wtp for the biofortified crop. Our randomized assignment of participants into the different treatment arms permits us to present clear evidence of the impacts of the two treatments. Using the framework of Equation 3, individual preference is specified as follows.

$$
\begin{aligned}
U_{njt} \quad = \quad & \mathrm{C}_n + \beta_1 Costseed_{njt} + \beta_2 Pprice_{njt} + \beta_3 SorPivte_{njt} + \beta_4 SorFarmr_{njt} + \\
& \beta_5 SorNGOs_{njt} + \beta_6 Bio\_Status_{njt} + \beta_7 Color_{njt} + \beta_8 Color_{njt} \# Bio\_Status_{njt} + \\
& \beta_9 Color_{njt} \# T1_n + \beta_{10} Color_{njt} \# T2_n + \beta_{11} Color_{njt} \# T3_n + \\
& \beta_{12} Bio\_Status_{njt} \# T1_n + + \beta_{13} Bio\_Status_{njt} \# T2_n + \beta_{14} Bio\_Status_{njt} \# T3_n + \\
& \beta_{15} Color_{njt} \# Bio\_Status_{njt} \# T1_n + \beta_{16} Color_{njt} \# Bio\_Status_{njt} \# T2_n + \\
& \beta_{17} Color_{njt} \# Bio\_Status_{njt} \# T3_n + \eta_{njt}
\end{aligned}
\tag{5}
$$

where C_n is constant representing the Neither option; $Costseed_{njt}$ is the cost of maize seed; $Pprice_{njt}$ is producer price of maize; $SorPivte_{njt}$, $SorFarmr_{njt}$ and $SorNGOs_{njt}$ represent the source of maize seeds that takes one if the source of seeds is private traders, other farmers and NGOs, respectively, where government is used as the base category. Bio_Status_{njt} is a dummy variable that takes 1 if the maize is biofortified and 0 otherwise, $Color_{njt}$ dummy variable that takes 1 if the maize is yellow and 0 otherwise. $T1_n$, $T2_n$and $T3_n$ represent the

treatment group of participants that takes 1 for information only, normative message only and information and normative messages. No treatment is used as the base category,

3.4-Results

3.4.1 Descriptive statistics and balance test

Table 6 shows the descriptive statistics for the sample and the balance test. 82.5% of the sample is male and the mean age of the sample is 48.6 years. Most of the participants are married (82.7%) and a little more than half of the participants (51.6%) have no formal education. Among those with education, primary education is the highest level achieved for 86.8% while the remaining 13.2% had some post-primary education.

The study was conducted in maize surplus-producing areas where farms are expected to participate in the maize market. Of 2,022 participants, 1,411 (67.4%) participated in the maize market as a seller. Use of improved maize seeds was common among the sample: 60.4% reported using improved seeds, which is more than the national average of 34% in 2017 (CSA, 2017). This characterizes the nature of the study areas as the main maize-producing regions. Maize is a main staple in the study areas, and almost 87% consume food prepared from maize regularly. 37.7% reported eating food prepared from maize every day, while another 21.3% consume foods prepared from maize at least twice a week. 41.6% of the sample had been exposed to nutritionally enhanced maize varieties previous. Participants were asked questions to measure their trust level. The results indicate that more than half of the sample (58.2%) answered the question, "when dealing with strangers, one is better off using caution before trusting"[10] affirmatively.

Table 6 also presents the means and the statistics of mean differences tests across the treatment groups for demographic characteristics and other pre-treatment measures. Scanning across each row reveals no significant difference among the different treatment groups in terms of observable characteristics. Though not conclusive evidence against randomization problems, the absence of notable imbalances provides some evidence that the randomization plan was successful.

[10] Using field experiment, the trust question has been shows to be a valid measures of trust (Glaeser et al., 2000)

Table 6: Descriptive statistics and balance table

Variable description	Pooled	Treatment arms 1	2	3	Control	P-value
Sex of household head						
Male	82.5%	80.3%	83.3%	80.8%$_a$	85.8%$_a$	0.083
Marital status						
Single	1.2%	1.4%	0.8%	1.7%	1.1%	
Married	82.7%	81.9%	84.9%	79.7%	84.6%	0.132
Divorced	5.2%	4.7%	3.3%	7.2%	5.5%	
Widowed/Widower	10.9%	12%$_a$	11.0%	11.4%	8.9%	
Education						
No education	51.6%	54.2%	53.3%	51.3%	47.2%	
Primary	42.0%	40%	40.9%	41.8%	45.7%	0.402
Secondary and above	6.4%	5.7%$_a$	5.8%	6.8%	7.2%	
Maize output market participation as seller	67.4%	67.1%	69.0%	66.7%	66.6%	0.869
Consumption of food prepared from maize						
Every day	37.7%	36.5%	39.3%	34.0%	41.2%	
Often (More than twice a week)	21.3%	21.9%	18.6%	23.4%	21.4%	
Sometimes (More than once a month, up to twice a week)	20.8%	20.5%	23.3%	21.1%	18.2%	0.121
Rarely (Once a month or less)	13.1%	15.0%	11.4%	12.4%	13.5%	
Never	7.1%	6.1%	7.4%	9.1%	5.7%	
Previous exposure to nutritionally enhanced maize variety	41.6%	39.3%	40.5%	43.3%	43.6%	0.422
Used improved maize seeds	60.4%	60.9%	61%	60.8%	58.7%	0.894
When dealing with strangers, one is better off using caution before trusting them	58.2%	59.2%	59.9%	55.5%	58.4%	0.501
Age of household head (years)†	48.6	49.3	48.8	48.1	48.4	0.392
Income (Birr)†	18,351	19,416	18,553	16,601	18,934	0.083
Number of observations	2022	507	516	526	473	-

Note: The p-values are for the test of association among the treatment groups. The test used for categorical variables is chi squared. For continuous variables (†) the statistics is F.

3.4.2. Results of model estimation

We estimated four models with different assumptions about the correlation of parameters (no correlations and full covariance) and about the interaction effect (with and without interaction), and two estimation methods (maximum simulated likelihood (MSL) and Hierarchical Bayes (HB)). The models are estimated in Stata using the user-written command "mixlogit" and MATLAB using the estimation command made available by Train (2006). The coefficients for sources, colour, and biofortification status are assumed to follow a normal distribution, while the monetary attribute - producer selling price of maize, is assumed to follow a lognormal distribution. The cost attribute–the price of maize seed– is assumed to be fixed. However, as we progress to the estimation of wtp, these assumptions have been relaxed and a more flexible mixing distribution– a logit formula – is adopted.

Table 7 reports the estimates of Model 1, Model 2, Model 3, and Model 4. Allowing interaction in the model increases the simulated log-likelihood (SLL) at convergence from -7596.50 (for model 1) to -7542.29 (for model 2). The results from Bayesian estimation procedures are presented in the third and fourth columns. We used 10,000 iterations for the burn-in period. After convergence, 10000 draws were specified of which every tenth is retained to calculate the relevant statistics. Compared to Model 2, Model 3 reached a higher SLL (-7354.40 compared to -7542.29). With regards to Goodness of fit statistics, model 3 also has lower AIC (14742.79 compared to 15154.58) and BIC (14873.54compared to 15462.22).

Allowing for full correlation amongst coefficients (model 4) further increases the simulated log-likelihood (SLL) at convergence from -7354.40 to -7240.00. The likelihood ratio test suggests that the hypothesis that the extra parameters in Model 4 are zero can be rejected at the 99% confidence level (χ^2 (136) = 228.8028, p = 0.000). In addition, model 4 attained lower AIC (14513.99 compared to 14742.79) and BIC (14644.74 compared to 14873.54). Since the model that allows full correlation among parameters fits the data much better than its alternative, it is used for further analysis.

Table 7: Estimates of the models

	Model 1	Model 2	Model 3	Model 4
Mean of coefficients				
Cost of maize seed (ETB/kg)	-0.207*** (0.005)	-0.214*** (0.006)	–0.291*** (0.0062)	-0.305*** (0.0052)
The selling price of maize (ETB/kg)	0.826*** (0.031)	0.974*** (0.033)	1.281*** (0.045)	1.217*** (0.034)
Source of seeds (ref government)				
Private traders	-2.307*** (0.103)	-2.48*** (0.116)	-3.447*** (0.177)	-2.469*** (0.189)
Farmers	-1.381*** (0.086)	-1.343*** (0.089)	-1.628*** (0.15)	-1.418*** (0.088)
NGOs	-1.316*** (0.084)	-1.288*** (0.089)	-1.619*** (0.1)	-1.25*** (0.104)
Biofortified maize (1=Yes)	3.054*** (0.09)	2.707*** (0.196)	4.239*** (0.124)	2.999*** (0.173)
Colour of the grain (1=yellow)	-2.064*** (0.086)	-2.546*** (0.204)	-3.117*** (0.169)	-2.925*** (0.194)
Biofortification # colour		-0.554** (0.258)	-0.901*** (0.098)	-0.763*** (0.197)
Colour # Info only		0.947*** (0.267)	0.549*** (0.147)	1.007*** (0.152)
Colour # Norm only		0.669*** (0.258)	-0.237 (0.203)	0.098 (0.17)
Colour # Infor and Norm		1.311*** (0.265)	1.266*** (0.14)	0.861*** (0.169)
Biofortification # Info only		1.232*** (0.263)	0.625*** (0.134)	0.981*** (0.21)
Biofortification # Norm only		0.81*** (0.263)	0.147 (0.107)	0.671*** (0.25)
Biofortification # Info and Norm		0.968*** (0.262)	0.863*** (0.094)	1.107*** (0.119)
		-0.157	-0.137	-0.357**

Colour # Biofortification # Info only		(0.344)	(0.103)	(0.163)
Colour # Biofortification # Norm only		-0.347 (0.343)	0.208** (0.099)	-0.188 (0.141)
Colour # Biofortification # Info and Norm		0.603* (0.336)	1.142*** (0.086)	1.089*** (0.17)
No purchase	0.318 (0.288)	0.202 (0.286)	1.103*** (0.369)	-2.218*** (0.254)
Variance of coefficients				
Selling price of maize (ETB/kg)	0.443*** (0.049)	0.657*** (0.076)	1.219*** (0.06)	2.127*** (0.07)
Source of seeds (ref government)				
Private traders	3.227*** (0.467)	5.366*** (0.605)	10.405*** (1.162)	11.77*** (1.269)
Farmers	0.024 (0.042)	0.006 (0.025)	0.518*** (0.116)	2.349*** (0.542)
NGOs	-0.014 (0.035)	0.003 (0.014)	1.184*** (0.2)	3.393*** (0.435)
Biofortified maize (1=Yes)	3.316*** (0.423)	4.707*** (0.459)	9.976*** (1.053)	10.849*** (1.279)
Colour of the grain (1=yellow)	2.87*** (0.376)	1.637*** (0.29)	6.821*** (0.67)	8.744*** (1.052)
Biofortification # colour		0 (0.001)	0.303*** (0.045)	1.81*** (0.417)
Colour# Info only		0.796* (0.413)	0.465*** (0.067)	2.803*** (0.531)
Colour# Norm only		0.774** (0.341)	1.374*** (0.327)	3.49*** (1.031)
Colour# Infor and Norm		0.363 (0.272)	1.33** (0.61)	2.208*** (0.469)
Biofortification# Info only		0.062 (0.12)	0.553*** (0.15)	3.139*** (0.427)
Biofortification# Norm only		0.183 (0.157)	0.374*** (0.082)	2.521*** (0.406)

Biofortification# Info and Norm		0.046	0.901***	3.273***
		(0.113)	(0.285)	(0.514)
Colour # Biofortification # Info only		0.001	1.375***	2.721***
		(0.013)	(0.239)	(0.748)
Colour # Biofortification # Norm only		0.007	1.02***	1.625***
		(0.04)	(0.199)	(0.215)
Colour # Biofortification # Info and Norm		0.518*	0.356***	3.727***
		(0.287)	(0.135)	(0.792)
No purchase	-38.45***	40.926***	69.93***	25.389***
	(2.88)	(2.741)	(6.963)	(2.645)
Number of observations	48,528	48,528	48,528	48,528
Number of participants	2,022	2,022	2,022	2,022
Estimation approach	Classical	Classical	Bayesian	Bayesian
Correlation among parameters	NO	NO	NO	YES
Interaction	NO	YES	YES	YES
Log-likelihood value at convergence	-7596.50	-7542.29	-7354.40	-7240.00
Akaike information criterion (AIC)	15222.99	15154.58	14742.79	14513.9903
Bayesian information criterion (BIC)	15354.84	15462.22	14873.54	14644.7421

Note: Data are presented as coefficient (standard error). Info only denotes Information treatment only; Norm only denotes social norm treatment only and info and Norm denote information and social norm treatment. *, ** and *** denote significance at 10%, 5% and 1% level respectively.

The estimates are reasonably stable across models and the coefficients have the expected signs (see table 7). All else equal, farmers preferred nutritionally enhanced maize seeds to seeds that are not nutritionally enhanced. However, if the seeds turned out to be yellow, their interest decreased significantly. Respondents preferred white maize to yellow, and the coefficient for the interaction of biofortification status with the colour attribute is significant and negative. White maize is more widely cultivated in Ethiopia, and a significant proportion of maize produced is consumed at home. The Colour of food has long been shown to affect how appealing or unappealing food is (Clydesdale, 1991; Delwiche, 2012). Since white maize is what the study participants are used to eating, uncertainty about the taste and flavour of food prepared from yellow maize may explain their hesitancy toward yellow maize. The preference for white maize is reported in other Sub-Saharan African countries where consumers showed a strong preference for white maize and required a significant price discount (37%) to accept yellow maize (De Groote and Kimenju, 2008). A study on orange

sweet potato in rural Mozambique finds different results where the colour of the crops was found to be not a barrier to adoption (Hotz et al., 2012). However, there is a small but significant difference between these two settings. The sweet potato study was conducted in areas where different coloured crops are commonly produced and consumed, which eased the resistance to one additional colour, while the current study was conducted in areas where most of the farmers produced only white maize. This result may partially explain why the adoption of nutritionally enhanced maize is limited in the country.

The respondents preferred maize seeds sourced from the government. Though the private sector and NGOs play a role in the seed market, the government is currently the main source of seeds for smallholder farmers. The least popular source of seed is the private sector. This is not surprising since the role of the private sector in seed supply is limited, and farmers might not have had adequate opportunities to try seeds from the private sector and form beliefs about their quality and performance.

Farmers preferred maize seeds that command a higher price in the market. In Ethiopia, farmers produce maize mainly for consumption. However, the study participants are in high maize producing zone and market considerations are incorporated in the farming decision.

The variance of each random coefficient is highly significant, indicating that there is heterogeneity in the preferences for the various attributes of maize seeds. For instance, white maize was preferred by 82.9% of farmers, and 82.6% of farmers were estimated to prefer having biofortified white maize, while the other one-fifth preferred the regular white maize.

3.4.3. Estimated willingness to pay

We used the results of Model 4 in table 8 to estimate the wtp for each attribute. The parameters of the wtp were estimated by maximum simulated likelihood method in Matlab using the code made available by (Train, 2015). The results are based on a random sample of 1500 points drawn independently for each person in the sample. The mixing distribution is specified as a sixth-order polynomial and standard errors are calculated by bootstrapping.

Biofortification had a positive effect on farmers' wtp for maize seed. Compared to non-biofortified white maize, farmers were willing to pay 12.18 birr per kg more for white biofortified maize seeds. However, as indicated before, the colour of the maize affected their

preferences: On average, farmers were willing to pay 12 birr less per kilo of non-biofortified maize seeds if the colour of the maize was yellow. Compared to non-biofortified white maize– which is what they usually buy, farmers were willing to pay 2.34 (12.18 -12 – 2.52) less per kilo of biofortified yellow maize seeds, without any interventions. Hence, on average our sample farmers are less likely to switch to biofortified yellow maize seeds without any intervention.

Table 8: Mean and standard deviation of wtps

Attribute	Mean wtp		Std Dev wtp	
	Estimate	SE	Estimate	SE
The selling price of maize (ETB/kg)	3.46***	0.105	4.17***	0.276
Source of seeds (ref government)				
Private traders	-10.40***	0.526	10.88***	0.404
Farmers	-5.10***	0.468	5.72***	0.267
NGOs	-4.86***	0.148	7.01***	0.097
Biofortified maize (1=Yes)	12.18***	0.418	11.42***	0.292
Colour of the grain (1=yellow)	-12.00***	0.652	9.70***	0.183
Attribute interaction				
Biofortification # Colour	-2.52***	0.372	5.12***	0.167
Attribute and treatment interaction				
Colour# Info only	4.03***	0.703	6.16***	0.081
Colour# Norm only	0.63	0.982	7.08***	0.268
Colour# Infor & Norm	2.66***	0.505	5.43***	0.138
Biofortification# Info only	4.31***	0.489	6.68***	0.078
Biofortification# Norm only	1.50***	0.508	5.76***	0.085
Biofortification# Info and Norm	4.30***	0.635	7.33***	0.259
Colour # Biofortification # Info only	-1.96***	0.599	6.16***	0.170
Colour # Biofortification # Norm only	-0.96***	0.368	4.93***	0.113
Colour # Biofortification # Info and Norm	2.34***	0.353	6.85***	0.407
No purchase	-4.19***	1.508	17.97***	0.351
Price/scale	0.744***	0.018	0.576***	.0054

Note: Data are presented as coefficient (standard error). Info only denotes Information treatment only; Norm only denotes social norm treatment only and info and Norm denote information and social norm treatment. *, ** and *** denote significance at 10%, 5% and 1% level respectively.

Though a significant proportion of maize production is used for household consumption, the results indicated that farmers were willing to pay more for maize seeds if they could sell the produce at a higher price. The estimates indicate that farmers were willing to pay 10.4 birr per kilo of maize seed to avoid seeds from private traders (Table 8). The output price of maize is positively associated with farmers' willingness to pay for seeds.

3.4.4. Treatment effects

The effects of the treatments on farmers' wtp for biofortified yellow maize seed can be calculated from table 8. To compute the treatment effect from table 8, which involves three-way interactions, first remember that wtp for biofortified yellow maize of farmers in the control group was -2.34 (computed in the previous section). Then computing the effect of each treatment involves adding the relevant interaction terms. For instance, wtp of farmers who received nutrition message was 4.04 (-2.34 + 4.03 + 4.31 -1.96) birr per kg. In other words, information only increased wtp for biofortified yellow maize by 6.38 (4.03 + 4.31 -1.96) as compared to the control group.

The effect is significant and consistent with a recent study conducted in Ethiopia, which showed a positive effect of nutrition messaging in changing consumption behaviours (Donato et al., 2020). The result is also consistent with a study conducted in Kenya and Uganda that also showed that availing nutrition information increases consumers' wtp for improved porridge flour (Chege et al., 2019). De Groote *et al.*, (2017) also reported a positive relationship between nutrition information and wtp for fortified pearl millet in Senegal

Similarly, the effect of the social norm treatment is found to be positive and statistically significant. In terms of magnitude, however, the effect on wtp is only 1.17 (0.63+1.50-0.96) birr per kg, which was not enough to counter the disinclination among farmers towards yellow maize, as demonstrated by a negative wtp (-2.34).

The two treatments are complementary and have a synergetic effect: Combining the treatments increased the wtp for biofortified yellow maize by 9.3 birr more (2.66+ 4.30+2.34), which is higher than the sum of the individual treatment effects (6.38 + 1.17= 7.55) and the difference is found to be statistically significant ($F1, 2013 = 21.30$, $p = 0.000$) We thus find evidence of information strengthening the effect of the social norm treatment. As the costs

of adding social norm information to a regular information campaign are small, combining the treatments in suggested in future behaviour change campaigns.

3.5- Discussion

We tested two interventions -nutrition education and normative messaging; to provide insights into the effect of these interventions on farmers' willingness to pay for biofortified maize in Ethiopia. Our approach is novel in the sense that the impact of nutrition education in conjunction with social norm messaging has not been explored before.

We find that nutrition education increased farmers' wtp for yellow biofortified maize. The social norm treatment also affected farmers' wtp positively but was not enough to compensate for the reluctance farmers showed towards yellow maize. However, combining the two treatments had synergistic effects in stimulating demand for biofortified maize.

Our study builds on public health literature examining nutrition and health education interventions on food choice. Our results are in line with the consistent pattern emerging from this literature that there is a strong relationship between nutrition knowledge and healthy food choice (Scalvedi et al., 2021; Snyder, 2007; Spronk et al., 2014; Wardle et al., 2000). Also, several studies in developing countries identify gaps in nutrition knowledge as one of the barriers to eating healthy. In Uganda, a nutrition knowledge gap is observed, and this in turn is shown to influence household dietary diversity (Nabuuma et al., 2021). Similar findings in reported for rural South Africa (Taruvinga et al., 2013) and Tanzania (Mbwana et al., 2016). Limited access to nutrition knowledge is also linked with worsened household nutrition outcomes in Bangladesh (Zongrone et al., 2018), Nepal (Osei et al., 2017), and Cambodia (Michaux et al., 2019). Based on randomized field experiments and causal mediation analysis, de Brauw et al. (2018) showed that maternal knowledge of nutrition messages had an effect, albeit small, on the adoption of nutritionally enhanced potato varieties in both Mozambique and Uganda.

Our study also builds on the health communication literature examining how social norms can be leveraged to promote healthy diets. Higgs et al. (2019) argued that the eating habits of others are used by people to guide their consumption. In their study, the authors demonstrated that exposure to a descriptive social norm message increased intake of vegetables in both laboratory and field settings. In addition, our results contribute to the

growing literature that demonstrates the utility of using nudging interventions to influence people's food choices (Bucher et al., 2016; Hollands et al., 2017; Lehner et al., 2015; Lycett et al., 2017). Our results are also consistent with the findings that knowledge about the social norms with regard to a new technology affects people's behaviour and that this, in turn, affects the decision to adopt the new technology (Bandiera and Rasul, 2006; BenYishay and Mobarak, 2019; Donato et al., 2020; Krishnan and Patnam, 2014).

To our knowledge, this is the first study that explores nutrition education and social norm intervention in a single study. As such, our results are a contribution to the limited literature that combines psychological insights into education interventions. The synergetic effect of the two treatments is consistent with the idea that people tend to conform to norms because they find it rewarding to do so (Higgs, 2015), such that knowing the consequence of following norms makes the tendency to conform even more strong.

3.6-Conclusion and implications

Malnutrition remains an important public health problem in Ethiopia, where the prevalence of child stunting and underweight is high. Biofortification is effective in availing essential nutrients to poor rural populations who have little access to nutritious food. A key concern, however, is how to effectively promote the adoption and consumption of nutritionally enhanced crops.

Nutrition messages have long been an important component of such efforts. In addition, describing how most people behave in a given situation –social norm treatment– has been shown to affect agents' information set and this, in turn, is expected to affect people's preferences. Combining these two approaches represents one potential solution that helps to prompt the adoption and consumption of biofortified crops. Overall, our results suggest that a nutrition message can be made more effective in bringing about behaviour change needed to adopt and consume biofortified crops by combining it with information about how common consumption of biofortified crops is.

Our results should be considered in light of the following limitations. First, the study assessed the short-term effect of the two interventions only. We measured the wtp of participants for nutritionally enhanced maize seeds immediately after exposure to the treatments and did not document the long-term effects. Second, the effect of the social norm messages is expected to be more effective if the target population strongly identifies with the reference group

(Higgs, 2015). People's eating behaviour is influenced by knowledge of how people with whom they are socially connected eat (Higgs et al., 2019). Our social norm message referred to the behaviour of farmers in general. The effects could be stronger for more specific reference groups. Third, the credibility and familiarity of the information provided under the two treatments are expected to affect the effectiveness of our treatment. If participants do not believe the information contained in the nutrition message or are already familiar with it, they are unlikely to update their information set and their choice would not be impacted by the treatment. Likewise, if different people evaluate the credibility and familiarity of the messages differently, then the effects of the treatment are likely to vary among the participants. In this study, we assumed that the majority of participants believed the information contained in our treatment and that the information was new to them. We did not explore the potential treatment heterogeneity that would emanate from variation in perceived credibility and familiarity of the information. Finally, though the two interventions are cost-effective to implement and have the potential to reach those who suffer the most from lack of inadequate intake of nutrients, whether the potential effect would be clinically relevant or meaningful is unclear.

From our results, we draw the following implications. First, our findings suggest that provision of nutrition education may be effective in promoting the production and consumption of biofortified staple crops. Our results also suggest that effort to encourage consumption of foods prepared from biofortified crops may find it useful to leverage people's tendency to follow norms and combine normative messages with nutrition education. Second, future studies that aim to improve the effectiveness of nutrition education by combining it with normative messages need to pay attention to the extent to which the target population identifies with the reference group. Finally, whether the positive impact of the two interventions considered here would have clinically meaningful effects remains an open question. This is an important consideration for future research for proposing the best policies to improve adoption of biofortified staple crops and ultimately promote intake of food prepared from these crops.

Chapter 4

Leveraging behavioural economics to inform nutrition-sensitive agriculture: An experimental study on the nutritionally-enhanced crop in Ethiopia

Abstract

There is an increasing interest in using insights from behavioural economics and psychology to influence people's decisions. However, little is known as to how to leverage these insights to inform educational campaigns in the context of nutrition-sensitive agriculture. We help to fill this void by investigating the effect of framed messages (gain vs loss) in stimulating demand for nutritionally-enhanced crops. We conducted a field experiment with 648 farmers and found the following key results. First, nutrition education stimulates demand for nutritionally-enhanced crops among smallholder farmers. Without nutrition education, farmers are less likely to switch from producing conventional maize to nutritionally-enhanced maize. Second, gain-framed messages are slightly more effective: they result in a higher willingness to pay for nutritionally-enhanced maize than loss-framed messages. Third, motivational orientations and risk perceptions of individuals moderate the effect of the framed messages. Finally, due to variation in risk perception among prevention and promotion-oriented individuals, the two moderator variables may reinforce or weaken each other.

Keywords: Framing; Regulatory fit, Agricultural decision maker; Auctions; Field experiment

JEL codes: D91 I12 Q12 C21 D83

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4.1-Introduction

Transforming food systems in order to deliver better nutritional outcomes to the growing global population is an immediate challenge and requires new ways of thinking and new approaches. The importance of agriculture as a core determinant of nutrition has long been recognized, and agricultural policies that incorporate nutritional outcomes have been promoted particularly in developing countries to address food and nutrition insecurity (Gillespie and van den Bold, 2017; IFPRI, 2011; Ruel et al., 2018; Ruel and Alderman, 2013). In recent years, the call to increase the nutritional status of smallholder farmers and their families through nutrition-sensitive agriculture has received a lot of attention (Kennedy et al., 2021; The EAT–Lancet Commission, 2019).

Promoting nutritionally-enhanced food crops is one of the efforts resulting from such calls (Ruel et al., 2018). As smallholder families consume a substantial share of their produce, the cultivation of such crops would directly improve the quality of their diets. However, as is the case for many agricultural technologies, adoption rates are still low (Ruzzante et al., 2021). One factor that has hindered the wide adoption of nutritionally-enhanced crops is the lack of information about their nutritional benefits (Ruel et al., 2018; van Campenhout, 2021). As a result, raising awareness and filling the knowledge gap are used to stimulate demand (FAO, 2016; Kodish et al., 2015). Yet, motivating and sustaining a behaviour change may require moving beyond the provision of knowledge to the engagement of emotions and activation of motivations. It has long been noted that individuals' motivational orientation guides behaviour (Craig, 1917) and that framed messages may activate this motivational system (Updegraff et al., 2007; Yan et al., 2012, 2010).

In this study, we aim to explore how insights from behavioural economics as well as from psychology can be leveraged to inform educational campaigns in the context of nutrition-sensitive agriculture. The education campaigns are meant to educate farmers about the consequences of their production choices for the health of their families through home consumption of their produce. The following questions guide our study: 1) Is providing nutrition education messages effective in stimulating demand for nutritionally-enhanced seeds? 2) How do differently framed nutrition messages affect farmers' willingness to pay

(wtp) for nutritionally-enhanced seeds? 3) How do individuals' motivational orientation and risk perception moderate the effectiveness of framed messages?

The framing effect is derived from the prospect theory of Tversky and Kahneman (1981), who demonstrated that preferences depend on the formulation of decision problems. A key conclusion is that people tend to be risk-avoiding when contemplating gains and risk-seeking when contemplating losses. The health communication literature examines framing effects in a variety of settings ranging from encouraging health-seeking behaviour (Banks et al., 1995; Ye et al., 2021) to physical activities (Drouin et al., 2018) to shaping attitude (Jean et al., 2021) to promoting healthy food choice (Binder et al., 2020; Elbert and Ots, 2018; Godinho et al., 2016). These studies explored the framing effect by providing gain- or loss-framed health messages and find support for the hypothesis that gain(loss)-framed messages would be effective in promoting safe(risky) behaviours in the health domain (Meyerowitz and Chaiken, 1987; Rothman and Salovey, 1997). The key insight here is that the perceived risk associated with the advocated behaviour determines which message framing would be more effective in bringing about the intended behaviour changes. If there is significant variability in the way behaviour is construed (e.g., whether the behaviour is perceived risky or less risky), then messaging strategies that do not take these insights into account tend to be less effective.

However, the empirical results on the relationship between risk perception and framed messages are mixed (Van 't Riet et al., 2014), indicating that there may be other relevant inter-individual differences that interact with risk perception. One of such differences is individuals' regulatory focus. For instance, Mann et al. (2004) show that the dominant regulatory focus of individuals moderates the effectiveness of differently framed messages. This approach categorizes people into two groups: promotion-focused individuals and prevention-focused individuals. Promotion-focussed individuals are geared towards achieving something, while prevention focussed individuals are geared towards preventing negative things from happening (Cesario et al., 2008). By framing messages such that they fit the regulatory focus of individuals, it is possible to increase their impact (Higgins, 2000): With proper regulatory fit, decision-makers feel right about the message; and their engagement is strong (Cesario et al., 2008). Put differently, a promotion-focused individual would respond better to a gain-framed message, whereas a prevention-focused individual would respond better to a loss-framed message. The implication is that apart from risk perception, an individual's dominant

motivation system also moderates the framing effect. However, the interaction of these two moderators has not been studied

A notable work in the health economic literature is by List and Samek (2015), who leveraged the framing effect to tackle child food choice and consumption. Unlike the literature in health communication, List and Samek (2015) explored the framing effect by using framed incentives. Children were given the choice between a healthy and an unhealthy snack. A random selection received a small price if they selected the healthy snack (gain-framed incentive), and another random selection received a price, but it was taken away if they selected the unhealthy snack (loss frame incentive). Contrary to the hypothesis that children would be loss averse and thus more responsive to the loss-framed incentive, List and Samek (2015) found both incentives to be equally effective in stimulating the choice of the healthy snack. In their set-up, List and Samek (2015) did not explore the role of key moderators such as risk perceptions of the promoted behaviour and motivational orientation of participants. Since the promoted behaviour in the study–switching to healthy snacks– can be thought of as of limited risk, risk perception might not be an important moderator. However, the motivational orientation can still be relevant in this context.

In this paper, we study the framing effect together with the two moderators discussed above –risk perception and motivational orientations– in the context of stimulating demand for nutritionally-enhanced maize among Ethiopian farmers. In Ethiopia, maize is the single most important cereal crop with 74% of the produce used for own consumption in 2014/15 (CSA, 2015). It is also the most important and cheapest source of calories in the country, providing 23% of per capita calorie intake (Berhane et al., 2012). Recognizing its potential, maize has been identified as an ideal candidate for biofortification interventions in Ethiopia, (Asare-Marfo et al., 2013). However, the adoption of biofortified (nutritionally-enhanced)[11] seeds is disappointingly low (Tessema et al., 2016). This paper seeks to assess whether active promotion with carefully framed messages could stimulate adoption.

This paper seeks to contribute to the literature in two ways. First, we document the framing effect in the context of a nutrition-sensitive agriculture intervention among smallholders. Most message framing studies are conducted on college students and have focussed on the

[11] In this paper we use biofortified and nutritionally-enhanced interchangeably.

health domain –disease detection (Williams et al., 2001), vaccination (Ferguson and Gallagher, 2007; Van 't Riet et al., 2014), and smoking cessation (Toll et al., 2008). Our results provide empirical evidence about the utility of using framed messages in a context markedly different from the context of these previous studies. Second, we contribute to the growing literature exploring the cross-fertilization of ideas and methods from economics and other social science fields such as psychology to refine strategies to promote healthy diets. From behavioural economics, we took the insight that people have reference-dependent preferences and that framing of choice problems affects behaviour. From the auction literature, we took the Becker–DeGroot–Marschak (BDM) method to elicit willingness to pay. BDM is an incentive-compatible valuation methods method that is widely used by economists in field studies. From psychology, we took the idea that people are more likely to engage in a given task when there is a match between orientation to a goal and the means used to approach that goal. Our results suggest that, by marrying concepts from different disciplines, it is possible to finetune behaviour change communication strategies in the promotion of healthy diets.

We find that nutrition education messages stimulate demand for nutritionally-enhanced crops among smallholder farmers. Without nutrition education, farmers are less likely to switch from producing conventional maize to nutritionally-enhanced maize. We also find that, on average, a gain-framed message is slightly more effective than a loss-framed message. This contradicts our hypothesis that farmers are loss averse and thus more responsive to loss-framed messages. Our results hold when controlling for socio-demographic characteristics, farm characteristics and behavioural tendencies of participants.

We show that message framing, risk perception, and individual motivational orientation interact in important ways that determine which framing is most effective. For instance, a gain-framed message is more effective than a loss-framed one when the perceived risk associated with the new crop is low. The converse is true when the perceived risk is high. On the other hand, if the perceived risk is medium both gain- and loss-framed are equally effective. The implication is that the framing effect becomes more noticeable when the perceived risk is sufficiently high or low. This is consistent with the notion that perceived risk associated with the advocated behaviour affects the relative effectiveness of gain-and loss-framed messages (Rothman and Salovey, 1997).

With regards to motivational orientation, we find that gain-framed messages are more effective than loss-framed messages for promotion-oriented individuals in stimulating demand for nutritionally-enhanced maize seed. For prevention-oriented individuals, both gain- and loss-framed messages seem to be equally effective.

These results suggest that insights from behavioural economics and psychology can be used to inform nutrition-sensitive agricultural interventions. We study the utility of these insights in the context of nutritionally-enhanced crops. Nevertheless, we believe that our findings on the framing effect and the moderating role of risk perception and motivation orientation could be generalized to other types of agricultural and nutrition interventions.

The remainder of the paper is organized as follows. Section 2 summarizes the underlying theoretical framework and related literature and presents the hypotheses. Section 3 describes the context and provides details on the experimental tasks and procedures, as well as the empirical strategy. Section 4 presents the empirical results, and section 5 discusses the findings. Finally, section 6 concludes the paper by discussing policy implications.

4.2. Analytical framework and hypotheses

We expect that the information value contained in the messages has a positive effect on participants' wtp for nutritionally-enhanced maize seeds because farmers are currently badly informed about the benefits of this new technology. There is ample evidence that shows informational interventions can make a substantive difference in people's behaviour (e.g. Bundala et al., 2020; Kulwa et al., 2014; Reinbott et al., 2016; Reinbott and Jordan, 2016). Consequently, we state our first hypothesis as follows.

> *Hypothesis 1:* The respondents who received a nutrition message are willing to pay more for nutritionally-enhanced maize seed than those in the control.

The core of our study is about the comparison of gain-framed and loss-framed messages. The relative attractiveness of two options can be influenced by the way decision problems are framed. The theoretical underpinning of this phenomenon can be found in Kahneman and Tversky (1979), who argue that people have a tendency to avoid risk when a decision is framed

in terms of potential gains but become risk-seeking when a choice is framed in terms of potential losses. Let's assume that overall utility $V(*)$ for a representative agent depends on consumption bundle c and a reference bundle r and is given as

$$V(c|r) = u(c) + R(c|r), \quad (1)$$

where $u(*)$ is consumption utility increasing and concave in c and $R(*)$ is a value function of prospect theory that satisfies the conditions stated in Kahneman and Tversky (1979). The formulation states that first, people encode information relevant to risky decisions in relation to a reference point *r*. Second, the value function is increasing ($R'(c) > 0$) and concave ($R''(c) < 0$) for consumption above the reference point and is steeper, increasing ($R'(c) > 0$) and convex ($R''(c) > 0$) below it.

The reference point may be determined by a diversity of factors such as social norms, expectations, aspirations, or by the way outcomes are framed. Tversky and Kahneman (1981) showed that a different way of framing choices (gain or loss for example) induces different reference points by implicitly designating the higher or the lower states as a normal reference. The important prediction of the above formulation as it relates to this study is that people are loss averse such that they are more likely to engage in risky behaviour (to adopt a new crop variety) when potential outcomes are framed in terms of losses (not adopting can have negative consequences) rather than as gains (adopting has positive consequences). This is because the value function is steeper for losses than for gains. Thus, we specify the following hypothesis.

> *Hypothesis 2:* Messages promoting nutritionally-enhanced maize seeds are more effective if they stress the negative consequences of nonadherence rather than the positive consequences of compliance. More specifically, the effect of a loss-framed message on participant wtp for a nutritionally-enhanced maize seed is higher than the effect of a gain-framed message.

Building on this, Meyerowitz and Chaiken's (1987) argued that in health communication, framing effects –the effectiveness of gain- vs. loss-framed information– is moderated by the perceived risk that is associated with the advocated behaviour. Risk perception refers to people's subjective evaluation of the likelihood of a negative outcome of a given decision problem. It determines which threats people care about and how they deal with them (Paek

and Hove, 2017). It is important to note that risk perception is not the same as risk preference, which refers to the decision maker's attitude to risks. While risk preferences appear to be moderately stable over time (Schildberg-Hörisch, 2018), risk perceptions are context-dependent (Ferrer and Klein, 2015). As such, different decision problems may elicit different risk perceptions from the same decision-maker.

The specific prediction is that gain(loss)-framed messages are expected to elicit stronger responses when recipients perceived the advocated behaviour as less(more) risky. Several empirical studies provide evidence for this hypothesis (e.g., Ferguson and Gallagher, 2007; Hwang et al., 2012; Rothman et al., 2006a; Rothman and Salovey, 1997). After conducting a meta-analysis on 94 peer-reviewed studies, Gallagher and Updegraff (2012) concluded that gain-framed messages appear to be more effective than loss-framed messages in promoting health behaviours perceived to be minimally risky to carry out. Translating this to our study, we expect farmers' risk perception to moderate the effect of our treatment. We exploit variation in risk perception among our study participants and specify the following hypothesis.

- *Hypothesis 3:* Loss(gain)-framed messages are more effective for farmers who perceive the risk associated with producing and marketing nutritionally-enhanced maize to be high(low).

As risk perceptions are not experimentally varied, we cannot formally test this hypothesis and any results must be interpreted as correlations rather than causal relations.

Another key moderator that has received much attention in framed message research is the motivational system of individuals (Mann et al., 2004; Sherman et al., 2008, 2006). In the psychology literature, the importance of making an approach-avoidance distinction has long been recognized as a useful conceptualization of peoples' motivational systems (Lewin, 1935). In approach motivation, behaviour is directed by a positive/desirable possibility, whereas in approach motivation, behaviour is directed by a negative/undesirable possibility (Elliot, 1999). Higgins (1997) introduced a similar characterization of the motivational system, namely promotion and prevention. Promotion-oriented individuals are concerned with accomplishments and aspirations and focus on making progress toward their hopes and aspirations, whereas prevention-oriented individuals are more concerned about safety and

security and tend to focus on avoiding mistakes. Under this framework, regulatory fit is assumed to be achieved when there is a match between motivational orientation and means used to pursue desired goals. Regulatory fit increases the value of what is being pursued and strengthens engagement (Higgins, 2005, 2000). The literature refers to this as regulatory fit theory. As it relates to framed messages, regulatory fit theory predicts that gain-framed messages are more effective for approach-oriented and promotion-focused people, whereas loss-framed messages are more effective for avoidance-oriented and prevention-focussed people.

This prediction is confirmed in several studies (Cesario et al., 2004; Mann et al., 2004). These studies showed that by directing gain-framed messages to approach-oriented individuals and loss-framed messages to avoidance-oriented focus individuals, it is possible to increase the effectiveness of messaging campaigns.

Cesario et al. (2008) provide a possible explanation as to why matching the framing of messages with the motivational orientation of individuals works. They argue that when messages are framed congruent with recipients' mindsets, message receipts *feel right* when receiving the message and their engagement with the messages increases. In the economics literature, confirmation bias –the tendency to interpret and use new information in a manner that fits existing beliefs– has long been identified as one of the heuristics that people employ when making decisions (Jones and Sugden, 2001). By combining brain imaging with financial decision tasks, De Martino et al. (2006) showed that the pattern of brain activation of subjects is different when decisions are in line with their general behavioural tendency and when they are not. This suggests that there is a neurobiological basis for the regulatory fit theory.

The key point is that the motivational orientation of individuals may accentuate (attenuate) the recipient's subjective experience of feeling right towards the advocated behaviour when exposed to framed messages so that the message recipients are more (less) likely to adopt the advocated behaviour.

> *Hypothesis 4.1:* For prevention-oriented individuals, loss-framed messages elicit higher wtp than gain-framed messages.

Hypothesis 4.2: For Promotion-oriented individuals, gain-framed messages elicit higher wtp than loss-framed messages.

Like risk perceptions, we did not experimentally alter motivational orientation, so the results reflect correlation rather than causation. The two moderator variables may reinforce or weaken each other.

4.3- Methodology

4.3.1. Context and Design

The research was conducted in West Gojjam Zone of the Amhara Region of Ethiopia. The Zone accounts for about 46% of maize produced in the region, and the region generates 25% of maize produced in the country (CSA, 2017). More than 70% of maize produced in the zone is used for own consumption. Child undernutrition is high[12]: prevalence of stunting is 38%, underweight 23%, and wasting around 19% (Motbainor et al., 2015). Thus, identifying effective nutrition interventions, like biofortification, is expected to lead to significant health and welfare gains.

The experiment was conducted on 648 participants in total selected from 7 districts. Districts were selected randomly from the list of maize-producing districts. From each district, three or four kebeles were selected randomly from the list of maize-producing kebeles. From each kebele, two villages were selected randomly. From each village, 12 farm households (four districts) or 15 farm households (three districts) were selected randomly from lists of maize-producing households. These farmers were stratified randomly divided into two treatment groups and a control group. Randomization was done at the village level. Each farmer was asked to express wtp for both conventional and biofortified maize in an incentive-compatible procedure.

[12] WHO classify stunting, underweight, and wasting high or serious when it becomes in the range of 30–39.9%, 20–29.9% and 10–14.9% in the community, respectively.

A power analysis was conducted prior to the fieldwork and showed that the sample size allows us to detect small effect sizes.[13] A pre-analysis plan (PAP) was registered in advance of carrying out the experiment.[14] Ethical approval for research protocols, process, data management and risks related to participation in the research was obtained from the Social Sciences Ethics Committee at Wageningen University. The Ethiopia Ministry of Agriculture and Amhara regional state Bureau of Agriculture granted permission to conduct the experiment. All participants provided written informed consent.

To solicit the wtp for biofortified maize seeds for each participant, we used the BDM approach, as detailed below. In the BDM elicitation procedure, subjects individually submit sealed bids for a good. A random price is then drawn from a prespecified distribution. Individuals with bids greater than the randomly drawn price "win" the auction and purchase a unit of the good at the randomly drawn price.

While the BDM mechanism is in theory incentive-compatible, it is not the only mechanism with this property. It has been shown that the choice of auction mechanism can influence the level of bids, despite their theoretical equivalence (Lusk et al., 2004). From a practical point of view, however, one is left to choose one method, since it is generally not feasible to use multiple incentive-compatible mechanisms to elicit preferences. We chose the BDM mechanism, which has been shown to be suited in low-literacy environments (Cole et al., 2020). While this may, for example, have resulted in higher bids than random nth price bids (Lusk et al., 2004, we have no reason to expect that this choice has affected our conclusions, which do not depend on the level of the bids but only on the relative effects of the different information treatments compared to each other.

Before the BDM procedure, an audio-recorded message with nutritional information was played to the two treatment groups. Group one received a gain-framed message and group two a loss-framed message about food prepared from biofortified maize. In constructing the messages, care was taken to ensure that the two messages delivered the same information

[13] Small effect size corresponds to Cohen's effect-size measure f which is the standard deviation of the standardized means (Cohen, 1988 pp285-287) where 0.1, 0.25 and 0.4 correspond to small, medium and large effect size.

[14] The pre-analysis plan was registered on American Economic Association (AEA) registration platform (https://www.socialscienceregistry.org/trials/6040).

and referred to the same outcomes but used different framing. (See table 9 for the exact messages.) The third group did not receive any treatment and served as a control.

Table 9: Messages used in the experiment

Gain-framed message	***Loss-framed message***
*If you rely on maize as the principal daily food and **consume** biofortified maize...*	*If you rely on maize as the principal daily food and **do not consume** biofortified maize...*
*...your household members, children especially **will be provided** with sufficient protein, which performs the fundamental role of protecting the body.*	*...your household members, children especially **will not be provided** with sufficient protein, which performs the fundamental role of protecting the body.*
*Sufficient consumption of protein leads to **better growth** in young children such as height and weight.*	*Insufficient consumption of protein leads to **poor growth** in young children such as height and weight.*
*It will **help** the functions of the immune system, which **works** in keeping you and your family healthy*	*It will **jeopardize** the functions of the immune system, which **will fail** in keeping you and your family healthy*
Various health problems may ***be prevented** by **adequate** consumption of food that contains protein, and **sufficient** protein intake leads to **rapid** growth in children. Biofortified maize is an excellent and cheap source of protein*	*Various health problems* are ***caused** by **inadequate** consumption of food that contains protein and **insufficient** protein intake **may delay** or **prevent** growth in children. Biofortified maize is an excellent and cheap source of protein*

4.3.2. Experimental procedure

Initially, the experiment was planned to be executed in groups where those assigned to a specific group would be brought into a room. However, in response to the COVID 19 pandemic, that idea was abandoned, and the procedure was executed with each participant individually.

In each village, 12 or 15 participants were invited to participate in the experiment. On the day of the experiment, each participant was informed about the objective of the experiment and that participation was voluntary. After obtaining their informed consent, participants were asked to pick a number from a box, which contained 12 or 15 pieces of paper numbered 1 through 12 or 15. Then Stata's "splitsample" command was used to split participants into three random samples of equal sizes.

To compensate for their time, farmers were given a participation fee that they could use in the auction experiment. Since participation fees can be considered as windfall income and can influence the bid, we used two levels of fee (120 and 240 birr, or 3.6 and 7.2 USD) to control for this effect on farmers bidding behaviour[15].

To increase the extent that the context in which subjects cast decisions resembles the real-life context we did the following. First, we conducted the experiment just before the planting period of maize, which is when farmers typically buy seeds. Second, we asked participants to bid for two types of maize seed: conventional maize and biofortified maize seed. In a market setting, farmers naturally compare new varieties with the conventional maize seed that they are accustomed to. By availing both seeds, we tried to make the experimental context resemble the natural environment that farmers would normally face. To control for ordering effects, the two maize varieties were offered in alternate orders. Third, participants were asked to bid for the quantity of maize seeds a typical farmer would buy (3-kg[16]). One of the two bids was selected randomly, and the bid was evaluated against a randomly drawn offer price. When the participant's bid was equal to or higher than the offer price, the respondent was asked to buy the maize at the offer price, and money was exchanged for the product.

We explained the BDM procedure in detail to the participants, emphasizing that the transaction must be executed if a participant's bid was higher than the random offer price (unknown to the bidders) drawn from a distribution. We informed participants that it was to their advantage to bid the highest price they were willing to pay. Otherwise, they would run the risk that they would not be able to buy the seed, although they would have liked to buy the product at the drawn price. We also explained carefully that they could buy a maximum of one bag of seeds. The type of seeds would be determined by a random draw, and whether they should purchase the seed would depend on their wtp and the offer price. This procedure was intended to ensure the independence of the two bids: the farmers did not have to worry

[15] To avoid possible tension the same fee was be given to all participants from the same village and the higher fee was given to the second of the two villages in a kebele.

[16] Discussions with maize farmers in the study areas revealed that a typical farmer buys around 3kg of maize seeds for a single production season.

to end up with more seeds than they needed or with a combination of more preferred and less preferred seeds.

To help the participants understand the procedure better, a test round with a polypropylene grain storage bag was organized. The participants were provided with 10 Ethiopian Birr (ETB) (ETB1=US$0.030 in May 2020). Participants were then asked to make a bid for the grain bag. Their bid was compared to an offer price previously unknown to the bidders. They were then asked if they thought they won the bid or not and to explain why. When the bid was equal to or higher than the offer price, the respondent was reminded that this implied purchasing the grain bag. It was only after the participants understood the auction procedure that the actual experiment proceeded.

As a manipulation check, all participants were asked an open-ended question to list reasons for consuming food prepared from nutritionally-enhanced maize immediately after they placed their bid. Placing the manipulation check after measuring the outcome variables rather than before is a slightly better approach in terms of reducing potential distortions (Kane and Barabas, 2019).

Finally, participants were interviewed to collect data on socioeconomic characteristics, farm characteristics, motivational orientation, and risk perception. These variables are used to study heterogeneity in treatment effects within the sample.

4.3.3. Moderating variables

We collected information about the motivational orientation of participants using a modified version of the Promotion/Prevention Scale by Lockwood et al. (2002). We excluded four questions from the original list of eighteen that are directly related to academic motivations (*e.g.*, schoolwork, exams). The remaining list contained eight items related to the endeavour of aspirations and an ideal self (the promotion subscale), and eight items related to the avoidance of negative events and a feared self (the prevention subscale). Two items were very similar when translated into the local language, and during the pilot test, participants indicated that they found it difficult to distinguish between the two. So, we only retained one of these, resulting in seven promotion questions and six prevention questions. Responses were given on a 9-point scale ranging from 1 ('not at all true of me') to 9 ('very true of me').

To construct an index of motivational orientation, we used principal component analysis of factor extraction and varimax rotation of factor loads. We used an iteration approach to get the final index, removing those items that showed very low communalities and repeating the whole procedure.[17] The final set of items comprised a total of eight items, four items for the promotion and prevention sub-scale, each. These items load highly on two factors with factor loadings > 0.65 and >0.71 for promotion and prevention factors, respectively. The two extracted factors have an eigenvalue greater than 1 and account for 74.2% of the variances observed. Cronbach's alpha is 0.70 for the promotion factor and 0.76 for the prevention factor, suggesting that the items have an acceptable level of internal consistency (>0.70). Since all items are measured using the same scale, the average score of items linked with the prevention sub-scale was subtracted from the average score of items linked with the promotion sub-scale to arrive at the motivational orientation score. Negative values are considered indicative of prevention focus and positive values are considered as promotion focus. We convert this into a dummy with 0 prevention-oriented and 1 promotion-oriented.

Risk perception is measured using the widely used agricultural risk assessment framework of the World Bank (World Bank, 2016). This framework takes into account multiple risks to provide a better understanding of participants' risk perception (Komarek et al., 2020). Participants were asked to state their perceived risk of planting nutritionally-enhanced maize seeds. Specifically, they were asked about their perception of the production (yield and diseases resistance) and marketing (output price and lack of demand) risks of the biofortified maize as compared to regular maize in terms of probability of occurrence and their perception of the intensity of the impact of these risks on their food availability and farm income (World Bank, 2016). A combined score was created by taking the mean[18] for each type of risk and categorized as highly probable (1 in 3), probable (1 in 5) and occasional (1 in 10) with regards to the probability of the event, and negligible (losses <5%), moderate (losses 5–15%), considerable (losses 15–50%) catastrophic (losses >50%) with regards to the intensity of the impact. Using the categorization rule of Table 10, participants' risk perception was coded as high, medium or low (World Bank, 2016).

[17] The output of the analysis is presented in the annexe
[18] The mean values are rounded to the nearest unit.

Table 10: Categorization of perceived risk

Probability of event	Severity of Impact			
	Negligible Losses <5%	Moderate Losses 5-15%	Considerable Losses 15-50%	Catastrophic Losses >50%
Highly probable (1 in 3)	Low	Medium	High	High
Probable (1 in 5)	Low	Medium	High	High
Occasional (1 in 10)	Low	Low	Medium	Medium

4.3.4. Empirical strategy

The random assignment of individuals to the different treatment conditions is central to this experiment's empirical strategy. Because of this random assignment, individuals with different treatment conditions are expected to be similar in every respect except for their treatment. Any difference in outcome between treatment groups can thus be attributed to the difference in treatment. As indicated before, our moderating variables are endogenous, so results for these variables must be interpreted with care.

We are primarily concerned with estimating the average effect of the two treatments on participants' absolute and relative wtp for biofortified maize seed, with relative wtp defined as the difference in wtp between biofortified and conventional maize. The main effect of the two treatments is estimated by a regression equation of the following form:

$$Y_i = \beta_{10} + \beta_{11} TreatD_i + \beta_{12} R_i + \beta_{13} M_i + \beta_{14} X_i + \varepsilon_i \quad (2)$$

Where Y_i is wtp for biofortified maize seed and relative wtp of farmer i; $TreatD$ is a dummy indicating whether a farmer is exposed to the treatment irrespective of the framing. It takes 1 if a farmer received either of the two messages and 0 otherwise. R is risk perception and *M* motivational orientation; X is a vector of covariates that we control for[19], namely household head sex, age, education level, household size, previous awareness of biofortified crops, land size, herd size (in TLU), previous maize harvest and proportion sold, and participation fee; and ε_i is the disturbance term for the regression. β_{11} indicates the average treatment effect of receiving a message on Y, which we hypothesize to be larger than 0.

[19] In the PAP of this paper, previous experience with the crop was also included among variables with interaction effects. However, since a large majority of the study participant (87%) said they had never planted biofortified maize seeds in the past, we excluded this variable from the analysis. Instead, we included age and risk perception of participants as controls.

Since we are also interested in testing the hypothesis that loss-framed messages are more effective than the gain-framed message in stimulating demand for nutritionally-enhanced maize seed, we estimated the following regression equation:

$$Y_i = \beta_{20} + \beta_{21}LOSS_i + \beta_{22}GAIN_i + \beta_{23}R_i + \beta_{24}M_i + \beta_{254}X_i + \eta_i \quad (3)$$

Where *Y*, *R*, *M*, and *X* are defined as in Equation 2; $LOSS$ and $GAIN$ are binary response variables indicating whether a farmer is subjected to a loss or a gain-framed message; and η_i is the disturbance term for the regression. We predict that $\beta_{21} > \beta_{22}$.

As noted previously, our two treatments are expected to work differently for promotion and prevention-oriented individuals. The interaction effects of the treatments with these covariates are estimated by a regression equation of the following form:

$$\begin{aligned} Y_i = {} & \beta_{30} + \beta_{31}LOSS_i + \beta_{32}GAIN_i + \beta_{33}LOSS_i * R_i + \beta_{34}GAIN_i * R_i + \\ & + \beta_{35}LOSS_i * M_i + \beta_{36}GAIN_i * M_i + \beta_{37}R_i + \beta_{38}M_i + \beta_{39}X_i + \in_i \end{aligned} \quad (4)$$

Where *Y*, *R*, *M*, and *X* are defined as in Equation 2; and $\in_i$ is the disturbance term.

To study how differences in risk perception for a given motivational orientation affect the treatment effect, we specify the following regression equation:

$$\begin{aligned} Y_i = {} & \beta_{40} + \beta_{41}LOSS_i + \beta_{42}GAIN_i + \beta_{43}LOSS_i * R_i + \beta_{44}GAIN_i * R_i + \\ & \beta_{45}LOSS_i * M_i + \beta_{46}GAIN_i * M_i + \beta_{47}R_i * M_i + \beta_{48}LOSS_i * R_i * M_i + \\ & \beta_{49}GAIN_i * R_i * M_i + \beta_{50}M_i + \beta_{51}R_i + \beta_{52}X_i + \mu_i \end{aligned} \quad (5)$$

Where *Y*, *R*, *M*, and *X* are defined as in Equation 2; and μ_i is the disturbance term.

Ordinary Least Squares (OLS) was used to estimate the treatment effects. We used robust standard errors, following the recommended practice of not clustering standard errors if treatment is assigned at the individual level (Abadie et al., 2017). We have largely followed the PAP. The only additional ex-post analysis that we did was the inclusion of risk perception. We corrected p-values for family-wise error rate using the highly conservative Bonferroni method accounting for the number of hypotheses ultimately tested.

4.4-Results

4.4.1 Descriptive Statistics

Descriptive statistics of variables that characterize the study sample are presented in Table 11. Three-quarters of the sampled households are headed by men. On average, study participants are about 44 years old with about 3 years of schooling. About two-thirds of the sample had heard about nutritionally-enhanced maize seed but only 16.2% had cultivated it. On average 4 people live in a household owning about 1.5 hectares of agricultural land and 4 livestock units (in TLU). The farm size is higher than the national average (0.9 hectares) but is similar to the average holding in high maize potential areas in the country (Headey et al., 2014).

During the production season preceding the survey period, the farmers planted 0.26 ha of maize on average, resulting in 0.115 tonnes of produce of which 25% was sold in the market. These figures are higher than the country averages, where a typical maize farmer grows maize on 0.20 hectares of land producing 39 quintals/ha and selling about 12% of the harvest. This is not surprising, since the study is conducted in high maize-producing areas. Most study participants (58.3%) rated the risk associated with adopting nutritionally-enhanced maize as medium (33.3%) or high (25%).

The average motivation orientation index is -0.66 with a standard deviation of 1.88, indicating that the regulatory focus for the majority (65.4%) of the study participants is prevention-oriented –they have a heightened sensitivity to losses. The distribution of the index among the study participants is moderately skewed to the right and has slightly high excess kurtosis.

We do not find significant differences among the treatment groups except for the proportion of maize sold, which is somewhat higher for treatment group 2. This absence of notable imbalances is the result of our individual-level randomization.

Table 11: Summary statistics of sample characteristics

Variable description		Treatment group			Test statistics	ALL
		1. Gain	2. Loss	3. Control		
Sex of participants (1=Male) ƒ		75.0%	75.5%	75.0%	0.017 (0.992)	75.2%
Participant's age (in years)		43.5	44.3	44.9	0.86 (0.422)	44.2
Highest educational attainment (in years)		2.7	3.0	2.8	0.59 (0.554)	2.8
Household size (in number)		4.2	4.2	4.4	1.99 (0.138)	4.3
Agricultural land (in hectare)		1.50	1.52	1.52	0.06 (0.940)	1.51
Household wealth (in 10000 birr)		4.61	5.05	4.59	0.34 (0.710)	4.75
Livestock ownership 2019/20PY (in TLU†)		3.92	3.89	4.16	0.49 (0.612)	3.99
Awareness about biofortified crops (1=Yes) ƒ		67.6%	69.0%	66.7%	0.268 (0.874)	67.7%
Plant biofortified maize in the past (1=Yes) ƒ		17.1%	15.3%	16.2%	0.273 (0.873)	16.2%
Risk perception	Low	44%	38.4%	42.6%	3.227 (0.520)	41.7%
	Medium	34.7%	33.3%	31.9%		33.3%
	High	21.3%	28.2%	25.5%		25%
Motivational orientation score		-0.65	-0.82	-0.51	1.42 (0.243)	-0.66
Areas planted with maize seed in the 2019/20 production season (in hectare)		0.26	0.26	0.25	0.12 (0.885)	0.26
Total maize produced n the 2019/20 production season (in quintals)		10.8	12.1	11.8	0.63 (0.531)	11.5
Proportion maize sold in 2019/20 (%)		0.23	0.27	0.24	4.20** (0.015)	0.25
Observations		216	216	216		648

Note: ***, ** and * denotes means difference between the treatment group is significant at 1% level, 5%, and 10% level

† TLU: tropical livestock units, equivalent to an animal of 250 kg weight (Cattle=0.7; sheep and goats=0.1; horses = 0.8, mules 0.7 donkey=0.5 Chicken: 0.01) (Jahnke, 1982).

The test statistics are for the test of association among the treatment groups with p-values in parenthesis. The test used for categorical variables (ƒ) is chi squared. For continuous variables, the statistic is F. Motivational orientation of participants is measured using a modified version of the Promotion/Prevention Scale by Lockwood et al (Lockwood et al., 2002). To capture participant risk perception, they were asked to assess the production (yield and disease resistance) and marketing (output price and lack of demand) risks in terms of probability of occurrence and their perception of the intensity of the impact of these risks on their food availability and farm income.

4.4.2. Manipulation check

All participants were asked to list reasons for consuming food prepared from nutritionally-enhanced maize immediately after they placed their bid. The responses to this question were categorized into two groups –reasons related to possible gains/benefits from consuming and reasons related to potential losses from not consuming. To check whether those provided with gain(loss)-framed messages mentioned more gain(loss)-related reasons on average, we then ran linear regressions of the number of gain (loss) related reasons that participants mentioned as a dependent variable and treatment status as an explanatory variable. Two specifications –with (1) and without (2) sociodemographic covariates were estimated to check the robustness of the results (Table 12).

As expected, those provided with gain-framed messages mentioned more gain-related reasons on average as compared to either of the remaining groups. Similarly, those provided with loss-framed messages stated more loss-related reasons than the remaining groups. The inclusion of socio-demographic covariates does not alter the results. In addition, the control group that did not receive any messages scored lower on both gain-related and loss-related reasons than either treatment group. The results provide evidence that the treatments elicited the expected difference among the treatment groups. This in turn allows us to estimate more precisely the effect of the treatment on the outcome variable.

Table 12: Manipulation check

	Dep. Var=number of ***Gain*** related reasons		Dep. Var=number of ***Loss*** related reasons	
	(1)	(2)	(1)	(2)
Gain	1.648***	1.645***	0.782***	0.796***
	(0.099)	(0.099)	(0.104)	(0.103)
Loss	1.004***	1.000***	1.250***	1.240***
	(0.099)	(0.098)	(0.104)	(0.103)
Constant	0.810***	0.878***	0.773***	0.120
	(0.070)	(0.372)	(0.074)	(0.388)
Control for socio-demographic covariate	No	Yes	No	Yes
Adjusted R-squared	0.30	0.32	0.18	0.23
N	648	648	648	648
F test for H_0: Gain=Loss	41.96***	43.28***	20.20***	18.61***

Notes: The table reports the results of running a regression on the number of possible benefits (loss) associated with consumption (not consumption) of food prepared from nutritionally-enhanced maize. The analysis allows us to check if participants retain some of the information from the educational message. Standard errors in parentheses. *, ** and *** denote statistical significance at 0.1,0.05 and 0.01 level. Covariates that we control for are household head sex, age, education level, household sizes, participation fee, previous awareness about biofortified crops, risk perception, motivational orientation, land size, herd size (in TLU), previous maize harvest and proportion sold.

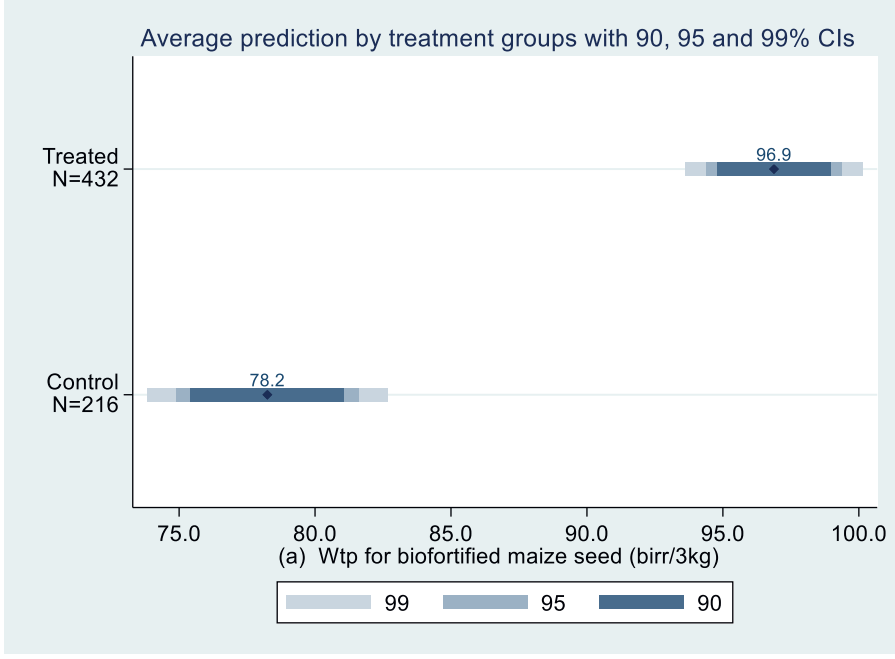
4.4.3. Model estimates

We start by presenting the results of Equation 2. As summarized in Figure 6a, wtp for biofortified maize seed was higher for those who received either of the two messages than those who did not (32.2 birr as compared to 26.1). The difference between the two groups is statistically significant (p-value<0.01). Since participants were asked to bid for two types of maize seeds –conventional and biofortified– we also compared the wtp differences for these two maize seed varieties, which we termed in this study as relative wtp. We find that those in the treatment groups are willing to pay 5.0 birr/kg more for biofortified maize seeds than conventional maize, and this was higher than for those in the control group, which are willing

to pay 2.2 birr/kg less (Figure 6b). The difference between the two groups is statistically significant (p-value<0.01). This gives our first result:

Result 1: Nutrition education messages stimulate demand for nutritionally-enhanced seeds among smallholder farmers**.** Without nutrition education, farmers are unlikely to switch from producing the conventional maize to biofortified maize, as they are willing to pay less for nutritionally-enhanced seeds which are yellow than for conventional seeds which are white. Farmers' preferences for white maize in our study areas mainly explain this result.

The effectiveness of health educational messages is consistent with results emerging from the public health literature that shows a strong relationship between nutrition knowledge and healthy food choice (e.g. Bundala et al., 2019; Scalvedi et al., 2021; Snyder, 2007; Spronk et al., 2014; Wardle et al., 2000; Worsley, 2002).



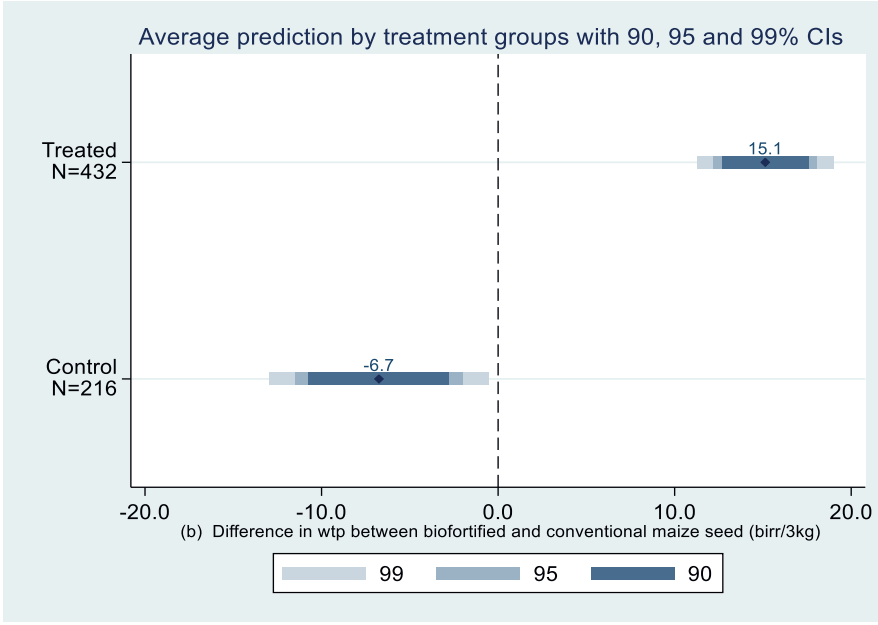
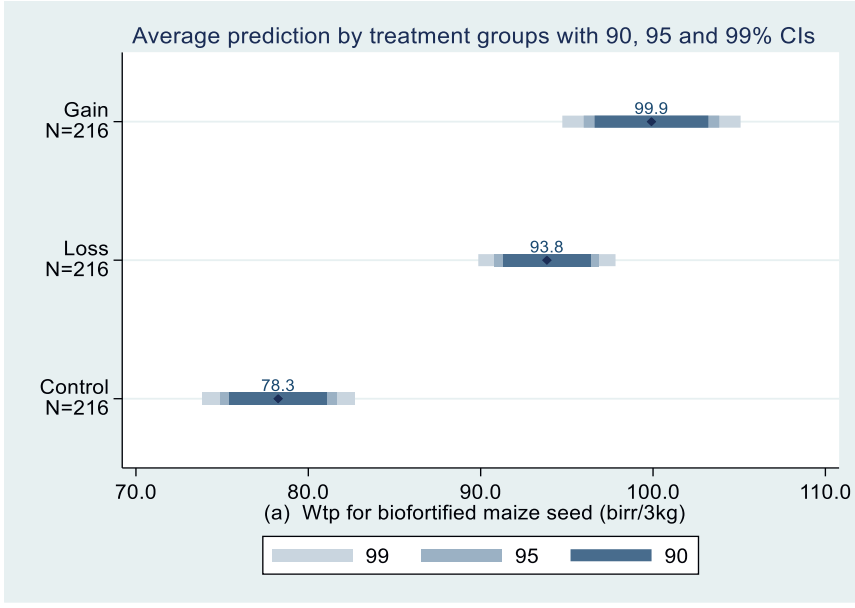


Figure 6. The effect of an information intervention on wtp for biofortified maize seed. Note: for (a) the dependent variable is participants' wtp for biofortified maize seed and for (b) the dependent variable is the wtp difference for biofortified and conventional maize seed. The estimates are average predictions where covariates are set at the observed value in the sample. The different shades of the bar graph represent confidence intervals at 99, 95 and 90 % levels. For the results in both figures, we control for household head sex, age, wealth, education level, household sizes, participation fee, previous awareness about a biofortified crop, risk perception, motivational orientation, land size, herd size (in TLU), previous maize harvest and proportion sold.

We also compared the relative effectiveness of the two treatments to test the predictions of the theoretical models. Contrary to the predictions of prospect theory, on average gain-framed messages (denoted GAIN) resulted in higher wtp for biofortified maize seed than the loss-framed message (denoted LOSS). As presented in Figures 7a and b, the wtp for biofortified maize of farmers in GAIN was 33.3 birr/kg, which is only slightly higher than those in LOSS, which is 31.2 birr/kg, but the difference is statistically significant (Bonferroni-adjusted p-value =0.052). We find similar results when using the relative wtp as the dependent variable. The relative wtp of farmers in GAIN is again higher than in LOSS (6.1 as compared to 4.0) and the difference is statistically significant (Bonferroni-adjusted p-value = 0.069). These two findings lead to our next result:

Result 2: Gain-framed messages are on average slightly more effective than loss-framed messages in stimulating demand for nutritionally-enhanced seeds among smallholder farmers.



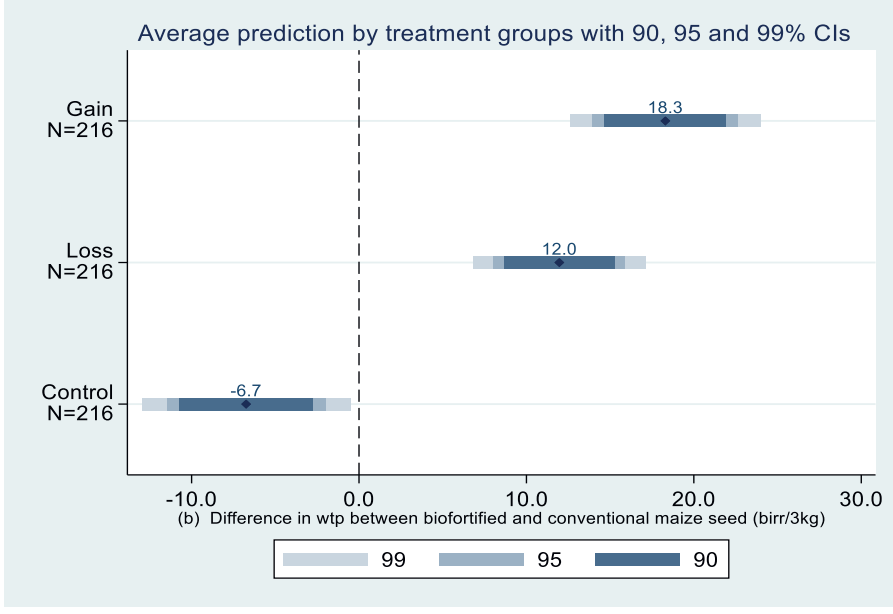


Figure 7. The effect of an information intervention on wtp for biofortified maize seed. Note: for (a) the dependent variable is participants' wtp for biofortified maize seed and for (b) the dependent variable is the wtp difference for biofortified and conventional

maize seed. The estimates are average predictions where covariates are set at the observed value in the sample. The different shades of the bar graph represent confidence intervals at 99, 95 and 90 % levels. For the results in both figures, we control for household head sex, age, wealth, education level, household sizes, participation fee, previous awareness about a biofortified crop, risk perception, motivational orientation, land size, herd size (in TLU), previous maize harvest and proportion sold. Hypothesis testing is based on robust standard errors.

We further explore the effectiveness of the differently framed messages by assessing the moderating role of risk perceptions. We, therefore, estimated the coefficients in equation 4. The regression results are presented in appendix 4.3 and the relevant results are summarised in Figure 8. We reject the null that the added interaction terms are not statistically different from zero (Bonferroni-adjusted p-value <0.01). Consistent with theoretical predictions assuming loss aversion, loss-framed messages resulted in higher wtp for nutritionally-enhanced maize seed than gain-framed for farmers who perceived the risk to be high (34 birr/kg as compared to 31 birr/ kg), and the difference is statistically significant (Bonferroni-adjusted p-value=0.018). For farmers who perceived the risk to be low, gain-framed messages were more effective. The wtp for biofortified maize of farmers in GAIN was 34 birr/kg, which is higher than those in LOSS, which is 29.1 birr/kg, and the difference is statistically significant (Bonferroni-adjusted p-value<0.01). By comparison, there is no statistically significant difference in wtp for nutritionally-enhanced maize between the two framing types for those who assessed the risk associated with adopting the new crop to be medium (Bonferroni-adjusted p-value= 0.696). We repeated the comparisons using the relative wtp as a dependent variable and we found similar results (not shown here). These insights lead to our next result:

Result 3: Gain-framed messages are more effective than loss-framed messages when the perceived risk associated with the new crop is low. The converse is true when the perceived risk is high. When the perceived risk is medium, the gain- and loss-framed messages are equally effective in stimulating demand for nutritionally-enhanced maize seeds among smallholders.

The moderating effect of risk perception on framed messages that we observe is consistent with several studies in health messaging literature. For instance, Hwang et al. (2012) find that the perceived risk of sunburn moderates the effect of framed messages in promoting sun safety behaviour in adolescents. Similarly, Gainforth and Latimer (2012) found that risk

perception moderate framed messages that aim to motivate women to get vaccinated. Other studies that report significant interaction between perception of risk and framed message include Maheswaran and Meyers-Levy (1990) in the areas of cholesterol screening and Gallagher et al. (2011) in the areas of screening mammography.

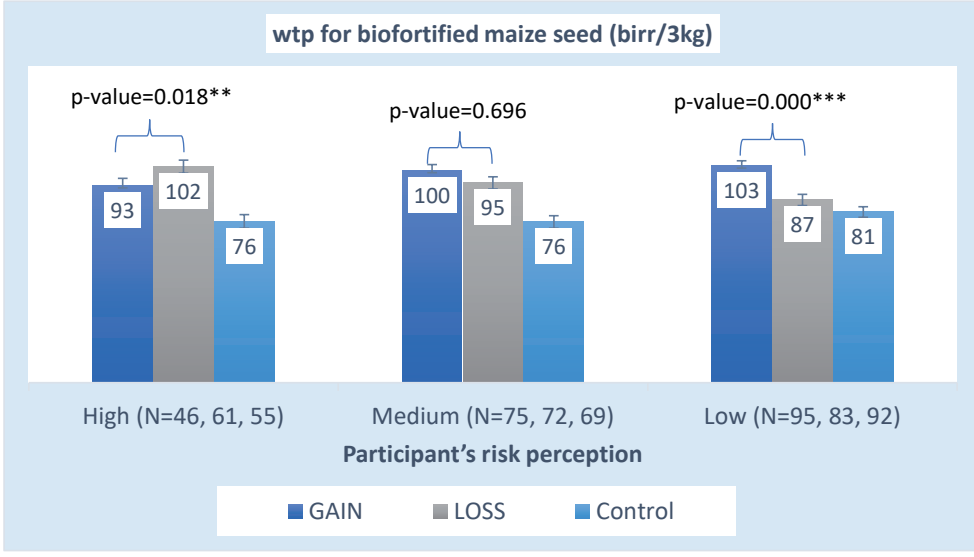


Figure 8: Average wtp of GAIN, LOSS, and the Control groups by perceived risk. The estimates are average predictions where covariates are set at the observed value in the sample. Due to multiple hypothesis testing, the reported p-values are corrected for Family-Wise Error Rate (FWER) using Bonferroni corrections. For the results, we control for household head sex, age, wealth, education level, household sizes, participation fee, previous awareness about a biofortified crop, land size, herd size (in TLU), previous maize harvest and proportion sold. *, ** and *** denote statistical significance at 0.1,0.05 and 0.01 level.

We also examined if motivational orientation moderates the relative effectiveness of loss and gain-framed messages. As summarized in Figure 9, loss and gain-framed messages induce significantly different wtp for biofortified maize seed only for promotion-oriented individuals. For promotion-oriented individuals, gain-framed messages resulted in higher wtp than loss-framed messages (35.3 birr/kg as compared to 30.7 birr/ kg), and the difference is statistically significant (Bonferroni-adjusted p-value=0.046). By comparison, there is no statistically significant difference in wtp for nutritionally-enhanced maize between LOSS and GAIN for prevention-oriented individuals (Bonferroni-adjusted p-value= 0.804). These data lead to our next result:

Result 4: Gain-framed messages are more effective than loss-framed messages for promotion-oriented individuals in stimulating demand for nutritionally-enhanced maize seed. For prevention-oriented individuals, both gain- and loss-framed messages seem to be equally effective.

These results are in line with the prediction of the regulatory fit theory, albeit partially. These Similar results are reported by Lee and Aaker (2004) who showed that motivational orientation moderates the effect of message framing on persuasion and by Kim (2006) who demonstrated that by matching framed messages with people's motivational orientation it is possible to increase the effectiveness of educational interventions in preventing smoking among adolescents. After conducting a systematic review of 30 studies, Ludolph and Schulz (2015) concluded that regulatory fit enhances the effectiveness of health messages. The implication is that apart from perceived risk, the motivational orientation of individuals also affects the effectiveness of framed messages. Our results are also consistent with the findings of research on health behaviour change interventions where gain-framed messages were found to be more effective in promoting healthy behaviour (e.g. Gerend and Shepherd, 2013; Mann et al., 2004).

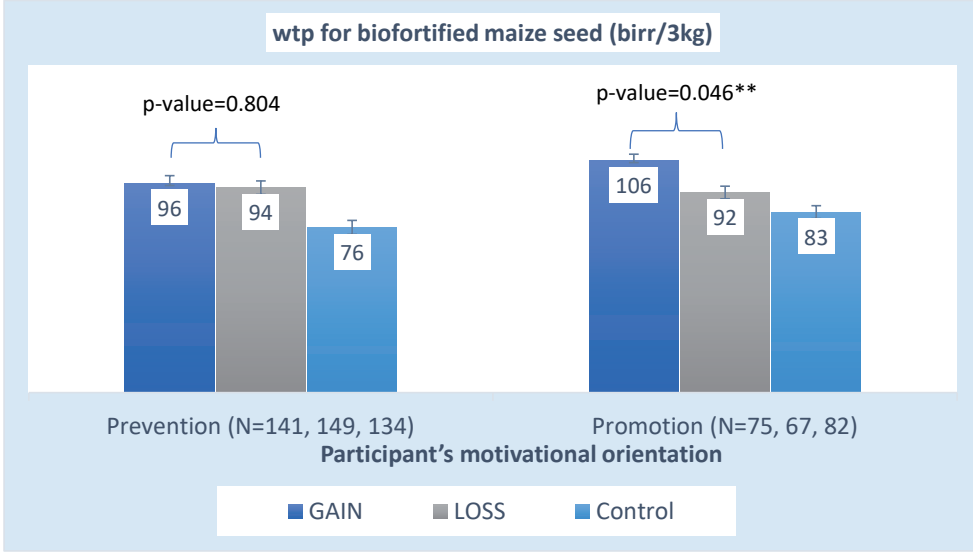


Figure 9: Average wtp of GAIN, LOSS, and the Control groups by Motivational orientation. The estimates are average predictions where covariates are set at the observed value in the sample. The reported p-values are corrected for Family-Wise Error Rate (FWER) using Bonferroni corrections. For the results, we control for household head sex, age, education level, wealth, household sizes, participation fee, previous awareness

about a biofortified crop, land size, herd size (in TLU), previous maize harvest and proportion sold. Hypothesis testing is based on robust standard errors. *, ** and *** denote statistical significance at 0.1,0.05 and 0.01 level.

Perceived risk and motivational orientation moderate the effect of the frame messages and the effects are not necessarily in the same direction. To investigate whether perceived risk reinforces or cancels the moderating effect of motivational orientation, we did a three-way interaction analysis: Treatment X perceived risk X motivational orientation. We estimated equation 5 and conducted a joint significance test of the interaction terms. The results are presented in Appendix 4.3 and the relevant coefficients are summarized in figure 10. We reject the null that the added interaction terms are not statistically different from zero (Bonferroni-adjusted p-value<0.01). We examine the relative effectiveness of the treatment (GAIN vs LOSS) on participants' wtp for nutritionally-enhanced maize seeds whose risk perception is either high or low for a given motivational orientation.

We find that the two moderating variables interact with the framed message in a complex yet expected way. For prevention-oriented individuals whose perceived risk is high, we find that the average wtp for those in LOSS is 34.3 birr/kg, which is statistically significantly higher than those in GAIN which is 29.7 birr/kg (Bonferroni-adjusted p-value=0.027). This was expected, as both moderating variables strengthen the effects of the loss-framed messages.

For prevention-oriented individuals whose perceived risk was low, wtp for the biofortified seeds was significantly higher for farmers in GAIN than LOSS (Bonferroni-adjusted p-value=0.040). We don't have theoretical predictions, a priori for this scenario. This is because the moderating effects of the two variables work in opposite directions and the net effect depends on the relative strength of the two effects. In this case, the moderating effect of risk perception is found to be stronger than the effect of motivational orientation, which results in GAIN being more effective than LOSS.

We find related results for promotion-oriented individuals. When the perceived risk is low, theory suggests that both moderating factors favour gain-framed messages for this group, and indeed GAIN resulted in higher wtps for nutritionally-enhanced maize seed than LOSS (Bonferroni-adjusted p-value<0.01). When the perceived risk is high, the two moderating factors are predicted to work in opposite directions. For these cases, we did not detect any

discernable difference between LOSS and GAIN. (Bonferroni-adjusted p-value=0.961). This brings us to our last results, which we summarize in a table format.

Results 5: Different combination of motivational orientation and risk perception requires different framing as shown below.

Motivation	*Risk perception*	*Effective framing*	*Percentage of participants*[20]
Promotion	High	Equally effective	7
Promotion	Low	Gain	10
Prevention	High	Loss	18
Prevention	Low	Gain	31

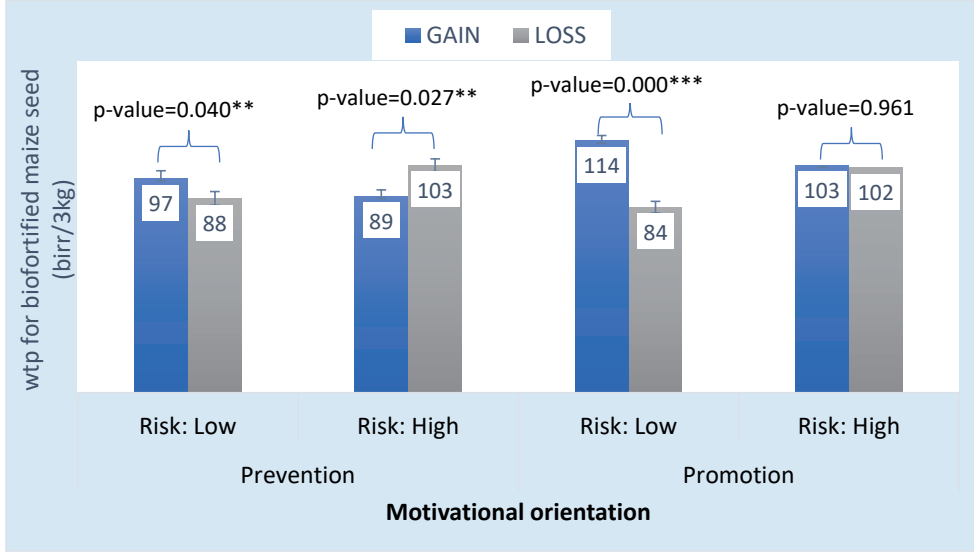


Figure 10: Average wtp of GAIN, LOSS, and the Control groups by individual motivational orientation. The estimates are average predictions where covariates are set at the observed value in the sample. The reported p-values are corrected for Family-Wise Error Rate (FWER) using Bonferroni corrections. For the results, we control for household head sex, age, education level, wealth, household sizes, participation fee, previous awareness about a biofortified crop, land size, herd size (in TLU), previous maize harvest and proportion sold. Hypothesis testing is based on robust standard errors. *, ** and *** denote statistical significance at 0.1,0.05 and 0.01 level.

[20] Since participants whose risk perception is medium are excluded in this analysis, the sum of the individual numbers does not add up to 100%.

4.5. Conclusion

We use a field experiment to investigate the relative effectiveness of framed messaging in stimulating demand for nutritionally-enhanced seeds. We find that without the nutrition messages, farmers preferred the conventional maize variety over the nutritionally-enhanced seeds. Educational messages significantly increased wtp for nutritionally-enhanced maize to a level higher than wtp for conventional seeds

Prospect theory suggests that loss framing is more effective in stimulating demand for a new crop than gain-framing since it induces more risk-seeking behaviour. We find very limited evidence for this hypothesis. Instead, this paper shows that risk perception and motivational orientation interact in a complex way, and the prediction from prospect theory only holds for a specific combination of risk perception and motivational orientation. We argue that this may be because the combination of these two variables either reinforces or cancels out their moderating effect on the effectiveness of framed messages. Though the two moderating variables are studied well in the health domain, our study is the first to study the three-way interaction of risk perception, motivational orientation, and framed messages in the agriculture domain.

It is important to note that promotion and prevention focus can be induced experimentally over very brief periods of time (Higgins, 1998). As such, framed message campaign may need to induce a specific motivational orientation congruent with the way the message is framed to increase its effectiveness of the messages. However, we did not examine the feasibility of experimentally inducing different motivational orientations in our study context, but rather detected the current state. This could be a consideration for future research in this area.

We base our conclusions on a short-term experiment. While our procedure was incentive compatible, we cannot be fully certain that the results translate fully to an actual market situation. In addition, we did not follow participants post-intervention to determine whether the nutrition education message resulted in an increased intake of food prepared from nutritionally-enhanced maize, which ultimately is the objective of the information treatment. We only speculate that since maize is a staple and most of the produce is used for home consumption, if the nutrition education message encourages farmers to buy nutritionally-enhanced maize then they are more likely to produce it and consume food prepared from that

crop. Moreover, we cannot assess the spillover effects of the intervention. Those who receive the treatment might share their knowledge about nutritionally-enhanced maize seed or neighbouring farmers might observe the performance of the new seed and adjust their perception and decide to adopt the new crop.

Despite these limitations, our study provides important insight relevant to agricultural technology adoption literature. Future research should investigate the impact pathways from nutrition education interventions to improvement in food and nutrition outcomes and investigate potential spillover effects of interventions similar to ours.

Our findings have important policy implications. The context of the experiment resembles the context of the rural setting of most developing countries where biofortified crops are expected to have a significant impact on nutritional status. Our results would be relevant to those areas.

Overall, gain-framed messages are generally more effective in promoting nutritionally-enhanced crops. Yet for the subgroup of people who perceived the new crop as risky, loss-framed messages were more effective, suggesting the need for a targeted approach when disseminating messages.

Our findings also have implications for future studies that aim to explore the theory behind the framed effect. We showed that framed nutrition education messages have a differential effect, and their effectiveness is moderated by risk perception and motivational orientation thus highlighting the importance of considering these moderators when studying framing effects.

Combining the insights from different disciplinary fields–here behavioural economics, auction literature and psychology – is key to having a comprehensive understanding of how people respond to interventions. The enhanced understanding then provides better input for policymakers. By applying multiple perspectives and ways of thinking, our paper shows that it is possible to design more effective promotion strategies to support nutrition-sensitive agricultural development. Leveraging insights from psychology to promote agricultural technologies is nothing new (Moser and Barrett, 2006; Streletskaya et al., 2020) and here we provide further evidence that economically important behaviours can be explained better and model predictions can be improved by borrowing concepts and ideas from psychology.

Appendix 4.1: Promotion/Prevention Scale

Using a 1-9 where 1 "Not at all true of me" and 9 "Very true of me" please rate yourself concerning the following statement.

1. In general, I am focussed on preventing negative events in my life.	Q1
2. I am anxious that I will fall short of my responsibilities and obligations.	Q2
3. I frequently imagine how I will achieve my hopes and aspirations.	Q3
4. I often think about the person I am afraid I might become in the future.	Q4
5. I often think about the person I would ideally like to be in the future.	Q5
6. I typically focus on the success I hope to achieve in the future.	Q6
7. I often imagine myself experiencing bad things that I fear might happen to me.	Q7
8. I frequently think about how I can prevent failures in my life.	Q8
9. I am more oriented toward preventing losses than I am toward achieving gains.	Q9
10. I see myself as someone who is primarily striving to reach my "ideal self"—to fulfil my hopes, wishes, and aspirations.	Q10
11. I see myself as someone who is primarily striving to become the self I "ought" to be—to fulfil my duties, responsibilities, and obligations.	Q11
12. In general, I am focused on achieving positive outcomes in my life.	Q12
13. I often imagine myself experiencing good things that I hope will happen to me.	Q13
14. Overall, I am more oriented toward achieving success than preventing failure.	Q14

Adopted from Lockwood, P. et.al (2002).

Notes: This list does not include four items related to academic achievements. Statement 5 was dropped after the pilot, as participants could not see a clear difference between 4 and 5

Appendix 4.2: Construction of motivational orientation index

Factor loadings (pattern matrix) and unique variances

Variable	Factor1	Factor2	Uniqueness
Q1	-0.7247	0.5853	0.1322
Q2	0.2053	-0.2301	0.9049
Q3	0.6482	0.5895	0.2324
Q4	-0.0293	0.0815	0.9925
Q5	0.6026	0.5431	0.3419
Q6	-0.7164	0.5809	0.1494
Q7	-0.6005	0.4993	0.3901
Q8	-0.6435	0.5541	0.2788
Q9	0.2871	0.3407	0.8015
Q10	0.6415	0.5285	0.3092
Q11	0.5846	0.529	0.3784
Q12	0.3376	0.2692	0.8136

Factor analysis/correlation

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	3.42262	0.91079	0.4278	0.4278
Factor2	2.51183	1.97843	0.314	0.7418
Factor3	0.5334	0.05102	0.0667	0.8085
Factor4	0.48238	0.10944	0.0603	0.8688
Factor5	0.37295	0.0841	0.0466	0.9154
Factor6	0.28885	0.03955	0.0361	0.9515
Factor7	0.2493	0.11062	0.0312	0.9827
Factor8	0.13868	.	0.0173	1

Method: principal-component factors

Rotation: (unrotated)

Number of obs = 648

Retained factors = 2

Number of params = 15

Factor loadings (pattern matrix) and unique variances

Variable	Factor1	Factor2	Uniqueness
Q1	0.7926	0.5062	0.1156
Q3	-0.5863	0.6668	0.2117
Q5	-0.5559	0.6217	0.3045
Q6	0.7739	0.5019	0.1492
Q7	0.6498	0.4492	0.376
Q8	0.7012	0.4801	0.2778
Q10	-0.5935	0.618	0.2659
Q11	-0.526	0.5987	0.365

Appendix 4.3: Regression results of equation 2-5.

	Dependent variable: wtp			
	(2)	(3)	(4)	(5)
Treatment				
GAIN	20.3***	21.7***	20.6***	18.3***
	(2.84)	(2.64)	(4.54)	(5.05)
LOSS	15.2**	15.6***	8.9***	8.3**
	(2.58)	(2.30)	(3.23)	(3.50)
Risk perception				
Medium			-4.7	-7.1*
			(3.50)	(3.90)
High			-4.4	-5.4
			(4.75)	(5.75)
Treatment X Risk				
GAIN X Medium			2.5	10.3

			(5.87)	(6.92)
GAIN X High			-4.9	-3.6
			(6.84)	(8.43)
LOSS X Medium			12.8***	15.1*
			(4.75)	(5.82)
LOSS X High			20.2***	20.4***
			(6.32)	(7.59)
Motivation (1=promotion, 0=prevention)			7.0*	4.1
			(3.68)	(4.57)
Treatment X Motivation				
GAIN X Promotion			3.5	12.3
			(5.49)	(9.41)
LOSS X Promotion			-9.2*	-7.4
			(4.86)	(6.71)
Risk X Motivation				
Medium X Promotion				5.9
				(7.40)
High X Promotion				3.2
				(10.31)
Treatment X Risk X Motivation				
GAIN X Medium X Promotion				-19.6
				(12.65)
GAIN X High X Promotion				-5.5
				(14.11)
LOSS X Medium X Promotion				-5.2
				(9.96)
LOSS X High X Promotion				-0.2
				(14.03)
Constant	78.8***	27.1***	31.3***	32.4***
	(1.84)	(9.17)	(9.28)	(9.39)
Adjusted R-squared	0.081	0.270	0.297	0.301
Observations	648	648	648	648

Notes: Standard errors in parentheses. *, ** and *** denote statistical significance at 0.1,0.05 and 0.01 level. Wtp is participants' willingness-to-pay for biofortified maize seed (birr/3kg). The (not listed) control covariates are household head sex, age, education level, wealth, household sizes, participation fee, previous awareness about a biofortified crop, land size, herd size (in TLU), previous maize harvest and proportion sold. Hypothesis testing is based on robust standard errors.

Chapter 5

Energy efficiency, women empowerment, and food security: the case of improved cook-stove in Ethiopia

Abstract

Addressing the problem of food insecurity in a sustainable manner requires leveraging innovations that contribute to food and nutritional security without compromising the environment. One example of such innovations is improved cook stoves (ICSs). Studies have shown that these technologies result in a reduction in carbon emissions and deforestation. ICSs have also the potential to improve food and nutrition security. Yet, empirical evidence that links ICSs with food and nutrition security is limited. Using a large household dataset, we explore linkages between ICS and food and nutrition security and identify possible impact ways. We instrumental variables method to establish a causal relationship. Households that own an ICS have better nutritional outcomes. ICS is linked with increased access to food, consumption of food groups rich in vitamin A and decreased incidence of food insecurity. Consonant with the extant literature, we found that adoption of ICS decreases women's work burden and allows women to engage in paid work, suggesting the impact, at least partially, is driven by women empowerment channels. These results are robust to controlling for individual-specific covariates, district fixed effect and estimation methods. We conclude that energy-efficient technologies that reduce women's home labour can also contribute to household food security.

Keywords: Improved cookstoves; food and nutrition security; women empowerment; dietary diversity

JEL: O13; Q56; I15; C26; C21

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5.1-Introduction

Development efforts that aim to improve food and nutrition outcomes are increasingly paying attention to empower women. Women empowerment is an intrinsic goal that should be valued as an end by itself (Kabeer, 2005). At the same time, it can also serve as an instrumental goal to achieve better child outcomes (Duflo, 2012). In particular, based on a growing body of literature (Malapit et al., 2015; Malapit and Quisumbing, 2015), nutrition-sensitive programs often make empowering women one of their pillars (Heckert et al., 2019). Recently, an international and intergovernmental platform for food security and nutrition has highlighted the influence that women have on food systems and diets, and how better nutritional outcomes can be achieved by reducing unpaid work performed by women around the world (HLPE, 2017).

Harnessing technological innovations that reduce home labour is one of the ways to unleash women's potential in improving nutritional outcomes. Improved cook stoves are one of such innovations. These stoves, at the same time, have a positive impact on the climate and human health (e.g., reduction of greenhouse gas emissions and indoor air pollution). The fact that improved cookstoves (ICSs) can contribute to multiple development goals makes them an efficient weapon in the fight against malnutrition.

This is particularly important since efforts to achieve key development goals such as the Sustainable Development Goals may have negative spill-over effects on the environment. Advances in food security, for example, often come with a cost to the environment (Donini et al., 2016; Godfray et al., 2010; Grafton et al., 2015; Tilman et al., 2011). Accordingly, there has been a call for food security interventions that have low environmental impacts (Johnston et al., 2014; Lairon, 2012).

Leveraging improved cookstoves to reduce the prevalence of malnutrition is also timely. More than three billion people lack access to modern cooking (Troncoso et al., 2013) to the detriment of their health and the environment. Hence, there is a big push by governments and international development partners to expand access to clean cookstoves. In fact, achieving universal access to clean cooking solutions by 2030 is one of the SDG goals (SDG -7).

Traditional cookstoves are highly inefficient and significantly contribute to indoor air pollution. Improved stoves, on the other hand, increase fuel efficiency leading to lower fuel consumption

and can reduce indoor pollution (Grieshop et al., 2011; Grimsby et al., 2016; Pant, 2013), pressure on forests (Chan et al., 2015; Jeuland and Pattanayak, 2012) and greenhouse gas emissions (Agurto Adrianzén, 2013; Bensch and Peters, 2011; Grieshop et al., 2011; Mehetre et al., 2017; Pennise et al., 2009).

Improved cookstoves also are linked with improved health outcomes. However, the empirical evidence in this regard is not conclusive. On one hand, some studies did not find significant improvement in health outcomes that are expected to be affected by these technologies such as the risk of pneumonia (Mortimer et al., 2017; Smith et al., 2011). Similarly, Hanna et al. (2016) reported that inappropriate use of ICSs was found to limit their long-run impacts on health outcomes and greenhouse gas emissions. On the other hand, Romieu et al. (2009) and van Gemert et al. (2019) found that ICSs significantly reduce the risk of respiratory problems. Overall, though the second-order effects (e.g. on health outcomes) of these technologies are less clear, their effect on household firewood consumption is well established (Munyehirwe et al., 2022) and ICS are increasingly sought by energy-poor households (Bensch and Peters, 2020; Pattanayak et al., 2019).

We argue that, apart from these relatively well-known benefits, ICSs have the potential to improve food security through their empowering effects on women. Improved cook-stoves are expected to substantially reduce the time spent on fuelwood collection and food preparation, which are usually the responsibility of women (Guzmán et al., 2020; Jagoe et al., 2020). This would directly empower women with respect to time allocation, which is one of the five empowerment domains distinguished by the Women Empowerment in Agriculture Index (Alkire et al., 2013). Indirectly, this may create opportunities for women to engage in income-generating activities and ultimately may positively affect households' food and nutrition security outcomes. In addition, women may spend some of the saved time on the preparation of more nutritious meals.

This paper aims to examine to what extent the adoption of ICSs affects household food and nutrition security status and to identify the associated impact pathway. We seek to contribute to the literature in two important ways. First, building on a large body of work on the benefits of ICSs, we analyse an additional potential benefit with the associated pathway. Second, we study the impact of ICSs in a natural setting where the decision to adopt ICSs was based on

market prices and perceived benefits. Most literature on the benefits of ICSs is based on artificial settings, such as demonstration sites (Habermehl, 2007; Mamuye et al., 2018) or simulated kitchens (Grabow et al., 2013; Jagger et al., 2017). We can study the impact in a natural setting by leveraging the availability of instrumental variables: the prices of cement and sand, important raw materials to produce ICSs.

From a policy perspective, the results of our paper provide evidence-based arguments for development practitioners to promote these technologies. Messages and awareness campaigns can be developed around the link between ICSs and food and nutrition security to encourage the use of these innovations.

We use a dataset that is representative of rural households in highland areas of Ethiopia. In rural Ethiopia, a significant majority (about 77 per cent of households) use traditional three-stone stoves made from clay. These are pots balanced on three stones over an open fire with poor ventilation and about 90 per cent energy loss (Padam et al., 2018). Wood is the most common fuel source, and women are generally responsible for cooking and collecting fuelwood. Improved cook stoves, specifically insulated fire stoves, are available in the market but not yet widely adopted (Padam et al., 2018). The lack of effective marketing messages that communicate product benefits contributes to this low adoption rate (`Orange, 2011; Fekadu Kedir et al., 2019). Understanding the potential impact of improved cook-stove ownership on household nutrition status in this setting is important for the following reasons. First, providing empirical evidence of the link between ownership of an improved cook-stove and household nutrition status is expected to improve the uptake of this technology. Second, there is a big push by the Government of Ethiopia to distribute 31 million improved stoves by 2030 and the empirical evidence could be used to encourage and push the government and its development partners to solidify their commitment.

We find the following. First, households who adopt ICSs have better food and nutrition security status than those who did not. These results are consistent with our hypothesis. On average, in households that use improved cookstoves, the household dietary diversity score increased by 1.1, the individual dietary diversity score for children under five increased by 1.4, the number of foods groups that are a rich source of vitamin A consumed by the household increased by 0.6, and the incidence of food insecurity decreased by 25 percentage points.

Second, the adoption of ICSs is linked with women's economic empowerment. Households who adopt ICS spent 14.4 minutes less per day collecting fuelwood time and women in the household are more likely (40 percentage points more) to work in paid jobs.

Taken together, our results suggest that ICSs can improve household food and nutrition security status and one of the impact pathways seems to be through women empowerment by reducing unpaid work. The effect of ICSs in reducing women's burden is well established. Similarly, the link between women's empowerment and household food security status is also well documented. Here we linked these two findings and showed that technologies that have the potential to reduce home labour can contribute to women's empowerment as well as to efforts to improve food and nutrition security.

The rest of the paper is structured as follows. In Section 2, we discuss the analytical framework and present the hypotheses. In Section 3, we describe the data, define key outcome indicators, and outline our identification strategy. In Section 4, we present the results. Section 5 concludes.

5.2-Analytical framework and hypotheses

There is a growing literature that links women's empowerment with other development outcomes. In the food and nutrition domain, studies have shown a link between women's empowerment and child health and nutritional status (Annan et al., 2021; Carlson et al., 2015; Galiè et al., 2019; Heckert et al., 2019; Pratley, 2016). This evidence suggests promoting innovations that contribute to women's empowerment ultimately could also improve household food and nutrition security.

Here, we take the ICS as a pro-poor innovation that has the potential to empower women and show how it could lead to better food and nutritional security. Following Kabeer (1999), empowerment refers to the expansion of people's capacity to make strategic life choices in a context where this ability was previously denied to them. While empowerment also has psychological and political dimensions (Malhotra and Schuler, 2005), we narrowly focus on economic aspects which are relatively easy to quantify using survey data and that are expected to be affected by the use of ICSs. The specific measure revolves around women's time use and, more specifically, time spent on fuelwood collection and on paid work.

ICSs use less fuel and reduce cooking time compared to traditional stoves (Habermehl, 2007; Mamuye et al., 2018). Since women are primarily responsible for food preparation and the collection of fuelwood, the use of ICSs is associated with women spending less time on fuelwood collection and more time engaging in economically productive tasks (Jagoe et al., 2020). Hence, we pose the following hypothesis:

Compared to households with no ICSs, for households that use ICSs, women spent less time on household chores (fuelwood collection) and more time on activities that allow them to earn income.

A review of the literature on the relationship between women's empowerment and household nutrition outcome provides support to the idea that women's empowerment is positively associated with households' and particularly children's nutritional status (Carlson et al., 2015; Pratley, 2016). Using mixed methods, (Galiè et al., 2019) reported a positive correlation between women's empowerment and their nutrition security, while based on a randomized controlled trial Heckert et al. (2019) showed that empowering women is an effective strategy to achieve nutritional goals in developing countries. More importantly, income earned by women is more likely to be used to improve household nutrition than income earned by men in the household (UNICEF, 2011).

Apart from the women empowerment channel, ICSs can contribute to a household's food security through the health channel. ICSs are expected to reduce health risks associated with indoor pollution (Bruce et al., 2015) and potentially improve productivity and ultimately increase income. However, inconsistent usage, stacking of stoves (use the traditional and ICSs stoves within the same household) and lack of ICSs that are appropriate for the local cooking contexts may hamper the long-term impact of ICSs on health outcomes (Hanna et al., 2016).

There is also a direct path from ICSs to food and nutrition security. ICS have higher energy efficiency as compared to the traditional stove, the use of ICS is likely to reduce time spent on meal preparation (Vahlne and Ahlgren, 2014). This in turn creates opportunities for households to prepare extra dishes. In addition, having ICSs means there is an additional burner in the household which makes the preparation of more dishes less burdensome. Taking these together, we specify the following hypothesis:

Compared to households with no ICSs, for households that use ICSs food and nutrition security is higher.

The specific indicators are defined and discussed in the next section.

5.3-Method

5.3.1. Empirical framework/Identification strategy

The aim is to estimate the effect of using an improved cookstove on household food security and diets. Let y represent the outcome indicators where y_1 and y_0 denote household food and nutrition security status with and without ICSs, respectively. We are interested in the difference between the two outcomes, $y_1 - y_0$. Since y_1 and y_0 are individual specific variables, we are interested in the average treatment effect (ATE) which is given by

$$\text{ATE}=\text{E}(y_1 - y_0) \quad (1)$$

Equation 1 represents the expected effect of the ICS on a randomly drawn person from the population. Since individuals either own or do not own ICS at a given point in time, we cannot observe both y_1 and y_0, and hence we cannot estimate equation 1. Let the variable w be a binary indicator where w=1 denotes ownership of ICS and w=0 otherwise. If the ownership of ICS (w) is statistically independent of a participant's food and nutrition security status, then estimating the following regression equation gives ATE (Wooldridge, 2010).

$$y= \tau w + X\beta + \mu, \quad (2)$$

where τ is ATE; X denotes a vector of observed covariates and μ is the error term. Estimating ATE from (2) is complicated by the fact that ownership of ICSs is not random. Since our analysis is based on observational data, the assumption that w is independent of y may not hold. For instance, wealthy households are more likely to own an ICS as they can afford them more easily. At the same time, wealthier households are likely to have a better food and nutrition status compared to poor households. To address the problem of endogeneity of w, we leverage the availability of instruments and use a control function estimator. This estimator is chosen because it handles endogeneity in nonlinear models similar to the one we are estimating in this paper (Wooldridge, 2010). Let Z denote a vector of instruments that satisfies the rank and exogeneity conditions. Roughly speaking this means Z is correlated with w and

does not directly affect y. The reduced-from equation for the endogenous variable w is given by

$w = X\gamma + Z\theta + \varepsilon,$ (3)

where ε has zero mean and is uncorrelated with X and Z. Since w is assumed to be endogenous, ε and μ are correlated and their relationship is assumed to take the following form.

$\mu = \varepsilon\rho + \nu,$ (4)

where $\rho = E(\varepsilon\mu)/E(\varepsilon^2)$, and $E(\varepsilon v) = E(Zv) = E(Xv)$=0. Plugging (4) into (2) gives the following reduced form equation for the outcome variable.

$y = \tau w + X\beta + \varepsilon\rho + \nu$ (5)

Since ε is the error term in the reduced form equation for w, it is not observed. However, it can be replaced with $\hat{\varepsilon}$, a probit residual from the first stage regression of w on X and Z in (3). Then (5) can be estimated by the appropriate model depending on the type of the outcome variable: OLS for continuous and probit for binary outcome variables. Here we estimate both (3) and (5) but ε replaced with $\hat{\varepsilon}$ using the generalized method of moments in Stata.

We used two instruments, namely the price of cement and sand at the time of 2017/18. A household that owns ICS at the time of the survey (2018) may not necessarily make the purchase in 2017/18. Nevertheless, since the average life of the stoves is around 2.5 years, the time of the purchases is expected to be not too far in the past, and the 2017/18 prices represent the situation at purchase fairly well.

Discussion with rural energy experts at regional and district levels revealed that affordability plays a key role in household decisions to adopt an ICS. In fact, adoption studies identified affordability as one of the main factors that limit the wide usage of ICS in Ethiopia (Fekadu Kedir et al., 2019; Mamuye et al., 2018). The price of ICSs varies locally and could therefore be a valid instrument. However, we do not have price data on ICSs. Further discussions with rural energy experts and manufacturers/suppliers of ICSs revealed that the stoves are constructed locally and that the cost of inputs used to manufacture ICSs; cement and sand, are the main contributing factors to their price. The local price of cement and sand is thus expected to be

correlated with the adoption of ICSs. For these prices to be valid instruments, they should not be directly correlated with food security. This is referred to as the exclusion restriction assumption. This assumption would obviously not hold if prices of construction inputs are correlated with food prices, for example, due to correlated transportation and other transaction costs. This is not the case in our study area. Most rural households in Ethiopia depend heavily on their own production for the consumption of staple foods. In addition, different factors affect the price of construction inputs and food crops. For instance, the absolute values of the correlation coefficients between the two construction inputs and the price of teff, wheat and maize–the top three crops produced, consumed, and sold by smallholder farmers– range from 0.02 to 0.11 and are statistically insignificant even at the 10% level (Table A1 in the appendix). Another threat to our exclusion restriction assumption is if the price of cement and sand drives employment in construction, hence income and consumption of respondents. However, for the study area agriculture is the main occupation (about 85% of farm households) and less than 2% of the households work in the construction sector. Even if construction input prices would drive employment in construction, its effect on household income and consumption is likely to be insignificant.

Another potential threat to our identification strategy is that measured at the district level. Hence, if district-level factors affect food and nutrition outcomes and if these factors are not controlled for in the reduced form outcome equation (equation 4), then the exogeneity conduction will be violated. To address this issue, we control for district-level factors in the reduced form outcome regression equation as detailed below. Overall, the context and our approach increase the plausibility of the assumptions that the proposed variables are correlated with the decision to adopt ICSs but do not directly affect the outcome variables and are thus uncorrelated with the error term.

As a robustness check, we carried out a fixed effect (FE) estimation to compute the treatment effect. One of the key assumptions that we need for FE estimation to work is the strict exogeneity of explanatory variables conditional on unobserved effects. It basically means ownership of ICS is as good as random after unobserved individual-level factors that are time constant are controlled for. In policy evaluation literature, FE methods are widely applied to deal with this kind of endogeneity (Imbens and Wooldridge, 2009). To conduct FE analysis, we use information that was collected at two periods of time: 2014 and 2018. During the 2014

survey, fuelwood collection time, the number of days women household members spent on paid jobs was not collected. To fill the missing data, a recall method was used during the end-line survey. Due to the lengthy recall period, these variables may be measured with some error. Thus, it is important to exercise caution while interpreting the relevant results. Here we present the results from the FE analysis to check the robustness of the IV results, which are what drives our main conclusions. For those of our outcome variables are binary (faced food security or not; employed in paid jobs or not and the existence of a female-owned business or not), we use the random effect probit effect estimator to obtain the average treatment effect. This estimator requires a strong assumption about the relationship between the observed covariates and unobserved effects: unobserved effects and observed covariates are independent and the unobserved effect has a normal distribution.

5.3.2. Data

We use data from the Livestock and irrigation value chains for Ethiopian Smallholders (LIVES) project from the International Livestock Research Institute (ILRI-Ethiopia). The project focuses on high-value livestock and irrigated crop commodities and identifies and promotes improved technologies as well as organizational and institutional innovations along the respective value chains to make the value chains competitive, sustainable, and more equitable. This dataset is representative of rural households in the four highland regions of Ethiopia (Tigray; Amhara; Oromia; and Southern Nations, Nationalities and Peoples). Participating households were selected randomly in each of 10 zones, which were defined by agroecology. Data were collected at two points in time: at baseline in 2014 and end-line in 2018. Participation was completely voluntary, and participants were informed that they could opt out of the survey at any time with no penalty. The study protocols, process, data management and risks related to participation in the survey is as per ILRI Policy and Guidelines of Research Ethics. The Ministry of Agriculture and Natural Resources and the relevant Regional Bureaus of Agriculture granted permission to conduct the survey. All participants provided verbal informed consent before participating in the survey.

For our main analysis, we mostly use the end-line survey. However, we use information from the baseline survey for several control variables to ensure exogeneity. This results in a total of 4,338 households of which 8.3% (362) owned and used ICSs. The use of ICSs was not associated with project treatment status: 8.6% of treatment households and 8.1T of control

households owned and used an ICS and the chi-square test of independence between these variables is insignificant ($\chi 2 = 0.470$, and $p = 0.493$). The average operating lifetime of ICS is only 2-3 years, so all user households have only recently purchased their device.

5.3.3. Definition of indicators

Household food and nutrition security status is the main outcome indicator of the study. Food security is widely thought of as comprising four pillars, namely: availability, access, utilization, and stability (CFS, 2009). Recognizing the importance of food composition and nutrient requirements for an active and healthy life, the concept of food security is further elaborated. Thus, food security is achieved when "... all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (CFS, 2009). This conceptualization highlights the nutrient aspect of food security. In this paper food and nutrition security is taken to be the application of the above concept as it pertains to households as well as individuals within the households.

Due to its multidimensional nature, there is no single indicator that captures the whole concept. Given the information contained in our dataset, this study uses four indicators that measure different aspects of household food and nutrition security. These are the Household Dietary Diversity Score (HDDS), the number of food groups that are rich in vitamin A consumed by the household (Micronutrient sensitive HDDS, or MHDDS), the number of food groups consumed by children in the household (CDDS), and the incidence of food shortage. The combined measures give a clearer picture of a household's food and nutrition security status and are more robust than any single measure.

HDDS is a widely used survey-based tool that is used to assess household food security status. HDDS captures the number of food groups consumed by a household during a fixed reference time usually, 24 hours or the last 7 days (WFP, 2009). It measures the food availability and access component of food security. Participants were asked about foods eaten by any member of the household during the last seven days preceding the survey date. A tool comprising 16 food groups was then used to record the answers (Kennedy, Ballard, & Dop, 2010: p8). To compute HDDS, the 16 food groups were recategorized into 12 food groups as suggested by

Kennedy, Ballard, & Dop (2010: p24), and HDDS was calculated by counting the total number of food groups consumed.

The same data is used to calculate the MHDDS. Instead of adding all food groups, now only those food groups that are rich in vitamin A are included in the calculation. These are: vitamin A rich vegetables or tubers (such as pumpkin, carrot, squash, or orange-fleshed sweet potato), dark green leafy vegetables, vitamin A rich fruits (e.g. mangos, apricots, ripe papaya), Organ meat, Eggs, and Milk and milk products (Swindale and Bilinsky, 2006: p27). The benefit of using this measure is that it highlights the nutritional aspect of food security by measuring household access to food groups that are rich in one of the key micronutrients.

CDDS is also measured using the same tools, but instead of being based on food consumed by any household member, this measures food consumed specifically by the child/children under the age of 5. Diet diversity score for children is expected to reflect the nutritional quality of the diet (Kennedy, Ballard, & Dop, 2010). To compute the score, the 16 food groups were aggregated into 10 food groups following (Kennedy, Ballard, & Dop, 2010:p24).

Finally, to measure the incidence of food shortage, the respondent was asked if they had faced the situation of not having enough food to feed the household during the last 12 months prior to the survey period. This is a binary variable where 1 indicates food insecurity incidence and 0 otherwise.

Regarding mediator variables, three indicators are the focus of the analysis: fuelwood collection time; if at any time over the 12 months preceding the survey, any female household members were employed in any paid job; and income generating activities owned and operated by women household members. As control variables, we use wealth, livestock ownership, and land size from the baseline survey, and sex and education level of household head, household size, distance to the nearest market town, distance to the nearest health post, and the amount of forest and woodlots available per capital in the kebele from the end-line survey.

5.4-Results

5.4.1. Data and summary statistics

Summary statistics of the sample households are presented in table 13. The summaries are presented for the whole sample and separately for those who owned improved cookstoves (ICS group) and for those who don't (Non-ICS group). In our sample, a slightly higher proportion of female-headed households own ICS (82% as compared to 78% and the difference is found to be statistically significant. This is consistent with the ICS adoption literature where female-headed households are more likely to adopt ICSs (Lewis and Pattanayak, 2012). Literacy level is very low: On average a household head completed only 2.2 years of schooling, owns about 1.43 hectares of land and 4.1 livestock (in TLU). The farm size is higher than the national average (0.9 hectares) but is close to the average holding reported by Headey et al., (2014) for high agricultural potential areas in Ethiopia. The value of household physical assets is estimated at 19.62 thousand birr[21] and this is slightly higher for those who own ICSs. Lewis and Pattanayak (2012) report similar findings. They find a statistically significant association between ICS adoption and income. The large standard deviation for wealth indicates that wealth varied quite a bit among the sampled households.

Table 13: Descriptive statistics by ICS ownership

Description of variables	Pooled	ICS	Non-ICS	Difference	Test statistics
Sex of household head (1=Male)	0.79	0.82	0.78	0.04*	3.02
	(0.41)	(0.38)	(0.41)		
Age of household head	49.02	48.00	49.11	-1.12	-1.66
	(12.29)	(9.40)	(12.51)		
Highest educational attainment	2.19	2.93	2.13	-0.81***	-4.15
(in years)	(3.54)	(3.95)	(3.49)		
Household size	5.07	4.99	5.08	-0.10	0.85
	(2.36)	(2.37)	(2.36)		

[21] The official exchange rate of 1USD was equal to 20.4322 Birr as of February 23, 2015

Land owned (hectare)[1]	1.43	1.38	1.43	-0.05	0.73
	(1.28)	(1.38)	(1.27)		
Household wealth (1000 birr)[1,2]	19.62	23.35	19.28	4.07***	-3.40
	(21.79)	(21.15)	(21.82)		
Livestock ownership (TLU)[1,3]	4.12	4.21	4.11	0.10	-0.53
	(3.48)	(3.78)	(3.46)		
Distance to nearest market town (one-way walking minutes)	108.37	100.59	109.08	-8.49*	2.19
	(70.50)	(64.01)	(71.03)		
Distance to nearest health post (one-way walking minutes)	34.54	31.29	34.84	-3.55	1.64
	(39.45)	(45.27)	(38.87)		
Forest and woodlot per capita in the kebele (ha.)	0.08	0.07	0.08	0.01	0.64
	(0.14)	(0.13)	(0.14)		
Intervention households (1=Yes)	0.51	0.53	0.51	0.02	-0.69
	(0.50)	(0.50)	(0.50)		
Observations	4,338	362	3,976		

Note: Standard deviations are in parentheses. The values are t-statistics except for the household head sex variable which is a chi square statistic. ***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 significant level. [1] Lagged (2014) values. [2] agricultural tools, water cans, water pumps, wheelbarrows, animal carts, mobile phones, radios, television, bicycles, motorcycles, pack animals, beehives and urban property. [3] TLU=Tropical Livestock Unit.

Regarding access to key institutions, the nearest market town and health post were located on average within 108 and 35 minutes of walking distance from the homestead. Forest and

woodlot coverage per capita is used to measure households' access to fuel sources. The average land covered with forest and woodlot was 0.075 hectares.

Turning to outcome variables, summary statistics in table 14 show that HDDS was 6.55, indicating that for the seven-consecutive days before the survey, a household consumed on average 6.55 food groups out of the possible 12 food groups. This is slightly higher than the national average reported by Mekonnen et al., (2020) for around the same time period (which is 6.2.) For those households with at least one child under the age of 5, the average number of food groups consumed by children was 4.9 out of the 8 food groups used to construct the CDDS. About one in four (25%) reported that they have faced a situation where they did not have enough food to feed the household in the 12 months preceding the baseline survey. This indicates undernutrition is not uncommon in our study population.

The average fuelwood collection time per day was 46 minutes. A recent study by Wassie and Adaramola (2021) reported a slightly higher number where the average fuelwood collection time per day was around 56 minutes per day in rural Ethiopia. However, their results are based on sampled households from Southern Nations Nationalities and Peoples Regional State (SNNPRS) of Ethiopia. Female household members in the household spend on average only 1.6 days per month on paid work, and only 14% of the sampled household reported that one or more women household members were engaged in income-generating activities such as petty trading, weaving, handicraft, trade in grain and livestock, collecting and selling firewood and selling local food and drinks. Taken together this shows that few women benefited from alternative income-generating opportunities.

Table 14: Descriptive statistics of outcome and mediator variables

Description of variables	Pooled	ICS	No ICS	Difference	Test statistic†
Household Diet Diversity Score (HDDS)	6.55 (1.60)	7.46 (1.73)	6.46 (1.56)	1.0***	-11.54
Number of Vitamin A rich food group (MHDDS)	2.09 (1.17)	2.69 (1.37)	2.04 (1.13)	0.65***	-10.31

Diet Diversity score for child under 5 (CDDS)	4.86 (1.48)	5.52 (1.42)	4.78 (1.46)	0.74***	-7.32
Incidence of food Insecurity (1=Yes)	0.27 (0.44)	0.16 (0.37)	0.28 (0.45)	-0.12***	-22.57
Fuelwood collection time per day (in minutes)	46.12 (19.42)	35.87 (23.82)	47.06 (18.69)	-11.19***	-10.63
Number of days in paid work by female members	1.61 (3.22)	2.06 (3.58)	1.57 (3.18)	0.49**	-2.79
Income generating activities owned by women (1=Yes)	0.14 (0.35)	0.15 (0.36)	0.14 (0.35)	0.01	0.42
Observations	4,338	362	3,976		

Note: Standard deviations are in parentheses. † The values are t-statistics except for food insecurity and the existence of female-owned business variables in which case the value is a chi square statistic. ***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 significant level

Comparing household with and without ICS, we see that both food and nutrition security and women empowerment was significantly higher for the ICS owners. However, based on the descriptive statistics alone it is not possible to say whether these differences are the result of ICS since factors that affect ICSs ownership can also affect food and nutrition outcomes. To tease out the impact of ICSs we rely on the quasi-experimental methods described above, and the results are presented in the next sections.

5.4.2. ICSs and food and nutrition security

Before presenting the results, we tested the key assumptions. For the instruments to be valid, they need to predict the treatment and should be unrelated to unobserved heterogeneity. We run a battery of tests to check under identification, weak identification, overidentification, and endogeneity. The Kleibergen-Paap test rejects the null hypothesis of under-identification at 1% level, indicating that the proposed variables are correlated with the household decision to

adopt an improved cookstove. To test for weak instruments, robust Kleibergen-Paap rk Wald F statistic was computed and compared with Stock-Yogo weak ID test critical values (Stock and Yogo, 2005). The test statistic is greater than the 10% maximal critical values, rejecting the null hypothesis of weak instruments. To test overidentifying restrictions, Hansen J statistic was used. Hansen's test cannot reject the null hypothesis that the instruments are uncorrelated with the residual of the regression on all instruments at 5% significance level. Finally, an endogeneity test rejects the null hypothesis that the decision to adopt ICSs can actually be treated as exogenous (p-value =0.052). These tests confirm that our instruments are valid and necessary.

The average effect of ICS ownership on food and nutrition security status is presented in table 15 below. The estimates from the control-function approach are presented in panel B. For reference, we also present the (biased) OLS/probit estimates in panel A. The results reveal a statistically significant relationship between ownership of ICSs and all four food and nutrition security indicators considered in this paper. Those households who adopted ICSs on average consume 1.1 more food groups out of the 12 food groups (table 15 column 2 panel B, significant at 1%), consumed 1.37 more food groups rich in Vitamin A (table 15 column 15 panel B, significant at 1%), fed 0.6 more food groups to their children under the age of 5 (table 15 column 4 panel B, significant at 5%) and are less likely to face food shortages (table 15 column 5 panel B, significant at 1%).

Table 15: Treatment effect on food and nutrition security indicators

	Dependent variables			
	HDDS	MHDDS	CDDS	faced food insecurity (1=Yes)
	Panel A: Estimates from OLS/probit approach			
Average Treatment effect	0.964**	1.638**	1.262***	-0.053**
	(0.094)	(0.077)	(0.116)	(0.026)
Unadjusted p-value	0.000	0.000	0.000	0.035
Adjusted p-value	0.010	0.010	0.010	0.010
	Panel B: Estimates from control-function approach			
Average Treatment effect	1.096***	1.374***	0.585**	-0.250***
	(0.437)	(0.477)	(0.325)	(0.104)
Unadjusted p-value	0.012	0.004	0.072	0.000
Adjusted p-value	0.009	0.007	0.019	0.001
	Panel C: Estimates from panel data approach			
Average Treatment effect	1.042**	1.233**	1.137*	-0.121**
	(0.124)	(0.900)	(0.047)	(0.025)
Unadjusted p-value	0.000	0.001	0.027	0.000
Adjusted p-value	0.010	0.030	0.079	0.010
Number of observations	4338	4338	2156	4338

Note: Robust standard errors clustered at the district level are in parenthesis. ***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 significant level. HDDS denote Household dietary diversity Score, MHDDS denotes micronutrient sensitive Household dietary diversity Score, CDDS denotes dietary diversity Score for children under the age of 5. Control variables are sex of household head, household age, household size, household year of schooling, lagged land size, lagged wealth, lagged livestock ownership, forest and woodlots in kebele, distance to a market centre, distance to the nearest health post and district level fixed effects. Adjusted p-value are Romano-Wolf stepdown p-values that correct for Familywise error rate (FWER) as a result of multiple hypothesis testing.

As a robustness check, we also present the results of fixed (for continuous outcome variables) and random effect (for binary outcome variables) estimators. All coefficients are significant and point in the same direction and are of a similar order of magnitude as the results of the control-function estimator.

5.4.3. Impact pathway

The effect of ICS on nutrition goes through women's empowerment and time use. Looking across the three panels, the results indicate that ICSs adopters spent less time collecting fuelwood and that the number of days their female members engaged in paid work was higher. However, there seems to be no difference between adopters and non-adopters of ICSs with regard to operating small businesses run by female household members. Looking at the control-function estimator results, those households who adopted ICSs spend 14.4 minutes less collecting fuelwood per day (table 16 column 2 panel B, significant at 5%), and the likelihood of women in the household worked in paid jobs in the 12 months preceding the survey is 0.4 more (table 16 column 3 panel B, significant at 5%). These results are consistent with a recent study in Ethiopia, where adoption of ICSs was linked with lower fuel consumption (Gebreegziabher et al., 2018). The results of the other two estimators are fairly consistent both in terms of significance and direction of effect.

These results provide support for our hypothesis that one of the ways ICSs affect a household's food and nutrition security is through the empowerment of women. However, there could be other pathways that we have not analysed in this paper.

Table 16: Treatment effect on mediator variable

	Dependent variables		
	Fuelwood collection time (minute/day)	Women members engaged in paid work (1=Yes)	Women owned business (1=Yes)
	Panel A: Estimates from OLS approach		
Average Treatment effect	-13.968**	0.217**	0.004
	(0.911)	(0.021)	(0.019)
Unadjusted P-value	0.000	0.000	0.839
Adjusted p-value	0.010	0.010	0.772
	Panel B: Estimates from control-function approach		
Average Treatment effect	-14.408**	0.400**	0.248
	(3.303)	(0.112)	(0.137)
Unadjusted P-value	0.000	0.000	0.071
Adjusted p-value	0.010	0.010	0.290
	Panel C: Estimates from panel data approach		
Average Treatment effect	-9.192**	0.067**	0.008
	(0.651)	(0.004)	(0.018)
Unadjusted P-value	0.000	0.000	0.657
Adjusted p-value	0.010	0.010	0.743
Number of observations	4338	4338	4338

Note: Robust standard errors at district level are in parenthesis. ***, ** and * denote statistical significance at 0.01, 0.05 and 0.1 significant level. The average marginal effect is reported in the last column. Control variables are sex of household head, household age, household size, household year of schooling, land size, wealth, livestock ownership, forest and woodlots in kebele, distance to a market centre, distance to the nearest health post and district level fixed effects. Adjusted p-values are Romano-Wolf stepdown p-values that correct for Familywise error rate (FWER) as a result of multiple hypothesis testing.

5.5-Discussion and conclusion

We investigate the impact of ICSs on household nutrition status. We use a large household dataset representative of the rural highlands of Ethiopia and exploit the availability of instrumental variables for ownership of ICSs. We measure household nutrition status by the household dietary diversity score, the child dietary diversity score, the consumption of vitamin A rich foods, and the incidence of food insecurity. We also examine possible pathways focusing on women empowerment since ICSs have been shown to decrease home labour, and free up women's time.

We find that ownership of ICSs leads to better food and nutrition outcomes. Those who own ICSs have higher HDDS, MDDS, CDDS than those who did not own ICS and the difference is statistically significant. In addition, ICSs result in a lower likelihood of facing food insecurity. Ownership of ICSs may affect food and nutrition outcomes both directly and indirectly. The direct impact pathway may go like this: Since ICS have higher energy efficiency as compared to the traditional stove, the use of ICS is likely to reduce time spent on meal preparation (Vahlne and Ahlgren, 2014). This in turn creates opportunities for households to prepare extra dishes. Since we do not have information on the number of dishes per day or per stove at a household level, we are not able to determine this effect empirically.

We also find that time spent on fuelwood collection was lower for households who owned ICSs as compared to those who did not. This is one of the indirect impact pathways from ICSs to a household's food and nutrition security. This finding is in line with Jagger and Jumbe (2016) who found that ICSs lead to a reduction in time spent collecting wood. The findings are also consistent with the empirical evidence that links ICS with lower fuelwood consumption (Gebreegziabher et al., 2018; Wassie and Adaramola, 2021). In the study setting, fuelwood collection and cooking are usually performed by women. The implication is that ICS reduces women's home labour and frees up their time. However, it should be noted that though ICSs significantly reduce fuelwood collection time (14.4 minutes per day on average) the economic significance is limited if women do not have control over household resources.

It is worth noting that in addition to reducing fuelwood collection time, ICSs also reduce time spent preparing meals. The additional burner in the household allows for simultaneous cooking which greatly reduces cooking time (Ochieng et al., 2020). The implication is that the

actual time saved because of ICSs adoption is expected to be more than 14.4 minutes per day. However, the economic significance is limited if women do not have control over household resources.

We observe that women in households with ICS were more likely to work paid jobs. A possible explanation for the observed effect is that women now have more free time as ICS reduces cooking as well as fuelwood collection time. The link between women's empowerment and household wellbeing has long been recognized in the literature, and our results add more evidence to this growing literature.

Taken together, our results suggest that ICS may affect food and nutrition security outcomes directly and indirectly. Our results also provide some evidence that one of the ways ICS affect nutrition outcomes is by reducing the time women spend collecting fuelwood which allows women to engage in paid jobs. Apart from the obvious selling points such as reduction of firewood consumption and deforestation, ICSs can lead to better nutritional outcomes and contribute to women's empowerment. This is consistent with the growing literature that links ICSs with improved welfare in energy-poor settings (Bensch and Peters, 2020; Onyeneke et al., 2018; Pattanayak et al., 2019).

Our study has some limitations. Using observational data to establish causal relationships invariably requires making assumptions. Here our results rely on the validity of our instruments which require assumptions that we cannot test directly. For instance, for estimating the treatment effect using IV, we assumed that the proposed instruments are independent of our outcome indicators. For the fixed effect estimator, we assumed that ownership of ICS is as good as randomly assigned conditional on observed and unobserved but fixed individual characteristics. Through indirect methods, we tested the key assumptions, and the results lend support to the assertion that the instruments are valid. Nevertheless, they are still assumptions and our results should be seen considering these key assumptions.

Moreover, the use of ICSs could have had heterogeneous effects that we were not able to detect. For example, the intensity of use and the quality of the ICS may differ between households. In addition, impacts may change over time and be different in different locations, especially where the role of women in the household is different. Finally, the impact pathways from adoption of ICSs to food and nutrition security are complex. Given our dataset, we only

considered the women's economic empowerment channel, which still provided important indicative results. Research using data from other countries or regions could contribute to a further understanding of the benefits of ICSs and the pathways of change.

Development actors and other development actors interested in reducing energy poverty would do well to recognize the potential impact of ICSs on food and nutrition outcomes and incorporate it into their messaging campaigns when promoting ICSs.

Appendix 5.1: Selected price correlation in study areas

	Cement	Sand	Teff	Wheat	Maize
Cement	1				
Sand	0.719*** (0.000)	1			
Teff	-0.021 (1.000)	0.019 (1.000)	1		
Wheat	-0.112 (1.000)	-0.110 (1.000)	0.312* (0.077)	1	
Maize	-0.064 (1.000)	0.010 (1.000)	0.371** (0.013)	0.383*** (0.009)	1

Bonferroni-correct p values are in parenthesis. ***, ** and* denote statistical significance at 1%, 5% and 10% level.

Appendix 5.2: First-stage regression

Explanatory variables	**Dependent Variable:** Ownership of ICS (1=Yes, 0= otherwise)					
	Coefficient	Robust Standard Error	t	P>t	[95% conf. Interval]	
Cement price (birr per 50kg)	-0.022***	0.001	-18.00	0.000	-0.025	-0.020
Price of sand (birr per M^3)	-0.044***	0.007	-6.01	0.000	-0.030	-0.059
Sex of household head (1=Male)	-0.008***	0.002	-3.39	0.001	-0.013	-0.003
Age of household head	0.210**	0.091	2.31	0.021	0.032	0.387
Highest year of schooling	0.011	0.009	1.14	0.256	-0.008	0.029
Household size	-0.014	0.016	-0.87	0.385	-0.045	0.017
Land owned (in hectare) †	-0.004	0.031	-0.14	0.887	-0.066	0.057
Household wealth (in thousand birr) †	0.000***	0.000	3.14	0.002	0.000	0.000
Livestock ownership (in TLU) †	-0.007	0.014	-0.53	0.594	-0.035	0.020

Distance to the nearest market town (one-way walking minutes)	0.000	0.001	-0.43	0.670	-0.001	0.001
Distance to the nearest health post (one-way walking minutes)	0.000	0.001	-0.30	0.767	-0.002	0.002
Forest and woodlot per capita in the kebele (ha.)	0.238	0.222	1.07	0.285	-0.198	0.674
Constant	-0.595	0.893	-0.67	0.505	-2.345	1.154

Note: Statistics robust to heteroskedasticity and clustering. ***, ** and* denote statistical significance at 1%, 5% and 10% level. † indicates that we use lagged values (2014 value) of these variables.

Chapter 6
Synthesis

6.1. Answers to the research questions in brief

The thesis set out to identify strategies to promote food system innovations. It also examined the role of innovations that reduce home labour in the fight against food insecurity. These innovations are shown to be effective in narrowing the nutrition gap and are cost-effective. The implication is that these innovations can realistically be scaled up. The studied innovations also have limited carbon footprints which is important in the face of ever-growing awareness of the environmental impact of transforming the food system. An additional benefit of these innovations is that they do not require a radical change in the way of life and food choices of the target populations, which enhances the likelihood of their success.

In Chapter 2-4, different informational interventions are evaluated. The overarching question that these chapters try to answer is to what extent information interventions can be used to persuade the target population to switch to nutritionally enhanced foods/crops. Each chapter, however, introduces a different set of interventions and examines their combined effect. Chapter 2 investigates an information intervention combined with food certification. Chapters 3 and 4 incorporate insights from psychology and examine how these can be incorporated into information interventions. In chapter 5, the role of technical innovation (improved cook stoves) that frees up women's time in improving household food and nutrition security outcome is investigated.

Overall, the results of the four studies paint a fairly positive picture. It is possible to improve dietary outcomes and ultimately the well-being of those in the global south by strategically implementing interventions across multiple fronts within the food system. In both urban and rural areas, health messaging seems to be effective in encouraging the intake of nutritionally-enhanced food, indicating that inadequate knowledge was one of the constraints contributing to unhealthy diets and, ultimately, malnutrition.

The studies also show that apart from imparting health information, addressing the target population's uneasiness about food safety and understanding the psychological makeup of the target population can help to bring about the intended behavioural change with regards to food choice. The results of chapter 2 show that addressing consumers' concerns about food

safety through certification increased their willingness to pay. This is particularly important since food safety is expected to be a growing concern for consumers in the global south as their income increases. Moreover, food safety threats are expected to be on the rise as food systems modernise and food value chains become longer.

Chapter 3 and 4 borrow insights from the psychology literature and explore how they can be leveraged to increase the effectiveness of information interventions. Chapter 3 combined normative messaging, which is widely recognised to be effective in changing behaviour and habits (Cialdini, 2003), with an information treatment and examined its effectiveness in the context of promoting nutritionally-enhanced crops in rural areas. Consistent with previous literature, bundling the awareness campaign with normative messaging is found to be more effective than providing just the information treatment. Chapter 4 explores another widely recognized insight from psychology, namely the framing effect (Levin et al., 1998), which taps into people's cognitive bias, to promote nutritionally enhanced crops. The results confirm the existence of a framing effect: messages that highlight the positive or negative aspects of the same decision have different effects. The results also show that irrespective of the type of framing employed, providing information interventions significantly improves willingness to pay for nutritionally-enhanced crops. The study further investigates potential moderating factors and finds out that the perception of risk associated with the crop and people's regulatory focus moderate the effect of the treatment.

With regards to pro-poor innovations, the results in this thesis show that improved cookstoves –an innovation that reduces home labour–improve food and nutrition outcomes. This technology frees up women's time as women perform the lion's share of household chores. Women seem to spend part of the saved time on income-generating activities. Taken together the results suggest that one of the mechanisms through which these stoves bring about better food and nutritional outcomes is through their effect on empowering women to use their time more effectively.

6.2. Contribution to research

The findings of the studies taken together provide the following additional insights.

Information interventions informed by psychological insights can be effective in increasing the adoption of agricultural technologies: Low adoption of improved technology and practices has been implicated as one of the causes of low agricultural productivity for sub-Saharan African countries (Minten and Barrett, 2008). Lack of knowledge about the existence and the associated benefits of improved practices and technologies has long been shown to partially explain the observed dismal adoption rate (Foster and Rosenzweig, 1995). The behaviour change literature shows that motivating and sustaining a behavioural change requires moving beyond the provision of information to the engagement of emotions, which can be achieved by leveraging individuals' behavioural tendencies and cultural and social norms (Aunger and Curtis, 2013). The results from Chapter three and four show the utility of incorporating psychological insights into the traditional technology adoption approach for increasing the uptake of new technologies. Chapter three shows how one can leverage the propensity to follow social norms to improve the effectiveness of information campaigns to promote nutritionally enhanced crops. Chapter four demonstrates how message framing and individuals' tendency to respond more strongly to information when it is aligned to their behaviour tendencies (motivational orientation) can be used to increase the uptake of new crop varieties. The utility of these insights is presumably not limited to a specific technology and can be used to increase the uptake of a wide variety of improved agricultural technologies and practices.

Closing farmers' nutrition knowledge gap and building upon the existing production pattern is key to leveraging their unique role in transforming the food system: The food system in the global south is changing rapidly with an increasing role of supermarkets in supply chains from farm to fork (Dakora, 2012; Reardon and Timmer, 2012). From a global perspective, change in the food system is marked by consolidation at both the production and distribution level, the emergence of longer and more complex value chains, and overall interconnectedness which become possible due to information and communications technologies (de Brauw & Bulte, 2021). Interestingly, however, smallholders still play a large role and contribute about one-third of the food supply, using a quarter of the agricultural land (Ricciardi et al., 2018). Thus,

any intervention that aims to transform the food system should recognize the unique role and opportunities they present. By addressing information barriers, the studies (Chapter three and four) showed that it is possible to encourage farmers to switch to biofortified crop varieties. Since the crop selected for biofortification is already known and widely grown and consumed by the targeted population, switching to new crop varieties is not expected to require radical change. This increases the likelihood of adopting these crop varieties. Given that the tested information interventions are presumed not to require huge upfront investments, the studies showed one approach of incorporating smallholders in food system intervention more efficiently.

An integrated approach that promotes both food safety and nutrition is needed: Food safety issues are expected to be a growing concern for consumers in the global south as the awareness level and purchasing power of consumers in these countries increases. Safeguarding food safety is also increasingly important in the face of intensification of agriculture which requires the use of agrochemicals. Failure to address food safety issues is costly as contaminated foods are a significant impediment to economic development worldwide (Havelaar et al., 2015). In fact, promoting food safety is linked to efforts to achieve the Sustainable Development Goals (FAO, 2021, 2018). The findings of this thesis (Chapter 2) are in line with this consensus about the importance of food safety in efforts to improve nutrition. The findings of chapter two indicate that food safety is an important concern for urban consumers, and even more so than the nutritional content of food. The results further indicate that if consumers have misgivings about the safety of the food or do not trust the source of the food, information interventions would be less effective in encouraging consumers to switch to nutritionally-enhanced foods. Thus, the study highlights the fact that an integrated approach to promoting food safety and nutrition is likely efficient.

Perceived quality of agricultural inputs affects the success and effectiveness of nutrition-sensitive agricultural interventions: Nutrition-sensitive agricultural interventions have been recognized as viable strategies to achieve better nutritional outcomes (Black et al., 2013). Among other things, this involves promoting nutritionally enhanced crops. However, limited access to quality inputs has contributed to the low adoption of these inputs. The implication is that access to quality agricultural inputs is key for transforming smallholder livelihood in Africa (Tilman et al., 2011). Recently de Brauw and Bulte (2021) have argued that the absence

of effective quality certification mechanisms –for both agricultural input and output– could lead to market failures and to poor quality products in the market.

Apart from the actual quality of inputs, our results (chapter 3) showed that perceived quality of input (which is subjective) also matters in farmers' technology adoption decisions. Any doubt about the quality of the seeds negatively affects the likelihood of adoption of nutritionally enhanced seeds even if farmers are made aware of the benefits of consuming food prepared from nutritionally enhanced crops.

Quality certification could increase farmers' income: The results in this thesis show that consumers would pay a premium for food they deem safe. Assuming that consumers' concern about food safety is not limited to processed food (cooking oil) but is an emerging trend that would extend to other food items (Melesse et al., 2019), it is conceivable that urban consumers would pay a premium price for safe and quality food products. Since smallholders are at the core of the food economy, addressing food safety issues should also include smallholders. However, research on quality certification on crops that are widely grown by smallholders is thin. The studies in the thesis contribute to this thin literature. The findings of chapter two provide suggestive evidence that encouraging smallholder farmers to produce quality products and certify their products would allow them to earn more income as consumers are willing to pay premium prices.

An intervention that aims to alleviate constraints on multiple fronts would be more effective: The advantage of adopting systems thinking rather than breaking down a system into its components and studying them separately has long been recognized. The systemic approach began to spill over into thinking about global supply chains and then to rural development. As it pertains to the supply and consumption of healthy food, a food system approach has been introduced as a useful conceptual framework for research and policy. The key insight that came out of the food system thinking is that relaxing constraints in a piecemeal fashion is unlikely to change the status quo sustainably. This insight has been made in the context of agricultural development in Africa (de Brauw and Bulte, 2021). The food system in the global south faces multiple constraints and addressing them on multiple fronts is expected to be more effective. The results of the chapters taken as whole lends support to this realization. For instance, in addition to availing nutritionally enhanced foods, it is important

to address the key constraints related to lack of nutrition knowledge at the same time addressing consumer uneasiness about food safety. The thesis also showed a link between rural energy uses and the role of technologies in empowering women which ultimately is shown to improve food and nutrition security status.

The selection of innovations and strategies to promote them should consider the local context: The chapters in the thesis also contribute to the growing body of work that recognizes the importance of devising context-specific solutions for problems faced by farmers in the global south. In the rural development literature, there seems to be a consensus that development interventions should be informed by the local context (Donovan et al., 2015; Ika, 2012; Stoian et al., 2016). Recent work gave the issue more impetus as it argued that though African farmers face similar development challenges, interventions must take local context into account (de Brauw and Bulte, 2021). The studies in this thesis contribute to this debate.

The thesis demonstrates how one can leverage the local context to improve diet quality. In urban areas, inadequate consumption of Vitamin A is found to be one of the public health problems. In this setting, cooking oil is usually used in food preparation. Taking this into consideration the innovation that we tested in urban areas is cooking oil fortified with vitamin A. Another relevant context that informs our study is the fact that since there is a shortage of cooking oil in the market, adulterated/unsafe products are also available in the market. This leads to a loss in consumer confidence and makes consumers more sensitive to safety issues. Cognizant of this we incorporate food safety issues and study the role of safety certification in the context of promoting fortified cooking oil. We find that an educational intervention bundled with the introduction of food certification is effective in increasing consumers' wtp for fortified cooking oil. The results highlight the importance of understanding the context and designing interventions in a way that addresses the important issues of the target population.

In rural areas, production and consumption decisions are inseparable and maize is a widely consumed staple. In this setting, biofortification is shown to be effective in delivering important nutrients. Another peculiarity of our study areas that informs our study is the fact that the colour of maize is one of the key considerations for farmers. In this setting what farmers are accustomed to is white maize, and the current process of increasing the nutritional value of maize usually leads to colour changes (in the study areas the colour of

biofortified maize is yellow). If farmers have a strong colour preference, their preference for white maize may outweigh their willingness to adopt yellow but nutritionally enhanced maize. Thus, the innovation that we chose to study in this area is nutritionally enhanced maize (chapter 3 and 4) since maize is already a staple food there. In addition, we study how the colour of the crop affects farmers' wtp for nutritionally enhanced maize (Chapter 3). Our results highlight the fact that the colour of the crop is an important consideration in farmer crop choice and educational information is needed to induce farmers to switch to these more nutritious crops.

Finally, in areas where there is a fertile ground to introduce alternative rural energy sources, improved cookstoves can be leveraged to improve diets as they are shown to increase women's access to resources which in turn have a positive effect on household food and nutrition outcomes. Without losing sight of the overall food system, it is not only possible but imperative to win local battles.

6.3. Policy implications

In terms of policy, the thesis has the following implications. Specific policy implications from each of the core studies (chapter 2-chapter 5) are discussed in the relevant chapter. Here I highlight three policy implications. Firstly, the fact that consumers are willing to pay more for food they consider safe than food that is fortified with nutrients (Chapter 2) suggests that nutrition interventions such as promoting nutrient-dense foods should also pay attention to the food safety concerns of the target populations and incorporate food safety interventions as well.

Secondly, the importance attached to the sources of seeds (Chapter 3), which is used by farmers to judge seed quality, suggests that nutrition-sensitive agriculture interventions such as the promotion of nutritionally enhanced seeds should pay attention to the complex relationship farmers have or develop over time with seed suppliers. Informed by their previous interactions or general trust level, farmers form their beliefs about the quality of seeds from suppliers and sometimes their beliefs may not correspond to the actual quality. Disregarding this issue may render otherwise effective interventions less successful.

Finally, the fact that risk perceptions and people's motivational orientations moderate the effectiveness of information interventions (Chapter 4) suggests that educational intervention can be made more effective by crafting educational materials that are in line with people's behavioural tendencies.

6.4. Limitations and considerations for future research

Important limitations of the study are discussed separately in each chapter. Here limitations that cut through the chapters are discussed along with considerations for future research.

One of the limitations of this thesis that runs through the core chapters is that we make assumptions that we are not able to directly test empirically. For instance, in chapter 2 and 3 participants are asked to make a choice between hypothetical alternatives, and there are no real consequences associated with the choice. Such responses to hypothetical choices may differ from real-world behaviour (Hensher et al., 2015). Nevertheless, since discrete choice experiments are well tested in the field and have theoretical links with real behaviour, they still allow researchers to gain an understanding of how people actually make choices (Louviere et al., 2010). Furthermore, to reduce the potential hypothetical bias, we present choice sets in a way that closely resembles the actual choice tasks farmers face. To further reduce the hypothetical bias and get more precise results, future studies should use incentive-compatible methods of eliciting preferences.

In chapter 5, we make another assumption to infer the causal impact that ICSs exert on food security and nutritional status. In this chapter, we harness observational data and use IV methods to estimate the impact of ICSs ownership. To attribute the difference in food security and nutritional status between ICSs and non-ICSs households, we assume that construction input (cement and sand) prices do not directly affect households' food security and nutritional status. In the literature, this is called the exclusion restriction. Through indirect methods, we tested this key assumption, and the results lend support to the assertion that the instruments are valid. Nevertheless, it is still an assumption and our results should be seen in light of these key assumptions. Thus, future studies that aim to establish the impact of ICSs on food security and nutritional status should preferably use experimental methods. If conducting experiments is not feasible, observational data with multiple data points (ideally more than two)–for both pre-and post-treatment periods– can be combined with quasi-

experimental methods that are appropriate for panel data (for example, Difference in Difference, two-way fixed effects or even the fixed effects IV estimator). Multiple data points would allow researchers to examine if the set of identifying assumptions is likely to hold and derive robust results (Cunningham, 2021).

Chapter 3 and 4 look at the impact of information interventions in farmers wtp for nutritionally enhanced seed. The implicit assumption is that increasing farmers' wtp for nutritionally enhanced seeds will lead to the consumption of food prepared from nutritionally enhanced crops. This is expected to improve nutrition security and eventually contribute positively to health outcomes. However, there are many steps from wtp for seeds to improved nutritional outcomes and ultimately health. Consideration for future study is thus to understand if the promoted behaviour–consumption of fortified cooking oil in chapter 2, and production and consumption of food prepared from biofortified maize (chapter 3 and 4) will actually translate into measurable changes in people's diet and have health impacts both in short and long terms. Along these paths, there may be key barriers that need to be identified and addressed for the envisioned food system transformation to materialize.

The results also revealed that seed quality is one of the key attributes that smallholders take into account in their production decisions (Chapter 3) and that they are willing to pay a premium for quality seeds. The next logical step is thus to examine the feasibility of supplying these nutritionally-enhanced crop varieties given the reservation price of farmers. Both the public and the private sector have a role in supplying agricultural inputs. Thus, a cost-benefit analysis needs to be conducted from the perspective of both the private as well as the public sector.

Another limitation is that the research in this thesis mainly focuses on a short time horizon and can only speculate about whether the observed intention and willingness to change one's food choice leads to habit formation. It is worth noting that interventions that aim to promote healthy food choices are successful only if they lead to long term-term behavioural change. In fact, incorporating habit formation into behaviour change interventions has been recognized as a way forward in behaviour change literature (Gardner and Rebar, 2019). Thus, future research with a longer implementation period should explore how the short-term impacts of educational interventions that are reported in this thesis can be sustained in the long term

and ultimately lead to habit formation. Such studies will provide evidence-based options to policymakers to change or improve the food environments for better food and nutrition results.

Chapter 3 and 4 tested information interventions that incorporate psychological insights. The results demonstrate the utility of aligning information interventions with people's behavioural tendencies and motivations. Based on a literature review the chapters discuss the expected effect of these treatments and develop testable hypotheses. The chapters do not provide formal models that incorporate all aspects of the interventions to predict the possible impacts of interventions and understand the mechanisms. Though these type of studies has high internal validity due to the randomization of treatment assignment, a lack of formal models with the required mathematical rigour may limit our understanding of why they work or did not work. Formal models would also provide additional insights that may not be so obvious at first glance. Empirical results backed by formal theoretical models would also increase the confidence in the results. Another consideration for future research that aims to assess the impact of interventions that leverage insights from different fields such as psychology is to incorporate formal behavioural models that help to explain key results and lay bare the mechanism. Such studies would be useful to identify which interventions have a high likelihood of success if they are implemented in another context or scaled up (Ioannidis et al., 2021).

6.5. Final remarks

The current food system is very efficient in one way –it allows for the production of enough food to feed everyone (Holt-Giménez et al., 2012). However, it is inefficient in another way – it fails to deliver nutritious diets for 2.4 billion people (WHO, 2021). Clearly, there is a need to identify interventions that would be effective in transforming the food system in a way that works for the world's poor. The research presented in this thesis responds to this need. It is informed by the food system framework of HLPE (2017). The core chapters deal with the different aspects of food systems: they explore aspects of food value chains, the food environment and consumer behaviour. Notwithstanding the above limitations, the results of the thesis contribute to the global wide effort of transforming the food systems to better deliver healthy and sustainable diets in a socially equitable way.

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English Summary

The thesis sets out to identify strategies to promote food system innovations. Information interventions informed by psychological insights were tested. It also examines the role of innovations that reduce home labour in the fight against food insecurity. The thesis adopts a food system approach and touches upon the different aspects of food systems. Within the food system framework, the chapters are interlinked as they relate to the food system and explore its key elements– food value chains, food environments and consumer behaviours.

Chapter one sets out the context and presents the research questions. It briefly discusses the prevalence of malnutrition and how transforming the food system to respond to the problem of malnutrition drives greenhouse gas emissions. The chapter also highlights the unique role of smallholders in the global food system and the fact that solutions for food system transformation should protect them. It then presents four research questions corresponding to the four core chapters of the thesis, argues how they relate to the different aspects of the food system and outlines the methodology that is used to answer the research questions.

In chapter two, the role of nutrition messaging and food safety certification in changing people's food choice behaviour is examined. A choice experiment with information treatment was conducted on urban consumers. Vitamin A deficiency is prevalent in the study area. At the same time, cooking oil, which is widely consumed by urban consumers, is identified as an ideal candidate for vitamin A fortification. Given this, the experiment focused on fortified cooking oil. The experiment was conducted on 996 participants who were divided into treatment (n=518) and control (n=478) groups. The treatment group was provided with a nutrition message that highlighted the benefit of substituting the cooking oil that they use with vitamin A fortified oil. Then participants were asked to choose between different types of cooking oil which differ in terms of price, certification status, the origin of the product and fortification status. Combining the nutrition messaging with a choice experiment allowed us to identify the effect of the nutrition message on participants' stated preference for fortified cooking oil. It also allowed us to study how certification status interacts with health messaging. The results show that addressing the information gap by providing health messages and addressing consumers' concerns on food safety through certification increases consumers' willingness to pay for fortified cooking oil.

Another choice experiment was conducted in a different context and with more treatment arms. This time, information provision was bundled with normative messaging and its impact on the preferability of nutritionally enhanced maize is examined (Chapter three). The experiment was conducted in rural areas where maize production is widely practised, and maize is a staple food. A between-subject design was used to examine the effectiveness of two treatments (information provision and normative messaging) with dichotomous treatment levels (received or not received) in encouraging farmers to adopt nutritionally enhanced maize. In this set up four groups were created, and 2022 subjects were assigned to the four groups randomly. The results show that increasing the awareness level of participants with regards to the consumption of food prepared from nutritionally enhanced maize increased their willingness to pay for maize seeds, which in turn is expected to lead to increased adoption of this variety. Bundling the awareness campaign with normative messaging further increased the acceptability of the new crop.

Chapter four discusses the results of a field experiment that was conducted to identify effective message framing in behaviour change communication for health. To identify the effect of differently framed messages, a between-subject design was implemented. Participants were divided into two treatments and a control group. The treatment groups received gain or loss-framed messages while those in the control group did not receive any message. The messages were designed to impart information about the benefit of consuming food prepared from nutritionally enhanced maize. Then BDM mechanisms were used to elicit participants' willingness to pay for biofortified and conventional (non-biofortified) maize seeds. The results show that the treatments increase wtp for nutritionally enhanced maize seeds indicating that lack of knowledge was one of the reasons for the low adoption of these crops. The results also show that the perception of risk associated with the crop and participant’s regulatory focus moderates the effect of the treatments.

In chapter five we show that technologies that reduce home labour and create opportunities for women to earn income can also improve households' wellbeing. We focused on improved cookstoves (ICSs) as a case study and used a cross-section dataset from a representative sample of rural households to study the impact of this technology on women’s time use and ultimately on household food and nutrition security. We use instrument variables for ownership of ICSs to identify the impact. The results indicate that the use of ICSs improves

food and nutrition security outcomes. Further analysis shows that ICSs reduce home labour and this, in turn, allows women household members to engage in income-generating activities, suggesting that the impact is driven by women empowerment channels. These findings suggest innovations that relieve women from the time constraint and domestic drudgery empower women economically and have positive spillover effects that affect their households and presumably their community.

Finally, chapter 6 synthesizes the results. The chapter briefly discusses answers to the research questions, spells out the contribution of the studies as it relates to the broad scientific debates, and puts forward consideration for future research.

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Kaleb Shiferaw Jada
Wageningen School of Social Sciences (WASS)
Completed Training and Supervision Plan

Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
Advanced Microeconomics, ECH 51806	WUR	2018	6
Advanced Econometrics, YSS-34306	WUR	2018	6
Experiments in Developing countries: Methods and Applications	University of Groningen Summer	2017	2
Behavioural and Experimental Economics, ECH 51306	WUR	2017	6
Advanced Behavioural Economic Theory	WASS	2018	4
B) General research related competences			
WASS Introduction course	WASS	2021	1
Writing research proposal	WUR	2018	6
Presentation Skills – Dealing with Nerves	WUR	2017	0.6
Techniques for scientific writing and presenting	WIAS	2018	1.2
C) Career related competences/personal development			
"The impact of health message and social norm interventions on farmers' willingness to pay for biofortified crops: Evidence from discrete choice experiment on biofortified maize in Ethiopia."	4th International Conference on Global Food Security (virtual)	2020	1
"Empowering women for better food and nutrition security: the case of improved cook-stove in Ethiopia"	3rd Sustainability and Development Conference (virtual)	2022	1
"Identifying effective message-framing techniques in behaviour change communication for healthy diets: An experimental study of promoting biofortified maize adoption in Ethiopia"	3rd Sustainability and Development Conference (virtual)	2022	1
"Information provision, certification and consumer interest in nutritious and safe processed foods: Evidence from discrete choice experiments among urban consumers in Ethiopia"	Health Economics Workshop organized by Development Economics Group, Wageningen University, International Institute of Social Studies and Erasmus University Rotterdam	2018	1
"Analysis of milk production, butter marketing and household use of inputs in rural Ethiopia"	30th International Conference of Agricultural Economists (ICAE)	2018	1
Total			**37.8**

*One credit according to ECTS is on average equivalent to 28 hours of study load

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