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A Latent Class Approach to Investigating Farmer Demand for Biofortified Staple Food Crops in Developing Countries: The Case of High-Iron Pearl Millet in Maharashtra, India

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ABSTRACT

This study explores farmer acceptance and valuation of a biofortified staple food crop in a developing country prior to its commercialization. We focus on the hypothetical introduction of a high-iron pearl millet variety in Maharashtra, India, where pearl millet is among the most important staple crops. A choice experiment is used to investigate farmer preferences for and trade-offs among various production and consumption attributes of pearl millet. The key pearl millet attributes studied included days it takes pearl millet to mature, color of the roti (flat bread) the grain produces, the presence of high-iron content (nutritional attribute), and the price of the pearl millet seed. Choice data come from 630 pearl millet-producing households randomly selected from 3 purposefully selected districts of Maharashtra. A latent class model is used to investigate the heterogeneity in farmers' preferences for pearl millet attributes and to profile farmers who are more or less likely to choose high-iron varieties of pearl millet. Our results reveal that there are three distinct segments in the sample, and there is significant heterogeneity in farmer preferences across these segments. High-iron pearl millet is valued the most by larger households that produce mainly for household consumption and currently have lower quality diets. Households that mainly produce for market sales, on the other hand, derive lower benefits from consumption characteristics such as color and nutrition. These results have implications for the design of targeted strategies to maximize adoption and consumption of high-iron pearl millet varieties.

Keywords: biofortification; choice experiment; latent class model; preference heterogeneity; pearl millet; Maharashtra

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CONTENTS

I. INTRODUCTION

Biofortification—the process of breeding staple food crops with higher micronutrient content—could prove to be an essential strategy for combating micronutrient deficiency in India, which has one of the world's highest rates of malnutrition. An estimated 66 percent of children in western India, for example, suffer from anemia (HarvestPlus 2010), which is one of the outcomes of iron deficiency. At the same time, a large segment of the Indian population is vegetarian for economic, religious, or personal reasons, and as is the case in many developing countries, access to food supplements and commercially marketed fortified foods is limited. This suggests that there is an urgent need to improve the quality of the diet of the poor in India in order to ensure better nutritional outcomes. Biofortification of staple food crops is one of the recent initiatives to achieve improved nutrition among the poor. Studies conducted by HarvestPlus suggest that biofortification is likely to be a more cost-effective public health intervention in rural areas, in comparison with commercial fortification and supplementation (see Meenakshi et al. 2010).

HarvestPlus recognizes the benefits of biofortification in developing countries on the one hand and the high consumption rates of staple crops among the poor on the other. The researchers in the program endeavor to solve the micronutrient malnutrition problem in developing countries by breeding varieties of staple crops that are rich in three critical micronutrients recognized by the World Health Organization (WHO) as most limiting: vitamin A, zinc, and iron (HarvestPlus 2009a). Projects are underway in several developing countries to breed and disseminate biofortified varieties of staple crops including bean, cassava, maize, pearl millet, rice, sweet potato, and wheat (see http://www.harvestplus.org/).

In India, HarvestPlus will introduce biofortified varieties of three staple crops, namely high-zinc rice and wheat and high-iron pearl millet, in order to take into account the regional differences in consumption of these grains in this country and the deficiency of these two micronutrients that are crucial for human health. Scientists from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in collaboration with HarvestPlus are currently breeding a high-iron open-pollinated variety (OPV) of pearl millet. HarvestPlus will disseminate this variety in 2012 in the state of Maharashtra, which is a major pearl millet producing and consuming state in India (Yadav 2011; HarvestPlus 2009b; HarvestPlus 2010). While biofortification adds desirable nutrients to staple crops, it may also alter certain pre-existing traits that farmers—who are also the primary consumers of pearl millet—highly value. Therefore, it is crucial to understand not only if farmers would prefer varieties with added nutritional value but also what other attributes they prefer and what are the trade-offs (if any) between a nutritional attribute and other important production and consumption attributes.

Since high-iron pearl millet varieties have not yet been introduced in Maharashtra, we employ the hypothetical stated preference choice experiment method in the present study to investigate farm households' valuation of a high-iron pearl millet variety, which may offer potential health benefits compared to currently available varieties. The choice experiment method allows us to investigate farm household preferences for various key pearl millet attributes including days it takes for the crop to mature, color of the *roti* (flat bread) prepared with the grain, high-iron content (nutritional attribute) of the pearl millet, and price of seed. The choice experiment data come from 630 pearl millet-producing households located in rural areas of three districts in Maharashtra. Data are analyzed using a latent class model (LCM), which enables simultaneous identification of the characteristics that differentiate pearl millet producing and consuming farm households and the values that these households derive from the tested pearl millet attributes.

The next section discusses the theoretical framework of the choice experiment method and the LCM and explains the choice experiment design and application. Section III describes the sampling design and the data. Econometric results are reported and discussed in Section IV. The last section draws conclusions and discusses implications for delivery of high-iron pearl millet varieties in Maharashtra.

II. CHOICE MODELING APPROACH

A. Theoretical Framework

The choice experiment approach is theoretically grounded in Lancaster's model of consumer choice (Lancaster 1966), which proposed that consumers derive satisfaction not from the goods themselves but from the attributes they provide. The choice experiment method also has an econometric basis in models of random utility (Luce 1959; McFadden 1974), which integrate behavior with economic valuation. In the choice experiment approach, the utility of a choice is comprised of both a deterministic component and an error component that is independent of the deterministic part and follows a predetermined distribution. The error component implies that predictions cannot be made with certainty; choices made among alternatives will be a function of the probability that the utility associated with a particular option is higher than that associated with other alternatives (Hensher, Rose, and Greene 2005).

When estimating preferences, the heterogeneity of the preferences in the sample should be accounted for through the use of an appropriate model. Accounting for preference heterogeneity enables unbiased estimation of individual preferences and hence enhances the accuracy and reliability of demand, marginal welfare, and total welfare estimations (Greene 2008). Furthermore, accounting for heterogeneity enables the formulation of policy recommendations or program actions that take equity concerns into account. Information about who will be affected by a policy change or introduction of a program and the aggregate economic value associated with such changes is necessary for designing targeted, efficient, effective, and equitable policies and interventions (Boxall and Adamowicz 2002).

A number of alternative models have been developed to account for heterogeneity, including the covariance heterogeneity (CovHet) model (Colombo et al. 2009), the random parameter (mixed) logit (RPL) model (McFadden and Train 2000; Train 1998; Greene and Hensher 2003; Rigby and Burton 2005), and the latent class model (LCM) (Swait 1994; Louviere et al. 2000). Colombo et al. (2009) provide a detailed comparison of these models for integrating and explaining preference heterogeneity in choice experiments. The LCM has been successfully used to identify the sources of heterogeneity at the segment (or group) level, whereas the CovHet and RPL models capture heterogeneity at the individual level. Investigation of heterogeneity at the segment level would be most relevant when assessing farmer demand and marketing and promotion strategies for new products, such as seeds for biofortified staple crops.

The LCM casts heterogeneity as a discrete distribution by using a specification based on the concept of preference segmentation (Wedel and Kamakura 2000). The approach depicts a population as consisting of a finite and identifiable number of segments or groups of individuals. Preferences are relatively homogeneous within segments but differ substantially across segments. The allocation of an individual into a specific segment is probabilistic and depends on the respondent-level characteristics. Furthermore, respondent characteristics indirectly affect the choices through their impact on segment membership.

An increasing number of studies have used this approach to estimate farmers' and consumers' preferences for various agricultural technologies and foodstuffs. For example, Scarpa et al. (2003) and Ruto et al. (2008) employed this model for the valuation of livestock attributes. Hu et al. (2004), Kontoleon and Yabe (2006), and Kikulwe et al. (2011) used it to investigate consumer preferences for genetically modified (GM) food. Birol et al. (2009) used it to examine farmer preferences for agro-biodiversity conservation and GM maize adoption.

Broadly, the product studied in this paper, i.e., hypothetical varieties of pearl millet seeds, has production, consumption, and marketing attributes with different trade-offs. In the specific case of farm households, which are producers, consumers, and sellers of pearl millet, these trade-offs are common in many choice problems that they face. Consider a farm household n that makes a choice of a pearl millet seed alternative among a set of J pearl millet seed alternatives, in each of the $T(n)$ choice occasions. Suppose the farm household n belongs to segment s, where $s \in S$, then the household's utility function for the preferred alternative $i \in J$ can be written as:

$$U_{nti/s} = \beta_s' X_{nti} + \varepsilon_{nti/s} \qquad (1)$$

where X_{nti} is a vector of attributes associated with pearl millet seed alternative i, farm household n, and choice occasion t, and β_s is a segment-specific vector of taste parameters. The differences in β_s vectors enable this approach to capture the heterogeneity in pearl millet seed attribute preferences across segments. Assuming that the error terms are identically and independently distributed (IID) and follow a Type I (or Gumbel) distribution, the joint logit probability of a set of choices $T(n)$ made by individual n, conditional on belonging to a given segment is:

$$P_{T(n)/s} = \prod_{t(n)}^{T(n)} \frac{\exp(\beta_s' X_{nti})}{\sum_{j=1}^{J} \exp(\beta_s' X_{ntj})} \qquad (2)$$

Now consider M^* is a segment membership likelihood function that classifies the farm household into one of the S finite number of latent segments with some probability, P_s. The membership likelihood function for farm household i and segment s is given by $M^*_{ns} = \lambda_s Z_n + \xi_{ns}$, where Z represents the observed characteristics of the farm household, such as their demographic and pearl millet production/consumption/sales characteristics. Assuming that the error terms in the farm household membership likelihood function are IID across farm households and segments and follow a Gumbel distribution, the probability that farm household n belongs to segment s can be expressed as:

$$P_s = \frac{\exp(\lambda_s Z_n)}{\sum_{s=1}^{S} (\lambda_k Z_n)} \qquad (3)$$

where λ_s (s=1,2,3...S) are the segment-specific parameters to be estimated. These parameters denote the contributions of the various farm household characteristics to the probability of segment membership. A positive (negative) and significant implies that the associated farm household characteristic, Z_i, increases (decreases) the probability that the farm household i belongs to segment s. P_{is} sums to 1 across the S latent segments, where $0 \leq P_{is} \leq 1$.

Equation (2) provides the conditional choice probability, conditional on segment membership of a particular segment s. The unconditional joint probability of a set of choices $T(n)$ for individual n is obtained by combining the conditional probability (2) with the segment membership probability (3) and by taking the expectation over all the S segments. The joint unconditional probability of farm household n belonging to segment s and choosing pearl millet seed alternative i can be given by:

$$\Pr(T(n)) = \sum_{s=1}^{S} \left[\left(\frac{\exp(\lambda_s Z_n)}{\sum_{s=1}^{S} \exp(\lambda_s Z_n)} \right) \times \left(\prod_{t(n)}^{T(n)} \frac{\exp(\beta_s X_{nti})}{\sum_{j=1}^{J} \exp(\beta_s X_{ntj})} \right) \right] \quad (4)$$

Equation (4) depicts a mixed-logit model that simultaneously accounts for pearl millet seed choice and segment membership. The log-likelihood function that is maximized to obtain the parameters λ_s and β_s is given by:

$$L = \Sigma_n \Sigma_{i \in J} I_i \ln Pr\,(T(n)) \quad (5)$$

where I_i is an indicator variable for observed choice.

B. Choice Experiment Design

The first step in choice experiment design is defining the pearl millet seed in terms of its attributes and the levels these attributes take. We identified the most important pearl millet seed attributes and their levels from the findings of a pearl millet varietal choice and adoption study (Asare-Marfo et al. 2010). This study collected information from 2069 randomly selected farm households in pearl millet-producing agroecological zones of Maharashtra. Data were collected on these households' various pearl millet production and consumption characteristics. Among the information collected was likert-scale questions that asked farmers to rate from 1 (unimportant) to 5 (very important) the importance they placed on various production, consumption, processing, and marketing traits in choosing a pearl millet variety.

According to the results of that study, early maturity was thought to be an important or very important production trait by the highest proportion of farmers, followed by yield. Even though the difference in proportions for these two traits was not statistically significant, we chose early maturity as the production attribute that got valued vis-à-vis other traits in this experiment. The reason is that the open-pollinated, high-iron pearl millet varieties that are currently being developed are expected to have as high as or even higher yields than the OPVs currently available in Maharashtra. Therefore, trade-offs between nutritional value (high-iron content) and yield for the open-pollinated, high-iron pearl millet varieties that will be released in Maharashtra in 2012 can be ruled out. In other words, the new high-iron varieties can be taken to be yield conserving (or enhancing) but nutritionally enhanced.

In the choice experiment, the early maturity attribute was defined as "days to maturity," i.e., the number of days it takes for pearl millet to mature. The levels used for days to maturity were gathered from the mean and the 5th and 95th percentiles of a distribution of days to maturity that were compiled from the 51 varieties that were identified in this state (Asare-Marfo et al. 2010). Days to maturity attribute took three levels, 40, 85 and 155 days. This attribute was coded in cardinal-linear form with the actual values for days to maturity. It was expected that farm households would prefer pearl millet varieties that mature in fewer days.

According to the results in Asare-Marfo et al. (2010), taste of *roti* (flatbread) was the consumption trait that was rated as very important or important by the greatest proportion of farmers. Since it would be difficult to describe taste in this hypothetical context, we opted to use color of *roti*, which was rated as the second most important consumption trait. Color was easier to describe with the help of digital technology that allowed us to generate *roti* photos in light, medium, and dark colors. This qualitative attribute with three levels was coded as two dummies (light- and medium-colored *roti*) with dark-colored *roti* as the base level. Therefore, estimated coefficients for light- and medium-colored *roti* indicate farmers' valuation of these *rotis* compared to dark-colored *roti*. Through our focus groups discussions, we found that taste and color of *roti* are thought to be correlated for the majority of consumers, though there was not a consensus as to which color was preferable. Therefore, we do not have any *a priori* expectations on farm households' preferences for this attribute.

The added nutritional value attribute is the main attribute of interest in this choice experiment. Various focus group discussions were conducted with pearl millet farmers (who are, most of the time, consumers, producers, and often sellers of this crop) to find an easily understandable definition of what nutritional value (in this case, higher iron content) is and how consumption of high-iron pearl millet could affect their families' health.

Enumerators explained to respondents that pearl millet breeders are using conventional breeding methods (which farmers were already aware of) to breed varieties that have additional nutritional value, specifically iron. These pearl millet varieties with added nutrition may contain up to 30 percent more iron compared to the other varieties, and this increment is beneficial for the health of the respondent and his/her family. It was explained that iron is found in animal-source foods (red meat, poultry, fish, eggs) and some plant-source foods (beans, nuts, leafy greens), though the human body absorbs iron from animal-source foods more easily.

Respondents were also informed that getting more iron in their diets could:

- Generate strength, stamina, and energy and ensure that health problems such as fatigue and headaches are reduced.
- Improve children's performance at school, for example, by increasing test scores.
- Benefit household members who undertake hard labor activities, pregnant women, women of childbearing age, young girls, and vegetarians who are more likely to be iron-deficient.

In the choice experiment, the pearl millet varieties evaluated either had this added nutritional value or did not. This attribute was effects coded, with -1 for no added nutrition and 1 for added nutrition."

Based on previous studies that used revealed choice experiments and experimental auctions to estimate consumer valuation of biofortified staple crops (Meenakshi et al. 2010; Chowdhury et al. 2011), we expect consumers *a priori* to prefer the pearl millet seed varieties with added nutritional value. Yet, based on the discussion above regarding preference heterogeneity, the valuation for the nutritional attribute could vary significantly across populations (and also within a population). Thus, similar results to Meenakshi et al. (2010) and Chowdhury et al. (2011) cannot be assumed to hold in the study presented here. Ex post we do obtain significant differences in valuation of the nutrition attribute within our population (section IV), thereby reinforcing the context specificity of the preference elicitation exercise.

Finally, the price of a 1.5 kg bag of pearl millet seed was included as the monetary variable. This attribute is included in order to estimate consumers' willingness to pay (WTP) a premium or willingness to accept (WTA) a discount for other attributes, i.e., days to maturity, color of *roti*, and added nutritional value. The levels of the price attribute were derived from the prices of the currently available pearl millet varieties collected from a survey of 789 agri-input suppliers located in 147 pearl millet producing blocks (subdivision under a district) of the state of Maharashtra (Asare-Marfo et al. 2010). The prices selected included the mean price, two lower prices (one and two standard deviations below the mean price), and two higher prices (one and two standard deviations above the mean price). The prices used therefore range from Rs 160 to Rs 315. *Ceteris paribus*, we expect households to prefer seed alternatives with lower prices. The seed price variable was coded in cardinal-linear form. The selected attributes and their definitions and levels are reported in Table 1.

Table 1: Attributes and Their Definitions and Levels

Attribute	Definition	Levels
Days to maturity	Production attribute (number of days it takes pearl millet seed to mature)	40, 85, 155
Color of *roti*	Consumption attribute (the color of the *roti* that is made with the grain of the pearl millet seed)	Light, medium, dark
Added nutritional value	Nutrition attribute (certain pearl millet varieties are bred to have higher iron levels that are beneficial for human health)	Yes, no
Price of seed	Monetary attribute (price of 1.5 kg (standard) pearl millet seed bag in Rupees)	160, 190, 225, 260, 290, 315

Statistical design methods (see Louviere et al. 2000) were used to structure the presentation of the levels of the four attributes in choice sets. More specifically, an orthogonalization procedure was employed to recover main effects, consisting of 16 pair-wise comparisons of pearl millet seeds. Even though there are concerns over the efficiency of orthogonal designs (Scarpa and Rose 2008), these are the most suitable designs that are currently available according to Louviere et al. (2000) (see Ferrini and Scarpa (2007) for a discussion on this issue), especially in the absence of prior values as was the case in this experiment.

The 16 pair-wise pearl millet seed alternatives were randomly blocked into two versions, each containing 8 choice sets consisting of 2 pearl millet seed alternatives: pearl millet (*bajra*) seed profile A and B and a *status quo* option that was defined as "neither A nor B; given these two alternatives, I prefer to continue to cultivate the variety I planted in the last pearl millet season (*Kharif* [rainy] season)". Data were collected on the pearl millet varieties farmers cultivated in the last *Kharif* season, including the days it took for the farmer's variety to mature, the price the farmer paid for a 1.5 kg seed bag, and the color of the *roti* they made with their current variety. For their current variety (*status quo*), the level for the added nutritional value attribute was assumed to be "no" since the currently available pearl millet varieties are not considered high in iron. Figure 1 gives an example of a choice set that was presented to the farmers.

The respondent in the household was the member who was identified as being the main decisionmaker in choosing the pearl millet variety to cultivate before every *Kharif* season. This respondent was identified as the head of the household 68 percent of the time, and 90 percent of the respondents were male. On the other hand, if we had selected the household member who is responsible for making the *roti* and other household food consumption decisions as the respondent, it is likely that the gender of this respondent would have been female a great majority of the time. Hence, the valuation and profiles of the segments identified in section IV below could have been different.

Prior to asking respondents to make their choices among three alternatives (A, B, or their current seed) in the eight consecutive choice sets, well-trained enumerators explained the attributes, their levels, and the choice exercise slowly and clearly. The enumerators asked respondents if they understood the attributes, their levels, and the choice exercise, and the enumerators repeated these definitions and instructions as many times as needed.

Enumerators also read a short "cheap talk" script, which told households that even though the choices they were going to make were hypothetical in nature, we expected them to think carefully about their choices, as if they were actually going to cultivate the seed they selected in each choice set in the coming *Kharif* season. This script told the households to consider their budget

Figure 1: Example of a Pearl Millet (*bajra*) Choice Set

ASSUMING THAT THE FOLLOWING TWO BAJRA SEEDS WERE THE ONLY CHOICES YOU HAVE, WHICH ONE WOULD YOU PREFER TO BUY AND GROW?

BAJRA SEED CHARACTERISTICS	**BAJRA SEED A**	**BAJRA SEED B**	**I LIKE NEITHER BAJRA SEED A OR B;** **GIVEN THESE TWO OPTIONS, I PREFER THE VARIETY I CULTIVATED IN KHARIF SEASON 2009**
DAYS TO MATURITY	85	40	
ROTI COLOUR	DARK 	MEDIUM 	
ADDED NUTRITION	YES	NO	
PRICE (Rs/1.5kg BAG)	225	190	

constraints, the kind of food they consume and they would like to consume, and their pearl millet and other crop production and variety practices in previous *Kharif* seasons before making their choices. As part of this script, the respondents were also told that even though their choices were hypothetical (that is, even though we would not expect them to buy the seed alternative they selected), it was likely that the results of this study would inform delivery of certain types of pearl millet seed in their blocks. This "cheap talk" script is expected to reduce the hypothetical bias that is inherent in stated preference studies (Carlsson et al. 2005; Chowdhury et al. 2011).

III. DATA

A. Study Sites and Sample Characteristics

The sampling strategy was designed to balance two criteria in addressing the hypotheses of the study:

1. To select districts with different levels of market access, agroecological zones, and anemia prevalence rates, where each one of these factors is hypothesized to have an impact on farmers' choice of pearl millet varieties; and

2. To select blocks within these districts with different intensity of pearl millet production in order to understand the importance of pearl millet consumption, production, and sale portfolio on farmers' choice of pearl millet varieties.

Based on these criteria, we chose Pune, Solapur, and Aurangabad districts from among the seven major pearl millet-producing districts in Maharashtra. Pune has the highest level of market access (measured in terms of distance to cities with more than 100,000 people), the highest anemia prevalence rate (for children under 5 and 5–14 years old), and the highest elevation among the three districts. Solapur has the lowest elevation and precipitation rate and the highest share of irrigated farmland among the three, whereas Aurangabad has the worst access to markets, lowest anemia prevalence rate, highest temperature, and lowest share of irrigated farmland. With these statistics, one could speculate on the relative valuation of production, consumption, and marketing traits across the three districts. District-level characteristics are reported in Table 2.

Across these three districts, blocks were ranked according to the share of farmland area allocated to pearl millet production, and a probability proportionate to size selection of blocks was conducted. Systematic sampling of the blocks across these districts resulted in selection of five blocks from Pune, three from Solapur, and one from Aurangabad. Within each district, four to six villages were

Table 2: District- and Block-Level Characteristics

	Pune (N=5)	Solapur (N=3)	Aurangabad (N=1)
Moderate or severe anemia prevalence for children under 5 years of age[a]	77.3%	58.1%	55.6%
Moderate or severe anemia prevalence for children 5–14 years of age[a]	72.0%	71.8%	63.4%
Travel time to cities with population greater than 100,000 (in hours)[b]	2.5 (.04)	2.7 (0.67)	4.27
Precipitation level (in millimeters)[c]	768.3 (284)	680.6 (366)	831.14
Mean temperature (in degrees Celsius)[c]	30.9 (0.88)	32 (1.2)	31.7
Maximum temperature recorded on average in a year (in degrees Celsius)[c]	36.6 (1.1)	37.8 (1.5)	39.1
Elevation (in meters)[d]	686 (77.9)	580.1 (74.2)	681.1
Share (%) of irrigated crop land area[e]	0.23 (0.12)	0.3 (0.15)	0.078

Source: [a] District Level Health Survey III (DLHS-3) (2007-08); [b] Nelson (2008); [c] Ijmans et al. (2005); [d] HYDRO 1K Elevation Derivative Database (1996); [e] Siebert et al (2007)
Notes: N is the number of sampled blocks in the district. Standard deviations are in parentheses.

randomly selected with varying distances to the center of the block. Finally, depending on the population of the village, 10 to 15 households were randomly selected to be interviewed. To select the households, a cross-sampling method was used; that is, a cross "X" was drawn on the village map, and every nth household along the "X" was interviewed. Figure 2 presents the block-level map of Maharashtra depicting the share of agricultural land area allocated to pearl millet in the *Kharif* season 2008 and the location of the blocks selected for this study.

Descriptive statistics on household characteristics (Table 3) reveal that compared to the average of the pool, households in Solapur are statistically significantly larger and those in Aurangabad are significantly smaller. Education levels of the household head and of the main pearl millet cultivation decisionmaker are both statistically significantly lower than the pooled average for those households located in Solapur. District-level averages for the numbers and proportion of children less than 5 years of age, number of children 5–15 years of age, and proportion of women of childbearing age are not statistically significantly different than the average of the pooled sample. Compared to the average of the pooled sample, households in Solapur have, on average, a smaller proportion of children 5–15 years of age and a larger number of women of childbearing age, whereas those in Aurangabad have, on average, fewer women of childbearing age.

According to the average of the pooled sample, 90 percent of the pearl millet cultivation decisionmakers are male, though this figure is lower (81 percent) for Aurangabad. In terms of their income sources, households in the pooled sample derive, on average, over half of their monthly household income from farming. For those households located in Pune, this figure is statistically significantly higher than the average of the pooled sample, but the opposite is true for households in the other two districts.

In terms of total cultivated land area in the past *Kharif* season, sampled households cultivated an average of less than three hectares. This is in line with the Government of India (GOI) Ministry of Agriculture's definition of small-scale farmers in India (Agriculture Statistics at a Glance, 2008, Ministry of Agriculture GOI). Average land areas are statistically significantly smaller in Solapur compared to the average of the pooled sample. The sampled households dedicated almost one-third of the land area to pearl millet production, with no statistically significant difference between the pooled sample and the three districts. On average, the sample households consumed 50 percent of their pearl millet produce, whereas this figure is lower for Pune and higher for Solapur, compared to the average of the pooled sample. Sampled households sold one-third of their produce with no statistically significant difference between the pooled sample and the districts. In terms of the type of varieties the households chose to cultivate, 17 percent of the sampled households cultivated OPV pearl millet seed, which means the rest of the households (83 percent) cultivated hybrid pearl millet varieties. This figure is mainly driven by households in Pune where over 25 percent cultivated an OPV pearl millet seed.

We also wanted to capture the quality of the current diets of the sampled households; however, time and budget constraints would not allow for a detailed dietary intake survey. We opted for a module on food frequency in which we asked if the household consumed in the past 24 hours or the past 7 days the 14 key food items that comprise the Maharashtrian diet. If the household stated that they had consumed the food item in the past seven days, they were further asked how many times it had been consumed during this period. Following Moursi et al. (2008), the 14 food items were combined into eight food groups, including cereals (rice, wheat, pearl millet and sorghum products); pulses (e.g., lentils, beans); edible oils (soybean, mustard, ghee); vegetables, roots, and tubers (e.g., carrot, green leafy vegetables, eggplant, potatoes); fruits (e.g., mango, banana, pomegranates, grapes); milk and dairy products (e.g., curd, paneer [cottage cheese]); meat (mutton, fish, poultry); and eggs. Using the answers to the binary questions on whether or not the household consumed at least one of the items in the food group in the last 24 hours or past 7 days, we generated daily and weekly dietary diversity scores. According to Moursi et al. (2008), such dietary diversity scores are good predictors of the micronutrient density of children's diets. The weekly dietary diversity scores reported in Table 3 do not exhibit any statistically significant differences between district-level averages and the average of the pooled sample. The daily dietary diversity score is, however, higher than the average of the pooled sample for Pune and Aurangabad and lower for Solapur.

When we look at the percentage of households that consumed pearl millet products in the last 24 hours, we see that over three-quarters of the pooled sample consumed food made out of pearl millet, and 84 percent of the sample consumed food made out of pearl millet in the last 7 days (an average of 4 times). This high consumption rate highlights the importance of pearl millet in the diets of rural households in Maharashtra. When we compare the pearl millet consumption frequency across the selected districts, we see that a significantly smaller proportion of households in Pune consumed pearl millet products in the last 24 hours and

Figure 2: Sampled Districts and Blocks

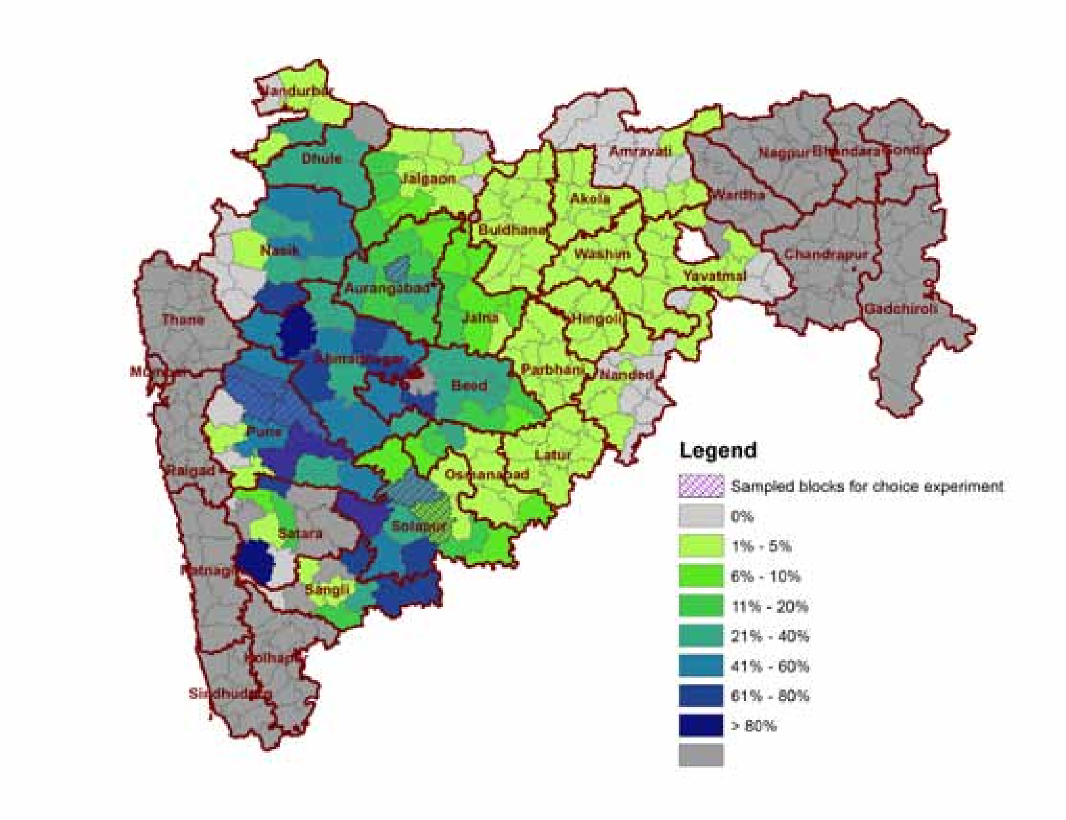

Table 3: Summary Statistics of Sampled Households

Household characteristics	Pool N=630	Pune N=394	Solapur N=166	Aurangabad N=70
	Mean (std. dev)			
Household size	6.28	6.18	6.77**	5.7**
	(2.47)	(2.4)	(2.73)	(1.96)
Household head education (in years)	7.97	8.23	7.34**	7.97
	(3.77)	(3.84)	(3.81)	(3.05)
Pearl millet variety decisionmaker's education (in years)	8.21	8.5	7.6***	8.1
	(3.5)	(3.6)	(3.5)	(3.2)
Pearl millet variety decisionmaker's age (in years)	44.3	43.7	46	43.9
	(11.5)	(11.2)	(12.2)	(10.9)
Number of children under 5 years of age	0.42	0.41	0.51	0.3
	(0.77)	(0.78)	(0.81)	(0.62)
Proportion of children under 5 years of age	0.05	0.05	0.06	0.04
	(0.1)	(0.09)	(0.11)	(0.1)
Number of children 5–15 years of age	1.06	1.08	1.07	0.94
	(1.1)	(1.02)	(1.33)	(0.99)
Proportion of children 5–15 years of age	0.16	0.17	0.14*	0.15
	(0.17)	(0.17)	(0.16)	(0.15)
Number of women 16–40 years of age	1.42	1.38	1.58***	1.24**
	(0.7)	(0.67)	(0.79)	(0.58)
Proportion of women 16–40 years of age	0.24	0.24	0.25	0.23
	(0.12)	(0.12)	(0.12)	(0.12)

Household characteristics	Pool N=630	Pune N=394	Solapur N=166	Aurangabad N=70
Share of monthly farm income in total household income (Rs)	53.07 (26.02)	56.66*** (25.65)	46.68*** (27.78)	48.02** (19.49)
Total land area (in hectares)	2.7 (1.84)	2.9 (1.81)	2.28*** (1.69)	2.56 (2.15)
Share of pearl millet land area in total land area	0.29 (0.28)	0.28 (0.28)	0.29 (0.25)	0.34 (0.35)
Share of pearl millet production consumed	0.52 (0.27)	0.5* (0.29)	0.57*** (0.21)	0.55 (0.27)
Share of pearl millet production sold	0.34 (0.26)	0.34 (0.28)	0.33 (0.2)	0.37 (0.27)
Number of times household consumed meat in the last 7 days	0.7 (1.03)	0.73 (1.2)	0.55*** (0.5)	1.29* (1.07)
Number of times household consumed pearl millet products in the last 7 days	4.37 (1.32)	4.19** (1.44)	4.54* (1.19)	4.84*** (0.66)
Daily dietary diversity score (1–8)	6.17 (0.95)	6.24* (0.82)	5.89*** (1.23)	6.43*** (0.71)
Weekly dietary diversity score (1–8)	7.03 (1.01)	7.04 (0.97)	6.98 (1.13)	7.13 (0.92)
	Percentage			
Household consumed pearl millet in the last 24 hours (1=yes, 0 otherwise)	77	72**	84**	89***
Household consumed pearl millet products in the last 7 days (1=yes, 0 otherwise)	84	79**	95***	89
Household consumed meat in the last 24 hours (1=yes, 0 otherwise)	16	13	20	19
Household consumed meat in the last 7 days	40	41	48**	20***
Household cultivated OPV pearl millet seed in the last *Kharif* season (1=yes, 0 otherwise)	17	26***	1***	1***
Gender of pearl millet cultivation decisionmaker (1=male, 0=female)	90	91	91	81***

Source: Maharashtra Pearl Millet Seed Choice Experiment (2010)
Notes: According to t-tests and Pearson's Chi-square tests, the district average is statistically significantly different than the pool average at 10% (*), 5% (**), and, 1% (***) significance levels.

the last 7 days compared to the average of the pool, while a significantly larger proportion of households in Solapur consumed pearl millet products in the last 24 hours and the last 7 days. The percentage of households in Aurangabad that consumed pearl millet in the last 7 days is not significantly different than the average of the pool, but this figure is significantly higher than the pool average for the last 24 hours. Not surprisingly, the frequency of pearl millet consumption is statistically significantly lower than the pooled average for households in Pune and statistically significantly higher than the pooled average for households in Solapur and Aurangabad.

Finally, we also looked at the frequency of meat consumption (an important source of bioavailable iron) in the districts. Only 16 percent of households reported that they consumed meat in the last 24 hours, and 40 percent reported that they consumed meat in the last 7 days (with an average of less than one meal that contained meat). These figures are not surprising given that a large proportion of households in Maharashtra are vegetarians. For the three districts, the percentage of households that consumed meat in the last 24 hours is not statistically significantly different than the average of the pool. In the last 7 days, however, a statistically significantly larger proportion of households in Solapur consumed meat, whereas a statistically significantly

Table 4: Criteria for Determining the Optimal Number of Segments*

Number of segments	Number of parameters	Log likelihood (LL)	ρ^2	AIC3	BIC
1	5	-4821	0.12931	9657	4842
2	15	-4745	0.14309	9534	4809
3	25	-4684	0.15398	9444	4791
4	35	-4662	0.15803	9429	4811
5	50	-4640	0.16202	9430	4853

*Notes: The sample size is 5040 choices from 630 households (N). Number of parameters is calculated as the sum of the number of parameters in the utility function (5 pearl millet seed attributes x number of segments) and the sum of the number of parameters in the segment membership function ([constant + 4 farm household characteristics] x number of segments -1). Equations: ρ^2 is calculated as 1–(LL)/LL(0); AIC3 (Bozdogan AIC) as (-2LL+3P); and BIC (Bayesian Information Criterion) as -LL+(P/2)*ln(N).

smaller proportion of households in Aurangabad consumed meat. When we look at the number of times meat is consumed in the last 7 days, we see that this figure is statistically significantly lower in Solapur than the pooled average for households, and it is statistically significantly higher in Aurangabad than the pooled average. Overall, however, meat consumption is very low, and the consumption of pearl millet products is high, thereby drawing attention to the potential role high-iron pearl millet varieties could play in contributing a significant amount of iron to the diets of rural households in Maharashtra when they are released.

IV. RESULTS

A. Latent Class Model[1]

To estimate the LCM presented in (5), we first specify the farm household-level characteristics, which we hypothesize to determine segment membership and the choices the households make. Following this, we construct the log-likelihood function of (4) as specified in (5) and use full information maximum likelihood to estimate the model for a specified value of S (number of segments). We repeatedly estimate the model for several segments up until a reasonable number of segments. We use statistical criteria to decide which model fits the data the best, i.e., we decide on the optimal or most appropriate number of segments that the sample consists of.

The best-fitting LCM includes total pearl millet area the household cultivated in the 2009 *Kharif* season, size of the household, percentage of pearl millet output the household sold, and household consumption of pearl millet in the last week. These household characteristics are tested for possible multicollinearity using Variance Inflation Factors (VIF; Maddala 2001).VIFs are calculated by running "artificial" ordinary least squares regressions using each of the independent variables as the "dependent" variable, with the remaining variables as the independent variables. None of the four household characteristics examined herein exhibit multicollinearity.

The model introduced above is estimated for up to five segments. The log likelihood, ρ^2, Bozdogan Akaike Information Criterion (AIC3), and Bayesian Information Criterion (BIC) statistics for the models are reported in Table 4.

Determination of the optimal numbers of segments requires a balanced assessment of the statistics reported in Table 4 (Louviere et al. 2000; Wedel and Kamakura 2000; Andrews and Currim 2003). The log likelihood decreases (improves) and ρ^2 increases as more segments are added; both level off after the fourth segment, indicating the presence of multiple segments in the sample. The BIC is minimized at segment 3 and AIC3 is minimized at segment 4, though the difference between segment 3 and 4 is small. As expected, the four criteria improve as more segments are added, but the marginal improvement diminishes after the fourth segment model, indicating that a model with four segments is the optimal solution in this empirical application. However, Andrews and Currim (2003) demonstrated that the BIC and AIC3 statistics never under-fit the number of segments but may sometimes over-fit and that over-fitting the true number of segments produces larger parameter bias. Therefore, given BIC is minimized at segment 3 and AIC3, though minimized at segment 4, may over-fit the model, we chose the three-segment model as shown in Table 5.

The results of the three-segment LCM are shown in

[1] We employed several other estimation methods, including the random parameter (mixed) logit model (RPLM) with interactions for various farm household characteristics. The best fitting RPLM with interactions is compared to the best fitting (three segment) LCM with the Ben-Akiva and Swait (1986) test for comparing for non-nested probabilistic choice models. Based on the results of this test we rejected the null hypothesis that the RPL model with interactions is the true specification. The details of the Ben-Akiva and Swait test and the RPLM with interactions are available from the authors upon request.

Table 5: Three Segment LCM Estimates for Pearl Millet Seed Attributes

	Segment 1 *Nutrition lovers*	Segment 2 *Mainly-for-sale producers*	Segment 3 *Small-scale producer-consumers*
Utility function: Pearl millet seed attributes			
		Coefficient (std. err.)	
Days to maturity	-0.006**(0.002)	-0.004***(0.0004)	-0.019***(0.001)
Light-colored *roti*	0.759***(0.143)	0.0306(0.022)	0.551***(0.038)
Medium-colored *roti*	0.684***(0.148)	-0.095***(0.02)	0.509***(0.039)
Added nutrition	2.985***(0.62)	0.358***(0.019)	0.762***(0.039)
Seed price	-0.004(0.003)	0.005***(0.0003)	-0.004***(0.0005)
Segment membership function: Farm household characteristics			
		Coefficient (std. err.)	
Constant	-2.182***(1.037)	0.2(0.629)	-
Percentage pearl millet output sold	-1.908**(0.809)	0.441(0.592)	-
Total pearl millet area	1.311**(0.644)	1.05*(0.614)	-
Household size	0.124*(0.076)	0.168**(0.068)	-
Whether or not the household ate pearl millet last week	0.602(0.932)	-1.309**(0.538)	-
Log likelihood		-4684.4	
ρ^2		0.15398	
Sample Size		5040	

Source: Maharashtra Pearl Millet Seed Choice Experiment (2010)
Notes: Coefficient significant at 10% (*), 5% (**), and 1% (***) significance levels.

Table 5. The first panel of Table 5 presents the utility coefficients associated with the pearl millet seed attributes, while the second panel gives the coefficients for segment membership. The membership coefficients for the third segment are normalized to zero, permitting us to identify the remaining coefficients of the model (Boxall and Adamowicz 2002). These three identified segments are labeled based on the relative significance and magnitude of the coefficients in the latent segment membership function (lower panel in Table 5) and the segment-level characteristics reported in Table 6. Similar to labeling factors from a factor analysis or clusters from a cluster analysis, labeling segments in LCM analysis is a subjective process as it is a function of the evident characteristics of each segment and the interpretation of these by the analyst.

For Segment 1, the utility coefficients reveal that households in this segment prefer light- and medium-colored *roti* (relative to dark-colored *roti*), pearl millet seed with added nutritional value, and pearl millet seed that matures in fewer days. Even though the coefficient on the pearl millet seed price is negative, as expected, this coefficient is insignificant, revealing that pearl millet seed price is not a significant determinant of choice for this segment. Among the binary attributes, the added nutritional value attribute has the largest absolute size, indicating that this attribute is the most important determinant of pearl millet seed choice and has a positive and highly significant effect on utility. This is followed by light-colored *roti*, which is preferred to medium-colored *roti*.

The membership coefficients for Segment 1 reveal that households that are larger in size and cultivate larger pearl millet areas are more likely to belong to this segment, whereas households that sell larger proportions of their pearl millet output are less likely to belong. We have labeled this segment, "nutrition lovers" because when the price attribute is used as the normalizing variable, households in Segment 1 derive the highest utility from the nutrition attribute.

For Segment 2, we see changes in the households' preferences for the attributes. Similar to Segment 1, households in Segment 2 prefer pearl millet seed that

Table 6: Characteristics of Households Belonging to the Three Segments

Household characteristics	Segment 1 *Nutrition lovers* (N=58)	Segment 2 *Mainly for sale producers* (N=406)	Segment 3 *Small-scale producer-consumers* (N=166)
		Mean (std.dev.)	
Household size***	7.5(2.5)	6.9(2.5)	4.4(1)
Household head education (in years)**	8.7(3.5)	8.2(3.8)	7.2(3.8)
Proportion of children under 5 years of age***	0.06(0.09)	0.06(0.1)	0.03(0.1)
Proportion of children 5–15 years of age***	0.14(0.13)	0.18(0.16)	0.13(0.19)
Proportion of women of 16–40 years of age***	0.23(0.1)	0.23(0.1)	0.29(0.15)
Share of monthly farm income in total household income (Rs)***	0.52(0.24)	0.55(0.24)	0.48(0.31)
Total pearl millet area (in hectares)	0.7(0.32)	0.65(0.38)	0.33(0.15)
Share of total pearl millet output sold***	0.01(0.04)	0.41(0.24)	0.29(0.24)
Weekly dietary diversity score (1-8)	7.2(0.87)	7(1)	7(0.98)
		Percentage	
Household ate pearl millet in last 7 days (1=yes, 0 otherwise)***	100	76	100
Household ate meat in last 7 days (1=yes, 0 otherwise)*	33	42	39
Household is located in Pune (1=yes, 0 otherwise)***	74	64	55
Household is located in Solapur (1=yes, 0 otherwise)**	17	26	30
Household is located in Aurangabad (1=yes, 0 otherwise)*	9	10	15
Household cultivated OPV pearl millet seed in the last *Kharif* season (1=yes, 0 otherwise)**	12	19	13
Gender of pearl millet cultivation decisionmaker (1=male, 0=female)	95	91	85

Source: Maharashtra Pearl Millet Seed Choice Experiment (2010)
Notes: T-tests and Pearson's Chi-square tests show significant differences among at least one pair of segments at the 10% (*), 5% (**), and 1% (***) significance levels.

matures in fewer days and has added nutritional value. This segment's valuation of color of *roti* is, however, significantly different than those of the other two segments. Even though the sign on the light-colored *roti* is positive, as expected, the coefficient is not significant, revealing that the *roti* being light colored is not a significant determinant of choice for households in this segment. Moreover, households in this segment prefer dark-colored *roti* to medium-colored *roti*, as can be observed from the negative and significant coefficient on the medium-color attribute. Finally, households in this segment prefer pearl millet seed that is higher in price, i.e., their demand for pearl millet seed increases with its price. It is possible that respondents in this segment took price to reveal quality or some other attribute that was not among the choices presented.

Membership coefficients for Segment 2 reveal that those households with more members and larger pearl millet areas cultivated are more likely to belong to this segment. Those households that ate food made out of pearl millet in the last week are, however, less likely to belong to this segment. We have labeled this segment "mainly for sale producers" as they are less likely to have eaten this staple food in the last week and do not value the consumption attributes (lighter color and nutrition) as much as the other two segments do. This could be a function of pearl millet sellers' inability to capture a price premium in the pearl millet wholesale market (mandi) where there is no product differentiation due to the invisibility of several pearl millet consumption characteristics and where higher quality products do not necessarily get higher prices.

The utility coefficients for Segment 3 reveal that households in this segment prefer pearl millet seed that matures early, produces light- or medium-colored *roti* relative to dark-colored *roti* (with light color being preferred to medium color), has added nutritional value, and is sold at a lower price. Although the significance and sign of all attributes and the ranking of the binary attributes are similar for Segments 1 and 3, we observe that households in Segment 3 relative to Segment 1 value earliness in maturity more and added nutritional value less if we use the seed price as the normalizing variable. The membership coefficients of this segment can be implicitly interpreted in relation to the signs of the estimated statistically significant parameters for the other two segments, as long as the parameters have the same signs in Segments 1 and 2 (Kontoleon and Yabe 2006). Consequently, households that are smaller in size and those that cultivate smaller pearl millet areas are more likely to belong to Segment 3. Therefore, we labeled this segment "smaller-scale producer-consumers".

B. Characterization of the Segments

The relative size of each segment is calculated by inserting the estimated coefficients into equation (3) and using it to generate a series of probabilities that a given consumer belongs to a given segment. Consumers are then assigned to a segment based on the largest of the three probability scores. Using this procedure, we find that Segment 1 is the smallest segment with only 9.2 percent of the respondents, whereas Segment 2 is the largest segment with almost two-thirds (64.4 percent) of the sample; the remainder of the sample (26.4 percent) belongs to Segment 3. Descriptive statistics for the characteristics of each segment are given in Table 6.

Among the three segments, nutrition lovers (Segment 1) have the largest households, highest level of education for household heads, largest land areas allocated to pearl millet cultivation, and smallest share of pearl millet output that is sold. These results, combined with the finding that all of the households in this segment ate food made out of pearl millet in the last week, reveal that households in this segment produce pearl millet mainly for household consumption.

When evaluating households based on members who fall in the target population for nutrition interventions, households in Segment 1 have a higher share of household members who are under five years of age compared to Segment 3 but a lower share of female household members who are of childbearing age. These figures do not statistically significantly differ between Segments 1 and 2. Even though the weekly diet diversity score does not statistically significantly differ across the three segments, Segment 1 had the smallest proportion of households that ate meat in the past week when compared to the other two segments. The greatest proportion of households in Segment 1 are located in Pune, where anemia prevalence rates for children under five and 5–14 years old are the highest among the three districts (Table 2). Across the three segments, Segment 1 contains the smallest proportion of households located in Solapur. The proportion of Segment 1 households located in Aurangabad is not statistically significantly different than the other two segments.

Regarding the type of seed cultivated, Segment 1 comprises the smallest proportion of households that currently cultivate OPV pearl millet seed. Considering that the high-iron pearl millet variety to be released soon in Maharashtra is an OPV, it is likely that this segment will not be adopting the high-iron pearl millet variety, despite this segment's high valuation of the nutrition attribute, high consumption rates of pearl millet, and high share of children under five, all attributes that make it a suitable target for biofortification.

Segment 2, mainly for sale producers, is the largest segment among the three segments. Compared to the households in the other two segments, households in Segment 2 derive the largest share of their income from farming. As a corollary to this, this segment sells the greatest share of its pearl millet output among the three segments. Combined with the fact that this segment comprises the smallest percentage of households that consumed food made out of pearl millet in the past week, we can deduce that this segment produces for market sale as much as it does for household consumption. Finally, across the three segments, a greater proportion of households in this segment cultivate OPV pearl millet seed. With almost one-fifth of households cultivating OPV, this segment could be targeted for high-iron OPV pearl millet.

Segment 3, small-scale producer-consumers, has the smallest families with the lowest share of children but the highest share of women of childbearing age. This segment also has the lowest education levels among household heads, lowest proportion of pearl millet cultivation decisionmakers who are male, and smallest share of total household income from farming compared to the other two segments. Even though the households in this segment have the smallest pearl millet fields, they sell greater proportions of their outputs compared to Segment 1. Perhaps owing to their smaller family sizes, these households can afford to sell some of their output without affecting their consumption rates since all of the households in this segment ate food produced with pearl millet in the last week. In terms of their location, this segment includes the smallest proportion of households located in Pune and largest proportion located in Aurangabad.

V. CONCLUSIONS AND PROGRAM IMPLICATIONS

In this paper we investigated farmer valuation of various consumption and production traits of pearl millet seed in one of the major pearl millet producing and consuming states of India— Maharashtra. A choice experiment study was conducted with a random sample of 630 pearl millet farmers in three districts, which were selected based on their level of market access, agroecological zone, and anemia prevalence rate. A latent class model (LCM) was estimated to simultaneously identify the characteristics that differentiate pearl millet farmers and the values that different types of farmers derive from pearl millet seed, such as the number of days it takes pearl millet to mature, color of the *roti* (flat bread) the grain produces, high-iron content (nutritional attribute) of the pearl millet, and price of the pearl millet seed.

Three distinct segments were identified. The first segment was named nutrition lovers because across the three segments this segment exhibited the highest valuation for the added nutrition attribute. Three-quarters of the households in this segment are located in Pune, the district with the highest prevalence of moderate or severe anemia for children under five. Even though this segment is the smallest segment, comprising less than 10 percent of the sample, it could be a good target segment for the introduction of high-iron pearl millet since across the three segments they have the largest family size and largest proportion of one of the target groups (children under five), cultivate the largest pearl millet areas, and regularly consume pearl millet but rarely consume iron-rich meat products. However, this segment comprises the smallest share of households that currently cultivate OPV, and it may be unlikely for hybrid farmers to switch to OPV despite their valuation of the added nutritional value given the yield differentials between the two types of seeds. At the same time, hybrid seeds are more expensive so the choice problem would involve choosing between a comparatively lower yield, lower price, and nutritionally enhanced OPV variety and a higher yield, higher price, and comparatively less nutritious hybrid variety. Thus, whether it would be best to wait for the development of hybrid varieties of high-iron pearl millet seed to target this segment remains an empirical question.

The second segment was termed mainly for sale producers because, compared to the other two segments, farm households in this segment had the lowest preference for consumption attributes of pearl millet (color of *roti* and nutrition), sold a greater proportion of their output, and were least likely to consume pearl millet products in the past seven days. This segment may not care about the consumption traits of pearl millet because there is very little product differentiation in the market, given that the majority of the pearl millet traits are invisible. With almost one-fifth of households cultivating OPV, this segment could be targeted for the introduction of the high-iron OPV pearl millet seed. However, for this segment to adopt the high-iron OPV seed as producer-sellers, mechanisms, such as labeling and branding for the high-iron trait, should be created for them to be able to capture a price premium for quality attributes.

The final segment was named small-scale producer-consumers due to their smallest pearl millet areas and family sizes compared to the other two segments. Similar to Segment 1, this segment values nutrition and color attributes highly (though the latter not as high as Segment 1). Combined with the fact that this segment has the highest proportion of one of the target populations (women of childbearing age) and consumes pearl millet products on a regular basis, this segment could also be a target segment for the introduction of high-iron pearl millet varieties. However, like Segment 1, the majority of households in this segment opted for hybrid varieties of pearl millet seed in the last *Kharif* season.

In terms of program implications, a straightforward recommendation from this study is that farmers should be offered a pool of varieties that provide different attributes given the preference heterogeneity shown above. If the nutrition attribute is enhanced for a variety that is not preferred in terms of other attributes (i.e., yield differences between hybrids and OPVs), trade-offs emerge and some segments might not choose the variety.

Another implication is implicit in the distinction between Segments 1 and 2, the latter being mainly sellers who placed lower value on the nutrition attribute. As discussed, markets do not reward for invisible attributes such as nutrition, and thus valuation of farmers who mainly produce for market sales could be biased. Higher valuations would emerge from a credible system of branding/certification and health information.

Finally, the results of this study should be taken with caution due to the hypothetical nature of the method used. At the time this study was conducted, a hypothetical choice experiment was considered as the only option to study farmer preferences for high-iron pearl millet because the high-iron pearl millet variety was still in the development phase. Now that the variety has been developed, we will be implementing preference elicitation studies with real *roti* made out of high-iron pearl millet and with real incentive mechanisms, such as participation fees. The findings of this present study are, however, indicative of the high and overall positive farmer demand for pearl millet with enhanced nutrition and the identification and definition of segments that are more or less likely to adopt high-iron pearl millet varieties.

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