Essays on consumer welfare and new food product development in West Africa

by

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B.Sc., Universty of Ouagadougou, Burkina Faso, 2006

M.Sc., Sub Regional Institute of Statistics and Applied Economics, Cameroon, 2010

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the
requirements for the degree

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Department of Agricultural Economics
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Abstract

Economic indicators (price, income, taste, and preference) and non-economic (information, time and equipment, food quality and safety) indicators are key elements of the food environment that need further investigation in developing countries. The main objective of this thesis is to evaluate the effect of these factors on consumer behavior in West Africa, especially in Niger and Burkina Faso.

The first essay analyzes the implications of world cereal price shocks on rural household welfare in Burkina Faso by establishing a link between farmers and world markets. The approach is grounded in agricultural household modelling with the world price for cereals, transmitted to farmers, through local producer and consumer prices. Household net welfare after a price shock is derived as a function of behavioral responses to local price change induced by the international price shock. The main result of this analysis is that the increase in prices during the period from 2006 to 2014 is translated to welfare improvement ranging from 0.02 percent for 2006 to 0.06 percent for 2011 for farmers in Burkina Faso.

The second essay assesses urban consumers' preference for food quality attributes of value-added cereal products in Niamey, Niger. It combines qualitative and quantitative methods to evaluate the effect of quality attributes on consumers' food choice. A particular focus is placed on assessing consumers' marginal willingness-to-pay (WTP) for quality attributes in an experimental setting. The evaluation accounted for taste and preference heterogeneity inherent to consumers' responses to changes in quality attributes. The results suggest market demand inferred from significant marginal WTP for the nutritional quality attribute as measured by the expiration date, the presence of micronutrients, and the country of origin of the product. In addition, demand is found to be highly heterogeneous across

consumers socio-demographic and economic characteristics. As a result, better communication and appropriate targeting by food processors and policymakers could be an additional tool to enhance food quality and diet through the market.

Finally, the third essay theoretically and empirically assesses the impact of a time-saving food attribute on consumer's food choice in urban areas of Niger. The theoretical assessment relied on a "Beckerian" time allocation model to derive how a time-saving food product affects consumers' utility and food choice. The empirical approach combines hedonic tasting, random utility and a latent class framework to identify taste heterogeneity patterns underlying consumers' choice. Both the hedonic and latent class models confirm the theoretical prediction that a time-saving characteristic can either increase or decrease the demand for food that embodies the attributes. A significant market segment of about 38% includes consumers with a positive valuation of the time-saving product, highlighting the potential of this attribute to increase consumers welfare, reduce energy use and prevent food preparation-related health issues.

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Chapter 1

Are Smallholder Farmers Better or Worse Off from an Increase in the International Price of Cereals?

Introduction

In 2008 and 2009, steep increases in international food prices raised concerns about negative welfare impacts on, and the overall poverty rates of, populations in low-income countries. From mid-2007 until mid-2008, the global prices of major cereals increased up to 130 percent with most of these increases passed on to domestic markets (Ivanic and Martin, 2014; Baquedano and Liefert, 2014). Such dramatic changes in food prices may increase poverty rates in developing countries, especially poor ones, where consumers spend most of their income on food and also heavily rely on agricultural production to earn a living (Headey, 2016). In addition, price shocks and the resultant social unrest could sharply increase political instability(Bellemare, 2015). In general, the literature uses three major methods to assess the effect of cereal price increases on household welfare. These are the net benefit ratio (NBR), econometric-based methods and computable general equilibrium models (CGE).

The approach of Deaton's elasticity of the cost of living with respect to the price of a staple good, also known as the net benefit ratio, is an important starting point for evaluating the welfare effect of a price change (Deaton, 1989). As pointed out by (Headey, 2016), most studies based on the NBR reached consistent conclusions of negative welfare impacts of food price increases since the poor are net consumers of staples (Ivanic and Martin, 2008; De Hoyos and Medvedev, 2011; Ivanic et al., 2012; Badolo and Traore, 2015). However, several critiques of these results have emerged. Recent studies indicate that consumption and production data based upon short-term recall and used to extrapolate to annual estimates suffer from significant downward biases compared to consumption-plus-sales diary methods (Beegle et al., 2016; Deininger et al., 2012).

Another drawback of the NBR approach is the assumption of no behavioral or market response to higher food prices (Headey, 2016). However, rural household engagement in farming provides scope to adjust production during and between cropping seasons in response to higher food prices (Headey and Fan, 2010; Magrini et al., 2017a,b) . Studies in Madagascar, Malawi, Zambia and Niger have found long-run reductions in poverty and food insecurity following price increases (Headey, 2016; Van Campenhout et al., 2013; Jacoby, 2016; Headey, 2011). Other studies have estimated the impact of price volatility on welfare (Bellemare et al., 2013; McBride, 2015; Magrini et al., 2017a). Previous literature did not relate household welfare to a world price shock in a way that underscores the role played by world price transmission to domestic markets.

The main objective of this paper was to highlight the theoretical and empirical relationship between world price shocks and household welfare for those individuals living in rural areas by taking price transmission into consideration. Based on both the agricultural household model and the law of one price, we extended Deaton's method to account for imperfect price transmission of global prices to local producer and consumer prices. We applied our model to rural households in Burkina Faso using a three-year nationally representative panel survey on expenditures collected using the consumption-plus-sales method. The study considered six major food commodities produced and consumed in rural areas including: pearl millet, maize, rice, sorghum, peanuts and cowpea. Together these commodities occupy more than 80 percent of the cultivated area of food crops in Burkina Faso (MASA, 2004) .

Our major contribution was to combine welfare analysis and price transmission literatures to identify household welfare implications of world price shocks. We also examined data collection differences of the NBR by using our own consumption-plus-sales survey method to estimate household annual consumption as opposed to recall-based approaches(Deininger et al., 2012). Finally, we accounted for behavioral responses in household demand and supply when evaluating the welfare effects of price changes. Under conditions of price certainty, we found that increases in world prices were associated with an improvement in rural household welfare. This was because the positive producer effect outweighed the negative consumer effect. The increase in price during the period from 2006 to 2014 translated into welfare improvement ranging from 0.02 percent in 2006 (the lowest improvement) to 0.06 percent in 2011 (the highest improvement) of the total purchases. The shocks generated positive welfare impacts for most of the crops, except sorghum and rice. Furthermore, consistent with (Baquedano and Liefert, 2014), we found that world cereal prices changes are transmitted to consumers and producer prices for almost all the commodities considered in this study. Finally, households had statistically significant behavioral responses to price signals on both the demand and supply sides for the majority of crops.

The remainder of the paper includes information about our conceptual framework, which was based on an agricultural household model to derive the relationship between household welfare and world cereal price changes. Our empirical strategy estimated the welfare effect, including identification of our demand, supply and price transmission elasticities. The three last sections respectively describe our data, the major findings and policy implications

1.1 Conceptual Framework

Consider a classic model of agricultural households (Singh et al., 1986; Deaton, 1989). In each production cycle, households are assumed to maximize their living standard (utility) over agricultural staples, purchased market goods, and leisure. Given a farm production technology and an income constraint, household living standard is represented as follows:

$$u_h = \psi(w \times T + A + \pi_h(v, w, p^p(p^w)), p^c(p^w)) \tag{1.1}$$

where the utility of household h (u_h) is determined by its income, composed of the value of its available total time ($WageRate(w) * TotalTime(T)$), the $transfer(A)$ received, profit (π_h) from farming or other family businesses, the consumer price (p^c), and the world price (p^w). Farm profit depends on input prices (v), the wage rate (w), producers price (p^p) and the world price. Thus, a price shock will have two effects: first, the change of household welfare through consumption, and secondly, through production. On the production side, the welfare change is a function of household marginal utility of income ($\frac{\partial \psi}{\partial I}$), sales of home-produced goods or commodities (y_i) and the transmission elasticity of world price to the producer price (ε_{p^w,p^p}). On the consumption side, the welfare change following an international price increase depends upon marginal utility of income ($\frac{\partial \psi}{\partial I}$) , purchases ($q_i$) and the transmission elasticity of the world price to the consumer price (ε_{p^w,p^c}). The effect of a change in the world price of commodity i on household utility is represented by: [1]

$$\frac{\partial u_h}{\partial p^w} = \frac{\partial \psi}{\partial I} y_i \varepsilon_{ip^w,p^p} - \frac{\partial \psi}{\partial I} q_i \varepsilon_{ip^w,p^c} \tag{1.2}$$

As with the standard agricultural household model, the net effect could either be positive or negative. Our model focused on the bias that can be introduced when differential price transmission exists ($\varepsilon_{ip^w,p^p} \neq \varepsilon_{ip^w,p^c}$). The welfare effect is trivial if and only if the world price is fully or equally transmitted to producer and consumer prices ($\varepsilon_{ip^w,p^p} = \varepsilon_{ip^w,p^c} = 1$

[1] See derivations in the appendix A

or $\varepsilon_{ip^w,p^p} = \varepsilon_{ip^w,p^c}$) or there is no temporal difference in marketing decisions. Using $\frac{\partial u_h}{\partial p^w} = (y_i - q_i)\frac{\partial \psi}{\partial I}$ as a measure of world price change welfare effect is equivalent to assuming full price transmission to producers and consumer prices which is empirically quite impossible. In this case, the status of household h as a net buyer or net seller is the only driver of the losing or winning status following a world price shock.

In addition to relaxing the assumption that price transmission is equal for consumer and producer prices, we also accounted for supply and demand responses when estimating the welfare impact of a change in world price. We approximated the change in consumer welfare using Compensating Variation (CV) defined as a change in the household expenditure (Irvine and Sims, 1998). Following Irvine and Sims (1998) and Martin and Alston (1997) the change in producer welfare (PW) is derived as a change in the profit function (π). As a result, the net welfare change is represented as

$$\Delta welfare = e(p^c(p_0^w), u_0) - e(p^c(p_1^w), u_0) + \pi(p^p(p_1^w), w_0, z_0) - \pi(p^p(p_0^w), w_0, z_0) \quad (1.3)$$

where $e()$ is the household expenditure function, and p_0^w and p_1^w are the levels of world cereal price before and after a price shock. Household utility before the price change is u_0. We assume that labor is perfectly inelastic in the short run causing input price stickiness.

1.2 Empirical strategy

Following Irvine and Sims (1998) and Martin and Alston (1997) , a second-order Taylor series approximation of the expenditure and profit functions was used to approximate Equation 1.3.[2] The following equations are used for welfare impacts:[3]

$$CV \cong -\sum_{i=1}^{n} q_i p_i^c \varepsilon_{ip^w,p^c} \zeta_{p^w} - \frac{1}{2}\sum_{i=1}^{n} q_i p_i^c \eta_{ii} \varepsilon_{ip^w,p^c}^2 (\zeta_{p^w})^2, \quad (1.4)$$

[2]See derivations in the appendix A.
[3]See derivations in appendix A.

$$PW \cong \sum_{i=1}^{n} y_i p_i^p \varepsilon_{ip^w,p^p} \zeta_{p^w} + \frac{1}{2} \sum_{i=1}^{n} y_i p_i^p \gamma_{ii} \varepsilon_{ip^w,p^p}^2 (\zeta_{p^w})^2, \tag{1.5}$$

with ζ_{p^w} being the relative exogenous price shock[4] in cereal world price , and η_{ij} and γ_{ii} the Marshallian demand and supply elasticity of commodity i, respectively. The price at which households buy and sell crops may be different, mainly due to marketing differences between purchases and sales. In fact, most crops' sales are conducted during the harvest period, when there is an excess of supply. Purchases occur during the lean season for farm households that are net buyers. As a result, production and consumption were considered as different activities and non-separable. Furthermore, y_i and q_i were estimated respectively as the country-level total quantities purchased and sold of all commodities. Our model imposed no cross-price effects, as discussed in the next section. Approximations of market demand (q_i) and supply quantities (y_i) could be considered to better capture household decisions on food market participation[5]. The survey collected household-level data on quantities of these variables each year in the local unit of measurement.

1.2.1 Estimation of demand and supply elasticities

Identifying the demand elasticity required isolation of price changes due to supply (demand) shocks. Demand identification was an issue because of the use of unit values as direct substitutes for true market prices. Consumers choose the quality of their purchases, and unit values reflect this choice (Deaton, 1988). This could be less of an issue in our case because our study focused on homogeneous staple commodities. Nevertheless, to check for robustness, we estimated demand equations using two approaches. The first approach used an instrumental variable technique following (Roberts and Schlenker, 2009) to identify own-price elasticities. In most of the empirical work on demand, weather is considered as

[4]The relative exogenous price shock stands for the percentage change in FAO cereal price index relative to the base 2002-2004.

[5]y_i and q_i are the weighted total of quantity purchased and sold. The weight is attributed to each household to ensure the sample represents the rural population

an instrument for unbiased identification (Wright, 1928). The reason being that weather events cause a shift in the supply curve unrelated to demand. As a proxy for weather-induced yield shocks, we used the deviation of province yield from the province-specific yield trend for a particular crop. The assumption was that the deviation of province yield from its trend is due to weather shocks[6]. The second approach estimated demand elasticities using the quadratic version of (Deaton and Muellbauer, 1980) Almost Ideal Demand System introduced by (Banks et al., 1997). This version allowed the budget share to react more flexibly to the log of expenditure while imposing the standard restrictions of demand theory, including adding-up, homogeneity, and Slutsky symmetry. Following (Ray, 1983) and (Poi et al., 2012) we also included a vector of demographic characteristics z_k to control for any changes in the consumption pattern not related to price or expenditure[7] .

On the supply side, we used lagged weather-related yield shocks as instruments to identify the supply curves (Roberts and Schlenker, 2013). Past weather shocks affected storage, and consequently expected prices for the upcoming growing season, in the case of smallholder farmers. The supply at the household level was equal to the current production ($Prod_{h,t}$) and the stock ($S_{h,t-1}$) from the previous period: $q_{h,t} = Prod_{h,t} + S_{h,t-1}$. Past weather did not affect current production but affected the inventory demand – a shift in demand for the current period – allowing unbiased and consistent identification of supply[8] .

Hendricks et al. (2014) shows that using the lagged yield shock as an instrument is not necessary when the supply equation includes pre-planting futures prices and controls for the current yield shock. In our setting, a futures price in Chicago, Illinois, USA may be a poor representation of prices facing producers in Burkina Faso. We utilized data on the actual price received by farmers, but this price is endogenous since it reflected actual supply conditions, rather than expectations of supply, as needed for the case of a futures price.

[6]Agriculture is rainfed in Burkina and weather explains quite high amount of yield variability (Ray, 1983).

[7]The reader can find an extended development and estimates of this model in the appendix A.

[8] Farmers' behavior regarding price expectations follow either naive expectations (Ezekiel, 1938); adaptive expectations (Nerlove, 1958); or rational expectations (Muth, 1961). Our approach in this paper assumed naive expectations since planting decisions were made using actual prices faced by the producer.

Therefore, we expected producer prices to be endogenous in our setting. Consequently, we estimated the supply and demand equations using standard two-stage least squares. The estimated supply and demand equations are as follows:

$$Supply = \begin{cases} \log(y_{h,t}) = \alpha_p + \gamma \widehat{\log(p^p_{h,t})} + \beta W_{h,t} + \mu_t \\ \log(p^p_{h,t}) = \rho + \phi W_{h,t} + \delta W_{h,t-1} + \lambda_h + e_t, \end{cases} \tag{1.6}$$

$$Demand = \begin{cases} \log(q_{h,t}) = \alpha_c + \eta \widehat{\log(p^c_{h,t})} + v_t \\ \log(p^c_{h,t}) = r_0 + r_1 W_{h,t} + \lambda_h + \epsilon_t, \end{cases} \tag{1.7}$$

where $\log(p^p_{h,t})$ and $\log(p^c_{h,t})$ are the logarithm of producers price and consumers price, λ_h are province fixed effects, $W_{h,t-1}$ and $W_{h,t}$ are the lagged and current yield shock. $y_{h,t}$ and $q_{h,t}$ are respectively household h acreage and consumption in period t.

The parameters to be estimated include α_p, γ, β, ρ, δ, λ, α_c, η, r_0, ϕ and r_1. The error terms, u_t, v_t , e_t and ϵ_t are assumed to be normally distributed, and u_t included the effects of policies and non-policy distortions including marketing margins found to be significant in affecting the supply response to price signals (Magrini et al., 2017b). Including the current yield shock ($W_{h,t}$) in the second stage equation for supply alleviated two concerns about the validity of the lagged yield shock as an instrument. First, weather may be serially correlated so that lagged yield shocks are correlated with current production. Second, a household may have yields systematically below the district-level trend so the lagged difference of household yield from the district-level trend is correlated with current production. By including the current yield shock as a control, these concerns were mitigated.

1.2.2 Price transmission elasticities estimation

The empirical analysis of price transmission relies upon the law of one price. This law states that once transaction costs are adjusted, and no policy intervention distorts the transaction, the price for a homogeneous commodity in two different markets should be the same. We examined this causal relationship between world cereal prices and domestic prices in an error correction framework following (Baquedano and Liefert, 2014). This framework allowed us to measure and separate long- and short-run effects on domestic prices from an exogenous change in world prices. Based on the law of one price, we defined the data generating process for the relationship between the domestic and world border price as:

$$p_{ijt}^{d} = \alpha_0 + \alpha_1 p_{ijt-1}^{d} + \beta_0 p_{ijt}^{b} + \beta_1 p_{ijt-1}^{b} + \varepsilon_t \tag{1.8}$$

where ε_t represents the error term, p_{ijt}^{d} and p_{ijt}^{b} represent domestic (consumer or producer) and border prices in real terms in country i of a homogenous commodity j at time t, respectively. However, with the border price equal to the world price in foreign currency, multiplied by the exchange rate, equation 1.8 is also equivalent to equation 1.9. In addition, by breaking p_{ijt}^{b} into two parts, dropping the subscript of country i and commodity j, and manipulating we have:

$$\Delta p_t^d = \alpha_0 + \delta p_{t-1} + \lambda_0 \Delta w p_t^f + \lambda_1 w p_{t-1}^f + \theta_0 \Delta e_t + \theta_1 e_{t-1} + \varepsilon_t \tag{1.9}$$

where wp_t^f and e_t represent the real-world price of the commodity in terms of foreign currency in natural log, and the exchange rate between the domestic currency and that of the rest of the world. The coefficients λ_n and θ_n measure the effect on the domestic price (p_t^d) of an immediate and lagged change in the world price (wp_t^f) and exchange rate (e_t), respectively. In the case of countries with market power, where domestic and world prices are endogenously determined by each other, price fluctuation in both series would be better modelled with approaches proposed by (Johansen, 1988). These approaches rely on systems of equations in the form of vector auto-correlation and were not relevant in our case.

Our model assumed that causality runs from world prices to domestic prices. Burkina Faso has no market power over the world market because of its small size with regards to the commodities under consideration. This unidirectional causal relationship is modelled relying on single equation error correction model (SEECM) instead of on the (Engle and Granger, 1987) two-step procedure considered as the standard approach when dealing with unidirectional causal relationships of co-integrated series. The choice of SEECM was motivated by two main advantages. First, as noted by (Baquedano and Liefert, 2014), the SEECM does not require that all the related series have a unit root to attempt to model their long run relationship in an ECM framework. Second, SEECM provides less biased parameter estimates and more robust tests compared to the (Engle and Granger, 1987) approach (De Boef and Keele, 2008; Banerjee et al., 1998). As a result, the estimated SEECM is as follows[9] :

$$\Delta p_t^d = \alpha + \beta \Delta wp_t^f + \rho \Delta e_t + \delta(p_{t-1}^d - \gamma wp_{t-1}^f - \varphi e_{t-1}) + \varepsilon_t \tag{1.10}$$

where ε_t represents the error term, β and ρ represent the short-run price transmission elasticities for the world price and exchange rate respectively, δ represents the error correction term coefficient and measures the speed at which the domestic price (Δp_t^d) returns to its long-run equilibrium relationship following a world price or exchange rate shock. Its sign is expected to be negative as it shrinks the gap between the series in each subsequent period (Baquedano and Liefert, 2014). The long run elasticities of transmission are γ and ϕ for the world price and the exchange rate respectively.

To simultaneously estimate long-term relationship elasticities and standard errors for wp_t^f and e_t, we used equation 1.9 and relied on (Bewley, 1979) transformation. The estimation method considered is the generalized least-squares with serially correlated error term structure. We tested our assumption that the error terms follow an autoregressive process of order one. The long-term world price transmission elasticities derived were used to simulate the welfare effect due to the world cereal price increase.

[9] See (Baquedano and Liefert, 2014) for a step by step derivation of equation 1.9 from equation 1.8

1.3 Data

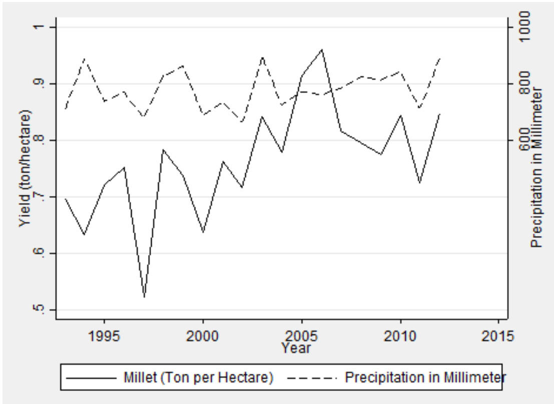
Data used to estimate the elasticities is taken from the Enquête Permanente Agricole (EPA), the"Continuous Farm Household Survey" of Burkina Faso. These data are collected by the Direction Générale des Études et des Statistiques Sectorielles (DGESS) of the Ministry of Agriculture and was used by (Haider et al., 2017) in their study on fertilizer adoption in Burkina Faso. The EPA is used to estimate farm input use, production, area, and yield of crops; it also provides information about livestock holdings and expenditures of rural households. We utilized data for the 2007-2008, 2009-2010 and 2010-2011 cropping seasons (three survey years) in this analysis as these were the last years for which clean data was available . The survey was a two-stage design with Probability Proportional to Size (PPS) sampling. The units in the first stage were the villages in each province and the unit of the second stage were farmers.

To capture household food availability and utilization, EPA uses the consumption-plus-sales approach and establishes a food balance sheet spanning the period of October 1 of the previous year and September 30 of the current year for each household and each rainfed food crop. Food supply information is collected on the beginning stock and primary sources of food inflows such as production, gifts and purchases. On the utilization side, information is collected on the primary sources of the food outflows at the household level, such as consumption, sales, gifts and ending stocks. All information is collected as quantities and in value, which allows for the derivation of the implicit price of each crop at the household level. Crop quantities are obtained in the local unit of measure and converted into a common unit. We estimated the household-level producer and consumer prices (p^p and p^c) for each commodity i by dividing total value of production (consumption) by quantity of production (consumption). The survey collected information on 25 commodities with millet, maize, rice, sorghum, peanuts and cowpea as the primary products since they are widely grown by 81 percent of farmers across the country. In order to comprehensively analyze the crops produced at the household level, the remaining crops were recorded as "others", while red and white sorghum were recorded as "sorghum".

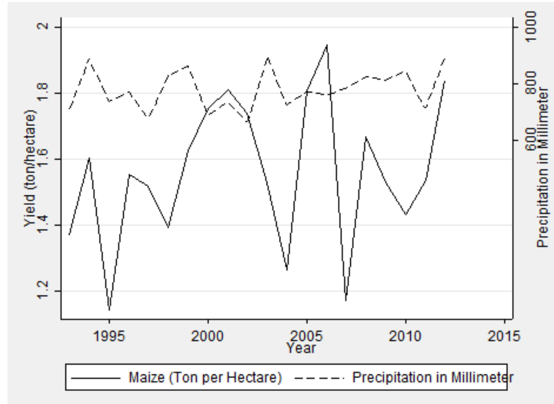
Using province-level yield data available for the period 2002 to 2012, yield shocks were calculated by taking the difference between household yield and the province-level linear yield trend. The province-level yield data were from The Ministry of Agriculture and Food Security. Figure 1.1 plots the national level yield versus the rainfall for each commodity. National crop yield estimates were obtained from (FAOSTAT, 2017b) and rainfall data are from (WorldBank, 2017a). The yields vacillated around their trend in a pattern similar to the rainfall suggesting that a deviation of yield around its trend is mainly due to the level of rainfall. This pattern also is likely observed at the province level. Thus, we have reasonable evidence to consider that the deviation of the province yield from its trend is more plausibly due to weather and is an adequate instrument to identify demand and supply curves. Furthermore, we highlight that during the three years the data are collected, no severe plague was reported.

We used a second data set to estimate price transmission because a more detailed time series of prices was needed, yet the household survey provided only three years of data. We used the monthly cereals world price index from (FAOSTAT, 2017a) as a proxy of world price. For domestic prices, we used the monthly consumer and producer prices data from Institut National de la Statistique et de la Demographie (the National Institute of Statistics and Demography).

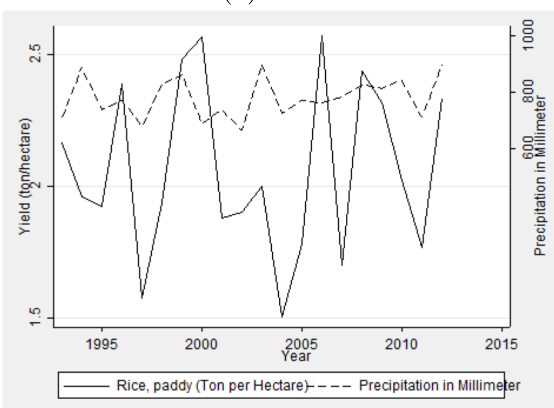
We computed consumer and producer price indices by dividing the price P_t of a year t by the average of the period 2002-2004 considered as the base price to coincide with the base of producer price index provided by FAOSTAT. Figures 1.2 and 1.3 plot the producers' and consumers' price index against world price, respectively. Producer prices and the world price index had the same general pattern with a matching of the peaks and trend suggesting a correlation between the two set of prices. The world cereal price reached its highest peaks in 2008, 2011 and 2012 with an increase of 132 percent, 141 percent, and 136 percent, respectively. On the other hand, the consumer price index (except for rice) did not display



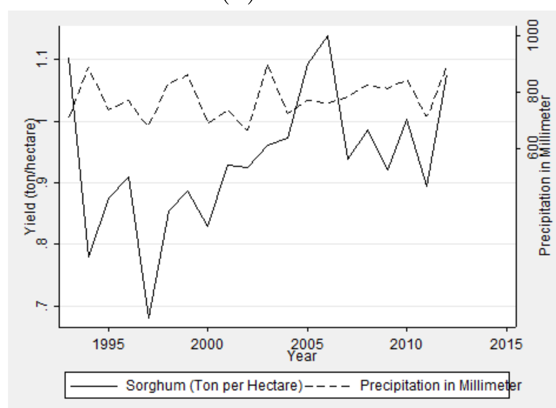
(a) Millet



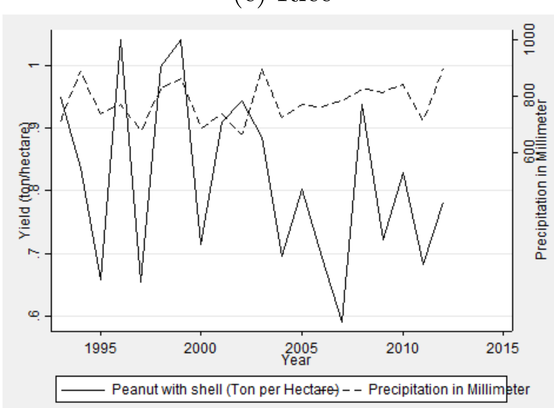
(b) Maize



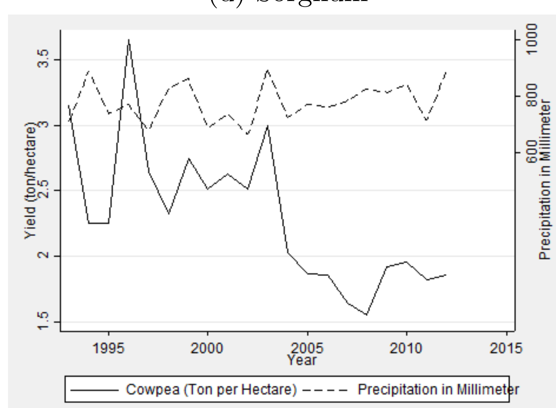
(c) Rice



(d) Sorghum



(e) Peanuts



(f) Cowpea

Figure 1.1: Yield of major commodities (tone per hectare) and rainfall (Meter) in Burkina Faso from 1994 to 2014.

a clear pattern compared to the world cereal price Dawe et al. (2015).

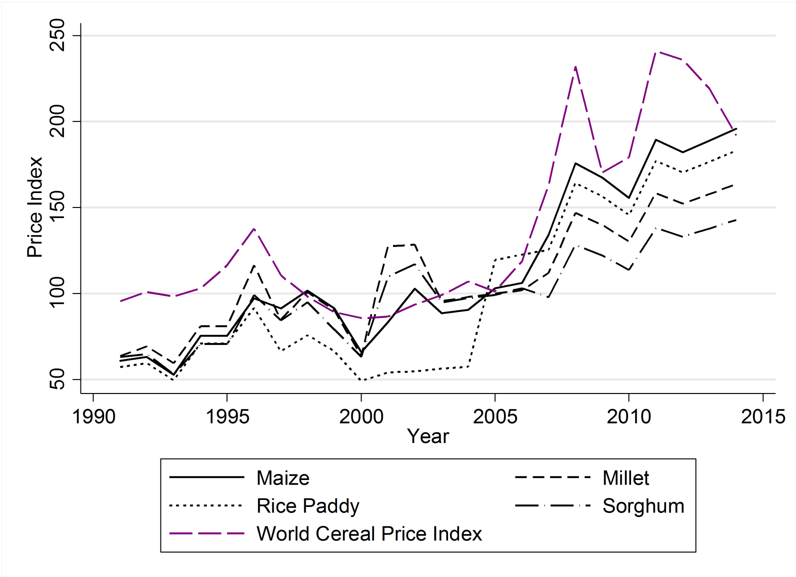


Figure 1.2: Relationship between world cereal price index and producers price index between 1991-2014.

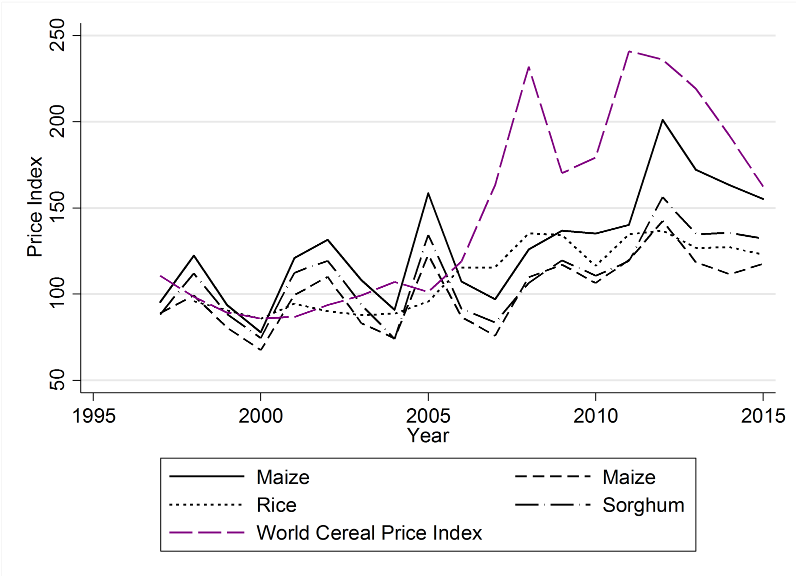


Figure 1.3: Relationship between world cereal price index and consumers price index between 1996-2014.

1.4 Results

1.4.1 Descriptive statistics

Table 1.1 shows rural households' socio-economic and demographic characteristics. Most household heads are males (94 percent). The average household's size (eight persons) is the same as what was reported by the official statistics in 2014. The head of household age ranges from 17 to 99 years old with the average being 50 years old. The average age seems high when considering that 65 percent of the population is more than 24 years old. Nevertheless, the high average age is partly due to the nature of the multinuclear household type that includes different generations. Moreover, most households are headed by the eldest male of the household. In addition, a high rate of illiteracy (75 percent) characterizes the sample, similar to the 76.6 percent of the rural illiteracy level reported in 2014.

Households are involved mainly in crop and livestock production. Millet, maize, rice, sorghum, peanuts and cowpea are the most produced food crops. On average, sorghum has the highest acreage (0.98 hectare) followed by millet (0.66) and maize (0.43). The lowest acreage is allocated to rice (0.04 hectare), partly because rice production is constrained by biophysical constraints (biotic and abiotic). Sorghum is also the most produced and self-consumed crop. With the exception of peanuts and cowpeas, households self-consume most of their produced food crops. This is in line with the subsistence agriculture system that characterizes rural households.

Even though the primary activity remains agriculture or farming, the economic activities in rural areas involve different sectors. For instance, about 93 percent of households combine crop production with livestock rearing. Few households are involved in secondary activities such as gardening during dry season (2.5 percent), handicrafts (7.5 percent), or foraging (18 percent). About 98 percent of the sampled households own their farmland, and most of them are involved in agriculture during the rainy season.

Table 1.2 presents the patterns of rural household market participation. The results

Table 1.1: Rural households' socio-economic and demographic characteristics in 2011 at the national level

VARIABLES	Mean	Standard error	Min	Max
Household socio-demographic				
Male	0.945	0.003	0	1
Female	0.055	0.003	0	1
Household size (# of individuals)	8	0.037	2	20
Age of household head (years)	50	0.197	17	99
Not literate	0.757	0.006	0	1
Household economic characteristics				
Plot owners	0.981	0.002	0	1
Livestock owners	0.934	0.003	0	1
Involved in rainfed agriculture	0.956	0.003	0	1
Involved in counter-season agriculture	0.025	0.002	0	1
Involved in handicraft	0.075	0.003	0	1
Acreage (hectare)				
Millet	0.661	0.482	0.079	2.499
Maize	0.431	0.452	0.001	1.579
Rice	0.036	0.041	0	0.181
Sorghum	0.979	0.4	0.326	1.901
Peanuts	0.219	0.138	0	0.734
Cowpea	0.061	0.046	0	0.173
Production (kilogram)				
Millet	442.693	790.203	0	14580
Maize	609.565	1370.463	0	23460
Rice	77.328	412.575	0	25010
Sorghum	748.966	834.942	0	15660
Peanuts	113.953	220.195	0	3146
Cowpea	108.34	175.048	0	3926
Own-consumption (kilogram)				
Millet	443.954	820.775	0	14094
Maize	527.2	1070.181	0	20062
Rice	64.722	183.997	0	5000
Sorghum	692.8	763.974	0	12256
Peanuts	38.265	89.12	0	2502
Cowpea	68.88	122.193	0	3918
Observations	5849			

highlight the presence of net buyers and sellers for all the crops considered. The proportions of net buyers ranged from 8 percent (peanuts) to 38 percent (rice) while the proportions of net sellers ranged from 9 percent (rice) to 44 percent (peanuts). In general, legumes exhibited the highest proportion of net sellers because they are grown mainly for cash purposes, as the own-consumed quantities were the lowest reported in Table 1.1. Among the grains, rice had the highest proportion of net buyers. Rice was not cultivated by the majority of households and was produced in only a few regions as highlighted earlier. Notably, Table 1.2 also shows a high percentage of autarkic households which supports the subsistence status of most rural economy. This percentage was high for millet (68 percent), sorghum (65 percent) and maize (71 percent), for which most of the production was self-consumed. The case of millet and sorghum especially may suggest that most households were self-sufficient, and the crops were for subsistence. Maize was grown mainly in four regions; Boucle du Mouhoun, Haut-Bassins, Comoe and Sud-Ouest and was not a staple food for the majority of households in rural areas. Finally, households participating in the market were typically either buyers or sellers. Few households were both buyers and sellers, with their proportion ranging from two percent for rice to six percent for peanuts.

Table 1.2: Proportion of market participation in rural Burkina Faso.

	Millet	Maize	Rice	Sorghum	Peanuts	Cowpea
Percent net buyers	0.16	0.16	0.39	0.13	0.08	0.1
Percent net sellers	0.16	0.13	0.09	0.21	0.44	0.34
Autarky	0.68	0.71	0.52	0.65	0.48	0.57
Total	1	1	1	1	1	1
Percent buying only	0.15	0.15	0.38	0.12	0.07	0.09
Percent selling only	0.15	0.11	0.07	0.19	0.39	0.3
Percent buying and selling	0.03	0.02	0.02	0.04	0.06	0.04
N = 13593						

1.4.2 Regression models estimates

Estimates from equation 1.6 and 1.7 are used to derive the elasticities of demand and supply, respectively, for the six commodities (Table 1.3 and figure 1.4). We performed Wu-Hausman tests for exogeneity and F-tests for instrument relevance. Wu-Hausman tests showed evidences of endogeneity for maize and peanuts at demand side and for millet at supply side. A weak instrument problem is recorded for peanuts at demand side and millet at supply equations. F-statistics for the remaining equations suggests no problem of weak instruments. We followed the approach of (Stock et al., 2002), which suggests that the F-statistic should exceed 10 for inferences to be reliable under 2SLS estimation including one endogenous regressor.

Overall, point estimates of the demand response (Table 3 upper panel) were highly significant for maize, rice, peanut, and cowpea. The point elasticities range from -1.738 (peanuts) to -0.487 (maize) with all the cereals having inelastic demand. This steeper demand curve was likely guided by rural household's rigid preferences for staples. Households in rural areas may be attached to their traditional dishes in a way that they are less willing to substitute among staples following a price increase below a certain threshold.

In addition, biophysical constraints of crop production – supply – dictated the availability of close substitutes for final consumption in a specific area. Maize and rice were predominantly grown in four regions (Boucle du Mouhoun, Centre-Sud, Cascades and Sud-Ouest). These two crops are not staple in the rural areas of other regions as argued by (Traore et al., 2016).

Finally, even with the availability of substitutes in consumption, the characteristics of the alternatives such as processing time could limit crop substitutability. For example, maize and rice may not be close substitutes for millet and sorghum because of the higher processing time that they require. More time-constraining crops for final consumption may have higher response following a price increase. Point elasticities estimates were higher for rice and maize than for sorghum and millet. As such, after a price increase of millet and sorghum, consumers were more willing to reduce their consumption as compared to millet and sorghum.

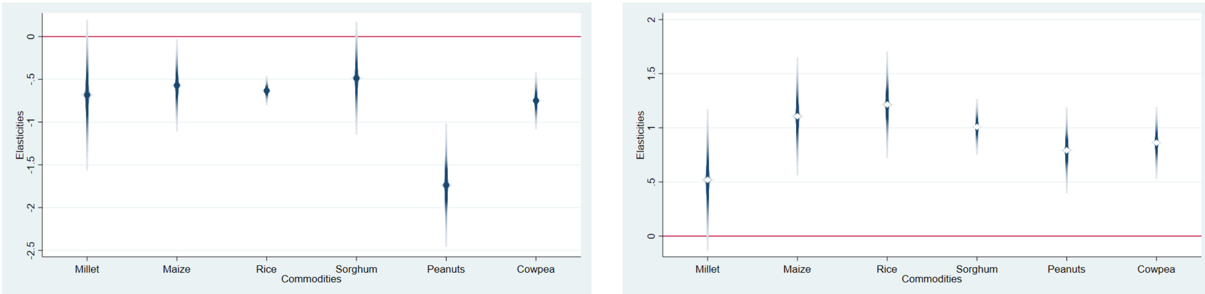
Table 1.3: Two-stage least square model estimates of demand and supply response by commodity.

	Millet	Maize	Rice	Sorghum	Peanuts	Cowpea
Demand						
Elasticity	-0.682**	-0.571***	-0.633***	-0.487*	-1.738***	-0.749***
	(0.342)	(0.209)	(0.0667)	(0.256)	(0.28)	(0.129)
Province dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,666	7,414	5,364	8,145	5,959	6,437
Tests						
1st-stage F-demand	24.68	22.07	36.6	12.87	2.99	13.9
Wu-Hausman p-value	0.2006	0.9115	0.001	0.6078	0	0.1826
Supply						
Elasticity	0.520**	1.107***	1.215***	1.009***	0.792***	0.862***
	(0.253)	(0.212)	(0.191)	(0.0997)	(0.154)	(0.128)
Province dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,813	2,079	1,465	2,237	1,623	1,749
Tests						
1st-stage F-supply	2.32	14.12	27.14	10.49	13.95	17.2
Wu-Hausman p-value	0.0217	0.7861	0.1635	0.5813	0.7924	0.6687

Standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Supply response elasticities in Table 1.3 (lower panel) and graphed by figure 1.4b were highly significant for all crops. Supply response was elastic for cereal (except millet) and inelastic for legumes. This suggests more important extensive margin (an increase in farm size) in the case of cereals than legumes. The strong supply response is in line with (Headey, 2016) in their study on less-developed countries including countries from sub-Saharan Africa.

Rice exhibited the highest supply elasticity (1.215) followed by maize (1.107), and sorghum (1.107). Given that farmers in Burkina Faso are primarily cereal growers, a price increase prior to land preparation, is likely to induce land reallocation in favor of a specific cereal, resulting in more elastic supply. The supply of peanuts and cowpea was inelastic even though both commodities are primarily grown for market purposes. It is most likely



(a) Demand response to price

(b) Supply response to price

Figure 1.4: Two-stage least square model estimates of demand and supply response to price change by commodity

that peanut and cowpea require a higher price increase to experience a supply change. Therefore, the price change might need to be strong enough to induce an acreage response. Agricultural land constraints faced by farmers may cause a primary allocation in favor of staples. In addition, this phenomenon may occur because the households' limited storage capabilities in rural areas. In any case, the number of substitutes for these commodities is limited, which makes it difficult for consumers to shift from one crop to another. Overall, farmers' responses to a price change may have thresholds that vary across commodities, which is beyond the scope of this analysis.

Table 1.4 and figure 1.5 show the estimates of producer and consumer price transmission elasticities. Our results for millet, maize, rice and sorghum showed that local consumers and producers' prices have a long-term, co-integrated relationship with world cereal prices. For all four-cereal crops, both the parameter on the error correction term and world price were significantly different from zero, except for millet consumer price. As a result, consumer and producer price for those commodities in Burkina Faso were co-integrated with world cereal prices; however, the results indicated that transmission of the changes from world price to local price is not high. The average of the long-term price transmission elasticities –over maize, rice, and sorghum – was 0.25 and 0.38, respectively, for consumers and producers. On the consumer and producer side, maize had the highest world price transmission elasticity. Sorghum had the lowest price transmission on the consumer side, while rice had the lowest price transmission on the producer side. Furthermore, on the producer's side, sorghum had the second-highest price transmission elasticity, which could be explained by its higher percentage of net sellers compared to other cereals, as indicated by Table 1.2. Our results did not show any significant findings for peanuts and cowpea, which may be due to the small sample size for those two crops. Policy intervention and market failures may also be reasons for lower price transmission elasticities.

Our findings of market integration and higher price transmission elasticity for maize and rice on the consumer side was consistent with (Baquedano and Liefert, 2014). They use an approach similar to ours to examine market integration and price transmission in consumer markets of developing countries. They find that on the consumer side, on average, the most traded crops (maize and rice) have a higher transmission elasticity than lesser or untraded goods (sorghum). Their results also reveal market integration and price transmission elasticity for maize equaling 0.12. In addition, these findings are in line with price transmission elasticities reported by (Zorya et al., 2012). They find that the spatial transmission of world price change is imperfect in developing countries and ranges from 0.20 to 0.70, and they propose that once global prices are transmitted to local consumers, price signals are passed further to producers, or conversely from production market to the consumer market depending on when the shock occurred. Notably, we found that the magnitude of the transmitted world price shock was asymmetric to the producer price was higher than what was transmitted to consumer price.

We attributed this asymmetry to a behavioral adjustment of middlemen, intermediaries such as collectors, wholesalers and processors providing a marketing role. Following a price shock, the derived inventory demand by intermediaries, at the producer level, shifts to the right. In addition, some of the final price of consumer products includes value-addition from post-primary production activities, such as transportation, processing, and retail sale, which is not affected by the change in the world cereal price (Baquedano and Liefert, 2014). Transmission of the world price to the domestic consumer price will therefore be less than

Table 1.4: Long-run world price and exchange rate transmission elasticities by commodities.

	Error Correction Term [a]	World Cereal Price	Real exchange rate[b]	*Obs.*[c]	Adj.R2[d]	*DW* [e]
Consumer						
Millet	-0.0853**	-0.102	-0.666	106	0.00401	1.286
	(0.0361)	(0.118)	(1.012)			
Maize	-0.189***	0.357***	0.750***	106	0.59	1.181
	(0.0538)	(0.117)	(0.196)			
Rice	-0.0861***	0.246***	0.897***	106	0.589	1.969
	(0.0266)	(0.0757)	(0.148)			
Sorghum	-0.105**	0.206*	1.015***	106	0.432	1.289
	(0.0417)	(0.107)	(0.2)			
Peanuts	-0.484	-0.0717	0.685	10	0.542	1.228
	(0.875)	(1.091)	(4.112)			
Cowpea	-0.879	0.623	0.666	10	0.542	1.228
	(0.955)	(2.458)	(0.911)			
Producer						
Millet	-0.0961**	0.293*	1.008***	106	0.582	1.616
	(0.0387)	(0.151)	(0.291)			
Maize	-0.218***	0.557***	0.514**	106	0.691	1.557
	(0.0583)	(0.158)	(0.254)			
Rice	-0.101***	0.246**	0.948***	106	0.65	2.09
	(0.0367)	(0.123)	(0.204)			
Sorghum	-0.145***	0.412**	0.791***	106	0.582	1.648
	(0.0476)	(0.162)	(0.265)			
Peanuts	-0.824	-0.393	0.362	10	0.542	1.228
	(0.771)	(1.451)	(3.621)			
Cowpea	-0.514	8.897	35.62	10	0.542	1.228
	(0.922)	(17.64)	(62.86)			

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. [a] represents the coefficient of error correction term, [b] the real exchange rate in US Dollars, [c] the number of observations used in the regression, [d] the Adjusted $R - Squared$, [e] Durbin Watson statistic.

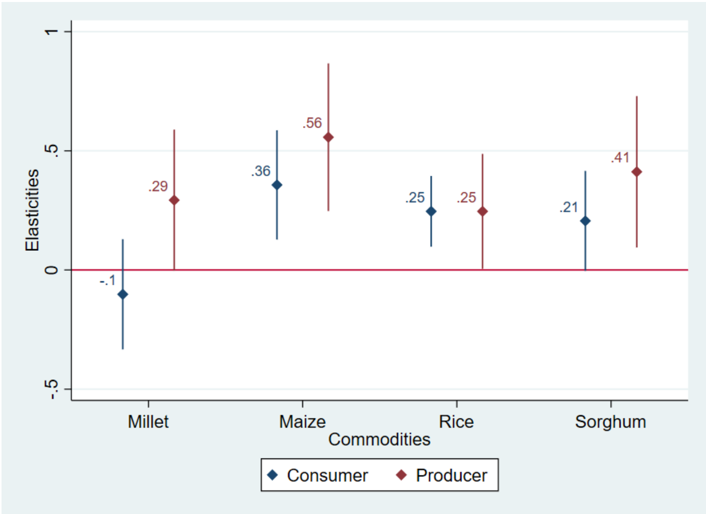


Figure 1.5: Short-run world price transmission elasticities by commodities for consumers and producers

price transmission to the producer price. Conversely, there is a lag in the transmission of the world price variation to consumer price mainly because of the existence of inventory and the policy interventions such as price floors or buffer stocks.

1.4.3 Welfare effect of price change

Using the estimated value of crops sold and purchased (Table 1.5), Equations 1.4 and 1.5 and parameters found in Tables 1.3 and 1.4 , we evaluated country level net welfare effects due to changes in world prices from 2006 to 2014. As shown by Equations 1.4 and 1.5 , country level quantities purchased and sold by commodity were used to evaluate welfare change. As a result, the average value in US dollars (USD)[10] of sales and purchases over the years 2008, 2009, and 2010 are respectively USD 1,064 and USD 490 million. In 2008, which is a year of important price spikes, these values are USD 1,406 million for sales and USD 619 million for purchases. These respectively represent 45 percent and 20 percent of the agricultural GDP, which amounts to USD 3,097 million (WorldBank, 2017b).

Comparatively, in 2010, the values of sales and purchases were 41 percent and 20 percent of agricultural GDP, respectively, estimated at USD 2,922 million (WorldBank, 2017b). The reduction in the agricultural GDP was partly due to bad weather because of a late rainy season in 2010. In 2011, the values of sales and purchases were the lowest, which seems counter-intuitive since the data show a price and agricultural GDP increase, leading to higher value crop sales. Nevertheless, over the three years, the two most-purchased crops by rural households were rice and sorghum, while the two most-sold crops were peanuts and cowpea in 2008, and peanuts and sorghum in 2010 and 2011.

The other parameters of the welfare estimates included the exogenous change in the world cereal price, the world price elasticity of transmission to consumers and producers

[10] To convert the total value of 2008, 2010, and 2011 from FCFA to USD, we used the exchange rate of the World Development Indicator database (WorldBank, 2017b). The exchange rate in 2008, 2010, and 2011 for one dollar was 447.8, 495.3, and 471.9 FCFA, respectively. The extrapolation was done using the sampling weight available in the database.

price, and the demand and supply elasticities. The contribution of the second-order terms to the welfare change (Equations 1.4 and 1.5) were negligible due to the behavioral factors that dampen the magnitude of the effect. Therefore, demand and supply elasticities played a small role in the welfare change. The aggregate welfare change, derived from the estimated parameters, is presented in Table 1.6.

Table 1.5: Estimated total value of crops purchased and sold by rural households in millions of USD.

	2008		2010		2011		Average Purchase Sale	
	Purchase	Sale	Purchase	Sale	Purchase	Sale		
Millet	94.9	152.7	81.4	100.8	35.2	55.5	70.5	103
Maize	92.5	147.6	76.7	152.8	32.8	49.8	67.3	116.7
Rice	108.5	85.1	103.2	119.9	61.2	40.1	91	81.7
Sorghum	279.1	265.7	294.8	258.4	121.6	164.5	231.8	229.5
Peanuts	29.3	402	13.9	379.6	8.8	162.3	17.3	314.6
Cowpea	15.7	352.8	14.6	183.3	6.4	117.8	12.2	218

We estimated the welfare effects considering equations 1.4 and 1.5, where the international price change was transmitted to the local commodities price according to our estimates in Table 1.6. Subsequently, we performed a sensitivity analysis to highlight how the elasticities of transmission affected the relative welfare change (Figures 1.6 and 1.7). The exogenous price change, ζ_{p^w} , as stated earlier, is the change in the world cereal price index relative to the base period of 2002 to 2004. The world price shocks were 132 percent in 2008, 141 percent in 2011 and 136 percent in 2012.

Overall, the increases in the world cereal price from 2006 to 2014 was translated into net welfare improvement for farmers. This improvement ranged from 0.02 percent in 2006 to 0.06 percent in 2011. Among the six crops considered, the relative gain in welfare improvement resulted from millet and maize while rice and sorghum induced welfare loss; cowpea and groundnuts had no effect because of insignificant parameters. Maize dominated the welfare effects over all the other crops with an increase of the welfare ranging from 0.12 percent in 2006 to 0.86 percent in 2011. This was largely due to two factors: maize had the highest

Table 1.6: Change in welfare relative to total purchase per commodity and year (in percentage).

	2006	2007	2008	2009	2010	2011	2012	2013	2014
World Price Increase ($\zeta_{p^w}\uparrow$)	19	63	132	70	79	141	136	119	92
Millet	0.08	0.27	0.56	0.3	0.34	0.6	0.58	0.51	0.39
Maize	0.12	0.39	0.81	0.43	0.49	0.86	0.83	0.73	0.56
Rice	0	-0.01	-0.03	-0.02	-0.02	-0.03	-0.03	-0.03	-0.02
Sorghum	-0.04	-0.13	-0.28	-0.15	-0.17	-0.3	-0.29	-0.25	-0.2
Total	0.01	0.03	0.05	0.03	0.03	0.06	0.05	0.05	0.04

price transmission elasticities and the producer's price transmission elasticity was greater than that of consumers. Second, maize sales exceeded purchases by a greater margin than any of the other crops (Table 1.5). The welfare gain from millet stemmed from the lack of transmission of the world cereal price to the consumer price resulting in the welfare gain equivalent to producer's surplus. Rice and sorghum generated welfare losses following a world price shock. The result for rice was consistent with the findings of (Badolo and Traore, 2015). The world price transmission to domestic rice market hurt farmers due to the fact that they were often net buyers. Similarly, there was a welfare loss from sorghum because purchases exceeded sales. As a result, any sorghum price increases adversely affected overall farmer welfare.

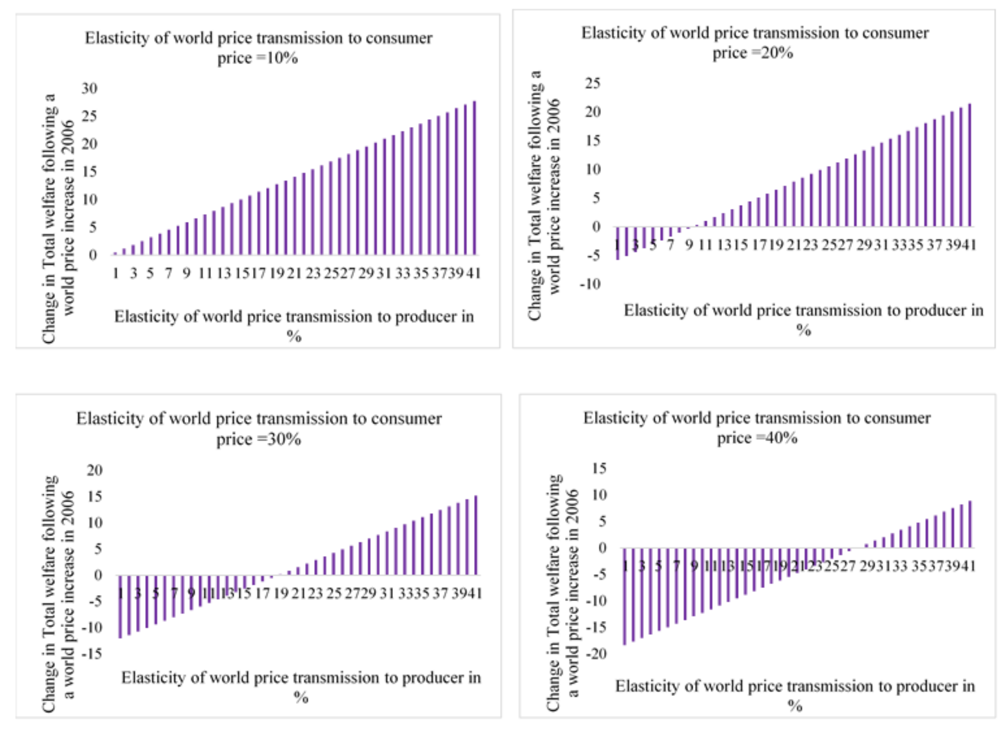


Figure 1.6: Total welfare effect of price transmission with and without full transmission

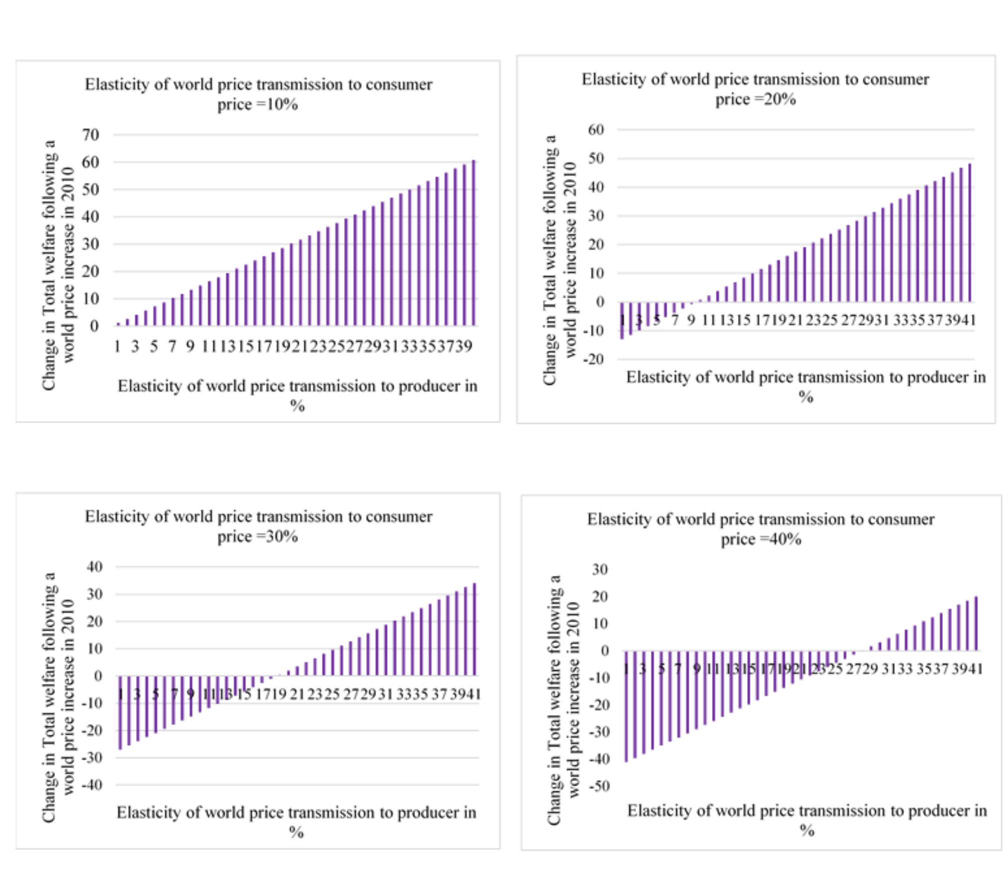


Figure 1.7: Total welfare effect of price transmission with partial price transmission by commodities

Finally, we conducted a sensitivity analysis to empirically assess the impact of variation in price transmission on rural welfare. For this, we performed a sensitivity analysis by setting consumer price elasticities to 10, 20, 30 and 40 percent. For each of these consumer elasticities, we allowed producer price transmission elasticities to vary in the range of 1 to 50 percent, with 1 percent increments. We observed that at a fixed level of purchase and sale, the welfare can be either positive or negative depending on elasticities values (1.6 and 1.7). Consistent with Equation 1.2, higher world price transmission to consumers' local price worsens farmers' welfare, while higher world price transmission to producers' local price was associated with welfare improvement. Nevertheless, it is worth noting that the mechanism through which world price shock is transmitted to domestic market is mostly distorted by trade policies from both importing and exporting countries. Studies by (Giordani et al., 2016; Gouel and Jean, 2012; Minot et al., 2010; Tovar, 2009; Piermartini, 2004; Zorya et al., 2012) argued that the restrictive policies imposed by exporters and tax reduction policies adopted by importers exacerbate the impact of world price spike on domestic prices. Most likely, the lack of appropriate domestic policies of food price monitoring and control leaves developing countries mostly with distortive trade policies (Giordani et al., 2016). Such mechanisms used in Burkina Faso can affect the magnitude of price transmission (Aker et al., 2010). The simulation of transmission elasticities conducted is partly mean to account for the effect of such distortions.

1.5 Conclusion and Policy Implications

We analyzed the implications of a world cereal price shock on rural household welfare in Burkina Faso to contribute to the empirical discussion on impediments to poverty alleviation. The link was established using an agricultural household model with the world prices for cereals transmitting to local producer and consumer prices. Household net welfare, after a price shock, is derived as a function of its behavioral responses to local price change induced by the international price shock. We estimated the model using nationally representative data on rural Burkina Faso and time series of world cereal producers and consumers price indices.

The causal relationship between world and domestic cereal prices was established using an error correction framework which allowed us to measure and separate long- and short-run effects on domestic price from an exogenous change in world price. The estimation resulted in transmission coefficients in the range of previous studies found in low-income nations. Importantly, we found that the magnitude of world price transmitted to the producer price was higher than that transmitted to consumer price. This asymmetry was attributed partially to behavioral adjustment by farmers, marketing (middlemen), and policy interventions following a world price shock. We demonstrated that the status of net buyer or net seller is not a sufficient condition for a household to be a winner or loser from an international price shock. Furthermore, we studied household behavioral response in commodity supply and demand to the price changes identified using lagged yield and yield shocks. Significant household responses to price changes were found on both supply and demand sides.

The price elasticities, transmission coefficients, purchases and sales were combined to estimate household-level welfare changes induced by a global price shock. Overall, price increases, such as those experienced during the 2008 to 2009 period, were associated with an improvement in rural farmers' welfare because the producer effect outweighed the consumer effect. Increases in prices during the period from 2006 to 2014 was translated into welfare improvement. This improvement ranged from 0.02 percent in 2006 (lowest) to 0.06 percent in 2011 (highest) of the total purchase. This suggested that price increases may be associated with poverty reduction for rural households. Price shocks on the majority of crops generated positive welfare impact, except for sorghum and rice. In addition, we evaluated the robustness of the welfare impact generated by variation in price transmission elasticities by conducting a sensitivity analysis. We observed, by holding purchases and sales constant, that the welfare effect can be either positive or negative, depending on values taken by transmission elasticities.

Cereal producers will benefit from increases in world prices and suffer from world price declines. However, stronger integration into world markets, reduced trade barriers, and transaction costs will benefit a country by allowing it and its producers to capture the gains from trade based on comparative advantage as well as the reduced cost of doing business. Public policies and investments that strengthen market incentives and activity, such as improving physical infrastructure, can thereby pay dividends. Although greater integration into world markets will make consumers more vulnerable to fluctuations in world prices, targeted compensation is a preferred policy response, rather than market-distorting policy intervention.

Our analysis and results apply to crop-producing rural households, and as such have some important limitations. First, we excluded from our analysis the negative welfare effects on urban cereal consumers from increases in world prices. Consequently, our estimated national welfare effects from such price growth were upwardly biased. Second, we also excluded livestock and other food products for which cereal-producing households may be net consumers. Nevertheless, our findings provide insight into the role played by global price transmission to welfare analysis. Future research could focus on linking international price volatility to rural household welfare.

Chapter 2

Are Urban Consumers in Niger Willing to Pay for Safe and Nutritious Food?

Introduction

Unhealthy diet and poor nutrition are leading causes of the global disease burden that disproportionally affects developing countries. About 30% of the world's population —1.6 billion people— is anemic, of which half can be linked to iron deficiency (Benoist et al., 2008; WH0, 2001) . While poor-quality diets are an underlying reason of hidden hunger such as anemia, there is limited research on consumer valuation of food quality attributes, and very little research has been conducted on consumer valuation of food quality attributes in developing countries (WHO, 2010). In fact, knowing consumers' willingness-to-pay (WTP) for food attributes is critical to effective policy intervention. Furthermore, it provides information about market demand on those attributes to value-added food processors for strategic marketing and segmentation (Caswell and Mojduszka, 1996). Another important consideration is that consumers consider high-price premiums as the strongest limiting factor when purchasing cereal products in West Africa (Naseem et al., 2013). Therefore, WTP estimates can be used to analyze marketability of new products (Van Loo et al., 2011). For example, high premiums charged combined with limited availability might restrict market growth (O'Donovan and McCarthy, 2002). Nevertheless, from a theoretical standpoint, WTP estimation in food economics literature rarely accounts for taste heterogeneity in a way that allows for isolation of utility-scale parameter variation across individuals that can be used for market segmentation.

Recent economic studies have been conducted on consumers' demand for food quality attributes in developed countries in hypothetical and non-hypothetical market settings (Lusk and Schroeder, 2004). Results of these studies show that nutrition and safety information have a positive effect on consumers' food choice, depending on whether they are price-conscious or not(Drichoutis et al., 2005; Nayga et al., 1998). In Sub-Saharan Africa however, very few studies have been conducted on this topic thus far. For instance,Fiamohe et al. (2015) conducted a study in West Africa on extrinsic characteristics, finding that Togolese consumers are willing to pay a premium of up to 46% of the actual price for cleanness and 53% for whiteness in locally produced rice. Taste plays an important role in consumer acceptance, and the provision of nutritional information translates to substantial premiums for the pro-vitamin A biofortified sweet potato varieties in Uganda(Chowdhury et al., 2011). Both studies did not account for taste heterogeneity and assumed fixed marginal utility across consumers. Also, to the best of our knowledge, no study has assessed consumer preference for food quality attributes and their WTP for safety attributes as measured by the products' date of expiration, as well as nutritional attributes as measured by levels of daily iron requirements contained in the products.

Additionally, nowhere in the literature has there been a focus on WTP distribution to identify heterogeneity in consumer segments, even though agribusinesses might be interested in specialized niche markets where consumer preference is different from the aggregate market. To address this gap in the literature, this study assesses consumers' WTP for food safety and nutritional attributes in a developing country for the purpose of assessing consumer preference for the expiration dates on products, the dietary composition of iron in food, and the country of origin for high-quality millet flour-based agglomerated cereal products. To accomplish this objective, the empirical scope of our paper aims to explicitly model consumers' marginal rate of substitution of income for quality attributes, accounting for taste heterogeneity across consumers and confounding scale parameter variation. This was accomplished using mixed multinomial logit models in both preference and WTP spaces proposed by Train and Weeks (2005) and Scarpa et al. (2008). We applied these models to a random representative sample of consumer data from a collective conjoint-based choice experiment method conducted in the capital of Niger. Our experiment identifies consumer valuation and transforms the attributes that are intrinsically credence attributes into search characteristics (Caswell and Mojduszka, 1996; Louviere et al., 2000). Our contribution to the literature and policy debate is twofold. First, in the global debate on the implication of date labeling for food waste, we evaluate consumers' valuation of expiration dates. Additionally, we provide empirical evidence for a plausible market-driven micro-nutrient supply, through fortified food products, in developing countries. Second, we assess the relevance of accounting for taste heterogeneity in evaluating consumer valuation of quality attributes in the food economics literature.

2.1 Experimental Methods

To evaluate consumer's WTP for quality attributes of value-added cereal food products, a random sample of 205 consumers was used to evaluate quality differentiated "Dègué." "Dègué" is an agglomerated food product similar to couscous but of a larger diameter. It has traditionally been marketed as a homogenous food commodity and developed for subsistence purposes. However, some small businesses owned mainly by women throughout West Africa are now involved in its processing using modern technologies to produce high-quality products, especially in urban areas. Quality characteristics of those products are not made explicit to consumers in a way that a relative demand for these quality attributes can be directly analyzed through market purchases. As such, this experiment has been conducted to analyze consumers' preferences for selected quality credence attributes embedded in these food products.

Packages of five hundred grams (500 g) of "Dègué" with varying quality attributes were chosen as the unit of analysis. Because the products with these quality attributes were either new or unavailable in the local market, demand for the attributes was uncertain. Consequently, this study represents a classical use of Choice Experiments (CEs) to determine relative preference for the product attributes and estimate the associated marginal WTP (Louviere, 1991). To estimate consumers' WTP for the different attributes, one might use revealed preference data such as grocery store data, which is used in developed countries. However, as stated by Lusk and Schroeder (2004), the problem with this approach is the difficulty in finding people to participate in such a study. In addition, the collection of demographic characteristics from each shopper purchasing "Dègué" in a store setting would be a major challenge. Without demographic information, one would question whether WTP estimates are a result of sample fabrications. Furthermore, it might not be possible to identify market niches by classifying consumers with the same preference structure. Finally, there are logistical problems associated with running the study at a point of sale that could be prohibitory.

Given these considerations, random participants were selected and recruited on-the-spot, most of whom were going to, or returning from, the market. To include a random factor during sampling, every fifth male or female passerby with an estimated age between 18 and 65 was approached. Following the methods of Demont et al. (2012), whenever we approached a group, a maximum of one participant was selected so that none of the participants knew each other. Subjects were offered 2000 FCFA ($4) cash to participate in "*Consumers' willingness to pay for Quality attributes of cereal value-added food products*", which was conducted in a school room near the spot of recruitment (the market). Individuals who agreed to participate were assigned a random identification number for the purpose of anonymity and then were directed to the experiment site. One and a half hour sessions were held once or twice per day depending on the difficulty of recruiting the participants from July 4, 2017 to July 10, 2017. The experiment was conducted in the five districts of Niamey to ensure the spatial representativeness of the sample with respect to the city population. Prior to the focus group discussion on May 30, 2017, a literature review and experts interview were conducted to identify the main drivers of consumer food choices. As a result, 10 attributes were selected to proceed for the focus group discussion. Those attributes encompassed price and brand, food safety, ecological certification, production process, health-related characteristics, and nutritional attributes. Subsequent refinement led to four attributes, which were further customized and improved through a series of pretests and expert advice.

Upon arrival at the session, subjects completed a short demographic questionnaire and were given the opportunity to examine a sample of "Dègué" made locally by processors in town packaged, without labels at this point. All attributes were credence attributes and as such required a label to convert them into search attributes, as discussed later in the paper. An information sheet and cheap talk script were read aloud, after which subjects responded to a series of eight repeated questions. Each question or choice set was displayed on the board, read aloud in French, and translated into the two major languages of Hausa and Djerma, which are spoken in the town.

In each set, three package options (See figure 2.2) were given to the subjects, including an "None of these" options. Subjects were asked to indicate which package was preferred (or none) in each scenario. Package price ranged between 450 FCFA, 500 FCFA, 550 FCFA, and 600 FCFA. The price levels were chosen to straddle the range of prices available in the market and as reported by the processors during a focus group discussion.

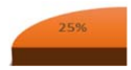
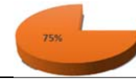
	Description	Attribute levels			
		1	2	3	4
Limit date of consumption	Limit Date of Consumption (DLC) “Date of Expiration”	No	Yes		
Product Nutritional Content	Highlight content of the product in Iron relative to the daily value requirement.	0 % of Daily Value	25 % of Daily Value 	75% of Daily Value 	100% of Daily Value 
National origin claim	Highlight the origin of the product and the pride related to the country	None	Proud Niger 		
Image of the product	Whether the image associated with the product is the family or not	None	Family 		
Product price (per 500g)	The buying price of the product per 500g in FCFA	450	500	550	600

Figure 2.1: Choice attributes and their levels

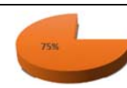
Attribute	Package A	Package B	Package C
Expiration Date	Yes	No	
Origin	Proud Niger 		
Image			None
Micronutrient: Iron	0 % Daily Value	 75% Daily Value	
Price	550	450	
I would Choose *(Check (√) only one choice)*	☐	☐	☐
Rank			

Figure 2.2: Sample choice set

In this setup, there are three options of packages (including none) varied at four price and micronutrient levels, as well as two origin and image levels (See figure 2.1). Subjects would have to be shown $2^2 \times 2^2 \times 2^2 \times 4^2 \times 4^2 = 16,384$ different choice sets if presented with every package at every combination of price, micronutrient, date of expiration, the origin of the product, and family image. To reduce the number of questions respondents had to answer, an orthogonal fractional factorial design was generated. In this design, attributes are totally uncorrelated between packages. The resulting design consisted of 64 sets of scenarios or choice sets, which were then formed into eight blocks of eight choice sets each. The $D-optimality$ criterion was used to obtain an optimal design using a modified Federov search algorithm.

2.2 Methodology

2.2.1 Consumers' Willingness to Pay

Consider a consumer's utility maximization problem subject to a budget constraint where the level of a good's quality (q) is fixed exogenously. In the case of agribusiness applications, q is most applicable as a measurement or index of a good's quality (Lusk and Hudson, 2004). The consumer chooses the level of the market good (x_m) that maximizes utility, producing the traditional Marshallian demand curve $x_m(p, y, q)$; where p is the market price of the good and y is income. The resulting indirect utility function is $V(p, y, q)$. Now assume that an agribusiness food processor and retailer considers improving the quality of an existing product from q_0 to q_1. A measurement of the value the consumer places on this improvement can be derived by determining the magnitude of the WTP such that the following equality holds: $V(p, y - WTP, q_1) = V(p, y, q_0)$. For the measurement of the WTP , a choice-based experiment as described above was followed and WTP estimated as described in the following section.

2.2.2 Model Specification

In each CE question or choice set, respondents had to choose between two packages and the "none of these" option. Let V_{njt} be the deterministic component of the nth consumer's indirect utility of choosing package j at choice occasion t. To ease the illustration, utility was specified as separable in price, at which alternative j is hypothetically bought by consumer n, with quality or non-price attributes, x_{njt}, describing alternative j, as well as decision maker n in choice situation t:

$$U_{njt} = -\alpha_n price_{njt} + \beta_n x_{njt} + u_{njt}, j = A, B, C \tag{2.1}$$

Where the scalar α_n is the price coefficient and vector β_n represents the marginal utility associated with the quality attributes. Both sets of parameters vary randomly across consumers $n = 1, ..., N$. u_{njt} is the utility stochastic component Gumbel distributed with variance $Var(u_{njt}) = \mu^2 \frac{\pi^2}{6}$, where μ_n is the scale parameter for consumer n. Train and Weeks (2005) demonstrated that the scale of utility is irrelevant to consumer's behavior. The utility can then be divided by μ_n without changing behavior which results in an i.i.d. new error term ε_{njt} type-one extreme value distributed with constant variance $\frac{\pi^2}{6}$:

$$U_{njt} = -\lambda_n price_{njt} + c_n^{'} x_{njt} + \varepsilon_{njt}, j = A, B, C \tag{2.2}$$

where $\lambda_n = -\alpha_n/\mu_n$ and $c_n = \beta_n/\mu_n$. Train and Weeks (2005) call this specification the model in preference space. It can be seen from Equation 2.2 that λ_n and c_n are correlated unless the scale parameter does not vary over individuals since μ_n appears in the denominator in both expressions. Specifying the coefficients to be independent implies that the random term is homoscedastic, which may not be a realistic assumption. By using the fact that the WTP is given by $w_n = \beta_n/\alpha_n = c_n/\lambda_n$ equation 2.2 can be rewritten as:

$$U_{njt} = \lambda_n [price_{njt} + w_n x_{njt}] + \varepsilon_{njt} \tag{2.3}$$

This is what Train and Weeks (2005) and Scarpa et al. (2008) called "utility in the WTP space". Models (2.2) and (2.3) are of course behaviorally equivalent but the key thing to note is that a standard assumption regarding λ_n and c_n in the preference space (equation

2.2) can lead to unusual distribution for the WTP. For instance, if the price coefficient has any positive density setting over zero then the distribution of this ratio has undefined moments (Daly et al., 2012). In addition, assuming that λ_n and c_n are both normally distributed implies that w_n is a ratio of two normal distributions, which does not have defined moments. This is an unlikely choice of distribution if we were to specify the distribution for the WTP directly as we did in the WTP space model. The coefficients in the preference space and WTP space models can be estimated by using maximum-simulated likelihood. We follow Scarpa et al. (2008) and estimate the models using maximum simulated likelihood as described in the next section.

2.3 Estimation Method

In this section we present the method of estimating coefficients in equations 2.2 and 2.3. We adopt the mixed logit specification under repeated choices by consumers with continuous taste known as panel mixed logit developed by Revelt and Train (1998). In our study, consumer n faces a choice among J alternatives (package A, Package B and None) in each of the T times periods or choice situations. For the simplicity of exposition, let θ_n represent the random terms entering utility, which are λ_n and c_n for model in the preference space (equation2.2) and λ_n and w_n in WTP space (equation(2.3)).

Consumer n chooses package j in period t if $U_{njt} \geq U_{nkt} \, \forall j \neq k$.Denote the consumer's chosen alternative in choice occasion t as y_{nt},and the consumer sequence of choices over the T_n choice occasions as $y_n = \langle y_{n1}, ..., y_{nT_n} \rangle$. Hence, conditional on θ_n, consumer's n sequence of choice probability is :

$$L(y_n|\theta_n) = \prod_{t=1}^{t=8} \frac{\exp(\theta_n z_{njt})}{\sum_{k=1}^{3} \exp(\theta_n z_{nkt})} \tag{2.4}$$

The unconditional probability of consumer n's sequence of choice is the integral over all values of θ_n weighted by its density:

$$P_n(y_n|\Omega^*) = \int L(y_n|\theta_n) f(\theta_n|\Omega^*) d\theta_n \tag{2.5}$$

where $f(.)$ is the density of θ_n which depends on parameters Ω^* to be estimated. The goal is to estimate Ω^* which is the population parameters that describe the distribution of individual parameters(Revelt and Train, 1998) using the log-likelihood function $LL(\Omega) = \sum_n \ln P_n(y_n|\Omega^*)$. The exact maximum likelihood is not possible since the integral of equation 2.5 cannot be calculated analytically. Hence, $P_n(y_n|\Omega^*)$ is approximated via simulation. The simulation is done by first drawing a value (θ^r) of θ_n from $f(\theta_n|\Omega^*)$ with Ω^* fixed at a given initial value. With R number of draws: $\widehat{P_n^{\mu}}(y_n|\Omega^*) = \frac{1}{R}\sum_{r=1}^{R} L_{n,j}(\theta^r)$ is an unbiased estimator of $P_n(y_n|\Omega^*)$. Finally, substitute $\widehat{P_n^{\mu}}$ into the Log Likelihood function yielding the simulated Log Likelihood: $SLL = \sum_n \sum_j d_{njt} \ln \widehat{P_n^{\mu}}(y_n|\Omega^*)$, where $d_{njt} = 1$ if consumer n chooses alternative j at choice situation t.

In this study, we first estimate a range of models in both preference and WTP space and afterward select the "best" model among a set of non-nested models using Akaike Likelihood Ratio Index proposed by Ben-Akiva and Swait (1986). For each model, we compute Akaike Likelihood Ratio Index(ALRI) to have a measure of how well the models best fit the data. We chose the model with significantly higher ALRI[1] .

2.4 Results

2.4.1 Descriptive Statistics

Table 1 presents sampled consumer distributions with respect to gender, age groups, marital status, education, and their corresponding average household monthly expenditure group. Also, the table compares our sample structure with that of our target population at both

[1]Following Ben-Akiva and Swait (1986) the Akaike Likelihood Ratio Index(ALRI) is $\bar{\rho}_A^2 = 1 - \frac{\widehat{P_n}(y_n|\Omega^*) - K}{\widehat{P_n}(y_n|C)}$ where $\widehat{P_n}(y_n|C)$ is the log likelihood of the sample for some naive model, K is the number of parameters.

city and national levels, even though our survey was exclusively in Niamey. These comparisons were chosen because the generalization of our findings will critically depend on how representative our sample is of the targeted population of consumers between 18 and 60 years old living in the city of Niamey. Our sample distribution was also compared to the national level to understand the similarities and differences of the sample typology with that of the same target population at the national level. Specifically, our sample is stratified with respect to the town districts and has similar spatial distributions as our targeted population. Overall, the randomization appeared to be well-conducted since our sample is relatively representative of consumers in Niamey. In addition, this similarity is extended to the national level despite some noticeable dissimilarities for education and marital status variables. When the city sample is compared to the national level population, consumers without any level of education are underrepresented in our sample.

Specifically, 17.53% of our sample has no education, which is low compared to the 47.7 % for the city of Niamey and 73.41% for the national level. The reticence of this population segment in participating in the survey may be due to lack of trust in the recruiter and the message being delivered. Finally, a noticeable fact is the discrepancy with regard to the top and bottom classes of participants' household food expenditures in Niamey. The bottom tier of the wealth class is overrepresented, while the top tier of the wealth class is underrepresented in our sample. This is probably due to the level incentives we proposed (US$4), which is 25 % of the average daily food expenditure in our sample. This may be a significant incentive for the lower-income group, but not for the higher-income group.

Similar to Niamey and the national level, our typical consumer is relatively young with an age between 18 and 34 years, married with a monthly food expenditure less than 12,000 FCFA (USD 22) , and lives in a household with 6-8 members. Specifically, about two thirds of the participants have a monthly food expenditure level less than 16,000 FCFA (USD 29)[2]. In terms of food poverty, 36.52% of the participants live in households with a per capita food

[2] 1 USD=550 FCFA

expenditure lower than the town threshold, which is calculated to be 9,925 FCFA (USD 18) per capita per month by official statistical services (INS, 2011). Comparatively, the chronic food insecurity estimated by the National Institute of Statistics was 33.5 %.

Table 2.1: Average Sample Socioeconomic and Demographic Characteristics by class

	Sample (1)	**Niamey** (2)	**Diff. Sample-Niamey**[a] (3)	**National** (4)	**Diff. Sample-National** (5)
Gender					
Male	42.27	48.91	-6.64***	49.37	-7.1***
Female	57.73	51.09	-8.82***	50.63	-8.36***
Age group					
18-24 years	25.26	27.27	-2.01*	23.99	1.27
25-34 years	27.32	29.74	-2.42*	28.12	-0.8
35-44 years	24.23	17.5	6.73*	18.35	5.88
45-54 years	14.95	12.99	1.96	13.87	1.08
55-64 years	6.19	7.81	-1.62	9.06	-2.87
65 years or older	2.06	4.99	-2.93	6.61	-4.55
Marital Status					
Single	33.51	35.11	-1.6	19.26	14.25***
Married	60.82	55.68	5.14	71.78	-10.96***
Divorced	4.12	3.8	0.32	2.64	1.48***
Widow	1.55	5.37	-3.82*	6.01	-4.46***
Education					
None	17.53	47.7	-30.17***	73.41	-55.88
Primary	24.23	22.04	2.19***	13.47	10.76
Junior High School	24.23	14.54	9.69***	7.43	16.8
Senior High School	10.31	2.72	7.59**	1.07	9.24
Professional School	5.67	4.5	1.17	1.91	3.76
Koranic school	8.25	0.8	7.45	0.23	8.02
Higher Education	8.25	7.6	0.65	2.42	5.83
Other	1.53	0.1	1.43***	0.06	1.47
Food expenditure (FCFA)[b]					
Less than 4000	10.4	0.66	9.74	1.89	8.51***
4000-6000	10.98	1.76	9.22**	7.47	3.51
6000-8000	12.14	5.29	6.85	13.3	-1.16**
8000-10000	12.14	9.14	3	16.39	-4.25*
10000-12000	4.62	9.03	-4.41	14.78	-10.16*
12000-14000	6.94	10.46	-3.52	12.53	-5.59
14000-16000	9.25	11.23	-1.98**	9.15	0.1
16000 or more	33.53	52.42	-18.89***	24.48	9.05

*** $p < 0.01$, $** p < 0.05$, * $p < 0.1$, with p the $p-value$ of the one sample t-test. [a] is the difference between national and the sample estimate, [b] Per capita monthly household food expenditure (FCFA). Niamey and National level information are official statistics by National Institute of Statistics.

2.4.2 Estimated Model Parameters

In this section we compare results from the estimated choice models. The models are estimated using maximum simulated likelihood with 1000 Halton draws. Table 2.2 presents estimation results for models discussed in the methodology—the models in both preference and WTP spaces. In both spaces, models are estimated with and without correlation between marginal utility of each attribute. The first two columns are the estimation results of models in preference space (Equation 2), without and with correlation between estimated coefficients respectively. The two last columns display estimation results of models in the WTP space, respectively, without and with correlation between the coefficients estimated.

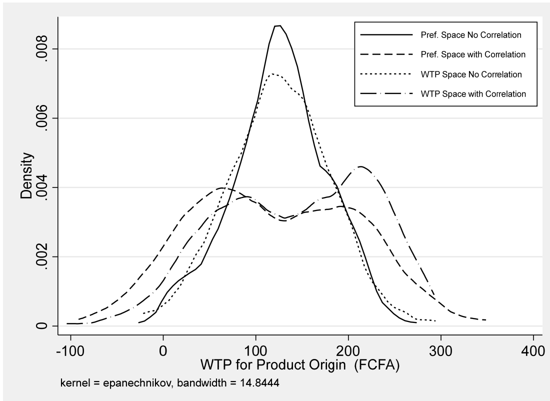
Table 2.2: Estimation results of utility parameters in preference and WTP space with and without correlation among coefficients

	Preference Space		WTP Space	
	Without correlation (1)	With correlation (2)	Without correlation (3)	With correlation (4)
Price	-0.004***	-0.006***	-5.090***	-4.930***
	(0.0005)	(0.0005)	(0.0986)	(0.0896)
Expiration Date	1.638***	1.709***	276.2***	242.6***
	(0.108)	(0.123)	(20.40)	(17.81)
Micronutrient (25 % of DR)	0.387***	0.400***	65.20***	63.60***
	(0.0461)	(0.0526)	(7.789)	(8.428)
Origin	0.752***	0.737***	122.0***	138.3***
	(0.107)	(0.121)	(15.12)	(16.61)
Family Image	0.129	0.0908	19.10	41.07**
	(0.109)	(0.122)	(18.12)	(18.60)
$\mathcal{L}^*$ at Convergence	-1136.574	-1104.790	-1135.927	-1093.286
Akaike Information Criterion	2299.148	2265.58	2299.853	2256.572
ρ_j^2	-1.24	-1.18	-1.24	-1.16
$Pr(\rho_4^2 - \rho_j^2)$	0.00	0.00	0.00	[a]
$Pr(\rho_2^2 - \rho_j^2)$	0.00	[a]	0.00	[b]
Observations	4272	4272	4272	4272

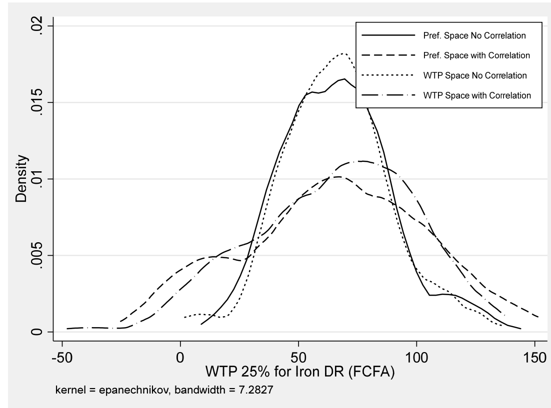
Standard errors in parentheses, *** $p < 0.01$, $** p < 0.05$, * $p < 0.1$, with p the $p-value$. [a] Probabilities are not calculated because of the auto-comparison, [b] The statistics is not computed because $\rho_2^2 - \rho_4^2$ is negative in this case.

The fit of alternative models of heterogeneity were compared using the Akaike Likelihood Ratio Index because the models estimated are non-nested. In addition, based on this index, a test procedure developed by Ben-Akiva and Swait (1986) was implemented to test the statistical difference of fit between models. The general result is that the model in WTP space with correlation outperforms all others because the probability that it is incorrectly specified is almost equal to zero, as shown in Table 2.2 lower panel. The result strongly suggests the suitability of its structure in explaining consumers' preference in our sample case and is the basis of subsequent model interpretation. Appendix B provides details on model selection procedure and Figure 2.3 presents the distribution of parameter estimates.

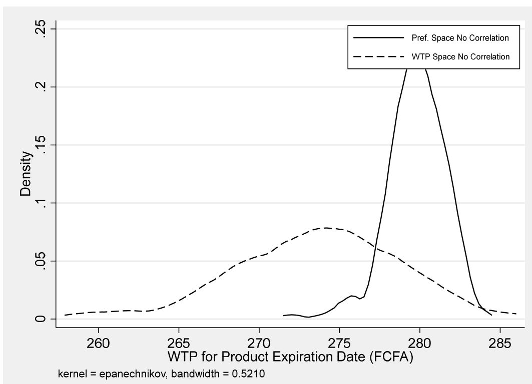
Appendix B provides the Cholesky matrix decomposition of parameters. This matrix decomposition in both preference and WTP spaces model shows significant diagonal and off diagonal elements. These suggest that standard error of attribute coefficients represented by the diagonal and correlation between coefficients uncover preference heterogeneity underlining consumer's choice.



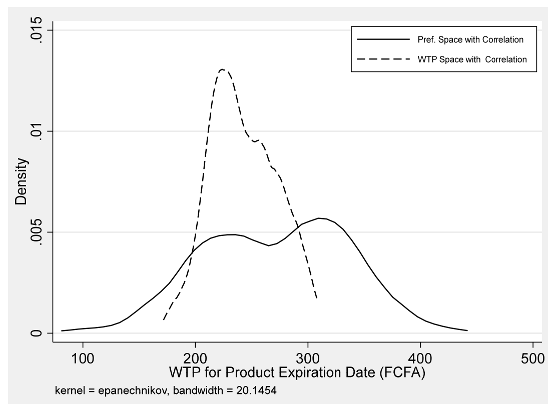
(a) Distributions of WTP for Product Origin for estimated models



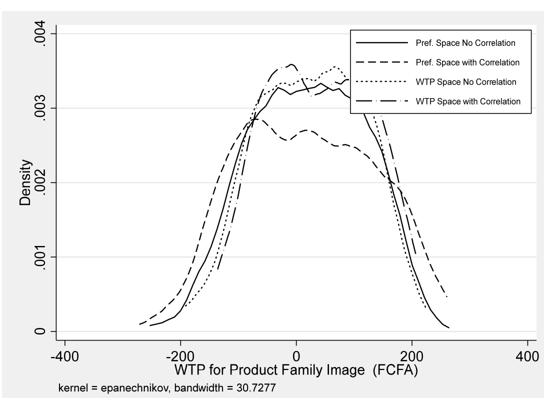
(b) Distributions of WTP for Micronutrient for estimated models



(c) Distributions of WTP for Expiration date in both preference and WTP spaces without correlation



(d) Distributions of WTP for Expiration date in both preference and WTP spaces with correlation



(e) Distributions of WTP for Family Image for estimated models

Figure 2.3: Estimated models coefficients distribution

All models produce reasonable estimates—the price coefficient is negative, while consumers have a strong preference for expiration date, micronutrient information, and the origin of the product. Image attribute is less important, although significant. Also, all standard deviations associated with the marginal utilities of attributes are statistically significant at the one percent level, denoting significant taste heterogeneity of consumers with regard to attributes. Therefore, the information on products' dates of expiration, which signals consumers about a product's safety for consumption increases utility by 1.7 (Column 3). As a result, consumers are willing to pay a premium of 247 FCFA to have this attribute. Initially, the result of 247 FCFA seemed to be an implausibly large value since it is roughly 1/3 of the average producer price of the product. Nevertheless, this high value may reveal a consumer's WTP to avoid a situation of consuming an outdated and unhealthy product.

The second-most important attribute is micronutrients—the percentage of daily iron requirements or daily value needed by human body. The willingness to pay for 25% of the Recommended Dietary Allowance (RDA) of iron is 65FCFA. Since micronutrient has three levels, it should be understood that consumers WTP for one additional level of daily requirement will be linear because our experiment design does not allow estimating non-linear effect by integrating dummy variable representing each levels in our model. For that our levels should have been considered as separate attributes in generating our choice sets. As a result, the willingness to pay for 50 %, 75% and 100% of daily requirement could be estimated as equal to respectively 127 FCFA, 191 FCFA and 254 FCFA. Nevertheless, 25% of RDA for a 500g of the product is a technological threshold since above that level, iron taste is distinguishable, and hence possibly confounding for consumer taste and preference.

The origin of the product is the third attribute for which consumers have strong preference. There are willing to pay for a premium of 138 FCFA for the product to be made in their country rather than an uncertain place of origin.

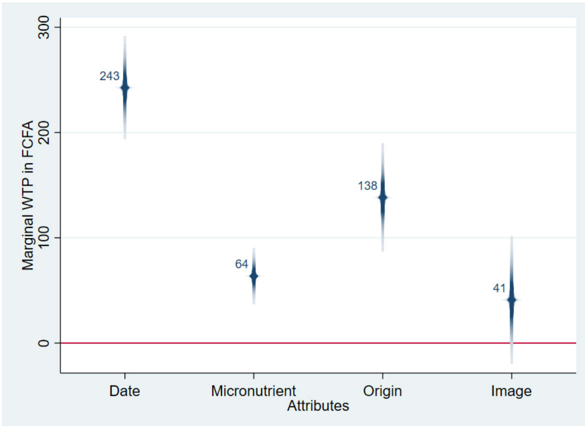
Table 2.3 and figure 2.4 present marginal WTP for attributes by income classes and gender using the utility model in WTP space with correlation between the marginal utility of attributes. Women have strong preference for iron content and expiration date of the product making them more inclined to pay a higher premium for those attributes. This is not surprising for micronutrients because cheap talk information given to the participants by the nutritionist highlights the benefit for pregnant and lactating women and for their babies. In contrast, men are more ethnocentric consumers due to their willingness to pay higher premiums than women when the product bears their country image. Also, younger consumers are even more ethnocentric consumers than older ones for their willingness to pay a higher premium for product that carries the country flag.

Table 2.3: Marginal Willingness to pay for all consumers, by gender and income classes in FCFA using utility model in WTP space

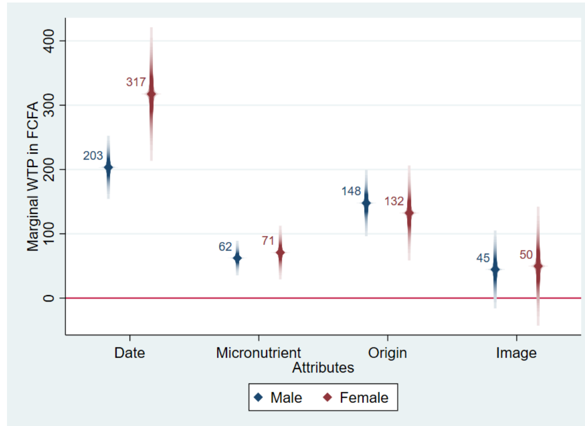
	Observation	Expiration Date	Micronutrient	Origin	Family Image
All Classes	4272	242.6***	63.60***	138.3***	41.07**
		(17.81)	(8.428)	(16.61)	(18.60)
Gender					
Male	2,520	203.4***	62.24***	147.8***	44.53*
		(19.05)	(10.39)	(20.01)	(23.52)
Female	1,752	317.4***	70.82***	132.4***	49.69
		(40.31)	(16.17)	(28.66)	(35.92)
Monthly Income class[a]					
Less than 60	888	297.6***	32.40*	145.2***	66.29
		(40.51)	(17.63)	(33.89)	(44.67)
60-120	1368	226.2***	55.05***	203.3***	92.84*
		(46.50)	(19.22)	(45.11)	(51.36)
More than 120	2,016	225.2***	84.89***	104.0***	30.75
		(24.08)	(12.17)	(22.20)	(24.07)
Age					
Less than 28 years old	1,704	249.8***	41.08***	114.7***	28.05
		(21.71)	(10.54)	(20.46)	(23.10)
28-38 years old	1,104	221.9***	89.24***	151.4***	77.59**
		(18.38)	(10.78)	(30.60)	(35.44)
More than 38 years old	1,464	266.7***	51.34***	185.1***	44.61
		(35.42)	(15.64)	(32.04)	(40.10)

Standard errors in parentheses, *** $p < 0.01$, $**\, p < 0.05$, * $p < 0.1$, with p the $p-value$. [a] Income class in thousands of FCFA

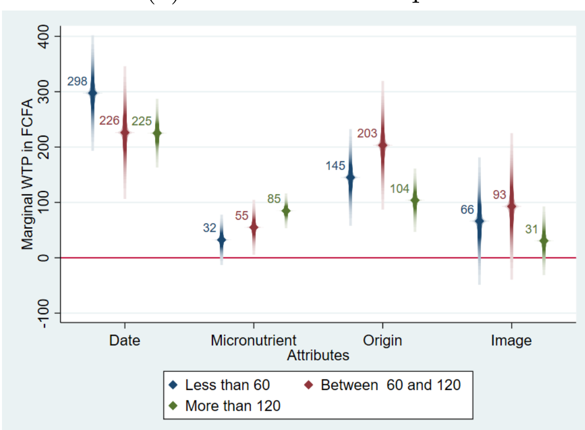
Men have strong preference for product origin and expiration date translating to higher WTP than that of women. Also, willingness to pay for the date of expiration is higher for



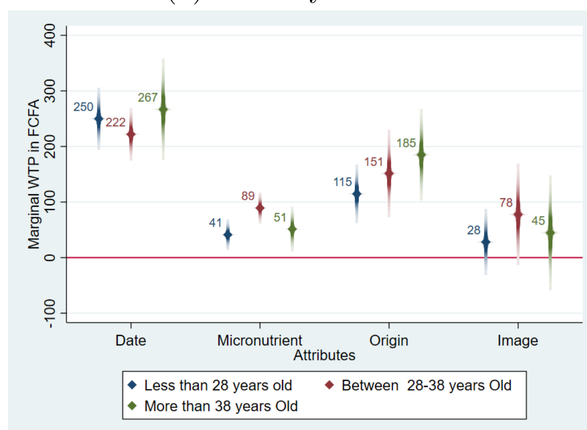
(a) WTP for all Sample



(b) WTP by Gender



(c) WTP by Income Group



(d) WTP by age Group

Figure 2.4: Marginal Willingness to pay for all consumers, by gender and income classes in FCFA using utility model in WTP space

low income classes and lower for higher income classes. This suggests that consumers that are more (less) likely to be risk averse are willing to pay a higher (lower) premium to get a product with a date of expiration that is a more certain situation.

Finally, consistent with Bennett's law on the relationship between income and food quality, WTP for micronutrient is significantly higher for higher income classes of consumers. Indeed, Bennett's law reflects the seemingly universal desire for variety in the diet and diversification towards higher quality.

2.5 Discussion and conclusion

Our study, focusing on urban consumers in one of the poorest nations in the world, yields findings in line with economic theory. Indeed, the hypothetical market intends to provide information on a range of food attributes related to health, nutrition and country of origin. The design of our experiment provides signals to consumers on product freshness, as described by the date of expiration, nutritional content, as described by the micronutrient density, and the origin of the product. In the presence of these treatments, consumers showed strong preference for the quality attributes compared to the situations where they are uncertain on attributes. Specifically, we inferred consumer demand for product safety through a statistically significant WTP for a product that bears a date of expiration compared to a product that does not have such information. In addition, consumers have a strong preference for products that clearly indicate being made in their home country opposed to a situation of uncertainty on the origin. Furthermore, consumers are willing to pay a price premium for iron fortification. These results are revealing how consumers may react when they are certain about the information given to them when making their food choices. The reduction of uncertainty drives higher willingness to pay for product related attributes. These results are consistent with theoretical predictions derived by Falconi et al. (1990) in their study on the economics of food safety. They show that consumer's beliefs, the certainty of beliefs, and the presence of information (signals) are important determinants of demand for goods as they are driven by the demand for health.

Our attributes and the information given to participants grounded or enhanced those beliefs. In addition, the effectiveness of how information is given to consumers has been crucial on consumers WTP. For examples, the low level of micronutrient WTP may be related to consumer-limited knowledge of its health benefit. The date of expiration or product origin is widely understood by consumer as well as straightforwardly explained, which is not the case of micronutrients. Hence, participants may be uncertain on the associated health benefit, which makes information less effective in reducing consumer's health outcome variance.

Aside from these results, findings are heterogeneous across socioeconomic characteristics, such as gender and consumer's income class, that segments market classes.

Because market demand is high for health related attributes such as date of expiration, public policy could be undertaken to create an enabling environment for supply of such attributes. This could be done by first taking appropriate measures on sensitizing food processors on the economic benefit that could be generated by following quality standards and clearly informing consumers on those attributes. This information could be provided to consumers using harmonized and high quality labels and packaging. This high quality label is critical in giving consumers trust on the claimed attributes. Furthermore, government could set some guidelines on the type of label that should be adopted by food processors. Such guidelines are already adopted by several countries in West Africa following FAO and WHO Codex Alimentarus Commission standards.

In addition, our study suggests that micronutrient demand is higher in wealthier income classes and for women. This finding is consistent with Abdulai and Aubert (2004) who found that in Tanzania the diets of high-income households were richer in all micro- and macronutrients. Likewise, Ecker and Qaim (2011) generally found that in Malawi, higher household incomes were associated with a more diversified diet as measured by the number of different food items consumed. This finding can be counterbalanced with the fact that demand for micronutrient is greater by women groups and suggests that targeted policy intervention to alleviate hidden hunger or food quality deficiency may be effective.

These results suggest possible micronutrient demand, especially by women and higher-income classes, in addition to necessary policies that may contribute to fight against malnutrition. Those critically in need of such micronutrients are less willing to pay for them mainly because of financial resource constraints, and lack of information on short and long-term health benefits. Furthermore, since the health outcome of these attributes is a public good, it is likely that the market provision of this would not be Pareto Optimal. Government intervention therefore would be necessary to achieve optimal provision of such attributes.

This kind of intervention could target those most in need such as women in low-income classes; however, this could be costly for the entire population especially when based on income.

Indeed, such an intervention would require records of all consumers, ultimately deciding who could benefit from the intervention or who could not. The transaction costs associated with this targeting could increase the cost of the program and the tax burden. Instead of income targeting, gender targeting seems easier to implement and could have the highest return per dollar invested because pregnant and women are the most in need of micronutrients, especially iron.

Finally, our study found that consumers are likely to be ethnocentric in food products, especially younger consumers. This is consistent with findings by Jin et al. (2015) in their study on consumers preference for a product image of country of origin. One explanation of this result is that with increased globalization and economic development, consumers in developing countries may have realized that locally produced products are becoming increasingly competitive, if not yet equal, to imported products. This is important for food processors from both developed and developing countries because they have the opportunity across such countries to exploit, and to support, the country associated with their companies. Such research therefore remains of significant relevance to international business (Chabowski et al., 2013).

This study has some limitations that could be taken into account in future research. First, the quality issue of alternatives in each choice task is important for avoiding any problem of price endogeneity. For example, a high price of an alternative could be interpreted as signal of higher quality product. As a result, consumers will select the alternative even though it is dominated that is not better than (or equal to) another alternative in all attributes. Omitting the quality aspect in choice experiments could cause biased and inconsistent estimates potentially inducing sign flipping of coefficient especially that of the price , one solution is to build the quality aspect in the choice experiment by selecting choice sets for which price will be positively correlated with a measure of quality defined by the researcher. The choice experiment may loose its orthogonality feature nevertheless. In addition, to better manage the choice experiment, especially in developing countries, it may be useful to have fewer attributes and limited levels since the number of choice sets could become tyrannical requiring larger sample size to detect effects.

Chapter 3

Consumer preference for a time-saving food attribute in Niger

Introduction

Food systems are evolving worldwide because of the changing patterns of consumption and the emphasis on food quality and safety (Minten et al., 2013; WorldBank, 2008). These changes are happening in a number of countries, both developed and developing (See for example Jaffee and Henson (2005); Josling et al. (2004); Pingali (2007)). However, despite the importance of food quality in food system transformation, especially in developing countries, previous literature has focused more on the effects of economic factors (price and income) than of consumer food choices. There are still relatively few analyses on food quality and safety impacts and magnitudes (Minten et al., 2013). More importantly, most of the studies on food quality in Africa focus on the effect of extrinsic or search attributes of food (Fiamohe et al., 2015; Demont et al., 2012) and less on the intrinsic (experience or credence) characteristics. One of the most intrinsic attributes that drives food demand is the amount of time or labor spent on home food production. Households combine market goods with time to produce basic goods like food that enter their utility function (Becker, 1965; Gronau, 1977).

The trend in consumption research can be grouped into three broad categories. First, a large body of research focused on consumer behavioral adjustment following a price shock and income shift (Nakelse et al., 2018; Magrini et al., 2017a). These studies reached the common conclusion that consumers in both rural and urban areas are price conscious. Changes in price affects their food choices and has important welfare effects, depending on the magnitude of the shock. Nevertheless, a consumer decision is also subject to non-price variables such as safety and food quality. Second, a few studies looked at the impact of extrinsic characteristics on consumer decisions. For example, in the case of Togo, Fiamohe et al. (2015) showed that consumers are willing to pay a premium for rice whiteness and cleanliness. Also, Demont et al. (2012), showed in the case of Senegal that consumers are willing to pay a premium for rice that is branded, using some cultural elements. The third body of research focused more on intrinsic or credence attributes of the food products.Their focus is on evaluating quality premium after raising awareness of consumers on those attributes. Most of these studies used bio-fortified food products as the object of investigation. For example, in the case of Uganda and in a choice experimental setting, Chowdhury et al. (2011) estimated a premium for pro-vitamin A fortified potatoes when consumers are aware of such an attribute. A similar premium is also evaluated in Kenya and Senegal in an experimental setting and using an auction mechanism De Groote et al. (2011, 2018) . The literature therefore has the need to look at both effects of price and non-price factors(nutrition enhanced, appearance, etc.) of food choice in developing countries. Nevertheless, there is a void when it comes to considering the interaction between a households' time allocation and food choices; specifically, how a time-related food attribute affects consumer preference and therefore, food choices. This is despite the fact that in lower income countries home cooking time consumes the greatest amount of energy and time of all household work (Jeuland and Pattanayak, 2012; Hawkes and Fanzo, 2017).

Therefore, improving input of commodity production, efficient cooking stoves, or time-saving food products would improve the health of households, save time, preserve forests and associated ecosystems, and reduce greenhouse gas emissions. We address this void in the literature by assessing the impact of a time-saving food attribute through extrusion and pre-cooking, on consumer food choices in an urban area of Niger in an experimental setting, using a randomly selected representative sample of consumers. Our main hypothesis is that a time-freeing attribute of a food product increases the likelihood of its choice by consumers. The underlining reason is that, consumers prefer more income and leisure. The freed-up time will be reallocated either to more productive and remunerated activities or to leisure. Either way, this increases the household incentive to adopt the new product because of higher utility. As argued by Ekholm et al. (2010) , freeing household work time could increase labor productivity, especially that of women and children, for more productive purposes. Nevertheless, this hypothesis may not hold in all cases. In fact, in cases where time spent on cooking is considered as leisure time, then we expect no increase in the probability of choosing the product because of disincentive implied by a negative marginal utility generated by adopting the product.

To assess our hypothesis, we used utility theory to highlight the conditions under which our inference holds. Specifically, we adopted a Becker (1965) time allocation model to derive how a time-saving food product affects consumer utility; hence, food choice. Our empirical approach of assessing the effect of time-saving attributes on consumer behavior relies on the random utility framework developed by McFadden (1973) and extended by Kamakura and Russell (1989) to a latent class framework. We used this model because of its inherent feature of explaining choices by both deterministic and stochastic factors, as well as segmenting consumers based on underlying taste heterogeneity. We used data collected in Niger in summer 2017 in a laboratory setting with a two-step approach. We first conducted with a hedonic valuation where all the products, including the improved and traditional product are tasted by participants. After the tasting, consumers took part in a choice experiment where cards of four alternatives varying in attributes were presented to them.

Our major contribution to the literature is that consumers are responsive, on average, to an embodied time-saving food technology. Nevertheless, the marginal utility is highly heterogeneous across consumers, with an important segment having a negative marginal utility and another segment having a positive marginal utility. In addition, consumer preference for new attributes vary by food products and pearl millet variety. Finally, we contribute to the general literature of household time allocation by showing how a choice experiment can be used to test a hypothesis in this framework. The remainder of this chapter is organized as follows: the second section discusses our methodology, showing how we use Becker (1965) time allocation model to explain the effect of time-saving food attributes on consumer standard of living. In addition, it describes our empirical methodology strategy and our experiment design, as well as data collection methodology. The third part presents the results and discussion.

3.1 Methodology

3.1.1 The analytical framework

Our theoretical model is based on the Becker-type time allocation model, where households only consume commodities that they produce. The goal of the model is to investigate how the introduction of a time-saving attribute in a consumption good changes the equilibrium of the household demand for a market good and time for home production. In this model, household is assumed to consume a commodity x that directly affects its utility. The household will be assumed to combine time and market good to produce a commodity Z, here considered as cooked millet-based meal:

$$Z = G(x, t, \phi) \tag{3.1}$$

where x is a market good and t is housework time of one or more household member used in producing the commodity and ϕ is a technology or efficiency parameter. Unlike Becker, we simplify this vector by considering that a single type of time is used in transforming market good x into commodity Z. Here x refers to a grain-based marketed product used by the household to produce a specific commodity (thick and thin porridge, cooked couscous, or *fourra*). The technology parameter ϕ relates precooked extruded products to traditional ones. Generally Z is increasing in its arguments, strictly quasi-concave, twice differentiable, homogenous of degree 1 which implies constant return to scale, so that $\gamma Z = G(\gamma x, \gamma t, \phi)$. In addition, $\lim_{x\to 0} G_x(x,t) = \infty$, $\lim_{x\to\infty} G_x(x,t) = 0$, $\lim_{t\to 0} G_t(x,t) = \infty$, $\lim_{t\to\infty} G_t(x,t) = 0$ In this setting, the household is both commodity producer and utility maximizer, and combines time and market good through a specific technology $G(.)$ to produce a commodity Z that maximize the following utility function:

$$U = u(Z, t; \tau) \tag{3.2}$$

where τ is a taste parameter. The utility function is assumed to have the usual regular properties that are increasing in each argument, strictly concave and twice differentiable with $\lim_{z\to\infty} u_z(z,t) = \infty,\ z > 0$ and $\lim_{t\to\infty} u_t(z,t) = \infty,\ t > 0$. In addition, the household has one unit of time to allocate between home food production and work or participating in the labor market for cash income. Therefore, household maximizes utility U subject to cash constraint,

$$px = I = V + hw \tag{3.3}$$

where V is the non-labor income, p is the unit price of x that we normalize to unity henceforward, h is the hours spent at work, w is the earnings per unit of work for pay. The time constraint can be rewritten as:

$$h = 1 - t \tag{3.4}$$

Combining 3.3 and 3.4 yields the following cash constraint:

$$w + V - x - wt = 0 \tag{3.5}$$

The new technology introduced is exogenous to the household and reduces by θ the amount of time t spent by the household to transform x into commodity Z. Hence the full income constraint is written as follows:

$$w + V - x - w(t + \theta) = w(1 - t - \theta) + V - x = 0 \tag{3.6}$$

The household chooses x and t so as to maximize 3.2 subject to the technology of producing Z , cash income and time constraints. One method of taking into account the technology constraint is to substitute 3.1 into 3.2. The new constrained optimization with Lagrange multiplier (λ) (marginal utility of full income) becomes:

$$\mathcal{L} = U(G(x, t, \phi); \tau) + \lambda(w(1 - t - \theta) + V - x) \tag{3.7}$$

The first order condition at an interior solution is:

$$\begin{cases} x: \quad U_Z G_x - \lambda = 0 \\ t: \quad U_Z G_t - \lambda w = 0 \\ \lambda: \quad w + V - x - w(t + \theta) = 0 \end{cases} \tag{3.8}$$

where U_Z is the marginal utility of commodity Z , G_x the marginal product of input x in producing Z and G_t is the marginal product of input time t in producing Z. A notable feature of the first order conditions is that for a household to maximize utility subject to resource and technology constraints, it must produce Z at minimum cost. In the above set-up we assume that the time used by the household is a source of household utility only through the production of commodity Z[1]. In order to assess how the time reduction parameter θ affects consumers' optimal demand of good x and labor supply, we proceed to a comparative static by taking the partial differential of the first order conditions:

$$\begin{cases} (U_{ZZ}G_x^2 + U_Z G_{xx})\frac{\partial x^*}{\partial \theta} + & (U_{ZZ}G_tG_x + U_ZG_{xt})\frac{\partial t^*}{\partial \theta} & -\frac{\partial \lambda^*}{\partial \theta} = 0 \\ (U_{ZZ}G_tG_x + U_ZG_{tx})\frac{\partial x^*}{\partial \theta} + & (U_{ZZ}G_t^2 + U_ZG_{tt})\frac{\partial t^*}{\partial \theta} & -\frac{\partial \lambda^*}{\partial \theta} w = 0 \\ -\frac{\partial x^*}{\partial \theta} & -w\frac{\partial t^*}{\partial \theta} & = w \end{cases} \tag{3.9}$$

The comparative static that yields the system 3.9 allows to derive the change in demand ($\frac{\partial x^*}{\partial \theta}$) of good and labor ($\frac{\partial t^*}{\partial \theta}$) after due to a time saving food product shown in the following propositions[2]:

Proposition 1. *Under regularity properties of the production function $G(.)$ and the utility function $U(.)$, the effect of an embodied time saving technology in a food product on its demand is:*

$$\frac{\partial x^*}{\partial \theta} = \frac{\frac{G_t}{G_x^2} U_Z(-G_tG_{xt} + G_xG_{tt})}{|BH_2|} \tag{3.10}$$

Under substitution in production between market good and labor ($G_{tx} < 0$), on one hand demand for the market good will increase if $|\frac{G_{xt}}{G_{xx}}| > w$. But on the other hand demand for the market good will decrease if $|\frac{G_{xt}}{G_{xx}}| < w$. Furthermore, if market good and household time are complements, $G_{xt} > 0$, a time saving technology will result in lower demand ($\frac{\partial x^*}{\partial \theta} < 0$).

Proposition 2. *Under regularity properties of the production function $G(.)$ and the utility function $U(.)$, the effect of an embodied time saving technology in a food product on household labor demand is:*

$$\frac{\partial t^*}{\partial \theta} = \frac{\frac{G_t}{G_x^2} U_Z(-G_tG_{xx} + G_xG_{tx})}{|BH_2|} \tag{3.11}$$

[1] One can assume that t also provide utilities or (dis)utility directly to household. As noted by (Huffman, 2011), time for cooking may directly lower or increase the utility irrespective to the utility obtained from the commodity produced. But this aspect could be for future work.

[2] See derivations in appendix C

Under substitution in production between market good and labor ($G_{tx} < 0$), on one hand demand for labor will increase if $\mid \frac{G_{tx}}{G_{xx}} \mid < w$. *But on the other hand demand for labor will decrease if* $\mid \frac{G_{tx}}{G_{xx}} \mid > w$. *Furthermore, if market good and household time are complement,* $G_{tx} > 0$, *a time saving technology will result in higher demand in labor*($\frac{\partial t^*}{\partial \theta} > 0$).

In propositions 1 and 2 $\mid BH_2 \mid$ is the determinant of the bordered Hessian which is positive (negative semi definite Hessian) because of the utility maximization assumption. The case of substitution between time and market good good is discussed in Becker (1965). The main reason substitution could take place is that, different commodities use time and the market good in different proportions. This is easily relatable to the case of cereal-based products considered in this study. For example, couscous takes more time compared to the other food products because of drying and millet grain de-husking processes. When there is substitution in production between market good and labor how time saving food attribute affects demands is linked to the ratio $\mid \frac{G_{xt}}{G_{xx}} \mid$ that could be interpreted as market good value of time. For example, labor demand will decrease if $\mid \frac{G_{tx}}{G_{xx}} \mid > w$ meaning that when good value of time is greater than the real wage rate the household will demand fewer labor for the production of Z good. Other factors may also affect demands. The time saving technology embodied in the market may alter taste properties of the Z good and therefore change consumers marginal utility or the marginal rate of substitution between the good and income.

3.1.2 Experimental Design

Choice experiment consumers survey

The aim of the choice experiment is to evaluate consumer preference or marginal utility for instant or extruded cereal food products versus traditional commodities, for a widely consumed product in West Africa and especially in Niger. To that end, the survey employed 214 consumers randomly selected in five districts of Niamey, the capital of Niger. The main task of the consumers is to evaluate quality differentiated value added cereal based products that are *fourra*, couscous and flour. *Fourra* and couscous are agglomerated food products, with *fourra* having a larger diameter and different processing procedures than couscous. Each product is locally produced and traditionally marketed as a homogeneous food commodity mainly for subsistence purposes. However, many small businesses, owned mainly by women throughout West Africa, are now involved in their processing, using modern technologies to produce high-quality products, especially in urban areas. Furthermore, the cooking time for these is about one hour for about six persons. Hence, improving food products by, for example, reducing cooking time by half, as in the case of the extrusion process, presents a promising avenue to enhance households' well-being. As such, this experiment has been conducted to analyze consumers preferences for such attributes.

Packages of five hundred grams (500 g) of three products with varying quality attributes were chosen as the units of study. Because the modified products with higher quality attributes were either new or unavailable in the local market, demand for the attributes was uncertain. Consequently, this study represents a classical use of Choice Experiments (CEs) to determine preference for the product attributes (Louviere, 1991). In addition, a tasting session that allowed respondents to experience the improved and traditional products preceded the choice experiments. To estimate consumers' preference for the different attributes, one might use revealed preference data such as grocery store scanner data collected at the point of sale, which is used often by studies on developed countries and known as better capturing consumers' true purchase behaviors. However, as stated by Lusk and Schroeder (2004), the problem with this approach is the difficulty in finding people to participate in such a study. In addition, the collection of demographic characteristics from each shopper purchasing our products in a store setting would be a major challenge. Without demographic information, one would question whether WTP or marginal utility estimates are a result of sample fabrications. Furthermore, it might not be possible to identify market niches by classifying consumers with the same preference structure. Finally, there are logistical

Food Product	Fourra	Couscous	Flour	None
Type	Not Extruded	Extruded	Extruded	
Millet Variety	Variety 2	Variety 3	Variety 3	
Price	600	550	500	
I would Choose ……	○	○	○	○

Figure 3.1: Example of a Choice Set presented to Consumers

problems associated with running the study at a point of sale that could be prohibitory.

Choice experiment and sample description

The design of the experiment followed Aizaki and Nishimura (2008) . The full factorial design for this study generates 72 profiles from which 12 profiles are kept using the fractional factorial design technique. The reduction of the number of profiles is mainly driven by the time and cost limit. The 12 profiles are split into three sub-blocks of four choice sets randomly associated with different groups of consumers for a balanced factorial design. For each question or choice set, consumers were asked to choose the most important option (See figure 3.1).

However, before the interview, the different attributes of millet products and their levels are explained to respondents. The sessions are conducted in the two most spoken languages of the country (Hausa and Djerma). The survey had two components: the tasting phase and the choice experiment. During the tasting phase, respondents were asked to choose between the extruded and non-extruded versions of each of the three millet varieties considered (local, improved, and bio-fortified variety). The improved variety was developed by the national agricultural research institute while the bio-fortified has high quantity of iron relative to the other two.

Table 3.1 presents the 214 consumer characteristics selected from the five districts of the town. The sample contains 15% of consumers that are also involved in cereal processing activities and the other 85% respondents that are only consumers of the processed products. The average age of the respondent is 36, with the youngest being 16, and the oldest respondent being 65 years old. The average household size of the respondent is about eight persons, which is higher than the average size presented in the 2012 census by the Niger government.

In addition, the majority of the respondents are married (54%) and a significant proportion is single (35%). The level of education of respondents is scattered mainly across primary (25%) middle school (24%), with a relatively important percentage of respondents having completed secondary school. Nevertheless, about 15% of the respondents have no education and therefore do not know how to read and write. Because of this last segment of respondents, the choice card is designed in a way that allows them to easily select the option they prefer. In terms of income class, the largest proportion of respondents has a monthly income less than 30000 FCFA (60 USD) and 14% have an income level more than 80000 FCFA(160 USD).

3.1.3 Empirical Model

Our choice experiment represents a typical case of a labelled choice experiment; that is, each option represents a known and distinct good. As such, each option provides to the consumers a specific utility. This feature will be taken into account when specifying the model of respondent utility generation. We assume that decision maker or consumer n obtains from alternative j in period or choice occasion t is linearly linked to some deterministic (V_{njt}) and random components(ε_{njt}) (i.e $U_{njt} = V_{njt} + \varepsilon_{njt}$). Building on Lancaster (1966), the observed utility of an alternative j during a choice occasion t, V_{njt}, is defined as a function of the attributes of the j^{th} alternative and β. Eq.(3.12) defines V_{njt} as a product between X and β, which is a vector of parameters associated with X attributes of alternative j

$$V_{njt} = \beta_{0j} + \sum_{k=1}^{K} \beta_k X_k \tag{3.12}$$

In modelling choice, we assume that consumers act rationally by evaluating all alternatives before proceeding to choose the alternative from which they are expected to derive the

Table 3.1: Descriptive Statistics

Variable	Min	Max	Average	S.D.
Age of the respondent	16	65	36.05	13.04
Household size	1	30	8.04	4.43
Marital Status				
Single	0	1	0.35	
Married	0	1	0.54	
Divorced	0	1	0.05	
Widowed	0	1	0.06	
Separated	0	1	0.01	
Education				
None	0	1	0.15	
Primary	0	1	0.25	
Junior High School	0	1	0.21	
Senior High School	0	1	0.14	
Technical School	0	1	0.07	
University	0	1	0.08	
Other	0	1	0.11	
Monthly Income (in Local currency (FCFA))				
1= less than 30,000	0	1	0.32	
2= 10,000-19,500	0	1	0.1	
3= 20,000-29,500	0	1	0.12	
4= 30,000-39,500	0	1	0.18	
5= 40,000-59,500	0	1	0.14	
6= 50,000-59,500	0	1	0.11	
7= 60,000-69,500	0	1	0.04	
8=70,000-79500	0	1	0.07	
9= More than 80,000	0	1	0.14	
Observation		214		

greatest relative utility. Therefore with this principle of utility maximization, alternative j will be chosen if and only if $U_j > U_i$. The probability that alternative j is chosen from a set of J alternatives can be written $P_{njt} = P(j|J) = P(V_{njt} + \varepsilon_{njt} > V_{nit} + \varepsilon_{nit})$ for all $i \epsilon J$ where $j \# i$. In our case the source of variability in consumers' behavioral responses contained in the deterministic component of the utility are: the type of the product (extruded vs non extruded), millet variety used (Variety 1, Variety 2 and Variety 3) and the price of the product. Nevertheless, some unobserved factors can influence consumer choice such as consumer risk loving status. Observational studies not including this factor could suffer from bias as it can be a source of endogeneity due to its omission. Risk-loving status can be correlated with both the treatment (here the attributes) and the consumers choices. This is a small issue in our case of choice experiment because our attributes are exogenous to the decision maker and is entirely controlled by the researcher. If ε_{njt} is distributed extreme value, independent over n, j and importantly, t, then, the choice probabilities

$$P_{njt} = \frac{e^{V_{njt}}}{\sum_j e^{V_{njt}}} \tag{3.13}$$

where j takes the values in {flour,*fourra*,couscous,none} which is the choice set faced by our respondents at each choice occasion. The deterministic component of utility in Eq.3.12 is written as follows:

$$\begin{aligned} V_{nfourra} &= \beta_{0fo} + \alpha \Pr ice + \beta_{1fo} Extruded + \beta_{2fo} Variety_1 + \beta_{3fo} Variety_2 \\ V_{nflour} &= \beta_{0fl} + \alpha \Pr ice + \beta_{1fl} Extruded + \beta_{2fl} Variety_1 + \beta_{3fl} Variety_2 \\ V_{ncouscous} &= \beta_{0cou} \alpha \Pr ice + \beta_{1co} Extruded + \beta_{2co} Variety_1 + \beta_{3co} Variety_2 \end{aligned} \tag{3.14}$$

Previous models highlight the homogeneity of taste and hence do not allow preference to vary in the population or sample. However, within the household sample there might be segments with noticeable taste differences. Latent class model analysis can be employed to identify the existence and the number of segment or classes in the population. In this context, belonging to a class is a probabilistic event and each consumer belongs to a class up to a certain probability. This probability of belonging to a class is linked to consumer characteristics. Latent class models are originated from the market research (Swait, 1994; Swait and Adamowicz, 2001a,b) and have been employed in other research area such as wilderness recreation, in a household time allocation study in Uganda (Aseete et al., 2018), choice models of transportation (Greene and Hensher, 2003).

Put simply, with C classes, the probability of each respondent with covariate z_i to belong to utility group c is :

$$\Pr(c) = \frac{\exp(z_i\theta_c)}{1 + \sum_{j=1}^{J-1} \exp(z_i\theta_c)} \tag{3.15}$$

Conditional on belonging to a given class c, the probability of choosing a given alternative k at choice occasion t is given by :

$$\Pr(y|c) = \frac{\exp(x_{ikt}\beta_c)}{1 + \sum_{k=1}^{K} \exp(x_{ikt}\beta_c)} \tag{3.16}$$

where θ_c and β_c are vectors of estimable parameters referring to the class c, J is the number of classes, K is the total number of alternative, z_i and x_i are respectively vector of consumer and attributes specific characteristics. For the last class C all the element of θ_c are set to unity for identification purposes. Also, following Malone and Lusk (2018) we address the issue that not all respondent “attend” or consider attributes when making choices. We address the issue that not all respondents attend to all the attributes. Some consumers proceed to randomly pick products or alternatives which is likely to have serious consequences on the derivation of estimates, especially when the object of neglect is the monetary attribute, such as the price of an alternative (Scarpa et al., 2009).As suggested by Malone and Lusk (2018) constraining one class attributes coefficients to zero allows to measure the Relative Risk

Share that is the proportion of respondents making purely random choice of alternatives. It also helps in automatically classifying those individual in a given class.

In our design respondents are provided with a sequence of four choices, so the probability of choosing this sequence given that the respondent is being in the class c is :

$$\Pr(y_1, ..., y_4|c) = \prod_{t=1}^{t=4} \frac{\exp(x_{ikt}\beta_c)}{\sum_{k=1}^{K} \exp(x_{ikt}\beta_c)} \tag{3.17}$$

Finally, the log-likelihood to maximize is:

$$L = \sum_i \sum_k I_k \ln \sum_c [\Pr(c) \Pr(y_1, ..., y_4|c)] \tag{3.18}$$

Where I_k is an indicator variable indicating the observed choice.

3.2 Results

3.2.1 Hedonic tasting results

Table 3.2 presents product tasting results in terms of percentage of consumers preferring extruded (instant) attribute by products, variety, age group and gender. The results concern selection between extruded and non-extruded of each of the 12 products (4 product×3 varieties). Hence participants tasted, in total, 24 samples of product following a specific protocol usually used in hedonic tasting. The table presents in column 1 the aggregated intensity of preference by products and varieties while columns 2, 3, 5 and 6 present disaggregated intensity (percentage) by gender and age group. Finally, columns 4 and 6 present the mean difference between gender and age subgroup percentage, as well as the student two-sided mean difference test.

At the aggregate level, the results show differencing preference intensity across product and varieties. Consumers prefer extruded flour used in thick porridge more than in any other product. The leading place of thick porridge is translated into all the three pearl millet varieties. Nevertheless there are differences related to varieties, extruded thick porridge, using local or traditional variety, outpace all other products, being preferred by 71% consumers compared to national improved variety (64%) and bio-fortified (59%). The percentage of consumers liking *fourra* products varieties ranges from 53 to 58%, suggesting an important share (42 to 47%) of consumers disliking extruded or time saving products. In addition, preference intensity for thin porridge and couscous ranges from 34 to 41%, implying that the majority of participants disliked these extruded products. The aggregated results help to provide a overall picture of preference patterns across products but hide heterogeneity underlined by socio-demographic characteristics.

Table 3.2: Proportion of consumers preferring extruded (instant) products by products, variety, age group and sex

		All	Gender			Age group		
		All	Male	Female	Diff (2-3)	Less 35	More than 35	Diff(5-6)
Product	Variety	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Thick Porridge (Flour)	Local Variety (hainikirey)	0.71	0.68	0.72	-0.04**	0.72	0.71	0.01
	National Improved (HKP)	0.64	0.65	0.68	-0.02	0.59	0.64	-0.05***
	International Improved (99001)	0.59	0.60	0.60	0.01	0.74	0.75	-0.01
Thin Porridge(Flour)	Local Variety (hainikirey)	0.39	0.46	0.32	0.13***	0.39	0.39	0.00
	National Improved (HKP)	0.36	0.43	0.32	0.11***	0.34	0.36	-0.02
	International Improved (99001)	0.41	0.49	0.38	0.11***	0.36	0.41	-0.05***
Couscous	Local Variety (hainikirey)	0.40	0.47	0.39	0.08***	0.34	0.40	-0.06***
	National Improved (HKP)	0.34	0.43	0.32	0.11***	0.27	0.34	-0.07***
	International Improved (99001)	0.38	0.47	0.37	0.10***	0.30	0.38	-0.08***
Fourra	Local Variety (hainikirey)	0.58	0.54	0.71	-0.17***	0.46	0.58	-0.12***
	National Improved (HKP)	0.53	0.50	0.61	-0.11***	0.47	0.53	-0.06***
	International Improved (99001)	0.58	0.60	0.61	-0.01	0.48	0.58	-0.06***

Hence, columns 2, 3, 5 and 6 present desegregated intensity (percentage) by gender and age group. And, columns 4 and 7 present the mean difference between gender and age subgroup percentage, as well as the student two-sided mean difference test. It appears that in 70 percent (17 out of 24) of comparison cases, student tests reveal statistically significant difference between subgroup, highlighting, the existence of heterogeneous preference by gender and age group. Especially, for the four most preferred products, women are significantly leading by 4 to 17% in terms of percentage of consumers liking extruded attributes. For the less preferred products, men are leading by 8 to 13% in terms of percentage of participants liking extruded products. Furthermore, the heterogeneity pattern lies also with participants' age group. For almost all the products, on average, older consumers prefer significantly extruded products than younger consumers. This difference is even more pronounced in the case of *fourra*, using local variety where the difference in terms of percentage of participants liking extruded attributes is about 12%.

The main message of this section is that there is taste variation across products and socio-demographic characteristics. Especially, extruded products using local or traditional variety stands out as the most preferred product compared to improved varieties. In addition, women and older consumers' preference are the major drivers of these variations. Before giving an interpretation of these patterns, we use in the next section, a much more rigorous method (latent class) to identify the underlying heterogeneity patterns.

3.2.2 Model preference evaluation selection

In this section we focus on describing our model selection procedure, goodness of fit, and findings. Table 3.3 shows the summary of the fit statistics for the latent class models, varying from one to four classes and following Adamowicz and Swait (2011) . Based on the three last criteria in Table 3.3, our data is best described by three classes because of the important inflexion at this point. For example, the criteria AIC and $AIC3$ decrease with the number of classes up to three classes before increasing. Therefore, the optimal number of classes that best describes our data is three. This suggests that our sample can be divided into three robust segments that appropriately display the underlining heterogeneity of consumer's preference.

Table 3.3: Comparative goodness-of-fit cereal food product panel latent class models

Classes	$Loglik$	$-2 * LogLik$	AIC	AIC3	BIC	K	N
1	-1054.3	2108.6	2134.6	2147.6	2196.4	13	856
2	-1025.5	2050.9	2102.9	2128.9	2226.5	26	856
3	-998.6	1997.2	2049.2	2075.2	2172.8	26	856
4	-986.6	1973.3	2051.3	2090.3	2236.6	39	856

$AIC = -2 * LogLik + 2K_c$, K_c = Number of parameters for $S - class$ model.
$AIC3 = -2 * LogLik + 3K_c$, $BIC = -2 * LogLik + LN(N)K_c$, N= Number of observations

After the choice of the number of class, we investigate the robustness of our estimates by using different algorithms that are Berndt–Hall–Hall–Hausman (BHHH), Broyden-Fletcher-Goldfarb-Shanno (BFGS), and Newton Rawson(NR). The change of algorithm does not have a noticeable effect on parameters estimates, suggesting that our results are not algorithm dependent and are likely to be global maximum. In addition, following Malone and Lusk (2018) we evaluated the Random Response Share (RRS) to evaluate the extent of the issue of not attending to attributes, that is the percentage of respondents not attending the attribute or making purely random choices.

The three-class solution of model 3.17 is shown in Table 3.4 and graphed by 3.2. The Random Response Share (RRS) that is the percentage of respondents not attending the attribute is 5%. For this latent class of utility model, coefficients are constrained to zero and therefore choices are determined solely by the random component utility function. As a result, it contains all the respondents not attending all the attributes or making purely random choices when trading attributes during the consumer decision making process leading to a choice. A low RRS is an indication that respondents are carefully evaluating alternatives based on attributes.

In addition, Table 3.4 contains Marginal Utilities (MUs) whose sign indicates the direction of change in choice probability in presence of an attribute or increase in price. A positive sign indicates a preferred attribute and a negative indicate a not-preferred attribute by the consumer. Classes 1 and 2 contain respondents who are attending attributes while making choices and will be further commented and characterized.

Consumers are grouped into two classes based on how they value attributes. Class 1 contains 38.7 % of respondents with positive valuation of the majority of attributes for all products. More importantly they have positive marginal utility for our attribute of interest that is the or extruded time-saving attribute. Consequently, extruded products are considered as improvement for this group of consumers. This holds for all the products with some difference in the magnitude of the MUs across product. Consistent with hedonic tasting results, extruded attributes of flour and *fourra* have the highest marginal utility or are more preferred compared to couscous. In addition, consistent with economic theory, the marginal utility of price is negative and statistically significant at 1% level. As a result, the increase in price is associated with a decrease in the choice probability or demand.

Class 2 is the largest class and groups 56.10% of respondents. Consumers in this group negatively value attributes of products including the time-saving attribute. The presence of attributes is not considered as a quality improvement and therefore decreases consumers likelihood to pick products presented to them. Another important fact is the positive coefficient of price. Even though not significant at 5% level, this may suggest that this group of consumer choices are driven by unobserved attributes of products that affect prices. For example, consumers of this group may be more quality conscious and see price as an indication of higher quality products. As pointed out by Train (2003), in modeling consumers' choices among products, it might be impossible to measure all of the relevant attributes of the various products, yet the price of the product can be expected to reflect unobserved (i.e. unmeasured) attributes. This is a main reason why price is affected. Insofar as the unobserved attributes are costly for the manufacturer, the price of the product can be expected to reflect these costs. The end result is that price is correlated with unobserved attributes, rather than being independent, as we have assumed in chapters 2 and 3.

Table 3.5 presents the relative change in demand for the different products following a relative change in attributes. These estimates give an idea of how sensitive product demand is following a change in attributes or price. Also, these estimates help to know what will happen to demand for other products when there is a change in a given product's attributes. It is important information to a seller because it can guide their decision of improving one product or not based on how market structure will change with an introduction of a new attribute.

Overall, the own price elasticities of demand (probability of choosing a product) are negative, which is consistent with demand theory, provided that we are not dealing with Giffen goods. Also, all the products are price inelastic as found by numerous studies in Sub-Saharan Africa on food products (Magrini et al., 2017b; Headey, 2016; Nakelse et al., 2018). In addition, consumers compensate for the decrease in the probability of choosing one good by increasing the demand of another good. For example, the change in the price of *fourra* by 1% lead to 0.30 % decrease in the probability to be chosen by consumers. This decrease of the probability is compensated for by an increase in the probability of couscous and flour by respectively 0.30 % and 0.31 %. Similarly, demand for couscous will decrease by 0.19% following 1% increase in the price of couscous. The two cases suggest that couscous is less price-elastic than *fourra*, which can be explained by the fact that couscous does not have close substitute as *fourra*, another version of thin porridge. Arc demand elasticity with

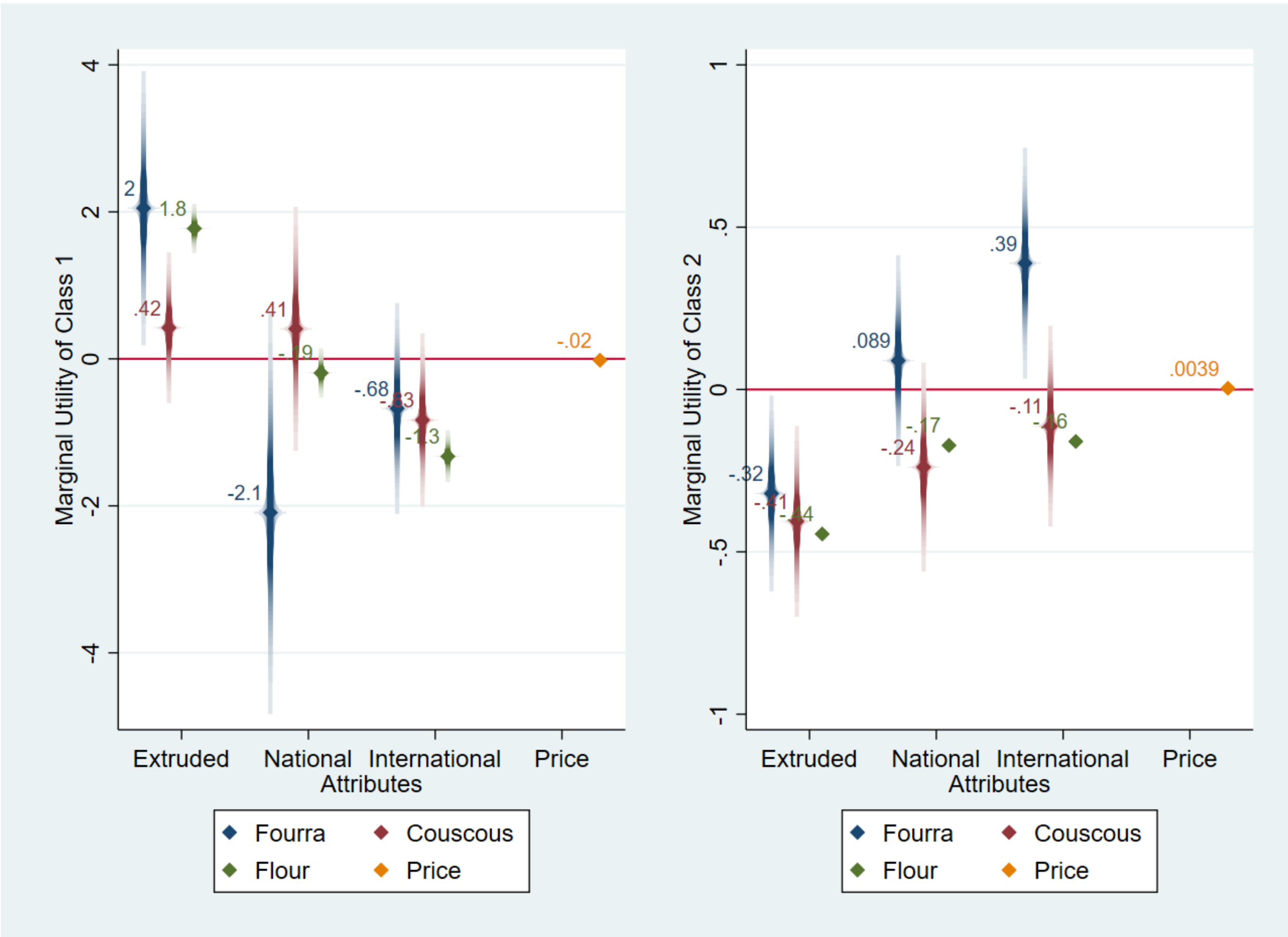


Figure 3.2: Latent Class Model Results

Table 3.4: Latent class model for cereal food products.

	Class 1			Class 2			Class 3
	$\hat{\beta}$	S.E of $\hat{\beta}$	P-value	$\hat{\beta}$	S.E of $\hat{\beta}$	P-value	
Utility function							
Price	-0.0195**	0.0087	0.026	0.0039*	0.007	0.060	
Fourra							
Extruded	2.050***	0.724	0.004	-.3201***	0.117	0.006	
National Improved (HKP)	-2.092**	1.065	0.049	0.089	0.126	0.479	.....(Fixed Parameter).....
International Improved (99001)	-0.675	0.557	0.225	.389***	0.138	0.004	
Constant	10.194**	4.155	0.014	0.347	0.599	0.562	
Couscous							
Extruded	0.423	0.398	0.288	-.406***	0.114	0.000	
National Improved (HKP)	0.408	0.645	0.527	-.239*	0.125	0.055	
International Improved (99001)	-.834*	0.458	0.068	-0.113	0.12	0.348	
Constant	11.406**	4.792	0.017	0.151	0.617	0.806	
Flour							
Extruded	1.774**	0.804	0.027	-.445***	0.13	0.000	
National Improved (HKP)	-0.192	0.599	0.748	-0.172	0.13	0.187	.....(Fixed Parameter).....
International Improved (99001)	-1.327***	0.514	0.009	-0.16	0.136	0.24	
Constant	10.827**	4.648	0.019	-0.166	0.622	0.789	
Goodness of fit							
Class Size	.387***	0.092	0.000	.561***	0.053	0.050	
Log likelihood function	-1041.76						
Restricted log likelihood	-1186.67						
P-Value of Chi squared	0						
McFadden Pseudo R-squared	0.122						
Estimation based on	N = 856	K = 32					
AIC/N	2.509						

respect to extruded or instant attribute is displayed in the second panel of table 3.5. Demand of product increases in percentage when their quality is improved from the non-extrusion to extrusion attribute.

Table 3.6 makes further characterization of classes in light of respondents' socio- economic demographic characteristics. Especially, column (3) tests the difference between class1 and class 2 by socio-economic and demographic characteristics. The variables for which we have a significant difference between class 1 and class 2 are: marital status, occupation status and the age of the respondents. It appears that class 1, which includes consumers with positive marginal utility for extruded attribute contains higher proportion married (68%), older (41 years old) consumers and those working the public sector. This group of consumers could be broadly designated as having higher opportunity cost of time.

On the other hand, class 2,which contains consumers with negative marginal utility for extruded products, is characterized by not married (50 %) housewives (10%) and younger (34 years old) consumers. In contrast to class 1 consumers, they could be characterized as

Table 3.5: Elasticity with respect to change in attribute (in row) choice on products choice probability (in Column)

	Fourra	*Couscous*	*Flour*	*Opt-out*
Change of Price				
Fourra	-0.378***	0.295***	0.313***	-0.224***
	(0.035)	(0.023)	(0.019)	(0.040)
Couscous	0.254***	-0.191***	0.189***	-0.375***
	(0.020)	(0.039)	(0.028)	(0.047)
Flour	0.183***	0.016	-0.399***	-0.302***
	(0.016)	(0.028)	(0.041)	(0.039)
Change to Extruded				
Fourra	0.0053***	-0.044***	-0.046***	-0.087***
	(0.007)	(0.004)	(0.003)	(0.008)
Couscous	-0.001	-.011*	-0.034***	0.017***
	(0.004)	(0.007)	(0.004)	(0.003)
Flour	-0.023***	-0.075***	0.088***	-0.049***
	(0.003)	(0.004)	(0.008)	(0.007)
Change to National Improved (HKP)				
Fourra	0.014**	-0.019***	-0.012***	-0.017**
	(0.007)	(0.004)	(0.003)	(0.009)
Couscous	-0.020***	0.030***	-0.025***	0.013***
	(0.002)	(0.0036)	(0.002)	(0.002)
Flour	-0.015***	-0.013***	0.034***	-0.014***
	(0.001)	(0.002)	(0.004)	(0.001)
Change of biofortified Improved (99001)				
Fourra	-0.034***	0.029***	0.017***	.028***
	(0.006)	(0.004)	(0.003)	(0.004)
Couscous	-.020***	.043***	-0.024***	-0.017***
	(0.002)	(0.004)	(0.002)	(0.004)
Flour	-0.042***	-0.038***	0.072***	-0.016***
	(0.002)	(0.004)	(0.007)	(0.006)

Standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

having lower opportunity cost of time.

Table 3.6: Profile of consumers in each class

	Class1 (1)	Class2 (2)	Difference (1-2) (3)	Class3 (4)
Marital Status				
Not Married	0.32	0.50	-0.18**	0.73
Married	0.68	0.49	0.19**	0.27
Gender				
Male	0.49	0.55	-0.06	0.50
Female	0.51	0.45	0.06	0.50
Income group				
Below 60 000	0.71	0.74	-0.03	0.50
Above 60 000	0.29	0.25	0.04	0.50
Occupation				
Farmer	0.14	0.07	0.07	0.25
Informal Sector	0.29	0.25	0.04	0.25
Formal Public	0.17	0.07	0.10*	0.25
Housewife	0.10	0.20	-0.10*	0.00
Student	0.12	0.20	-0.08	0.00
Others	0.17	0.21	-0.04	0.00
Age	41.00	34.00	7.00***	33.45
Household Size	8.31	7.82	0.49	8.00
All	0.39	0.56		0.05

Conclusion and discussion

In this chapter, we theoretically and empirically assessed the impact of a time-saving food attribute on consumer food choice in an urban area of Niger. Our theoretical assessment relied on Becker (1965) time allocation model to derive how a time-saving food product affects consumers' utility, hence food choice. Our empirical approach of assessing the effect of a time- saving attribute on consumer behavior relies on the random utility framework developed by McFadden (1973) and extended by Kamakura and Russell (1989) to a latent class framework. This framework allowed for identification of a taste heterogeneity pattern underlying consumer choice.

Hedonic tests highlighted a heterogeneous preference for the time-saving food attribute (extrusion). This heterogeneity varies across millet varieties, gender and age group. For example, male consumers prefer more extruded thin porridge and couscous whereas female consumers, in return, prefer more extruded thick porridge and *fourra*. Gender difference in food tasting is established by several studies in the literature (Dalton et al., 2002). Also, age is highlighted in the literature as a defining factor in taste variation. In a study for detection of the threshold of five basic tastes among different age group,Mojet et al. (2001) found significant effects for age as well as interaction between age and gender. They found that the older men were less sensitive than younger men and women for acetic acid, sucrose, citric acid, sodium and potassium chloride. Therefore, different preferences found in the hedonic data is mainly due to physiologic gender-based or age-based attributes that condition detection of major components of taste such as acetic acid, sucrose, citric acid, sodium and potassium chloride.

The hedonic model highlights some taste variation across gender and age, which is also revealed by the latent class model. Also, the latent class model highlights two groups of consumers with opposite preference for time-saving attributes across products. The first group of consumers has a positive marginal utility and mainly includes higher proportion married and older consumers as well as those working the public sector. The main explanation is that the opportunity cost of those consumers is high, and technology that will allow them to have additional time will be desired. In Niger, as in many households in West Africa, women are responsible for cooking and experience its daily burden. Therefore, additional free time will allow them to have more time for other tasks or leisure. This explanation holds also for the older consumers and workers in the public sector. The size of this class (37.8%) highlights the relative importance of a market segment in this product. Nevertheless, further financial investigation that includes evaluating the cost of production of extruded products as well as evaluating consumer willingness to pay is needed in order to assess the segment profitability. The financial analysis could also be supplemented with an economic analysis to thoroughly evaluate the direct (preference, profit, revenue, etc.) and indirect (environment, health, education, etc.) benefits of a large scale adoption of this type of food.

Another major finding is the preference for local variety compared to improved ones, in both hedonic tasting and econometric results. The direct implication of this is that, creation of the two varieties (improved national and biofortified improved international) may have failed to integrate a taste or demand dimension. In fact, market profiling segment is a missing piece in many breeding programs in Sub-Saharan Africa. Most of the breeding programs are supply driven programs that start with existing technologies (seeds, fertilizers) and focus on experimentation to remove constraints on adoption. This is the case of the variety International Improved (99001) developed by The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). It was one of the most preferred varieties by farmers during field experiments mainly because of its high yield and early maturity characteristics (Omanya, 2004) . Nevertheless, it occupies only 6% of the planting area (Ndjeunga et al., 2015). This is consistent with the low adoption rate of new improved cereal varieties in SSA which is rarely above 30% as highlighted by De Janvry and Sadoulet (2018). One major reason for this ceiling is the lack of a needs assessment and a business model that helps in assessing the economic benefit of breeding processes. Therefore, needs assessment can be a starting point for varietal creation. In doing so, varieties will be customized in response to consumers or demand heterogeneity and Willingness to Pay.

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Appendix A

Appendix of Chapter 1

A.1 Derivations

A.1.1 (Equation 1.2)

For a given commodity i, let be (u_h) the utility of household h, w the wage rate h hired-in and family labor supported by h, A the transfers received, π_h the profit function, (p^c) consumer price, (p^p) producers price, world price v input prices, and p^w world price. For the purpose of simplicity we drop the indices.

Given a farm production technology and an income constraint, by extension of Deaton (1989) household h living standard is represented as follows:

$$u_h = \psi\Big(w * T + A + \pi_h(v, w, p^p(p^w)), p^c(p^w)\Big) \tag{A.1}$$

Taking the partial derivative of both sides with respect to p^w, setting household income $I = (w * T + A + \pi_h(v, w, p^p(p^w))$ and by chain rule we have:

$$\frac{\partial u_h}{\partial p^w} = \frac{\partial \psi}{\partial p^c}\frac{\partial p^c}{\partial p^w} + \frac{\partial \psi}{\partial I}\frac{\partial \pi}{\partial p^p}\frac{\partial p^p}{\partial p^w} \tag{A.2}$$

From Roy's identity household $q = -\frac{\partial\psi}{\partial p^c}/\frac{\partial\psi}{\partial I}$ hence $\frac{\partial\psi}{\partial p} = -q\frac{\partial\psi}{\partial I}$. From Hotelling's Lemma we have the optimal output supply $y = \frac{\partial\pi}{\partial p}$. Equation A.2 becomes:

$$\frac{\partial u_h}{\partial p^w} = -q\frac{\partial\psi}{\partial I}\frac{\partial p^c}{\partial p} + y\frac{\partial\psi}{\partial I}\frac{\partial p^p}{\partial p} \tag{A.3}$$

Multiplying first term of equation A.3 right hand side by $\frac{p^w}{p^c}\frac{p^c}{p^w}$ and the second term by $\frac{p^w}{p^p}\frac{p^p}{p^w}$

$$\frac{\partial u_h}{\partial p^w} = -q\frac{\partial\psi}{\partial I}\frac{\partial p^c}{\partial p}\frac{p^w}{p^c}\frac{p^c}{p^w} + y\frac{\partial\psi}{\partial I}\frac{\partial p^p}{\partial p}\frac{p^w}{p^p}\frac{p^p}{p^w} \tag{A.4}$$

As a result

$$\frac{\partial u_h}{\partial p^w} = \frac{\partial\psi}{\partial I}y_i\varepsilon_{p^w,p^p} - \frac{\partial\psi}{\partial I}q_i\varepsilon_{p^w,p^c} \tag{A.5}$$

With $\varepsilon_{p^w,p^p} = \frac{\partial p^c}{\partial p}\frac{p^w}{p^c}$ and $\varepsilon_{p^w,p^c} = \frac{\partial p^p}{\partial p}\frac{p^w}{p^p}$ world price transmission elasticity to consumer and producer price, respectively.

A.1.2 Derivation of Equations 1.4 and 1.5

The net welfare change (equation 1.2) is represented by :

$$\Delta welfare = e(p^c(p_0^w), u_0) - e(p^c(p_1^w), u_0) + \pi(p^p(p_1^w), w_0, z_0) - \pi(p^p(p_0^w), w_0, z_0) \tag{A.6}$$

where $e()$ is the household expenditure function, p_0^w and p_1^w are the levels of world cereal price before and after a price shock, respectively. The levels of household utility before the price change is u_0. Notably, we assumed that labor is perfectly inelastic causing input price stickiness.

$$CV = e(p^c(p_0^w), u_0) - e(p^c(p_1^w), u_0)$$

Expanding $e(p^c(p_1^w), u_0)$, which is a composite function of $p^c(p_1^w)$, around the initial world price $(p_0^w)$and utility combination by means of a Taylor series, chain rule, and considering only one price change, we obtain:

$$
\begin{aligned}
e(p^c(p_1^w), u_0) \cong & e(p^c(p_0^w), u_0) + \frac{1}{1!}\sum_{i=1}^{n} \frac{\partial e(p_0, u_0)}{\partial p_i}\frac{\partial p_i^c}{\partial p^w}\Delta p_i^w \\
& + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \frac{\partial^2 e(p_0, u_0)}{\partial p_i \partial p_j}\frac{\partial p_i^c}{\partial p^w}\frac{\partial p_j^c}{\partial p^w}\Delta p_i^w \Delta p_j^w \\
& + R_2
\end{aligned}
$$

R_2 is the remainder term in the series, Δp_i^w and Δp_i^w are commodity i and j world price change, respectively.

$$
\begin{aligned}
e(p^c(p_1^w), u_0) \cong & e(p^c(p_0^w), u_0) + \frac{1}{1!}\sum_{i=1}^{n} h_i(p_0, u_0) p_i^c \frac{\partial p_i^c}{\partial p^w}\frac{p_i^w}{p_i^c}\frac{\Delta p_i^w}{p_i^w} \\
& + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \frac{\partial h_j(p_0, u_0)}{\partial p_i^c}\frac{p_i^c}{h_j} h_j p_j^c \frac{p_i^c}{p_i^c}\frac{\partial p_i^c}{\partial p_i^w}\frac{p_i^w}{p_i^c}\frac{\partial p_j^c}{\partial p_j^w}\frac{p_j^w}{p_j^c}\frac{\Delta p_i^w}{p_i^w}\frac{\Delta p_j^w}{p_j^w} \\
& + R_2
\end{aligned}
$$

$$
\begin{aligned}
-CV = e(p^c(p_1^w), u_0) - e(p^c(p_0^w), u_0) \cong & + \frac{1}{1!}\sum_{i=1}^{n} h_i(p_0, u_0) p_i^c \varepsilon_{p^w, p_i^c}(\zeta_{p_i^w}) \\
& + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} h_j p_j^c \eta_{ij} \varepsilon_{p^w, p_i^c} \varepsilon_{p^w, p_j^c} (\zeta_{p_i^w})(\zeta_{p_j^w}) \\
& + R_2
\end{aligned}
\tag{A.7}
$$

$\varepsilon_{p^w, p_i^c} = \frac{\partial p_i^c}{\partial p^w}\frac{p_i^w}{p_i^c}$, $\eta_{ij} = \frac{\partial h_j(p_0, u_0)}{\partial p_i^c}\frac{p_i^c}{h_j}$, $\zeta_{p_i^w} = \frac{\Delta p_i^w}{p_i^w}$ and $\zeta_{p_j^w} = \frac{\Delta p_j^w}{p_j^w}$. Since we are considering the world cereal price index for all the commodities and assuming there is no cross price effect, $\zeta_{p_i^w} = \zeta_{p_j^w} = \zeta_{p^w}$ and $\eta_{ij} = 0$. In addition If the quadratic terms alone form a good approximation, then :

$$CV \cong -\sum_{i=1}^{n} q_i p_i^c \varepsilon_{p^w,p_i^c} \zeta_{p^w} - \frac{1}{2}\sum_{i=1}^{n} q_i p_i^c \eta_{ii} \varepsilon^2_{p^w,p_i^c} (\zeta_{p^w})^2$$

Similarly,

$$PW \cong \sum_{i=1}^{n} q_i p_i^p \varepsilon_{p^w,p_i^p} \zeta_{p^w} + \frac{1}{2}\sum_{i=1}^{n} q_i p_i^p \gamma_{ii} \varepsilon^2_{p^w,p_i^p} (\zeta_{p^w})^2$$

with $\varepsilon_{p^w,p_i^p} = \frac{\partial p_i^p}{\partial p^w}\frac{p_i^w}{p_i^p}$, $\gamma_{ii} = \frac{\partial h_j(p_0,u_0)}{\partial p_i^p}\frac{p_i^p}{h_j}$, $\zeta_{p_i^w} = \frac{\Delta p_i^w}{p_i^w}$ and $\zeta_{p_j^w} = \frac{\Delta p_j^w}{p_j^w}$.

A.2 Demand estimation using QUAIDS approach

Demand elasticities estimation relies on the quadratic version of Deaton and Muellbauer (1980) Almost Ideal Demand System. The quadratic version is introduced by Banks et al. (1997). It allows the budget share to react more flexibly to the log of expenditure while respecting demand theory restrictions that is adding-up, homogeneity and Slutsky symetry. Following Ray (1983) and Poi et al. (2012) we also include the demographic characteristics z_k to control for any changes in the consumption pattern not related to price or expenditure. Therefore, in this QUAIDS model, the share of good $i = 1, ..., N$ consumed by household $h = 1, ..., H$ is defined as:

$$w_i^h = \alpha_i^h + \sum_{j=1}^{n} \gamma_{ij} lnp_j^h + (\beta_i + \eta_i z)\ln(\frac{m^h}{\bar{m}_0 a(p^h)}) + \frac{\lambda_i}{b(p^h)c(p,z)}\ln(\frac{m^h}{\bar{m}_0 a(p^h)})^2 + \mu_i^h \quad \text{(A.8)}$$

Where w_i^h is the share of total expenditure m^h is the household total expenditure allocated to i^{th} good by household h, p_i^h the price of j^{th} good; α_i, γ_{ij}, β_i, η_i, λ_i are vectors of associated parameters estimated. $\bar{m}_0(z)$ and $c(p,z)$ are two functions which measure the change in household expenditure as function of z, p and the parameters p and η. For the full specification of $\bar{m}_0$ and $c(p,z)$, see Magrini et al. (2017a).

We deal with the high proportion of zero expenditure shares registered for those commodities not consumed in the year of the survey by consumers. We address the situation using consistent two-step procedure. Following Shonkwiler and Yen (1999) and Zheng and Henneberry (2010), we first estimate a probit to calculate the probability for a given household to consuming a specific commodity. Following Magrini et al. (2017a) the covariates used in the estimations are households demographic characteristics (z_k). Second from the models estimated we compute for each commodity the standard normal Cumulative Distribution Function (CDF) and the standard normal Probability Density Function (PDF) in order to augment the QUAIDS specification as follows:

$$w_i^{h*} = \Phi(\hat{\tau}_i z) w_i + \delta_i \phi(\hat{\tau} z) + \xi_i \tag{A.9}$$

where w_i^* is the observed share of commodity i, Φ_i and phi are the (CDF) and (PDF) respectively, $\hat{\tau}_i$ is the vector of associated parameter estimated in the simple probit models. Since the budget shares no longer sum up to one, we adopt Yen et al. (2003) correction, treating the others crops as resitdual with no specific demand and imposing the following identity:

$$w_k^{h*} = 1 - \sum_{i=1}^{k-1} w_i^{h*} \tag{A.10}$$

The parameter of QUAIDS model is estimated using an iterated feasible generalized nonlinear least square. With the parameters estimated we compute the commodities expenditure and price elasticities, μ_i and ϵ_{ij} as follows:

$$\mu_i = \frac{\partial w_i^*}{lnm} = 1 + \frac{1}{w_i}[\beta_i + \eta_i z + \frac{2\lambda_i}{b(p)c(p,z)} ln\{\frac{m}{\bar{m_0}(z)a(p)}\}]\Phi(\hat{\tau_i} z), \tag{A.11}$$

$$\epsilon_{ij} = \frac{\partial w_i^*}{lnp_j} = \frac{1}{w_i}(\left\{\gamma_{ij} - [\beta_i + \eta_i z + \frac{2\lambda_i}{b(p)c(p,z)} ln\{\frac{m}{\bar{m_0}(z)a(p)}]\right\}$$
$$\times(\alpha_j + \sum_k \gamma_{ij} lnp_k) - \frac{(\beta_j + \eta_i z)\lambda_i}{b(p)c(p,z)}[ln\{\frac{m}{\bar{m_0}(z)a(p)}\}]^2) \tag{A.12}$$
$$\times\Phi(\hat{\tau_i z}) + \varphi_i \tau_{ij}(1 - \frac{\delta_i}{w_i}) - \delta_{ij}$$

where τ_{ij} represents the coeficient for price for the price j for the commodity i in the stage probit estimation and δ_{ij} is the Kronecker delta, meaning that it takes the value of "1" when $j = i$ and "0" otherwise. We skip the expenditure and price elasticities of other crops because the heterogenous nature of this group makes it difficult to interpret those elasticities. The compensated price elasticities are calculated as follows:

$$\epsilon_{ij}^H = \epsilon_{ij} + w_i \mu_i. \tag{A.13}$$

Finally, elasticities from equation A.13 can be directly plugged into equations 1.4 and 1.5.

A.3 Tables

Table A.1: Summary of estimated demand, supply and world price transmission elasticities

	Demand elasticities	Supply elasticities	Price transmission (consumer)	Price transmission (Producer)
Millet	0^a	0.120	0^a	0.29
Maize	-0.91	0.247	0.36	0.56
Rice	-0.75	0.00	0.25	0.25
Sorghum	0^a	0.084	0.62	0.41
Peanuts	-1.51	0^a	0^a	0^a
cowpea	-0.557	0.0925	0^a	0^a

[a] We set the value of the elasticity to zero in our welfare estimation whenever it is not significant at 10%

Table A.2: Summary of some estimates

	Purchases	Sales	CV^a	PW^b	Absolute Net Welfare	RelativeNet Welfare
Millet	70.50	103.00	0.00	0.40	0.40	0.56%
Maize	67.30	116.70	0.32	0.86	0.54	0.81%
Rice	91.00	81.70	0.30	0.27	-0.03	-0.03%
Sorghum	231.80	229.50	1.90	1.25	-0.65	-0.28%
Peanuts	17.30	314.60	0.00	0.00	0.00	0.00%
Cowpea	12.20	218.00	0.00	0.00	0.00	0.00%
Total	490.20	1063.60	2.51	2.77	0.26	0.05%

[a] Compensating Variation, [b] Change in Producer Welfare

Table A.3: Food Balance sheet in tons

	Variables	Total Quantity
Consumption	Millet	2.902e+09***
		(1.944e+06)
	Maize	2.972e+09***
		(2.355e+06)
	rice	3.805e+08***
		(373,711)
	sorghum	5.581e+09***
		(2.015e+06)
	Peanuts	2.995e+08***
		(256,643)
	cowpea	5.028e+08***
		(301,155)
Production	Millet	(1.864e+06)
		3.478e+09***
	Maize	(3.231e+06)
		4.747e+08***
	rice	(773,320)
		5.935e+09***
	sorghum	(2.215e+06)
		9.901e+08***
	Peanuts	(658,632)
		8.705e+08***
	cowpea	(482,545)
		2.652e+09***
sold	Millet	2.329e+08***
		(320,949)
	Maize	5.940e+08***
		(1.649e+06)
	rice	1.886e+08***
		(487,311)
	sorghum	8.110e+08***
		(701,664)
	Peanuts	5.138e+08***
		(417,700)
	cowpea	3.389e+08***
		(284,557)

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A.4: Food Balance sheet in tons (Continued)

	Variables	Total Quantity
Gifts	Millet	8.271e+06***
		(22,714)
	Maize	1.174e+07***
		(31,961)
	rice	1.547e+06***
		(8,316)
	sorghum	1.676e+07***
		(34,554)
	Peanuts	1.141e+07***
		(33,612)
	cowpea	2.941e+06***
		(12,569)
Seed	Millet	7.180e+07***
		(48,914)
	Maize	7.340e+07***
		(53,095)
	rice	2.391e+07***
		(40,758)
	sorghum	1.387e+08***
		(69,414)
	Peanuts	2.009e+08***
		(136,311)
	cowpea	4.857e+07***
		(30,287)
Stock	Millet	2.970e+09***
		(2.114e+06)
	Maize	2.944e+09***
		(2.403e+06)
	rice	3.694e+08***
		(371,659)
	sorghum	5.680e+09***
		(2.087e+06)
	Peanuts	2.501e+08***
		(253,647)
	cowpea	4.858e+08***
		(312,261)

Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A.5: Food Balance sheet in ton (Continued)

Seed	Millet	8.974e+06***
		(19,846)
	Maize	7.512e+06***
		(12,955)
	rice	23,528***
		(693.7)
	sorghum	2.454e+07***
		(28,135)
	Peanuts	44,495***
		(868.8)
	cowpea	0
		(0)
Losses	Millet	1.009e+07***
		(22,028)
	Maize	4.869e+06***
		(16,353)
	rice	1.174e+06***
		(6,415)
	sorghum	7.789e+06***
		(20,007)
	Peanuts	231,583***
		(1,350)
	cowpea	1.731e+06***
		(5,582)
	Observations	7,025,645

Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A.6: Expenditure and Hicksian price elasticities for cereals and legumes at population means

	Income Elsticity	Hicksian price elasticities					
		Millet	Maize	Rice	Sorghum	Peanuts	Cowpea
Millet	1.622***	-1.174***	0.211*	-0.271	0.250**	-1.129	0.304**
	(0.248)	(0.157)	(0.0837)	(0.263)	(0.0557)	(0.641)	(0.0611)
Maize	1.203***	0.878*	-0.630***	-0.365	0.337**	0.424***	0.201**
	(0.0520)	(0.281)	(0.0287)	(0.262)	(0.0982)	(0.0586)	(0.0480)
Rice	-1.099	-0.354	-0.0826	1.805	-0.434	-0.257	-0.341**
	(1.038)	(0.253)	(0.149)	(1.534)	(0.314)	(0.262)	(0.103)
Sorghum	2.353**	0.583*	0.164	-0.504	-0.689**	0.710	-0.205
	(0.620)	(0.205)	(0.126)	(0.624)	(0.193)	(0.331)	(0.0875)
Peanuts	0.992***	-0.482	0.112	-0.0369	0.228*	-0.316	0.359***
	(0.00393)	(0.226)	(0.0501)	(0.0172)	(0.0878)	(0.285)	(0.0327)
Cowpea	1.030***	0.279*	0.0424***	-0.241	-0.135	0.611	-0.389***
	(0.0280)	(0.0920)	(0.00509)	(0.150)	(0.0908)	(0.303)	(0.0461)

Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A.7: Marshallian price elasticities for cereals and legumes at population means

	Marshallian oprice elasticities					
	Millet	Maize	Rice	Sorghum	Peanuts	Cowpea
Millet	-1.304***	0.0864**	-0.0266	0.201***	-1.227	0.0665
	(0.111)	(0.0228)	(0.0469)	(0.0191)	(0.673)	(0.0551)
Maize	0.432	-0.944***	-0.206	-0.0706***	0.159	-0.351
	(0.185)	(0.0164)	(0.122)	(0.00602)	(0.0858)	(0.163)
Rice	-0.682	-0.296*	1.843	-0.526***	-0.439	-0.969
	(0.339)	(0.0974)	(1.590)	(0.0691)	(0.237)	(0.601)
Sorghum	0.229	-0.133**	0.0556	-0.454***	0.477	-1.072***
	(0.123)	(0.0246)	(0.152)	(0.0359)	(0.257)	(0.133)
Peanuts	-0.639*	0.00652**	-0.000206	0.266***	-0.406	0.0402
	(0.254)	(0.00199)	(0.00465)	(0.0230)	(0.325)	(0.0198)
Cowpea	0.197*	-0.0183***	-0.194	-0.441***	0.560	-0.257
	(0.0805)	(0.00284)	(0.108)	(0.0501)	(0.307)	(0.123)

Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A.8: Estimation results of the QUAIDS model at the second budgeting stage

Price	$\gamma 11$	-0.250***	$\gamma 31$	-0.0105	$\gamma 51$	-0.194***	$\gamma 61$	0.122**
		(0.0857)		(0.0383)		(0.0566)		(0.0575)
	$\gamma 12$	0.176***	$\gamma 32$	-0.130***	$\gamma 52$	-0.0294	$\gamma 62$	-0.213***
		(0.0581)		(0.0419)		(0.0586)		(0.0626)
	$\gamma 13$	-0.0105	$\gamma 33$	0.162***	$\gamma 53$	-0.00471	$\gamma 63$	0.0571
		(0.0383)		(0.0338)		(0.0360)		(0.0421)
	$\gamma 14$	0.157**	$\gamma 34$	-0.0732	$\gamma 54$	0.0898	$\gamma 64$	-0.184***
		(0.0632)		(0.0452)		(0.0665)		(0.0672)
	$\gamma 15$	-0.194***	$\gamma 35$	-0.00471	$\gamma 55$	-0.0386	$\gamma 65$	0.218***
		(0.0566)		(0.0360)		(0.0723)		(0.0729)
	$\gamma 21$	0.176***	$\gamma 41$	0.157**	$\gamma 16$	0.122**		
		(0.0581)		(0.0632)		(0.0575)		
	$\gamma 22$	0.130*	$\gamma 42$	0.0680	$\gamma 26$	-0.213***		
		(0.0747)		(0.0651)		(0.0626)		
	$\gamma 23$	-0.130***	$\gamma 43$	-0.0732	$\gamma 36$	0.0571		
		(0.0419)		(0.0452)		(0.0421)		
	$\gamma 24$	0.0680	$\gamma 44$	-0.0582	$\gamma 46$	-0.184***		
		(0.0651)		(0.0850)		(0.0672)		
	$\gamma 25$	-0.0294	$\gamma 45$	0.0898	$\gamma 56$	0.177***		
		(0.0586)		(0.0665)		(0.0594)		
	Observations	1,274						

Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table A.9: Estimation results of the QUAIDS model at the second budgeting stage(Continued)

Constant	$\alpha1$	-0.106	Expenditure	$\beta1$	0.183***	Demographic Characteristics	$\eta11$	-0.00127
		(0.147)			(0.0316)			(0.00206)
	$\alpha2$	0.599***		$\beta2$	0.227***		$\eta12$	0.00991***
		(0.138)			(0.0419)			(0.00279)
	$\alpha3$	0.0913		$\beta3$	-0.413***		$\eta13$	0.00236
		(0.0983)			(0.0228)			(0.00170)
	$\alpha4$	0.274*		$\beta4$	0.554***		$\eta14$	-0.00102
		(0.159)			(0.0356)			(0.00240)
	$\alpha5$	-0.0168		$\beta5$	-0.0878**		$\eta15$	-4.46e-05
		(0.147)			(0.0414)			(0.00334)
	$\alpha6$	0.159		$\beta6$	-0.464***		$\eta16$	-0.00993***
		(0.152)			(0.0417)			(0.00311)
Expenditure squared	$\eta21$	-0.00857	Expenditure squared	$\lambda1$	0.0348***	Probability density	d1	0.434***
		(0.00783)			(0.00758)			(0.104)
	eta22	-0.0183*		$\lambda2$	0.000386		d2	-0.0121
		(0.0100)			(0.0108)			(0.125)
	$\eta23$	0.0223***		$\lambda3$	-0.0417***		d3	0.802***
		(0.00513)			(0.00537)			(0.130)
	$\eta24$	-0.0231***		$\lambda4$	0.0514***		d4	0.762***
		(0.00871)			(0.00888)			(0.144)
	$\eta25$	0.0227**		$\lambda5$	-0.00631		d5	0.187
		(0.00935)			(0.0108)			(0.126)
	$\eta26$	0.00486		$\lambda6$	-0.0386***			
		(0.0102)			(0.0108)			
Observations	1274							

Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.4 figure

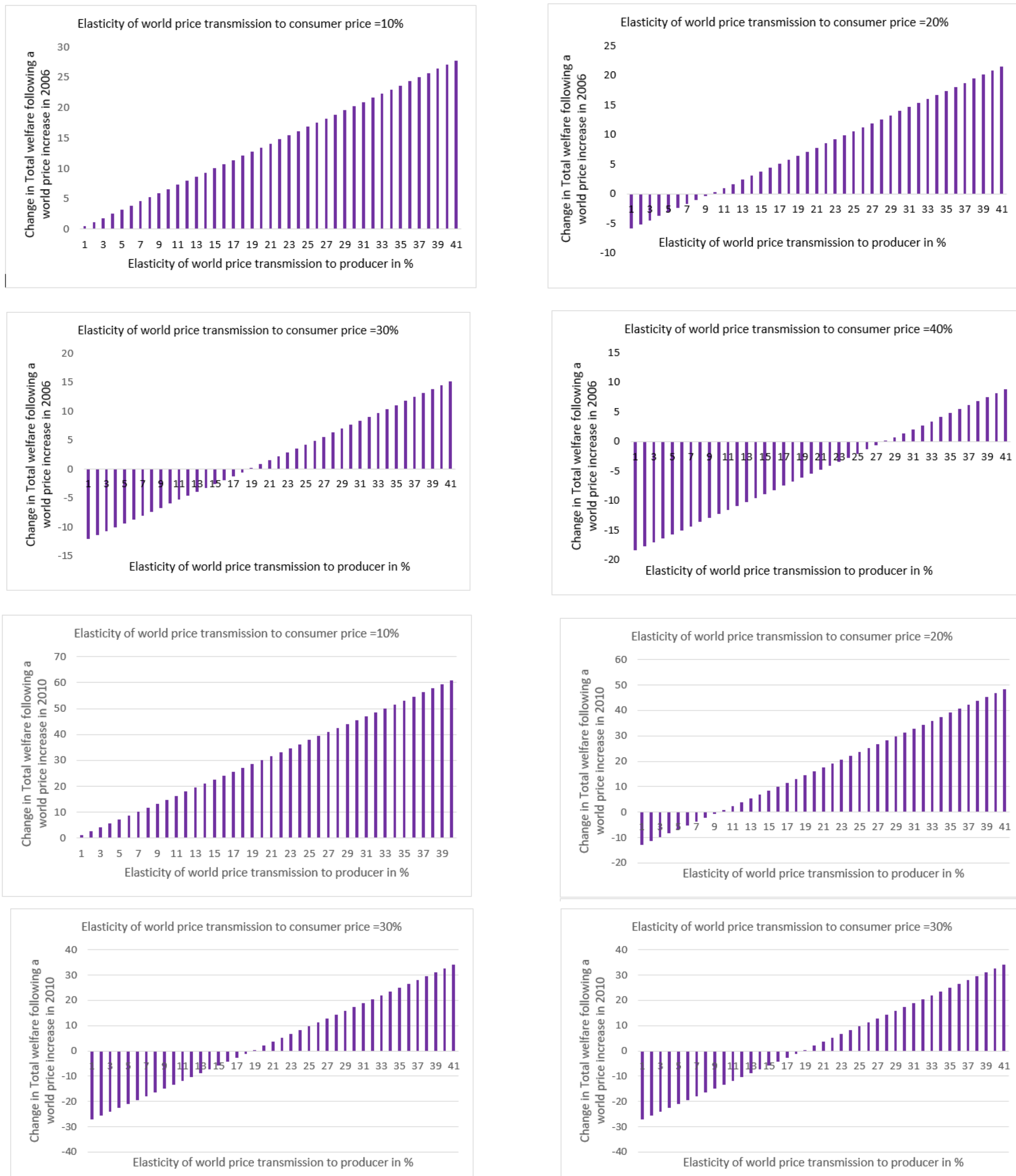

Figure A.1: Simulation of relative welfare change based on world price transmission elasticities variation

A.5 METHODOLOGY OF THE SURVEY

The evaluation of the agricultural campaign was carried out by the statistical system of the Ministry in charge of Agriculture through the permanent agricultural survey under the statistical visa No. AP2008002CNSCS4 of October 7, 20 08 by the National Council of Statistics in accordance with the Law on National Statistical Activities.

A.5.1 Objective

The primary purpose of the scheme is the evaluation of areas, yields and productions of the main crops in the rainy season and in the dry season. This assessment is done in two stages: August and September, for forecasts season, and at the end of harvest for the final results. The specific objectives of the investigation are:

- evaluate areas, yields and final agricultural productions by provinces and country for each crop.
- make forecasts of cereal harvests in September each year to inform the government and its partners early on development in an objective way about the campaign. These forecasts enable a forecast cereal balance to be established;
- make estimates of residual peasant stocks during September;

In addition to these data, the device makes it possible to collect credit information, use of inputs, marketing, the agricultural population, the occupation of the agricultural population, the sources of money income, the livestock attached to agricultural households, the demography of farm households, etc. The data being collected with a sufficiently detailed level, more in-depth analyzes can be done, especially on household food security, the analyzes differentiated by sex, ...

A.5.2 Field of investigation

The agricultural survey covers the entire rural area of the country. Survey plan: This is a random sample survey at two degrees, with stratification at each degree. Sample frame: At the first stage the sampling frame consists of the list of villages from the 2006 census. At the second stage the frame is obtained in listing the agricultural households in the villages drawn from first stage. Sample size: At first level, the number of sample villages per province is proportional to the population of the province. The sample is drawn by province in proportion to the size of the village, systematically after classification villages in order of increasing size. The number of sampled villages is 706 in total. In fact, this sample is a subsample of the national census on 2006. In the second stage, in each sampled village, one draws 8 farming households with probability proportional to the size of the village.

A.5.3 Fact Sheet

- Fact Sheet 1: Census of Household Members

  Section F.1.0: Identification Elements

  Section F.1.1: Census of Household Members

- Fact Sheet 2: Inventory and Characterization of Household Parcels

  Section F.2.0: Identification Elements

  Section F2.1: Inventory and Characterization of Household Parcels

  Section F2 .2: Inventory and Characterization of Abandoned Parcels

- Fact Sheet 3: Measuring Surfaces, Installation and Weights of Yield Squares

  Section F3.0: Identification Elements

  Section F3.1: Surface Measurement, Installation and Weighting of Performance Squares

- Fact Sheet 4: Acquiring and Using Inputs

Section F.4.0: Identification Elements

Section F4.1: Use of Inputs During This 2011/2012 Campaign

Section F4.2: Acquisition of Inputs During the Present Campaign 2011-2012

- Fact Sheet 5 And 6: Estimation of Farming Stocks and Forecast of Harvesting Section F.5.0: Identification Elements Section F5.1: Estimation of Farming Stocks

  Section F6.1: Forecast For 2011/12 Crops and Production of the 2010/2011 Campaign

  Section F6.2: Estimated Production of Cultivated Plots Past And Abandoned Campaign Presents

- Fact Sheet 7: Household Chef

  Section F.7.0: Identification Elements

  Section F7.1: Household Chef

- Fact Sheet 9: Nutritional Monitoring of Children Under 5 Years Section F.9.0: Identification Elements

  Section F9.1: Nutritional Monitoring and Anthropometric Measures for Children Under 5 Years Old

- Fact Sheet 10: Agricultural Equipment and Infrastructure

  Section F10.1: Agricultural Equipment and Household Infrastructure

  Section F10.2: Charges Supported In 2011 In the Operation of Household Equipment and Infrastructure

- Fact Sheet 12: Employment and Labor Section F12.0: Identification Elements

  Section F12.1: Employment and Labor

- Fact Sheet 13: Food Security

  Section F.13.0: Identification Elements

Section F13.1: Food Consumption

Section F13.2: Level of Food Security of Households

- Fact Sheet 14: Trees

Appendix B

Appendix of Chapter 2

B.1 Model Selection Test Procedure

In order to test the appropriateness of we apply the test on non-nested choice models which is based on the AIC proposed by Ben-Akiva and Swait (1986). The test is carried out as follows. Assumed there are two models (model 1 and model 2). Model 1 explains choices using K_1 variables and model 2 explains the same choices using K_2 choices. Also, assume that the models are different either by their functional form or by the number of variables. The fitness measured is defined as follows: $\bar{\rho}_j^2 = 1 - \frac{L_j - K_j}{L(0)}$ where L_j is the log(simulated) likelihood for model $j = 1, 2$. $L(0)$ is the log-likelihood for a model —multinomial logit in our case— with constant only. Under the null hypothesis that model 2 is the true model, its fitness measure will be higher. More importantly the difference between the two fitness measures of both models is : $\Pr(|\bar{\rho}_2^2 - \bar{\rho}_1^2| \geq Z) \leq \Phi(-\sqrt{-2ZL(0)})$ where Z is the difference of the fitness measures between models. This probability is calculated for all the pairwise combinations of models 2.2 and 2.3 estimated with and without correlation. Using above definition we calculated that the probability that the model 2 under correlation of the coefficients is incorrectly specify is almost equal to zero as shown in table 2.2.

B.2 Survey Materials

B.2.1 Questions on Choice Experiment

Imagine you are purchasing a package of Dègué at your local store or market. You can choose between two packages of Dègué that Package A and B. Package A has a date of expiration on it so that you know if it is expired or not. Package B did not have this information that is you do not know if it is expired or not. In addition, on package A has a Family picture on while package B does not. Package A has zero percent of iron daily requirement that is it does not contain iron micronutrient to satisfy your body daily requirement. By contrast, Package B contains iron that represents 75% (three quarter) of your body daily requirement. But to have Package A you must pay 550FCFA and to have package B you must pay 450. If you choose package A check the corresponding box, if you decide to choose package B check its corresponding Box. If you do not prefer package A nor B then check the box corresponding to package C

B.2.2 Information on Micronutrient (Iron)

including, red cell production in quantity and quality, the productivity that comes from having good quality blood, allows a pregnant woman to have a healthy baby, to prevent anemia particularly for in pregnant women, allows the brain to function properly, allows a good growth and learning skills of the child, prevent certain diseases of the liver and pancreas, etc. Without enough iron, your body can't produce enough of a substance in red blood cells that enables them to carry oxygen. As a result, iron deficiency anemia may leave with the following symptoms: extreme fatigue, weakness, pale skin, chest pain, fast heartbeat or shortness of breath, cold hands and feet, headache, dizziness or lightheadedness, poor appetite, especially in infants and children with iron deficiency anemia. One of the causes A lack of iron in your diet. Your body regularly gets iron from the foods you eat. If you consume too little iron, over time your body can become iron deficient. Examples of iron-rich *foods include meat, eggs, leafy green vegetables and iron-fortified foods. For proper growth and development, infants and children need iron from their diets, too. Women, infants and children are greater risk of iron deficiency anemia. Infants, especially those who were low birth weight or born prematurely, who don't get enough iron from breast milk or formula may be at risk of iron deficiency. Children need extra iron during growth spurts. If your child isn't eating a healthy, varied diet, he or she may be at risk of anemia.*

B.2.3 Cheap Talk Script

We are here today to conduct a study on your preferences for millet products. In particular, we want to know how you will react if we give you information on the Dègué. We will give you information about two packets of Dègué and ask you what you will choose. Your answers will be anonymous. At the end of the study you will be paid an amount of 2000 FCFA for your time.

In addition, the information we gather from this study will be very useful in designing an appropriate labeling and promotion strategy that will improve the sales of women producing this product and also the nutrition of the population. Therefore, it is important that you understand the experience and think carefully before making your answers. In a recent study, several different groups of people were asked whether they would purchase a new food product similar to the one you are about to be asked about. This purchase was hypothetical for these people, as it will be for you. No one actually had to pay money when they indicated a particular preference. The results of this study were that over 80% of people said they would buy the new food. However, when a store actually put the same new food on their shelf, but where payment was real and people really did have to pay money if they decided to purchase the new food, the results were that only 43% of people actually bought the new food. That's quite a difference, isn't it? We call this "hypothetical bias." Hypothetical bias is the difference that we continually see in the way people respond to hypothetical purchase questions as compared to real situations.

Why this is so? In my opinion when you go the market and wants to buy a product you have a limited budget to make purchases for you or your household. You really think twice before spending your money. So you don't waste your money buying something that you or your household doesn't need. This is what is happening in the real life. But in the hypothetical life you may think that you really don't lose money or since you don't have to eat the product you are more incline to make a decision that may not represents what you will do in real market. So if I were in your place, I would ask myself: I were really shopping at the local store or market and I had X FCFA to have a package of Dègué. Do I really want to spend X FCFA to have package A or Y to have package B ? If the answer is yes in either of the case, I check the corresponding box and left blank the other cases. If my answer is no in both of the cases, I check the last box. In any case, I ask you to respond to each of the following purchase questions just exactly as you would if you were really in a local store or market and were going to face the consequences of your decision: which is to pay money if you decide to buy a food.

B.3 Estimation outputs

Table B.1: Cholesky Matrix from MSL Estimates in Preference Space

	Expiration Date	Micronutrient	Origin	Family Image
Expiration Date	0.811***			
	(0.139)			
Micronutrient (25 % of DR)	-0.595***	0.207**		
	(0.158)	(0.0844)		
Origin	-0.0457	0.0904	0.196	
	(0.213)	(0.153)	(0.188)	
Family Image	0.178	0.240	-0.973***	-0.105
	(0.654)	(0.149)	(0.192)	(0.534)

Standard errors in parentheses, *** $p < 0.01$, $** p < 0.05$, * $p < 0.1$, with p the $p-value$.

Table B.2: Cholesky Matrix from MSL Estimates in WTP Space

Parameter	$ln\lambda_n$	Expiration Date	Micronutrient	Origin	Family Image
$ln\lambda_n$	-116.5***				
	(19.95)				
Expiration Date	41.38*	-33.23***			
	(21.69)	(11.56)			
Micronutrient (25 % of DR)	3.163	0.438***	-25.73		
	(27.68)	(0.105)	(21.30)		
Origin	1.407	-82.36***	0.291**	40.46***	
	(16.65)	(31.01)	(0.134)	(10.92)	
Family Image	-85.62***	0.128	-42.21	0.0163	0.0518
	(30.37)	(0.131)	(46.82)	(0.178)	(0.182)

Standard errors in parentheses, *** $p < 0.01$, $**\,p < 0.05$, * $p < 0.1$, with p the $p - value$.

Appendix C

Appendix of Chapter 3

C.1 Derivations

Matricial form of system 3.9 is :

$$\begin{pmatrix} U_{ZZ}G_x^2 + U_Z G_{xx} & U_{ZZ}G_t G_x + U_Z G_{xt} & -1 \\ U_{ZZ}G_t G_x + U_Z G_{tx} & U_{ZZ}G_t^2 + U_Z G_{tt} & -w \\ -1 & -w & 0 \end{pmatrix} \begin{pmatrix} \frac{\partial x^*}{\partial \theta} \\ \frac{\partial t^*}{\partial \theta} \\ \frac{\partial \lambda^*}{\partial \theta} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ -w \end{pmatrix}$$

The bordered hessian matrix of 3.9 is :

$$BH_1 = \begin{vmatrix} U_{ZZ}G_t^2 + U_Z G_{tt} & -w \\ -w & 0 \end{vmatrix} = -w^2 < 0$$

Computing the determinant:

$$BH_2 = \begin{vmatrix} U_{ZZ}G_x^2 + U_Z G_{xx} & U_{ZZ}G_tG_x + U_ZG_{xt} & -1 \\ U_{ZZ}G_tG_x + U_ZG_{tx} & U_{ZZ}G_t^2 + U_ZG_{tt} & -w \\ -1 & -w & 0 \end{vmatrix}$$

$$= (-1)\begin{vmatrix} U_{ZZ}G_tG_x + U_ZG_{xt} & -1 \\ U_{ZZ}G_t^2 + U_ZG_{tt} & -w \end{vmatrix} + w\begin{vmatrix} U_{ZZ}G_x^2 + U_ZG_{xx} & -1 \\ U_{ZZ}G_tG_x + U_ZG_{tx} & -w \end{vmatrix}$$

$$= (-1)\left[-w(U_{ZZ}G_tG_x + U_ZG_{xt}) + U_{ZZ}G_t^2 + U_ZG_{tt}\right] + w\left[-w(U_{ZZ}G_x^2 + U_ZG_{xx}) + U_{ZZ}G_tG_x + U_ZG_{tx}\right]$$

$$= w(U_{ZZ}G_tG_x + U_ZG_{xt}) - U_{ZZ}G_t^2 - U_ZG_{tt}) + w[-U_{ZZ}G_tG_x - U_Z\tfrac{G_t}{G_x}G_{xx} + U_{ZZ}G_tG_x + U_ZG_{tx}]$$

$$= U_{ZZ}G_t^2 + U_Z\tfrac{G_t}{G_x}G_{xt} - U_{ZZ}G_t^2 - U_ZG_{tt} + w[-U_{ZZ}G_tG_x - U_Z\tfrac{G_t}{G_x}G_{xx} + U_{ZZ}G_tG_x + U_ZG_{tx}]$$

$$= U_Z\tfrac{G_t}{G_x}G_{xt} - U_ZG_{tt} + w[-U_{ZZ}G_tG_x - U_Z\tfrac{G_t}{G_x}G_{xx} + U_{ZZ}G_tG_x + U_ZG_{tx}]$$

$$= U_Z\tfrac{G_t}{G_x}G_{xt} - U_ZG_{tt} - U_{ZZ}G_t^2 - U_Z(\tfrac{G_t}{G_x})^2G_{xx} + U_{ZZ}G_t^2 + U_Z\tfrac{G_t}{G_x}G_{tx}]$$

$$= U_Z\tfrac{G_t}{G_x}G_{xt} - U_ZG_{tt} - U_Z(\tfrac{G_t}{G_x})^2G_{xx} + U_Z\tfrac{G_t}{G_x}G_{tx}$$

$$= 2 * U_Z\tfrac{G_t}{G_x}G_{xt} - U_ZG_{tt} - U_Z(\tfrac{G_t}{G_x})^2G_{xx}$$

A for a constrained maximization $|BH_2|$ must be positive for the Hessian to be negative semi definite and therefore admit solution to our maximization. A sufficient condition to satisfy $|BH_2| > 0$ is $G_{tx} > 0$. Solving for $\frac{\partial x^*}{\partial \theta}$ using Cramer's rule gives:

$$\frac{\partial x^*}{\partial \theta} = \frac{\begin{vmatrix} 0 & U_{ZZ}G_tG_x + U_ZG_{xt} & -1 \\ 0 & U_{ZZ}G_t^2 + U_ZG_{tt} & -w \\ w & -1 & 0 \end{vmatrix}}{|BH_2|}$$

$$= \frac{w(-w(U_{ZZ}G_tG_x+U_ZG_{xt})+U_{ZZ}G_t^2+U_ZG_{tt})}{|BH_2|}$$

$$= \frac{\frac{G_t}{G_x}(-\frac{G_t}{G_x}(U_{ZZ}G_tG_x+U_ZG_{xt})+U_{ZZ}G_t^2+U_ZG_{tt})}{|BH_2|}, w = \frac{G_t}{G_x}$$

$$= \frac{\frac{G_t}{G_x}(-U_{ZZ}G_t^2-U_Z\frac{G_t}{G_x}G_{xt}+U_{ZZ}G_t^2+U_ZG_{tt})}{|BH_2|},$$

$$= \frac{\frac{G_t}{G_x}(-U_Z\frac{G_t}{G_x}G_{xt}+U_ZG_{tt})}{|BH_2|}$$

$$= \frac{\frac{G_t}{G_x}U_Z(-\frac{G_t}{G_x}G_{xt}+G_{tt})}{|BH_2|}$$

$$= \frac{\frac{G_t}{G_x^2}U_Z(-G_tG_{xt}+G_xG_{tt})}{|BH_2|}$$

Solving for $\frac{\partial t^*}{\partial \theta}$ using Cramer's rule gives:

$$\frac{\partial t^*}{\partial \theta} = \frac{\begin{vmatrix} U_{ZZ}G_x^2 + U_ZG_{xx} & 0 & -1 \\ U_{ZZ}G_tG_x + U_ZG_{tx} & 0 & -w \\ -1 & w & 0 \end{vmatrix}}{|BH_2|}$$

$$= \frac{w(-w(U_{ZZ}G_x^2+U_ZG_{xx})+U_{ZZ}G_tG_x+U_ZG_{tx})}{|BH_2|}$$

$$= \frac{w(-\frac{G_t}{G_x}(\frac{G_x}{G_t}U_{ZZ}G_tG_x+U_ZG_{xx})+U_{ZZ}G_tG_x+U_ZG_{tx})}{|BH_2|}$$

$$= \frac{w(-U_{ZZ}G_tG_x-\frac{G_t}{G_x}U_ZG_{xx}+U_{ZZ}G_tG_x+U_ZG_{tx})}{|BH_2|}$$

$$= \frac{\frac{G_t}{G_x}U_Z(-\frac{G_t}{G_x}G_{xx}+G_{tx})}{|BH_2|}$$

$$= \frac{\frac{G_t}{G_x^2}U_Z(-G_tG_{xx}+G_xG_{tx})}{|BH_2|}$$