Policy, Prices, Expenditures and Dietary Diversity of Rwandan Households

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Abstract

Over the past two decades, Rwanda has experienced impressive economic growth, resulting in considerable improvements in living standards and poverty reduction. Despite these gains, progress on nutritional status, especially those of rural children, continues to be a serious concern. This paper seeks to analyze dietary quality relative to income status and prices based on geographic location and other demographic variables. Findings begin to fill the analytic gap in our understanding of how agriculture and food policy can improve smallholder dietary diversity in ways that can in turn contribute to better health outcomes. Dietary diversity for the poor was largely influenced by household expenditures, meat prices, pulse production, fruit and vegetable production, ownership of animals, and land size. Policies/programs had an overall small and mixed effect on dietary diversity. Rwandans are price and expenditure sensitive on the demand side and thin markets exist on the supply side with distant markets that provide little diversity of foods in the rural markets. Multipronged policy and programs focused on increasing incomes, diversifying production, addressing relative prices, and nutrition education are required to increase dietary diversity and rural household health outcomes.

Keywords:

Dietary Diversity

Rwanda

Income Status

Introduction

Rwanda, like many developing countries, faces the paradox of improvements in economic and agricultural productivity growth and the reduction in poverty (79% in 2001 to 63% in 2014), but not being able to significantly improve nutrition and health outcomes (World Bank 2015). Key indicators of nutritional health include child nutrition status, childhood stunting in Rwanda is one of the worst in the world, 44% in 2010 (World Bank 2015), and 18% of Rwandan children under 5 years of age were underweight in the same year (Fernandez, Himes, and Onis 2002, Christian 2010, WHO 2010). Translating economic growth into considerable improvements in nutritional status is critical to countries like Rwanda. Although food and nutrition are important factors, programmatic recommendations to address household level malnutrition remain difficult.

Recently, development agencies have focused on the lack of dietary diversity as a critical impediment to the reduction of the high rates of malnutrition in developing countries (Jones, Shrinivas, and Bezner-Kerr 2014, Cordeiro et al. 2012). Increased dietary diversity is thought to increase the probability of a healthier diet (Thorne-Lyman et al. 2010, Marshall, Burrows, and Collins 2014) and positive anthropometric outcomes, in Africa (Arimond and Ruel 2004, Headey 2013). However, it is not clear how to facilitate this dietary change in poor rural households. Many development programs focus on increasing production through increasing access to crop inputs with the premise that households will subsequently also benefit by increasing their consumption of diverse healthy foods (Ricker-Gilbert 2013, Ochola and Fengying 2015). While improved income outcomes have been shown for these types of programs in Sub-Saharan Africa (SSA), neither the relationship between crop productivity and nutritional outcomes nor between income changes and healthy diets are well understood (Masters et al. 2015).

Rwanda provides a fascinating context for studying the impacts of dietary diversity on the nutritional status of poor African populations. The vast majority of the rural population are smallholders and farm sizes are among the smallest in the world. The high altitude and hilly topography limit the advantage of large scale production of staple grains. The Rwandese dietary staples comprise a mix of beans, banana, cassava, grains notably maize and sorghum, potato and sweet potato, and some fruits and vegetables (Republic of Rwanda 2012). News reports have mentioned that paradoxically, even in areas where most of the residents report eating "enough" food, malnutrition is still present (Malyon 2015). Recognizing this paradox, in 2012 the government of Rwanda partnered with other organizations to collect primary data to understand the risk factors for undernutrition, and to provide an analytical basis for government programming and policy to improve nutrition and related health outcomes.

There are two, non-exclusive approaches to increasing dietary diversity among smallholders and their families. The first and most direct is for smallholders to diversify their own production for home consumption, resulting in more diverse diets (Pellegrini and Tasciotti 2014, Jones, Shrinivas, and Bezner-Kerr 2014). Own food production and household food security have been strongly promoted by the Rwandan government--but sometimes in the form of mono-cropping instead of diversification in an effort to increase productivity on what are already small farms. The second approach emphasizes smallholder production decisions that maximize income generation, sometimes to the detriment of production diversification or use for home consumption, and reliance on market purchases for dietary diversity (Isaacs et al. 2016). Without consistent market availability of a variety of foods, even non-poor households may not be able to access diverse and nutritionally healthy diets. Thus, it is a priori unclear which approach affords the greatest potential nutritional improvement, what the appropriate production recommendations are, and what policy environment best enables smallholders to improve nutrition and achieve better health outcomes for them and their families.

This paper seeks to fill the analytic gap in our understanding of how agriculture and food policy can improve smallholder dietary diversity in ways that in turn contribute to better health outcomes. The specific objective of this paper is to better understand how smallholder dietary diversity is influenced by the households' production and consumption decision making, market prices and location, as well as government policy. The next section details the dietary diversity measures, and is followed by the data section. Then the methods and results are presented and conclusions are discussed.

Dietary Diversity Measurement

There are several methods used to measure dietary diversity in developing countries. Food variety, quality, and patterns of consumption are often measured based on 24-hour recalls or 7-day food frequency assessment data (Kennedy, Ballard, and Dop 2011, Ruel 2003). Analyses are then usually conducted at the individual food group level or by grouping the food items based on food type or the food's nutritional attributes (Arimond and Ruel 2004, Abdulai and Aubert 2004, Hatluy, Torheim, and Oshaug 1998). Then the data is transformed into a food consumption score or diversity score and analyzed (Kennedy, Ballard, and Dop 2011, WFP 2008).

The Food Consumption Score (FCS), created by the Vulnerability Analysis and Mapping Branch of the World Food Program is a composite score based on dietary diversity (number of different food groups), food frequency (number of days that food group is consumed) and relative nutritional importance (WFP 2008). The advantage of this method is that it is standardized and repeatable, making it also easily comparable between studies and datasets. Another benefit of this measure is that it captures both dietary diversity and food frequency. Some disadvantages of this score is that it is based solely on current consumption, hence ignoring any seasonality or other shocks which could affect future consumption. Secondly, the weights are biased towards animal proteins which automatically yields a lower FCS for Rwandans since animal products are not a major part of their diet. The score is calculated using the food group frequency of consumption within the last 7-days based on the survey. Seven-day food frequency intake gives an indication of dietary diversity and can serve as a proxy for the food security situation (WFP 2008).

Another commonly used dietary diversity score is the Food and Nutrition Technical Assistance Household Dietary Diversity Score (HDDS). The food group classifications for HDDS and FCS are similar, the main difference is the weights applied to each food group. The equal weighting of all food groups for the HDDS is of concern since the nutritional quality varies by food group (WFP 2008). Another concern is that the HDDS tends to be more accurate for 24-hour recall data than varying 7-day food frequency data (Swindale and Bilinsky 2006). However, the benefit of the HDDS is that it is easy to interpret, calculate, and it does not penalize the lack of animal proteins in the diet.

Habyarimana (2015) examined what determines household food insecurity in Rwanda utilizing FCS. This analysis focused on the contribution of demographic explanatory variables to food insecurity (Habyarimana 2015). He used a probit model to analyze the probability a household was classified as food insecure based on the FCS method. He found that location and gender (i.e. rural or urban area and whether the household head was male or female) explained much of the household food insecurity. Habyarimana (2015), however, failed to consider the role economics and policy play in household decision-making and ultimately their nutritional status. Weatherspoon et al. (2017) shows that rural Rwandans demand for key food groups and individual food items are sensitive to prices and expenditure changes (Weatherspoon et al. 2017 Forthcoming). Hence, we expand on Habyarimana (2015) by evaluating the interplay among prices, household expenditures, household production, and policy in addition to the demographic explanatory variables.

For completeness and the fact that consumption of animal derived proteins is limited in this population sample, both FCS and HDDS are used in this paper as a measure for dietary diversity. This study utilizes the same dietary diversity data as Habyarimana (2015) to calculate dietary diversity but instead of classifications, we use a continuous score for both FCS and HDDS to better depict the responsiveness to policy, price, and expenditure changes.

Data

In 2012 the Ministry of Agriculture and Animal Resources (MINAGRI), National Institute of Statistics of Rwanda (NISR), and the World Food Program (WFP) conducted the Rwanda Comprehensive Food Security and Vulnerability Analysis (CFSVA) and Nutrition Survey. The CFSVA includes household demographic, agricultural production, expenditures, and consumption and village level market and policy data that allow a unique exploration of rural Rwandan households' food consumption preferences and dietary diversity of more than 7,000 households. Monthly food prices for the food products were collected by MINAGRI.

Figure 1 shows the 7-day food frequency averages per week that a food item was consumed on the y-axis with the food items depicted on the x-axis. The shaded area represents the poorest quintile income group's average consumption per food item. All income levels have similar shaped curves with the exception of the richest quintile group, represented by the top line, which diverges from the rest of the income groups. This suggests that preference for food are similar for all income groups except the richest group. Therefore, it is implied that dietary diversity may not improve much unless income increases dramatically for the poorest rural Rwandans. Beans are the most notable food item consumed by all income groups, consuming them approximately every day of the week and 45% of rural Rwandans claiming beans as their main cultivated crop. However, the consumption of animal proteins and sugary items are more frequent for the richest group than the others. Overall, dietary diversity and animal protein intake appear to be low for all households, but particularly for the lower income groups. The lower income groups have a high carbohydrate diet that is significantly lower in fruit and vegetables, milk, and meat consumption. Based on this sample, some of the key nutrients of concern for everyone in the household are protein, vitamins A and C, Folic Acid, Calcium and Iron. The limited intake of these nutrients in the diet can be related to deficiency diseases such as: iron deficiency anemia, xerophthalmia, and compromised immune status. Specific concerns for mothers and children are: poor pregnancy outcomes, stunted growth, Kwashiorkor, wasting, and neural tube defects in children (Murphy and Allen 2003, Allen 2008, Hotz and Gibson 2007).

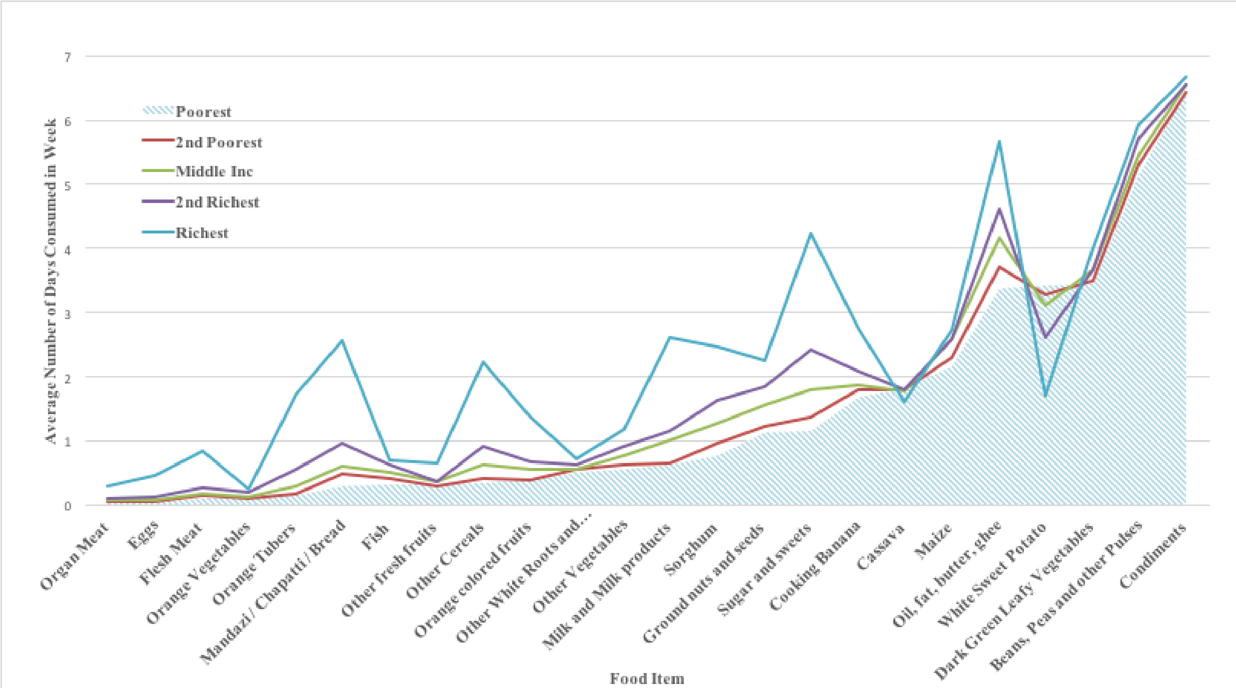

Figure 1: Average Number of Days/Week a Food Item is Consumed by Household Income Group

Expenditures

Table 1 shows the average total household monthly expenditure, the average monthly household food expenditure, as well as the average share of expenditure dedicated to food for the different income groups. The household expenditure rate of increase from the poorest to the richest quintile is U-shaped from 1.5, 1.21, 1.19 to 2.4. The monthly food expenditure rate of increase also has this same U-shaped curve, which may reflect the upgrading in the quality of goods purchased as income increases. However, the food expenditure share (food expenditures divided by total expenditures), shows that the poorest group has the largest food expenditure share (39%) followed by the 2nd richest group. The poorest having a limited income and the second richest group most likely reflecting an upgrading of diet.

Table 1: Expenditures and Food Shares by Income Quintiles in Rwandan Francs.

	POOREST	2ND POOREST	MIDDLE	2ND RICHEST	RICHEST
Total Monthly Expenditure	19,292	29,594	35,707	42,623	102,536
Monthly Food Expenditure	7,451	9,544	11,178	14,355	20,936
Food Expenditure Share	0.39	0.32	0.31	0.34	0.20

Demographics

Table 2 provides descriptive statistics for the demographic, price, policy, and production variables for this study. The dietary diversity indicators; FCS is 45.8 and HDDS is 4.92 for the entire sample (a detailed description on how to calculate FCS and HDDS is described in the methods section). On average, the total monthly expenditures per household is RF 39,939 (approximately US $57) for the sample. The average head of HH was male, with a mean age of 48 years and a primary school education level or lower. On average, households had 2.5 children living at home during the survey period.

Price Aggregation

The price data are aggregated to correspond with the food consumption groups: Cereals; Roots & Tubers; Pulses; Meats; Fruits & Vegetables; and Milk. Then a weighted average is calculated for each of the six food groups using the number of days consumed as a weight. These weights make the price specific to each household and realistically reflects what is actually consumed. All prices are in kg, except for milk, which is in litters. The most expensive food group is meats and the least expensive is roots and tubers. Meats being more than 4.7 times more expensive than the next highest priced food group (pulses).

Policy

Several government policy and donor programs have focused on improving dietary diversity in Rwanda to address malnutrition in general and the severe stunting and wasting in children specifically. For each program, dummy variables were constructed as 1 when the household was located in a village where the program was implemented and 0 otherwise. The government sought to increase the productivity of the agricultural sector with the: Land Consolidation policy; Integrated Development Program (IDP); Land Husbandry, Water Harvesting, Hillside Irrigation program; and the Rwanda Milk Quality Initiative which took place in 65%, 20%, 44%, and 11% respectively, of the villages at the time of this survey in 2012 (Rwanda 2012). A poverty reduction program called The Vision 2020 Umurenge Program (VUP) was implemented in 21% of the rural households surveyed (RLDSF 2012).

Production and Markets

Agricultural production captures the own production-consumption effects on dietary diversity. The impact food production diversity has on dietary diversity and household tradeoffs of own production-consumption versus utilizing the market to increase dietary diversity per income group is not well understood (Altman, Hart, and Jacobs 2009, Jones, Shrinivas, and Bezner-Kerr 2014). The most commonly produced crop groups are: pulses (90%), roots & tubers (77%), cereals (43%), and F&V (29%). Sixty-five percent of the households owned at least one animal, specifically: Goats or Sheep (35.1%); Cattle (32.6%); Poultry (23.3%); Pigs (14.8%); and Rabbit or other animals (8.2%).

Access to inputs and the rate at which they are used can also influence dietary diversity. About 75% of households own some of the land they crop. Land size is captured through a categorical variable (0 to 0.1 ha, 0.1 to 0.19 ha, 0.2 to 0.49 ha, 0.5 to 0.99 ha, 1 to 1.99 ha, 2 to 5 ha, and more than 5 ha). Over 95% of households cropped on less than 2 ha of land. Sixty-seven percent of the rural households used at least one of the following: fertilizer, insecticide, and/or irrigation.

Access to markets can be measured in terms of distance and time. Markets play a critical role for rural households in terms of a place to sell but also as a place to purchase food items the household cannot produce. The average walking time to a market is 70 minutes for this rural population sample and the average distance to a main road is 4 kilometers.

Methods

Two steps are required to estimate the extant of these variables' impact on household dietary diversity. First, FCS and HDDS are calculated for each individual household. Second, regression models are estimated. Both FCS and HDDS are estimated for three reasons: completeness, the low amount of animal proteins consumed in Rwanda, and the way the survey question was administered.[1]

The FCS calculation follows what other studies have done (Kennedy, Ballard, and Dop 2011, Jones, Shrinivas, and Bezner-Kerr 2014, Habyarimana 2015). The 7-day food frequency items from the survey are grouped according to Table 3. Consumption of all the food items within a group are summed up and capped at 7 days a week. Then the number of days each food group was consumed is multiplied by the group weight which is taken from the World Food Program Vulnerability Analysis and Mapping Branch Technical Report (WFP 2008). Lastly, the weighted food group scores are added up to yield the household FCS.

[1] The exact question asked on the survey in Kinyarwanda was "Could you please tell me how many days in the last 7 days your household has eaten the following foods and what the source was?".

Table 2: Descriptive Statistics for the Rwandan Rural Households

VARIABLE NAME	VARIABLE DESCRIPTION	MEAN	MIN	MAX	SD
DEMOGRAPHIC VARIABLES					
FCS	Food Consumption Score	45.8	1.5	112	16.3
HDDS	HH Dietary Diversity Score	4.92	1	7	1.18
totalExp	Total monthly HH expenditure	39939	83	6155200	159391
LogTotalExp	log (Total monthly HH expenditure)	9.81	4.4	15.6	1.18
HHheadGender	= 1 if HH head male	0.71	0	1	0.45
HHsize	# of people living in HH	4.92	1	16	2.07
headHHage	Age of the HH head	47.7	15	103	15.6
HHheadEdu	Education level (Categorical)	2.05	1	7	1.10
num_children	# of children living in HH	2.53	0	13	1.75
LoanTaken	= 1 if HH took loan	0.16	0	1	0.36
%UrbanHHs	Percent of Urban HHs	10.3	1.6	74	12.36
PRICE VARIABLES					
CerealP	Cereals Price (RF/kg)	442.4	306	933	123.2
RootP	Roots & Tubers Price (RF/kg)	192.7	64	277	27.9
PulseP	Pulse Price (RF/kg)	535.5	416	1066	66.8
MeatP	Meat Price (RF/kg)	2547.4	1813	3000	243.7
FruitVegP	Fruit & Vegetable Price (RF/kg)	306.2	71	870	102.5
MilkP	Milk Price (RF/l)	247.0	175	314	43.3
POLICY VARIABLES					
LandHusb	= 1 if HH in village where Land Husbandry was implemented	0.44	0	1	0.50
MilkQuality	= 1 if HH in village where Milk Quality was implemented	0.11	0	1	0.32
VUP	= 1 if HH in village where VUP was implemented	0.21	0	1	0.41
landCons	= 1 if HH in village where Land Consolidation was implemented	0.65	0	1	0.48
IDP	= 1 if HH in village where IDP was implemented	0.20	0	1	0.40
RestructuredU	= 1 if HH in village where Restructured was implemented	0.33	0	1	0.47
PRODUCTION VARIABLES					
TimeToMarket	Time - village to nearest market (in minutes)	70.02	0	190	49.3
distToMainRoad	Distance - village to main road (km)	4.03	0	21.9	3.73
OwnLand	= 1 if HH owns land	0.75	0	1	0.43
landSize	Land size (Categorical)	3.11	1	7	1.41
AgInputUse	= 1 if HH uses fertilizer, insecticide, or irrigation	0.67	0	1	0.47
CerealsCropped	= 1 if HH cropped any cereal	0.43	0	1	0.49

PulsesCropped	= 1 if HH cropped pulses	0.90	0	1	0.31
RootsCropped	= 1 if HH cropped roots & tubers	0.77	0	1	0.42
FVCropped	= 1 if HH cropped fruit or vegetable	0.29	0	1	0.45
OwnAnimal	= 1 if HH owns an animal	0.65	0	1	0.48

Source: World Food Program

The HDDS for the 7-day food frequency data has equal weights per food group as shown in Table 3. Hence, HDDS is calculated by a simple summation of the number of food groups the household consumed. Although the HDDS is typically calculated from food groups from a 24-hour recall, rural Rwandan diets are fairly basic and consistent. Therefore, the 7 day food frequency is deemed to resemble a 24-hour recall from a food choice perspective, and the ability to obtain food categories/classes and assign HDDS points to calculate the HDDS is not impacted (Swindale and Bilinsky 2006).

Figure 2 shows that both FCS and HDDS follow the same trend, increasing as income increases. The change in FCS is higher than the change in HDDS when comparing the poorest to the richest income group (140% versus 124%, respectively) because the diets are increasing in the number of food groups but also in terms of the nutritional quality which the FCS takes into account but the HDDS does not. The animal protein consumption reflects most the nutritional quality increase as income increases for FCS.

Table 3. Food Consumption Score Groups and Weight Calculation by Food Category

FOOD ITEM (FROM SURVEY)	FCS FOOD GROUP CLASSIFICATION	GROUP WEIGHT IN FCS CALCULATION	HDDS FOOD GROUP CLASSIFICATION	GROUP WEIGHT IN HDDS CALCULATION
Maize / Maize Meal	Main Staples	2	Cereals, Roots & tubers	1
Sorghum	Main Staples	2	Cereals, Roots & tubers	1
Other Cereals	Main Staples	2	Cereals, Roots & tubers	1
Cassava	Main Staples	2	Cereals, Roots & tubers	1
White Sweet Potato	Main Staples	2	Cereals, Roots & tubers	1
Other White Roots and Tubers	Main Staples	2	Cereals, Roots & tubers	1
Bread	Main Staples	2	Cereals, Roots & tubers	1
Sweet Potato and other Orange Tubers	Main Staples	2	Cereals, Roots & tubers	1
Cooking Banana	Main Staples	2	Fruits*	1
Beans, Peas and other Pulses	Pulses	3	Pulses & Legumes	1
Dark Green Vegetables	Vegetables	1	Vegetables	1
Orange Vegetables	Vegetables	1	Vegetables	1
Other Vegetables	Vegetables	1	Vegetables	1
Ground Nuts and Seeds	Pulses	3	Pulses & Legumes	1
Orange colored Fruits	Fruit	1	Fruits	1
Fish	Meat and Fish	4	Meats, Seafood and Eggs	1
Organ Meat	Meat and Fish	4	Meats, Seafood and Eggs	1
Flesh Meat	Meat and Fish	4	Meats, Seafood and Eggs	1
Eggs	Meat and Fish	4	Meats, Seafood and Eggs	1
Oil, fat, butter, Ghee	Oil	0.5	Oils and Fats	1
Sugar and Sweets	Sugar	0.5	N/A	N/A
Milk and Milk Products	Milk	4	N/A	N/A
Condiments	Condiments	0	N/A	N/A

***:** Cooking Banana is classified as a Fruit in the HDDS classification and in the price calculations although FCS classifies it as a staple. For economic interpretation and clarity, bananas are placed in the F&V prices versus creating a staples food category.

Source: (Vhurumuku 2014)

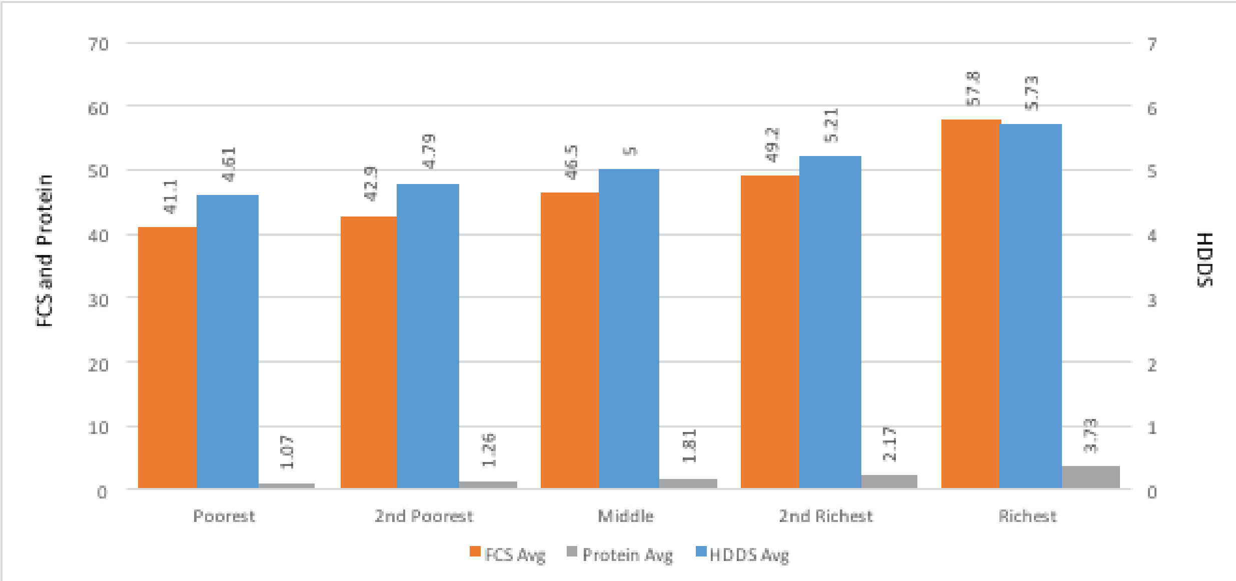

Figure 2: Average HDDS, FCS and Animal Protein FCS Consumption by Income Group

OLS Models

Multivariate Ordinary Least Squares (OLS) regressions are estimated for all households and then estimated per income group. This allows the analysis of price and expenditure elasticities and other factors by income group. The model is then,

$$y_i = \beta_0 + \beta_1 \text{ Demo}_i + \beta_2 \text{ Price}_i + \beta_3 \text{ Policy}_i + \beta_4 \text{ Prod}_i + e_i$$

where y_i represents household i's FCS or HDDS. Demo, Price, Policy and Prod are vectors of demographic, price, policy dummy, and production variables respectively, and e is the error term. The dependent variable HDDS is technically classified as a count variable, but since we observe y over its entire range (1-7), the results from a linear model estimated by OLS will be unbiased (Wooldridge 2010). We take the log of both dependent variables and of the prices and total expenditures so that the coefficient results represent elasticities.

Results

The OLS models fit the data well with R^2s ranging from 0.2 to 0.47 for the individual income groups and a R^2 of 0.31 for the all households model (Table 4). All of the models are computed using standard errors clustered at the village level to control for any correlation within the villages. The results from the FCS and HDDS models are similar, so only the FCS results are reported.

Expenditure Elasticities

In support of Figures 1 and 2, increasing households' total expenditure positively influences a more diverse diet for all income groups. The overall FCS-total expenditure elasticity was 0.11%, which means that a 1% increase in total expenditure leads to a 0.11% increase in rural Rwandan household's FCS. By quintile, a 1% increase in total expenditure is associated with 0.1%, 0.09%, 0.1%, 0.09% and 0.12% increase in the FCS for the poorest, 2nd poorest, middle, 2nd richest, and richest income groups, respectively. This is strong evidence that programs that increase wages, sales, or have a positive income/expenditure effect will increase dietary diversity of rural Rwandans. However, these elasticities are relatively small, which requires a large effect to improve the extremely low FCS levels for all income groups, except the richest. The total expenditure per household was captured in the survey along with how that expenditure was split between all the possible expenditure categories (i.e. housing, education and etc.). These results beg the policy question; how much does total expenditure have to increase to significantly increase FCS per income group since it is not clear that additional income is being spent on diverse foods.

Table 4: Food Consumption Score Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	**All**	**Poorest**	**2nd Poorest**	**Middle**	**2nd Richest**	**Richest**
DEMOGRAPHIC VARIABLES						
Log(TotalExp)	0.107***	0.099***	0.088***	0.096***	0.091***	0.115***
HHheadGender	-0.006	-0.038	0.012	-0.011	0.027	0.011
HHsize	-0.012***	-0.018**	-0.008	-0.015	-0.013	-0.002
headHHage	0.000	0.000	-0.000	0.001	0.001	-0.000
HHheadEdu	0.023***	0.019	0.019*	0.017*	0.016	0.022**
num_children	0.004	0.015	0.009	0.010	0.012	-0.002
LoanTaken	-0.008	0.000	0.038	-0.003	-0.013	-0.061**
%UrbanHHs	-0.002	-0.004	0.002	-0.001	-0.003**	-0.000
PRICE ELASTICITIES						
Log(CerealP)	0.199***	0.093*	0.159***	0.183***	0.225***	0.251***
Log(RootP)	0.008	-0.004	0.012	0.127	-0.049	-0.014
Log(PulseP)	0.156*	0.234	-0.068	0.138	0.447**	-0.080
Log(MeatP)	-0.000	0.230*	0.176*	0.087	0.015	-0.166**
Log(FruitVegP)	0.135***	0.064*	0.074**	0.171***	0.175***	0.208***
Log(MilkP)	-0.073*	-0.127	-0.019	-0.154**	-0.004	-0.037
POLICY VARIABLES						
LandHusb	0.004	-0.027	-0.017	0.006	-0.017	0.025
MilkQuality	0.012	-0.061	-0.013	-0.002	0.103***	0.088*
VUP	-0.008	-0.004	0.014	-0.010	-0.008	-0.080***
landCons	-0.036***	-0.044	-0.001	-0.046*	-0.047**	-0.013
IDP	0.004	-0.020	0.029	0.030	0.009	0.022
StructuredU	0.039***	0.042	0.043*	0.045*	0.044*	0.033
PRODUCTION VARIABLES						
TimeToMarket	-0.000***	-0.001***	-0.001**	-0.000	-0.000	0.000
distToMainRoad	-0.001	0.003	0.001	0.001	-0.006**	-0.006*
OwnLand	0.008	0.002	0.027	0.005	-0.035	0.036
landSize	0.030***	0.028***	0.016**	0.020***	0.017**	0.018**
AgInputUse	0.018*	-0.003	0.029	0.048*	0.027	0.016
CerealsCropped	0.007	0.019	-0.004	-0.006	0.013	-0.012
PulsesCropped	0.107***	0.202***	0.161***	0.168***	0.028	0.075**
RootsCropped	0.008	0.034	0.016	-0.006	0.037	-0.050*
FVCropped	0.050***	0.071***	0.076***	0.036	0.075***	0.006
OwnAnimal	0.063***	0.107***	0.056**	0.064***	0.032	0.079***
Constant	-0.092	-0.971	0.258	-0.891	-2.210	1.870
Observations	5,906	1,004	991	1,003	832	666
R-squared	0.312	0.230	0.203	0.284	0.351	0.467

Clustered Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Utilizing the FCS-total and FCS-food expenditure elasticities for each income group, the amount of additional expenditure required to obtain a diet with the same FCS as the highest income group is calculated. The total or food expenditure elasticities, ε_{exp}, is then:

$$\varepsilon_{\text{exp}} = \frac{\text{FCS}_{\text{income group}} - \text{FCS}_{\text{highest inc group}}}{\text{FCS}_{\text{income group}}} \Bigg/ \frac{\text{avg exp}_{\text{inc group}} - \text{X}}{\text{avg exp}_{\text{inc group}}}$$

Let X be defined as the expenditure required for the comparison income group to achieve 57.8 (the highest income group's average FCS), then the extra expenditure needed is X – average expenditure of the comparison income group. HDDS expenditure elasticities are also calculated the same way by substituting in HDDS for FCS figures.

Table 5 shows the average FCS and HDDS (in parenthesis) per income group in column 1, total FCS and HDDS expenditure elasticities in column 2, FCS and HDDS food expenditure elasticities in column 3, average-total and average-food expenditures in columns 4 and 5. Column 6 shows how much total expenditure must increase to attain a diverse diet equivalent to the richest group. The poorest group's total expenditures must increase between RF59,329 to RF79,180 to reach an HDDS of 5.73 or higher or an FCS of 57.8, stated another way total expenditures have to increase between 307% to 410%. The same calculations for the 2nd poorest, middle, and the 2nd richest reveal the need to increase expenditures 289% to 395%, 200% to 253%, and 148% to 192%, respectively. The required increases in total expenditures are extremely large and may not be in the realm of possibilities; hence, the question is modified to, how much do food expenditures have to increase for the other income groups to consume as diverse a diet as the diversity of foods as the richest Rwandans?

Analyzing how much food expenditures have to increase to obtain a diverse diet as the richest income group allows for the different income groups to have unique preferences, allocations, and reflects the different constraints. To do this, the models are rerun with the log of total food expenditure instead of the log of total expenditure. Those elasticities are shown in column 3 for FCS and HDDS. The poorest groups' total food expenditures have to increase between 368% to 655% to reach a HDDS of 5.73 or higher, or an FCS of 57.8. The same calculation for the 2nd poorest, middle, and 2nd richest shows expenditures have to increase by: 446% to 655%, 331% to 476%, 184% to 233%, respectively.

Table 5: Additional Total Expenditure and Food Expenditure Needed by Income Group to Attain an Acceptable Diet or the Highest FCS diet in Rwanda.

	(1) FCS (HDDS)	(2) FCS (HDDS) Total Expend. Elasticity	(3) FCS (HDDS) Food Expend. Elasticity	(4) Average Total Expend.	(5) Average Food Expend.	(6) Extra Total Expend. Needed for Highest Inc FCS (HDDS)	(7) Extra Food Expend. Needed for Highest Inc FCS (HDDS)
Poorest	41.1 (4.61)	0.099 (0.079)	0.062 (0.066)	RF 19,292	RF 7,451	RF 79,180 (RF 59,329)	RF 48,831 (RF 27,428)
2nd Poorest	42.9 (4.79)	0.088 (0.068)	0.053 (0.044)	RF 29,594	RF 9,544	RF 116,802 (RF 85,406)	RF 62,543 (RF 42,567)
Middle	46.5 (5.0)	0.096 (0.073)	0.051 (0.044)	RF 35,707	RF 11,178	RF 90,387 (RF 71,414)	RF 53,262 (RF 37,091)
2nd Richest	49.2 (5.21)	0.091 (0.067)	0.075 (0.054)	RF 42,623	RF 14,355	RF 81,872 (RF 63,494)	RF 33,456 (RF 26,532)
Richest	57.8 (5.73)	0.115 (0.056)	0.094 (0.055)	RF 102,536	RF 20,936	RF 0 (RF 0)	RF 0 (RF 0)

The fact that food expenditures have to increase more than total expenditures from a percentage perspective, reflects the fact that food FCS-expenditure elasticities are very small. Further analysis is needed to determine why these elasticities are so low. One hypothesis is that other household needs crowd out the demand for a diverse diet, rural markets do not have diverse food products, and that rural Rwandans lack nutritional knowledge. These results clearly show that policies that only focus on increasing income will not address overall nutritional concerns.

FCS - Price

The FCS-price elasticities measure the percentage change in FCS due to a one percent change in the price of a food category. As expected, Rwandan rural households are price sensitive and dietary diversity is influenced by all food group prices with the exception of roots & tubers prices. Only two food groups' prices positively impact FCS for all income groups, cereals and F&V. A 1% increase in cereals and F&V prices increases FCS for all income groups by: 0.09% and .06% (poorest), 0.16% and .072% (2nd poorest), 0.18% and 0.17% (middle), 0.23% and 0.18% (2nd richest), 0.25% and 0.21% (richest). Prices are an important signal to food producers and consumers and they affect the different income groups uniquely. Positive relationships between prices and FCS can be partly explained through the substitution among the different food groups as prices increase or because households are able to sell their own production for a higher price, thereby increasing their income and ability to purchase different food items that they could not produce themselves and/or afford before. Only a few group prices increases lower FCS, meat price increases for the richest group and milk prices for the middle income group lower their FCS. The poorest and 2nd poorest FCS increases the most from meat price increases. The poorest Rwandans lack diversity of protein in their diet but already consume beans almost 7 days/week meaning that their FCS will only increase marginally with increased bean consumption. However, FCS can increase dramatically if the poor consume animal derived proteins. Meat is not consumed often; we assume because of its relatively high price.

The price and expenditure findings alone help explain how Rwanda can experience economic growth resulting in considerable improvements in living standards and poverty reduction, but yet make little progress on the household nutritional status. These findings support those of Moss et al. (2016).

Policy and Demographic Influencers

Policy and programs had no significant impact on the poorest's nutritional status. The 2nd poorest group that lived in households located in a village where the RestructuredU program was implemented had an FCS that was 4.3% higher. Living in a village that had implemented the Milk Quality Initiative program was associated with a 10.3% and 8.8% increase in the 2nd richest and richest FCS, respectively. Lastly, Land Consolidation only impacted the middle and 2nd richest groups, lowering their FCS by 4.6% to 4.7%. VUP also lowered the richest FCS score by 8% but had no significant impact on the poor.

As the household size increases by one person, the household FCS decreases by 1.2% on average for all households and 1.8% for the poorest. Household head's education for the overall sample but particularly for the 2nd poorest, middle, and the richest is associated with the household having a higher FCS. These results are similar to what Habyarimana (2015) found with the exception of gender not being significant in this study.

Inputs and Production Influencers

Rwandan households that have larger plots of land have higher FCS's. The average plot size is between 0.2 and 0.49 hectares, indicating that Rwandans are sensitive to small changes in land size and the use of land. Time to market negatively influenced FCS for the poor and the 2nd poorest only but the coefficient is approximately zero. The use of an agricultural input increases the household FCS by 1.8% overall and specifically by 4.8% for the middle income group.

The production of pulses and F&V and owning an animal positively influenced the household FCS for most households. Cropping pulses is associated with a significant increase in FCS for the poor through the middle income groups. In fact, for the poor, 2nd poorest and middle income, cropping pulses positively impacts their FCS by 20%, 16% and 17%, respectively. Owning an animal has the second largest FCS booster for the poor (10%) and is positively associated with increasing FCS for all income groups except for the 2nd richest income group. Producing F&V is associated with a significant increase of a little more than 7% in FCS for the poor, 2nd poorest and 2nd richest.

Conclusions and Policy Implications

Dietary diversity for the poor was largely influenced by expenditures, meat prices, pulse production, F&V production, ownership of animals, and land size. Policies/programs had an overall small and mixed effect on dietary diversity. Rwandans are price and expenditure sensitive on the demand side and thin markets exist on the supply side with distant markets that provide little diversity of foods in the rural markets.

The importance of household expenditures in enabling households to consume a diversified diet cannot be underestimated. However, the amount needed for households to allocate enough expenditures towards diverse foods is disproportionately high. The higher income quintiles consume more of a variety of food groups and have higher dietary diversity scores, but the rich allocate only 20% of their expenditures to food while all other income group's food expenditures range from 31% to 39%.

The magnitude of expenditure increases required to achieve a higher level of dietary diversity offers an explanation for why Rwanda's success in reducing poverty has not translated into reducing household level malnutrition and more specifically the stunting and wasting rates in children. These findings are similar to Moss et al. (2016) who used a different Rwandan dataset (Moss et al. 2016). The hypothesis is that emergence from poverty occurs at far lower income levels than does emergence from under-nutrition.

The difference in dietary diversity scores by income group reflect two things; the poor do not consume as many food groups (HDDS measure) and the quality of the foods consumed is lower (FCS measure) than the richest rural Rwandans. The consumption of animal based proteins is limited in the diets of all income groups, but especially for the poor. Increasing the amount of protein in the diet may be partially addressed by improving relative prices; currently proteins are relatively expensive except for pulses. If households are not able to afford animal based proteins then increasing the availability of Vitamin A content and other nutrients can be accomplished through fortifying flours, protein complementation of pulses (Jackson et al. 2013), and expanding nutrition education efforts (Low et al. 2007). A public-private partnership that promotes a fortification policy may address the high rates of household and childhood malnutrition. Although the Milk Quality Initiative is a good example of a public-private partnership to increase the consumption of protein, only 11% of the households lived in a village that had access to this program in 2012. Therefore, more research is needed to determine the effect it has on dietary diversity.

The policy implication is that Rwanda needs to use multiple approaches to increase dietary diversity and reduce compromised nutrition. Masters et al. (2015) discussed how dietary diversity through production and improved access as well as reducing contamination and enhancing nutrition quality are all needed for improving nutrition and nutrition status in targeted high need populations in the developing world (Masters et al. 2015). These authors' recommendations are appropriate for Rwanda, which first needs to address production systems and policy for the poorest, recognizing the serious challenges of being able to purchase nutritionally complete diets in current local markets and thus enable dietary improvement through home production and improved food choices. Emphasis here might be on home production of animal based proteins. Second, non-farm rural employment and other non-farm income sources should be considered as key levers to increase smallholder total income to extend food purchasing power and choices with appropriate education. Third, extension and education programs promoting dietary diversity should be seriously considered or enhanced including at point of purchase locations. These programs could positively affect both current cropping practices and the proportion of income allocated to the purchase of nutritious foods. This could catalyze both a near term improvement in dietary diversity, and increase the effectiveness of other, longer-term policy actions. Finally, local markets and related infrastructure can be improved to lower costs, improve access, and provide a diverse variety of foods throughout the year. By better linking smallholders to local markets, as both producers and consumers, market development has the potential for the win-win outcome of improving smallholder incomes by increasing the market availability and affordability of diverse foods. These recommendations are not necessarily mutually exclusive. Additional research should focus on optimizing the policy and programmatic portfolio within government budget constraints and other parameters.

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