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Determinants of Household Food Insecurity in Developing Countries Evidences From a Probit Model for the Case of Rural Households in Rwanda

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Abstract

This study uses probit model to identify determinants of food insecurity among rural households in developing countries. The model used in this study, that allowed us to estimate coefficient and marginal effect for each independent variable vis-à-vis dependent variable, guarantees large applications among food security actors and policymakers to find out factors that significantly explain food insecurity and the level of their predictability. The ability of the model used to correctly classify food insecure and food secure households is good for the overall model and for households headed by males while it is fair for households headed by females. The empirical results show that rural households are more exposed to food insecurity than urban households. Gender disaggregation by the head of households shows that among food insecure rural households, the majority of them are headed by females. It also shows that the mean and median of predicted probability of becoming food insecure among rural households headed by males and females is 0.21 and 0.28 for mean and 0.15 and 0.24 for median respectively. This indicates that households headed by females are more likely exposed to food insecurity than those headed by males. However, as the majority of rural households in developing countries depend on agriculture, this study found that it is worthwhile for developing countries to adopt new agricultural technologies to urgently increase productivity and to implement and facilitate programs supporting rural households pathways to increase households' livelihood capacities.

Keywords: developing countries, food insecurity, marginal effect, predicted probability, probit model, rural households

1. Introduction

The majority of households in developing countries depend on the agricultural sector to provide the main source of food consumed in households, employment and income. Different research and debates have proved that agricultural transformation could be the engine of economic growth and development in these countries. Prior to the implementation of agricultural transformation policies, agricultural systems were more critical and did not gruantee achieving food security in these countries. However, the recent reforms and changes in agricultural policies have emphasized the adoption of new technologies for development of a more industrial and market oriented agricultural sector to develop non-agricultural sectors and meet food and nutrition security in these countries. Uncertainty surrounding the prediction of food security in developing countries has been the result of agricultural instability and represents a vital opportunity for agricultural modelers to analyze and provide information on what should be the pathways to render the agricultural sector more stable to ensure food security. The failure to meet food security for all has been contextualized as food insecurity in these countries. However, in one way or another, food insecurity hurts both households and the economy as a whole. Large unexpected increase of households' food insecurity prevalence would jeopardize the economic development at a micro level and unexpected changes would risk the livelihood of a large portion of the population that depends on agriculture. Excessive food insecurity threatens the economy as a whole, too. When food insecurity prevalence increases in an economy, the percentage of the population depending on the country's support also increases. For developing countries in which tax revenue collection does not keep pace with the required government expenditure, increased number of households with food insecurity characteristics expands government deficit and renders these countries more dependent on foreign aid and support; this remains one of the main challenges to address

the issues of poverty in these countries. Achieving, however, food security for all, offers various benefits to the country. Achieving household food security for all is an important factor helping governments to make effective policies and efficiently plan for inclusive rural development. However, establishing household food security in developing countries has its own costs as it requires efforts and resources to sustainably transform the agricultural sector in the ways to meet food and nutrition security. The requirements include urgent adoption of new agricultural and food transformation technologies; policies to slow-down population growth; efficient meteorological infrastructures to predict climate and weather changes, developed infrastructures in producing and distributing improved agricultural inputs.

Nonetheless, food security is not a new term and its terminology has undergone evolution. The first attempt to measure food consumption and assess nutritional problems date back to the First World War (in 1936) and its interest was considerably increased during the Second World War (Food and Agriculture Organization [FAO], 2001). This tool has ever since experienced different improvements but it provides information on the food situation at the level of individual countries. Even though the Food Balance Sheet was developed, the world has experienced different challenges related to food crisis, food prices volatility climate change and food insecurity. Hence, to address these issues, World Food Summit held in early 1974, defined Food Security as the availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and food prices (United Nations [UN], 1975). This definition, however, brought at least food security analysis at micro-level but with the system already established in early 1936; macro-level analyses were constrained by the lack of well disaggregated data. To reduce complexity and even impracticability of the food balance sheet at micro-level, different forms of food balance sheets were developed for emergency needs assessments. Even though the development of food balance sheets for emergency assessment was a success, structuring household food balance sheets was found to be more complex and they were not commonly used. The world waited 22 years after the first attempt to define food security in 1975 to come up with a comprehensive definition of food security. The world food summit of 1996 suggested that food security at individual, household, national, regional and global levels is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 1996). The adoption of this definition resulted in successfully estimating household food security. The well-known estimations emanating from this definition include: Food Consumption Score that provides estimations on households with poor, borderline and acceptable food consumption (World Food Programme [WFP], 2008) and Integrated Food Security Phase Classification which is a tool that classifies households by regions into five phases in respect to the severity of food and nutrition insecurity. However, with this definition, analysis of food security at micro-level experienced a new era in terms of modeling household food security and disentangling micro food insecurity determinants.

With rapid population growth, increased effects of climate change on agricultural stability and food security, food insecurity is defined in different ways by international organizations and researchers but without much difference in the basic concept. According to the World Bank, food insecurity is defined as “the lack of capability to produce food and to provide access to all people at all times to enough food for an active and healthy life” (WFP, 2009). In this context food insecurity is defined as limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways. Food insecurity exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development, and leads an active and healthy life. In contrast, the most used definition of food security is the one that integrates food availability, access, utilization and stability for a good and healthy life. However, for the purpose of this research we adopted this definition and apply it at the household level to disentangle the determinants of food insecurity in developing countries especially for households located in rural areas.

The recent population growth in developing countries has led to the prodigious increase in food demand. The factor that agriculture remains the core sector for economic growth in these countries, the low agricultural technology and impact of climate change on agriculture and food security remain the main challenges to these countries to feed their populations and ensure food security. To address these challenges and meet food security, developing countries have recently adopted different strategies for agricultural transformation. A high number of new initiatives to strengthen food and nutrition security in these countries have been proposed and among those a significant number is using space technology and information whilst others aim at the development of integrated measurement methods and increased resilience. To meet food security in these countries, addressing household food acquisition problems and ensuring households’ water availability, access and sustainability are emerging as factors that could lead to food security.

1.1 Problem Statement and Research Questions

A wide array of models have been used by agricultural economists and food security modelers to analyze the causes of food insecurity. With the evolution in the production and use of agricultural statistics, the area of modeling the causes of food insecurity has expanded to the household level with more emphasis on developing countries. However, modeling the causes of food insecurity in these countries has been more complex and challenging at the macro-level as well as at the micro-level due to the lack of timely and reliable data. The recent food insecurity modeling in these countries shows that different models using different data have been developed. The well-known models are those which try to link: climate change and agricultural production failure; sudden changes in weather conditions and crop and livestock production instability; food price volatility and household food consumption; food insecurity and limited access to markets, low infrastructure development as factors that hamper food distribution systems and lead to food price volatility; and low household income and limited food acquisition. However, all these models developed can be grouped into three categories: food insecurity as a function of climate change and failure of agricultural performance; food insecurity as function of low adoption of new agricultural technologies and food insecurity as function of low rural infrastructures and poverty. In essence, the practice of modeling food insecurity is a blend of socio-economic theories and econometric procedures and simplified representations of factors determining household food insecurity. When building household based empirical models to identify factors contributing to household food insecurity, this study tries to contribute to the recent literature by identifying determinants of food insecurity in developing countries. To undertake this task and make approximations on household food insecurity determinants, this study uses a Probit model. The main objective of this study, however, is to model household food insecurity determinants in developing countries.

Since 2000 with the implementation of Vision 2020, the government of Rwanda has adopted different policy and reforms emphasizing on transforming the agricultural sector from subsistence level into a modernized and more industrial and market oriented agricultural sector. Agricultural policy changes and reforms in the country have also contributed to the decline of yield and crop production instability, improvement in food distribution system, investing in new products that can generate more revenues and has facilitated households to access foodstuff at fair prices. Nonetheless, food security statistics show that about 81 percent of all households in Rwanda continue to depend on agriculture and 41 percent and 87 percent of households living in urban and rural areas respectively, depend on agricultural activities. Among households headed by males and females and living in rural areas, 86 percent and 90 percent of them are headed by males and females respectively. Statistics also show that 21 percent of households in the country are food insecure. When statistics on food insecurity are disaggregated, 6 percent of households living in urban and 23 percent of the households living in rural are food insecure. Among food insecure households about 96 percent of those are located in rural areas while only 4 percent of them are in urban areas. Among households located in rural areas, households headed by females are more food insecure when compared to those headed by males. 30 percent and 21 percent of households headed by females and males are food insecure respectively. This study, however, tries to answer the following question: What are the determinants of food insecurity among households located in rural areas of Rwanda, disaggregated by the gender of the head of households?

1.2 Literature Review

Different researches have been undertaken to determine factors that are behind food insecurity in developing countries. Those researches have shown that the causes of food insecurity in Africa and other third world countries include (Note 1): drought and extreme weather events; pest, livestock diseases and other agricultural problems; climate change; military conflicts; lack of emergency plans; corruption and political instability; cash crops dependence; human diseases and rapid population growth. The literature shows that the characteristics of food insecurity in these countries do not much differ from households located in urban areas to households located in rural areas.

To empirically characterize household food security, different works (WFP, 2009; Von Braun et al., 1992; Bonnard, 2000; Mucavele, 2001; Bahiigwa, 1999) have identified the determinants of household food security. The main determinants identified in those works include: household size; sex of the head of household; education level of the head of household; unemployment level; dependency ratio; land size; climate shocks such as floods, landslides, dry spell, rainfall deficit and drought; whether the household has enough income to purchase food at prevailing prices; food price volatility; access to agricultural credit; ownership of saving account; total income per adult equivalent; expenditure level on food and non-food items; asset possession; access to social services; owner of home garden; access to subsidized food; source of food; availability of food commodities and supply of food commodities; inadequate labor; inadequate land; not growing enough food

during the season and soil infertility; poor health; lack of planting materials and low agricultural technology; rapid growth of the population; food availability instability and problem to supply markets with sufficient quantity to meet food demand; and problems related to food access and low purchasing power. In contrast, those works shows that the ability to achieve household food security is derived from the household's human capital, material, agricultural technology adaptation, farm size, land quality, agricultural extension services and institutional resources such as education and employment status, household demographics, assets, employment and saving, rural and urban agriculture, formal social assistance or direct transfer, informal social networks, access to clean water and sanitation, household food tastes and preferences.

Nevertheless, most of the works that have tried to identify the determinants of household food insecurity in developing countries have used logit and probit models (François, 2010; Abimbola et al., 2013; Mesfin, 2014). Even though, few of them have tried to disaggregate households by the gender of the head of the household and to model and estimate, ceteris paribus, the marginal effect of each independent variable but none in the literature has tried to predict a household's probability of becoming food insecure with respect to the gender of the head of household. This study, however, tries to contribute to the available literature by using probit model to approximate food insecurity determinants among households located in rural areas by the gender of the head of household; estimate marginal effects for each independent variable in each category of household head and predict household's probability to become food insecure.

2. Methodology

A Probit Regression analysis is applied to address the main objective of this study and answer to the question of this study. Food insecurity characteristics could not be the result of a single factor. Modeling food insecurity at micro-level requires the combination of different data. These data range from weather forecasting data, basic and current agricultural statistics and information, to population statistics. The main challenge in modeling the determinants of food insecurity in developing countries, however, is the lack of timely and reliable data on all these components. In the country where agriculture sector is the main sector of the economy, food insecurity increases as crop and livestock production instability increases. Accordingly, a household's probability to become food insecure increases given that the failure of agriculture production increases and economic shocks rise. In this study, we therefore try to model food insecurity determinants in developing countries and find out a household's probability to become food insecure. This approach enables us to apply the Probit regression model to investigate the links between agricultural related factors and food insecurity. This study therefore models food insecurity as a function of 24 agricultural related variables (see Table 1).

2.1 Empirical Model: Probit Regression

A probity model assumes that there is a latent, unobserved continuous variable Y* which can take all values in (-∞, +∞) and that determines the value of Y and includes believable error term distribution as well as realistic probabilities. However, the underlying latent model can be specified as follows (Chris, 2008; Bruce, 2013):

$$Y = \{1, Y_i^* > 0;\ 0,\ Y_i^* \leq 0\} \text{ and } Y^* = X'\beta + \varepsilon \quad (1)$$

However a probit model is based on latent variable and Y can be observed as an indicator for whether this latent variable is positive. In our study we specify that for Y; 1 = Food Insecurity, 0 = Food Security; X stands for vector of explanatory variables in table 1, β stands for coefficients and ε stands for random errors. In our study we use marginal effect at mean for both continuous and dummy variables. From the probit model we estimate marginal effect of "i" variable as the effect of a unit change of this "i" variable on the probability P(Y = 1| X = x), given that all other variables are constant and can be specified as follow:

$$\partial \mathrm{P}(\mathrm{y_i} = 1|\mathrm{x_i})/\ \partial \mathrm{x_i} = \partial \mathrm{E}(\mathrm{y_i}|\mathrm{x_i})/\ \partial \mathrm{x_i} = \varphi(\mathrm{x_i'}\beta)\beta \quad (2)$$

Average Marginal Effect for each continuous variable in our model is computed as follows:

$$AME = \frac{1}{n} \sum_{i=1}^{n} \varphi(x_i'\beta)\beta \quad (3)$$

And the Average Marginal Effect for each dummy variable in our model is computed as follows:

$$AME = \frac{1}{n} \sum_{i=1}^{n} [\vartheta(x_i'\beta | x_i^k = 1) - \vartheta(x_i'\beta | x_i^k = 0)] \quad (4)$$

In this study we use equation (1) to compute predicted probability for a household to become food insecure when Food Insecurity is equal to one (1) and Food Security if equal to zero (0).

2.2 Data Description

To model household food insecurity determinants, we use the data set of Comprehensive Food Security and Vulnerability Analysis and Nutrition Survey conducted in 2012 in Rwanda. This survey covered a sample of

7500 households randomly selected around the country. The volume of the questionnaire of this survey was composed of 486 questions including demographics of the household members, characteristics of the home shelter, household income and questions related to food and nutrition security. We decided to use 96 questions from the survey questionnaire and some of them were transformed and combined to reach a total of 25 variables used in the model. The reduction of the number of questions has allowed as using the "level of importance of combined questions" in the survey questionnaire to explain household food insecurity characteristics. This study used food consumption groups to create the dependent variable in our model. The transformation of this variable followed the creation of two distinct groups: Food Insecure Households with the value of one (1) and Food Secure Households with the value of zero (0). Food Insecure households groups all households with borderline and poor food consumption score while Food Secure households groups all households with acceptable food consumption score.

Table 1. Explanatory variables and their measures

Variable name	Variable description	Measure
FI	Food Insecurity	Insecure = 1& Secure =0
AHH	Age of Household Head	Age in years
HHE	Household Head Education	Able to ready & write =1 other=0
HS	Household Size	Number persons in a household
HLS	Household's Land Size	Scale of 0 to 1
HLAL	Household's Land Amendment Level	Scale of 0 to 1
HFA	Household's Farm Animal	Scale of 0 to 1
DM	Distance to Market	Minutes
FA	Food Assistance	Scale of 0 to 1
HAI	Household Asset Index	Scale of 0 to 1
HFAL	Household Food Acquisition Level	Scale of 0 to 1
HFAP	Household Food Acquisition Problem	Scale of 0 to 1
NLA	Number of Livelihood Activities	Scale of 0 to 1
HSL	Household Spending Level	Scale of 0 to 1
MFE	Monthly Food Expenditure	In Rwandan Francs
PCE	Per Capita Expenditure (Year)	In Rwandan Francs
GS	Government Support	Scale of 0 to 1
OPC	Own Production used for Own Consumption	% of food from own-production
MCHFC	Market Contribution to Household Food Consumption	% of food from market
LSPC	Land Suitability per Cell	% of suitable land per cell
SEIV	Soil Erosion Index per Village	% of land vulnerable to erosion per village
CSI	Coping Strategy Index	Reduced coping strategy index
MAC	Membership to Agricultural Cooperative	Member=1 & Not member=0
AL	Agricultural Loan	Acquired=1 Not acquired=0

3. Results

Table 2. Food insecurity profile in Rwanda

				Rural (Head of HH)	
	All	Urban	Rural	Male	Female
Households depending on agriculture (%)	81	41	87	86	90
Households depending on informal sale, agro seller and artisan (%)	14	36	11	11	10
Households depending on salaries and business (%)	5	23	2	3	1
Food Insecure Households (%)	21	6	23	21	30
Food Secure Households (%)	79	94	77	79	70

Table 3. Descriptive Statistics for Rural Households

	Mean		Correlation FI		Covariance FI		Male and Female Combined		
	Male*	Female*	Male*	Female*	Male*	Female*	Mean	Cor.	Cov
FI	0.21	0.30	1	1	0.16	0.20	0.23	1.00	0.18
AHH	44.37	54.46	-0.0004	0.0093	0.00	0.00	47.30	0.03	0.00
HHE	0.70	0.37	-0.0864	-0.0921	-0.02	-0.02	0.61	-0.11	-0.02
HS	5.33	3.88	-0.0487	-0.0777	-0.04	-0.06	4.91	-0.08	-0.07
HLS	0.92	0.89	-0.2001	-0.1837	-0.04	-0.04	0.91	-0.20	-0.05
HLAL	0.33	0.29	-0.1011	-0.1256	-0.01	-0.01	0.31	-0.12	-0.01
HFA	0.78	0.69	-0.1125	-0.1527	-0.02	-0.03	0.75	-0.13	-0.02
DM	78	76	0.0485	0.0472	1.36	1.68	77.50	0.05	1.42
FA	0.01	0.01	-0.0203	0.0396	0.00	0.00	0.01	0.00	0.00
HAI	0.23	0.17	-0.2875	-0.2224	-0.01	-0.01	0.21	-0.28	-0.01
HFAL	0.34	0.31	-0.1511	-0.1908	-0.01	-0.02	0.33	-0.17	-0.01
HFAP	0.19	0.24	0.2543	0.2895	0.02	0.03	0.20	0.27	0.03
NLA	1.73	1.55	-0.0808	-0.0455	-0.02	-0.01	1.68	-0.08	-0.02
HSL	0.29	0.23	-0.2983	-0.3009	-0.02	-0.02	0.27	-0.31	-0.02
MFE	13940	9539	-0.1632	-0.1554	-986	-915	12673	-0.17	-1031
PCE	105297	96896	-0.1113	-0.0612	-10752	-15650	102872	-0.08	-12142
GS	0.02	0.02	-0.0104	-0.0292	0.00	0.00	0.02	-0.02	0.00
OPC	32.63	32.46	-0.1521	-0.1604	-1.24	-1.52	32.58	-0.15	-1.31
MCHFC	62.80	59.01	0.1166	0.0665	0.95	0.64	61.70	0.09	0.81
LSPC	43.10	44.12	-0.1308	-0.1808	-1.56	-2.37	43.40	-0.14	-1.78
SEIV	6.38	6.28	0.0905	0.1795	0.15	0.33	6.35	0.12	0.20
CSI	5.17	6.78	0.2196	0.2560	0.68	0.96	5.64	0.24	0.78
MAC	0.18	0.13	-0.1201	-0.1449	-0.02	-0.02	0.16	-0.13	-0.02
AL	0.18	0.11	-0.0986	-0.0764	-0.02	-0.01	0.16	-0.10	-0.02

Note. FI = Food Insecurity where (Insecurity = 1 and Security = 0); Male* = Households headed by Males; Female* = Households headed by Females.

Table 4. Summary results of probit regression model for the determinants of rural household food insecurity

	Households headed by Males			Households headed by Females			All households Combined		
FI	Coef.	.dy/dx	Sig.	Coef	.dy/dx	Sig.	Coef	.dy/dx	Sig.
AHH	0.053	0.0117		0.0307	0.0092		0.0455	0.0112	
HHE	-0.009	-0.0021		0.0031	0.0009		-0.0008	-0.0002	
HS	0.032	0.0072	**	0.0240	0.0072		0.0325	0.0080	***
HLS	-0.112	-0.0251	**	-0.0487	-0.0145		-0.0892	-0.0219	**
HLAL	-0.035	-0.0079		-0.3103	-0.0925		-0.1290	-0.0316	
HFA	-0.137	-0.0305	**	-0.1184	-0.0353		-0.1325	-0.0325	***
DM	0.000	0.0001		0.0003	8.82E-05		0.0004	0.0001	
FA	-1.147	-0.2558	*	-0.6425	-0.1915		-0.9785	-0.2399	**
HAI	-1.903	-0.4244	***	-0.5999	-0.1788		-1.4851	-0.3642	***
HFAL	-0.403	-0.0900	***	-0.3180	-0.0948		-0.3840	-0.0942	***
HFAP	0.815	0.1817	***	0.9389	0.2798	***	0.8479	0.2079	***
NLA	-0.085	-0.0189	**	-0.0391	-0.0116		-0.0740	-0.0181	**
HSL	-2.248	-0.5014	***	-2.3095	-0.6882	***	-2.2839	-0.5600	***
MFE	-1.72E-05	-3.83E-06	***	-0.000027	-8.04E-06	***	-0.0000186	-4.55E-06	***
PCE	-3.86E-07	-8.61E-08		-2.86E-08	-8.54E-09		-3.13E-07	-7.69E-08	
GS	-0.271	-0.0603		-0.4802	-0.1431		-0.3424	-0.0840	
OPC	-0.004	-0.0008		-0.0047	-0.0014		-0.0041	-0.0010	**
MCHFC	0.005	0.0011	**	0.0023	0.0007		0.0037	0.0009	**
LSPC	-0.004	-0.0009	***	-0.0044	-0.0013	***	-0.0043	-0.0010	***
SEIV	0.015	0.0034	**	0.0297	0.0088	**	0.0201	0.0049	***
CSI	0.006	0.0014	*	0.0124	0.0037	**	0.0089	0.0022	***
MAC	-0.231	-0.0516	***	-0.4542	-0.1353	***	-0.2897	-0.0710	***
AL	-0.041	-0.0091		0.0462	0.0138		-0.0287	-0.0070	
N. of Ob.		4149			1634			5783	
Waldchi2(23)		1454			506.98			1938.68	
Prob > chi2		0.00			0.000			0.000	
ROC Curve*		0.8090			0.7907			0.8048	

Note. Sig. = Significant: ***, **, * at 1%, 5% and 10%; Coef = Coefficient ; dy/dx = Marginal Effect; ROC Curve* = Area under Receiver Operating Characteristics curve.

Table 5. Descriptive statistics of predicted probabilities for a rural household to become food insecurity

FSG	variable	mean	min	max	cv	p50	iqr
Insecure	Households headed by Males	0.372	0.001265	0.885	0.530	0.359	0.287
	Households headed by Females	0.439	0.029424	0.904	0.475	0.435	0.350
	Households headed by Males and Females	0.393	0.000572	0.896	0.511	0.380	0.310
Secure	Households headed by Males	0.162	1.19E-15	0.834	0.950	0.114	0.200
	Households headed by Females	0.219	4.84E-20	0.852	0.813	0.177	0.246
	Households headed by Males and Females	0.178	5.86E-16	0.825	0.912	0.130	0.217
Total	Households headed by Males	0.205	1.19E-15	0.885	0.899	0.151	0.252
	Households headed by Females	0.281	4.84E-20	0.904	0.753	0.237	0.314
	Households headed by Males and Females	0.227	5.86E-16	0.896	0.855	0.175	0.274

Note. Max: maximum; min: minimum; cv: coefficient of variation; p50: median; iqr: Interquartile range.

Table 6. Predicted probabilities for a rural household to become food insecure

Predicted Probability	HHs Headed by Males	HHs Headed by Females	All HHs
Less than 0.11	37.89	23.75	33.77
Between 0.11 and 0.21	21.50	19.89	20.77
Between 0.21 and 0.31	13.93	17.01	15.29
Between 0.31 and 0.41	10.34	12.18	11.00
Between 0.41 and 0.51	7.81	9.06	8.04
Between 0.51 and 0.61	4.17	7.47	5.29
Between 0.61 and 0.71	2.31	6.12	3.3
Between 0.71 and 0.81	1.71	3.55	2.09
Between 0.81 and 0.91	0.34	0.92	0.45
Between 0.91 and 1.00	0.00	0.06	0.00
Observations (Households)	4,149	1,634	5,783

Note. HHs = Households.

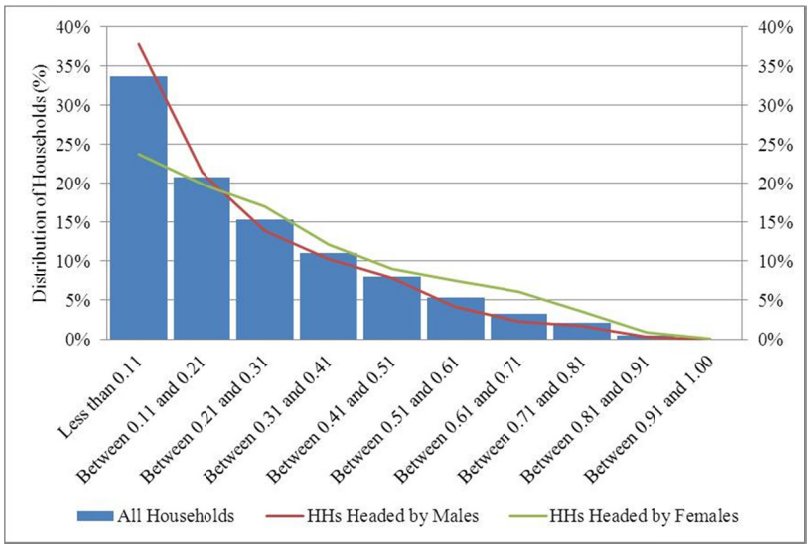

Figure 1. Predicted probabilities for a rural Household to become food insecure

5. Discussion

When compared to urban population, rural areas accommodate the majority of households in developing countries. With a predominant agricultural sector, most households located in rural areas depend on agricultural activities. Even though some food is sourced from market, the large share of food consumed in rural households is sourced from their own production. The own production consists of agricultural production. In most cases, this production is not processed due to the lack of efficient food transformation technology. However, food availability and access in rural areas is the result of agricultural performance and food acquisition from the market is function of income from agriculture. Both, food availability and access and income from agricultural activities in rural areas are highly linked to the performance of agricultural season. Any instability in agricultural production results in food availability instability and reduces households' income from agriculture and limit household to food diversification. However, agriculture performance in rural areas is function of household land size, land amendment, rainfall performance, adoption of agriculture cooperatives to efficiently channelize improved agricultural inputs and agricultural loans. In one way or another government and/or non-government support and assistance have a role to ensure food security in the case of food needs due to hazards. For subsistence, household structural counts a lot to define a household's livelihood, expenditure and income level. When it is on the side of food utilization, education matters. Rural households whose members have a low education level are more likely to be not aware on the efficient utilization of available food and are less likely to access to skilled livelihoods activities that can be one way to generate an income and increase household's purchasing power and saving level. It is in this context that we model rural household food insecurity as a function of households characteristics, household income, household food acquisition, household's agricultural characteristics, household's assistance related variables (see Table 1).

5.1 Food Insecurity Profile in Rwanda

Even though the agricultural system in Rwanda is predominantly rainfall fed, agriculture is the core sector of Rwandan economy. Food security statistics shows that about 81 percent of all households in the country depend on agriculture. When urban and rural areas are compared, 41 percent of urban households and 87 percent of rural households depend on agricultural activities. Among households headed by males and females and living in rural areas, 86 percent and 90 percent of them are headed by males and females respectively. Statistics also show that 21 percent of households in the country are food insecure. When statistics on food insecurity are disaggregated, 6 percent of households living in urban and 23 percent of households living in rural areas are food insecure. Among food insecure households about 96 percent of them are located in rural areas while only 4 percent of them are in urban areas. Among households located in rural areas, households headed by females are more food insecure when compared to those headed by males. Among households headed by females, 30 percent of them are food insecure, while those headed by males 21 percent of them are food insecure. This profile shows that food insecurity is a serious rural problem in Rwanda when compared to food insecurity situation in urban areas. This becomes more sensitive in rural areas when households headed by males are compared to those headed by females. This, however, indicates that rural household food insecurity is more prevalent in household headed by females which may be the results of the fact that more households headed by females depend on agriculture (90 percent) when compared to those headed by males (86 percent).

5.2 Description of Rural Households

In this study we use three types of descriptive statistics: mean, correlation and covariance. Even though covariance is similar to correlation, we use covariance to understand how independent variables are related to dependent variable in the model and to find out if each independent variable and dependent variable tend to increase or decrease together or tend to increase as the other variable decreases. We use correlation to assess the strength of linear relationship between each of dependent variable with dependent variable. To make a difference, correlation (Note 2) is computed when data are converted to a standardized scale of -1 to +1 while covariance is expressed in units that vary and not standardized to scale of -1 to +1.

The mean age of head of households shows that the mean age of males heads of households is below the mean age of females heads of households, the education level shows that males heads of households are more educated than females heads of households, mean household size show that households with large size are those headed by males and are also endowed with large land when compared to those headed by females, land amendment is large among households headed by males, households headed by males have farm animal more than those headed by females, household asset index for households headed by males is greater than that of households headed by females, household food acquisition level among households headed by males is greater than that of households headed by females, households headed by males have less household food acquisition problems

when compared to households headed by females, expenditure on food shows that households headed by males spend more on food than those headed by females, per capita expenditure among households headed by males is greater than that of households headed by females, the share of food sourced from market is large among households headed by males when compared to those headed by females, households headed by males are more participative in agricultural cooperatives and in requesting agricultural loans when compared to households headed by females, and the coping strategy index is high among households headed by females when compared to those headed by males. Even though rural households have less food acquisition problem, the general observation shows that within a scale of 0 to 1, Household's land amendment level, household food acquisition level, household spending level, membership in agricultural cooperatives and agricultural loan access are very low.

For households headed by males, food insecurity has a weak relationship with household land size, household asset index, household food acquisition problem, household spending level and coping strategy index; while it has a very weak relationship with age of household head, distance to market, food assistance, government support, market contribution to household food consumption, soil erosion index per village, household head's education level, household size, household's land amendment level, household's farm animal, household food acquisition level, number of livelihood activities, monthly food expenditure, per capita expenditure (year), own production used for own consumption, land suitability per cell, membership to agricultural cooperative and agricultural loan. For households headed by females and when households headed by males and females are combined, only household asset index, household food acquisition problem, household spending level and coping strategy index have a weak relationship with food insecurity while other variables have a very weak relationship with food insecurity.

For households headed by males and females and when all households are combined, the covariance between the age of the head of household, distance to market, food assistance, household food acquisition problem, government support, market contribution to household food consumption, soil erosion index per village, coping strategy index and food insecurity indicated a positive relationship while the covariance between household head education, household size, household's land size, household's land amendment level, household's farm animal, household asset index, household food acquisition level, number of livelihood activities, household spending level, monthly food expenditure, per capita expenditure (year), own production used for own consumption, land suitability per cell, membership to agricultural cooperative, agricultural loan and food insecurity indicated a positive indicate a negative relationship.

5.3 Determinants of Food Insecurity Among Rural Households

In this study we use both coefficients and average marginal effects. Coefficients are used to understand how changes in independent variables explain changes in dependent variable while average marginal effects are used to estimate the effect of a unit change in each independent variable on the probability of being food insecure, given that all other variables are hold constant. To identify determinants of food insecurity among rural households, we use three models. Probit models for households headed by males and those headed by females are used to identify how determinants of food insecurity differ depending on the gender of household head. In addition to this, we use the overall Probit model (when all households headed by males and those headed by females are combined).

For households headed by males, we found that significant variables to explain changes in rural household food insecurity are: household asset index, household food acquisition level, household food acquisition problem, household spending level, monthly expenditure on food, land suitability (fertility) per cell and membership to agricultural cooperatives significant at 1%; household size, land size, farm animal, number of livelihood activities, soil erosion index per village and market contribution to household food consumption significant at 5%; and food assistance and coping strategy index significant at 10%. When one variable is considered and keeping all other variable constant, average marginal effect shows that a unit increase in household size, household food acquisition problem, market contribution to household food consumption, soil erosion index per village, and coping strategy index would results in increasing the household's probability of becoming food insecure by 0.7 percent, 18 percent, 0.1 percent, 0.34 percent, and 0.14 percent respectively while a unit increase in household asset index, household food acquisition level, household spending level, monthly expenditure on food, land suitability (fertility) per cell, membership to agricultural cooperatives, land size, farm animal, number of livelihood activities, food assistance would result in decreasing household's probability to become food insecure. The area under ROC cover of 0.81 shows that the ability of probit model constructed for households headed by males to correctly classify food insecure and food secure households is good (Note 3).

For households headed by females, we found that significant variables to explain changes in rural household

food insecurity are: household food acquisition problem, household spending level, monthly expenditure on food, land suitability (fertility) per cell and membership to agricultural cooperatives significant at 1%; soil erosion index per village and coping strategy index significant at 5%. When one variable is considered and keeping all other variable constant, average marginal effect shows that a unit increase in household food acquisition problem, soil erosion index per village, and coping strategy index would results in increasing the household's probability of becoming food insecure by 28 percent, 0.9 percent and 0.3 percent respectively while a unit increase in household spending level, monthly expenditure on food, land suitability (fertility) per cell and membership to agricultural cooperatives would result in decreasing household's probability to become food insecure. The area under ROC cover of 0.79 shows that the ability of probit model constructed for households headed by females to correctly classify food insecure and food secure households is fair.

When all households are combined, we found that significant variables to explain changes in rural household food insecurity are: household size, household's farm animal, household asset index, household food acquisition level, household food acquisition problem, household spending level, monthly food expenditure, land suitability per cell, soil erosion index per village, coping strategy index and membership to agricultural cooperative significant at 1%; and household size, household's farm animal, household asset index, household food acquisition level, household food acquisition problem, household spending level, monthly food expenditure, land suitability per cell, soil erosion index per village, coping strategy index and membership to agricultural cooperative significant at 5%. When one variable is considered and keeping all other variable constant, average marginal effect shows that a unit increase in household size, household food acquisition problem, market contribution to household food consumption, soil erosion index per village and coping strategy index would results in increasing the household's probability of becoming food insecure by 0.8 percent, 20 percent, 0.1 percent, 0.5 percent and 0.2 percent respectively while a unit increase in household's farm animal, household asset index, household food acquisition level, household spending level, monthly food expenditure, land suitability per cell, and membership to agricultural cooperative, household's land size, food assistance, number of livelihood activities, and own production used for own consumption would result in decreasing household's probability to become food insecure. The area under ROC cover of 0.80 shows that the ability of probit model constructed for households headed by both the males and females to correctly classify food insecure and food secure households is good.

5.4 Predicted Probability for a Household to be Classified a Food Insecure Household

In this study we use estimated probit models to predict the probability that each household in the sample has to become food insecure. The interpretation of this probability is stated as follows "as a household's predicted probability is getting higher and approaching an unit (1) the same household is more likely to become food insecure while as a household's predicted probability is low and approaching zero (0) the more the same household is likely to become food secure". The mean of predicted probability for households previously (from survey results) categorized as food insecure to stay food insecure is 0.372, 0.439 and 0.393 probability for households headed by males, females and when all households are combined respectively. This indicates that the majority of those households are more likely to become food secure. In the other way round, the mean of predicted probability for households previously (from survey results) categorized as food secure to become food insecure is 0.162, 0.219 and 0.18 probability for households headed by males, females and when all households are combined respectively. This indicates that the majority of those households are more likely to stay food secure and few of them are likely to move to the category of food insecure households. Households categorized as food insecure have less variability relative to their means, while households categorized as food secure have more variability relative to their means. The median of predicted probabilities among food insecure households is greater than the median of predicted probabilities among food secure households. This indicates that a half of food insecure households have about 0.38 probability and less of staying food insecure while a half of food secure households has about 0.13 and less probability of becoming food insecure. The overall observation shows that the mean of predicted probability of about 0.22 indicates that there is a low probability for household to become food insecure. Even though, the majority of households located in rural areas have the low probability of becoming food insecure, the predicted probability shows that households headed by females are more likely to become food insecure than those headed by males (see Table 6 and Figure 1).

6. Conclusion and Policy Implications

Most of the works that have tried to identify determinants of food insecurity in developing countries have used logit and probit models. Even though, few of them have tried to disaggregate households by the household heads' gender and to model and estimate marginal effect for each independent variable when others variables are assumed to be constant but none in the literature have tried to predict a household's probability to become food insecure in respect with the gender of the head of household. This study, however, contributes to the available

literature by using probit model to approximate food insecurity determinants among households located in rural areas by head of household's gender; estimate marginal effects for each independent variable in each category of the head of households (males and females) and predict a household's probability to become food insecure. Hence, this study investigated the determinants of food insecurity among rural households by the gender of the head of household.

Using descriptive statistics, this paper demonstrates that food insecurity is more prevalent in rural areas than in urban areas. The paper also shows that among food insecure rural households the majority of them are headed by females. This paper assumed that food insecurity in rural areas and by the gender of the head of household is function of the age of household head, household head education, household size, household's land size, household's land amendment level, household's farm animal, distance to market, food assistance, household asset index, household food acquisition level, household food acquisition problem, number of livelihood activities, household spending level, monthly food expenditure, per capita expenditure (year), government support, own production used for own consumption, market contribution to household food consumption, land suitability per cell, soil erosion index per village, coping strategy index, membership to agricultural cooperative and agricultural loan. Using Probit model, this study found that significant factors to explain changes in rural household food insecurity are: household size, household's farm animal, household asset index, household food acquisition level, household food acquisition problem, household spending level, monthly food expenditure, land suitability per cell, soil erosion index per village, coping strategy index and membership to agricultural cooperative significant at 1%; and household size, household's farm animal, household asset index, household food acquisition level, household food acquisition problem, household spending level, monthly food expenditure, land suitability per cell, soil erosion index per village, coping strategy index and membership to agricultural cooperative significant at 5%. The analysis of average marginal effects by household head gender shows that the number of significant factors to influence food insecurity at household level whether positively or negatively is different among households headed by males and those headed by females. Households headed by males have more determinants than those headed by females. The predicted probability for a household to become food insecure shows that households headed by females are more likely exposed to food insecurity than those headed by males.

This study also shows that the majority of rural households in developing countries depend on agriculture and that subsistence agriculture system is the predominant agricultural system applied in those areas. As the probit model used in this study tried to model agricultural related variables as factors affecting household food insecurity, we found that it is worthwhile for developing countries to adopted new agricultural technologies to increase productivity and to implement and facilitate programs supporting rural households to increase their livelihood capacities.

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Notes

Note 1. http://www.harvesthelp.org.uk/causes-of-food-insecurity-in-african-and-other-third-world-countries.html

Note 2. In this study we considered that 0.00-0.2; 0.2-0.4; 0.4-0.6; 0.6-0.8 and 0.8-1 indicate a very weak, weak, moderate, strong, and very strong relationship

Note 3. In this study we consider that 0.5-0.6; 0.6-0.7; 0.7-0.8; 0.8-0.9; 0.9-1 area under Receiver Operating Characteristic curve indicate that the ability of our model to correctly classify food insecure and food secure households is “Fail”; “Poor”; “Fair”; “Good” and “Excellent” respectively. http://gim.unmc.edu/dxtests/roc3.htm

Appendix

Appendix A

Corrélation		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
FI	A	1																							
AHH	B	0.03	1																						
HHE	C	-0.11	-0.29	1																					
HS	D	-0.08	0.03	0.15	1																				
HLS	E	-0.20	0.09	0.11	0.17	1																			
HLAL	F	-0.12	0.03	0.10	0.12	0.16	1																		
HFA	G	-0.13	0.09	0.02	0.16	0.19	0.26	1																	
DM	H	0.05	-0.04	-0.04	-0.03	-0.04	0.05	-0	1																
FA	I	0.00	0.04	-0.04	0.00	-0.01	-0.03	-0.06	0.05	1															
HAI	J	-0.28	-0.08	0.28	0.25	0.33	0.21	0.17	-0.09	-0.1	1														
HFAL	K	-0.17	-0.08	0.07	0.04	0.19	0.13	0.07	-0.01	0.01	0.17	1													
HFAP	L	0.27	0.04	-0.13	-0.01	-0.27	-0.10	-0.11	0.07	0.07	-0.31	-0.1	1												
NLA	M	-0.08	-0.13	0.06	0.16	0.03	0.07	0.12	0.00	0.02	0.17	0.07	-0	1											
HSL	N	-0.31	-0.08	0.21	0.29	0.28	0.26	0.19	0.00	0.01	0.46	0.24	-0.19	0.21	1										
MFE	O	-0.17	-0.07	0.11	0.24	0.10	0.07	0.02	-0.06	-0.01	0.31	0.12	-0.06	0.15	0.36	1									
PCE	P	-0.08	0.00	0.06	-0.01	0.08	0.04	0.01	-0.03	-0.01	0.18	0.06	-0.06	0.05	0.23	0.26	1								
GS	Q	-0.02	0.02	-0.01	0.01	-0.03	0.00	0.04	0.01	0.04	-0.04	-0.01	0.05	0.05	0.04	0.00	-0.01	1							
OPC	R	-0.15	0.19	0.01	0.01	0.25	0.09	0.19	0.00	-0.06	0.11	0.13	-0.24	-0.07	0.08	-0.24	-0.01	-0	1						
MCHFC	S	0.09	-0.21	0.03	0.05	-0.21	-0.05	-0.13	-0.04	0.02	-0.02	-0.07	0.17	0.08	0.01	0.30	0.03	-0	-0.9	1					
LSPC	T	-0.14	-0.03	0.01	0.03	0.06	-0.22	-0.11	-0.12	0.03	0.08	0.04	-0.12	-0.01	0.05	0.10	0.05	-0	0.07	-0	1				
SEIV	U	0.12	0.04	-0.01	0.01	-0.05	0.20	0.11	0.08	-0.01	-0.05	-0.01	0.07	0.03	0.00	-0.03	-0.03	0.05	-0.1	0.06	-0.7	1			
CSI	V	0.24	0.04	-0.11	0.03	-0.28	-0.13	-0.12	0.02	0.11	-0.32	-0.15	0.50	0.00	-0.22	-0.06	-0.07	0.02	-0.2	0.14	-0	0.06	1		
MAC	W	-0.13	0.00	0.09	0.11	0.12	0.17	0.11	-0.02	0.02	0.18	0.06	-0.10	0.02	0.17	0.06	0.02	0.02	0.06	-0.03	0.02	-0.02	-0.08	1	
AL	X	-0.10	-0.08	0.09	0.12	0.12	0.11	0.05	0.01	0.03	0.17	0.04	-0.04	0.11	0.30	0.16	0.11	0.11	0.00	0.02	0.03	0.00	-0.07	0.1	1