An Investigation into the Dynamic Nature of Food Security Using Markov Switching Models

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ABSTRACT

People are considered to be food secured when they have adequate access to food which helps to maintain their health lives. Food availability, access, utilization and stability are the four main facets of food security. Rather than dropping over time, food insecurity has become a repetitive problem. This research was led to study the state transition behaviors in the four dimensions of global food security (Availability, Access, Utilization and Stability) by creating a two state (Crisis and Success) Markov-switching model. Markov Switching Model is a method applied to explore structural changes of nonlinear time series. In this study Markov Switching Auto Regressive Model was used because the data used were lower frequency data. Secondary data were obtained for five main regions in the world (Africa, America, Asia, Europe, and Oceania) and one sub region (South Asia). Results highlighted that growth rate of food availability was high in developing regions than developed. America, Asia, and South Asian regions showed longest time period in crisis state in accessibility to food. Utilization of food in South Asian region was in the crisis state and in European region it was in the success state. Asian region showed the highest stability in other three dimensions of food security. African region has to face a long-lasting food insecurity in all four dimensions. American, Asian, European and South Asian regions have to face food insecurity not critically in terms of food availability, but in the case of access, utilization and stability. Therefore, this study emphasizes that to eradicate food insecurity all four dimensions should be considered and appropriate policies and investments should be made.

KEYWORDS: Food security, Markov switching model, Transition behavior

Introduction

Food security is a crucial component of overall well-being and it "exists when all people at all times have physical, social and economic access to satisfactory, safe and nutritious and adequate food to provide the basis for lively and healthy lives" (World Food Summit, 1996). Food security is a multi-dimensional occurrence and the first dimension is physical availability of food and it emphasis the supply side of food and is determined by the level of food production and net trade. Second one is economic and physical

access to food and it concerns about the ability to produce one's own food or buy it. Third one is food utilization and it is understood as reassurance of safe and nutritious food which meets their dietary needs. Fourth is the stability and it must be present at all times in terms of availability, access and utilization for food security to exist (World Food Summit, 1996).

Food insecurity can be transitory, seasonal, or chronic. Transitory food insecurity is temporary and occur when there is an unexpected drop in the ability to produce or access to adequate food to sustain good healthy lives. Chronic (or permanent) food insecurity occur when people are incapable to meet their minimum food necessities over a sustained period of time. The concept of seasonal food security falls between chronic and transitory food insecurity (FAO, 2015).

There are many multifaceted reasons which prevent achieving global food security. These complications include extreme poverty, concerns in food distribution, and issues in food supply, food waste, population growth, climate change, water scarcity, price volatility and government policies that constrain trade. Policy makers should give equal importance to both transitory and chronic food insecurity because if transitory food insecurity is neglected it can transform into a chronic food insecurity.

Regional Overview of Food Security in World

Africa has made some development towards halving the percentage of its population suffering from hunger which was proposed in Millennium development goal 1.C target. Overall, the prevalence of hunger in the region declined by 31 percent by 2015 (FAO, 2015a). Although, Asia and pacific region has achieved the largest reduction in the number of undernourished people, this was not sufficient to meet the target set by the World Food Summit (WFS) of halving the number of undernourished people by 2015 (FAO, 2015b).

In America, although most of the households have a steady access to sufficient food, minority of American households face food insecurity (Jensen et al., 2014). European region has been undergoing a decrease in the prevalence of undernourishment since 2000 (FAO, 2015c).

Though food security has improved in almost every region of the world during the past, it is still a major concern around the world. Millions of money and lot of time are spent annually on food aid programs projected to minimize food insecurity. For these programs to work effectively there is an urgent need to identify current and future states (crisis state or growing state) and the movement of all four food security dimensions (availability, access, utilization and stability) with time, because food insecurity occur with the lack of all these four dimensions. Therefore, the objective of this study is to identify these four dimensions of food security, so that the appropriate food aid programs can be directed to where it needs most.

Methodology

Theoretical Framework

Markov Chain

When we have a set of states as S = $\{s_1, s_2 ... s_t\}$ the process starts in one of these states and moves consecutively from one state to another and each move is called a step.

Transition Probability Matrix

By a matrix, named as the transition probability matrix (P_{ij}), the transition probabilities of a stationary Markov chain can be represented.

$$\begin{pmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{pmatrix} \quad P_{ij}$$

Where:

$$P_{11} + P_{12} = 1$$
$$P_{21} + P_{22} = 1$$

P_{11} is the estimated probability of staying in state one in next period given that the state the process is in the current period. And P_{22} denotes the probability of staying in state two.

Markov Switching Autoregressive Model

This study used the simplest form of the model, where the transition was determined by a two state Markov chain. A time series (Y_t) following a Markov Switching Auto-Regressive (MSA) model (with two regimes) was used because these models are often applied to lower frequency data (quarterly, yearly, etc.). The function derived for Markov Switching Auto Regressive model was expressed as,

$$Y_t = C_1 + \varphi_t : s_t Y_{t-1} + \varepsilon_t$$

Where,

Y_t - Average value of variable related to food security given in Table 1

C_1 - State-dependent intercept which denotes growth rates as the data series is in the differenced form

$\varphi_i; s_t$ - i^{th} AR term in state s_t

t - 1, 2... T

ε_t - Error

Variable Selection

As the food security is measured with four main dimensions such as availability, accessibility to food, utilization of food and stability of these three, several indicators to represent these variables are used in the analysis as given in Table 1.

Data Collection

All the data in this study was obtained from the database available in the suite of food security indicators of "Food and Agriculture Organization" (FAO) and from United Nations Statistics division-National Accounts Main Aggregates Database (unstats.un.org). Data covered the period from 1960 to 2014 for four dimensions except for Utilization (which had data from 1990-2014 only) for five main regions (Africa, America, Asia, Europe and Oceania) and one sub region of Asian region.

Table 1. Variables Used in the Study

Dimensions of Food Security	Indicator	Description
Food availability	Average value of food supply	The total value of annual food production expressed in international dollars per head.
Accessibility to food	Gross Domestic Product per capita($)	Average income per person in a region.
Utilization of food	Access to improved water sources (%)	Percentage of the population with access to an adequate amount of water from improved water source
Stability of other Dimensions	Percentage of arable land equipped for irrigation (%)	Share of land irrigated over total land area

Data Analysis

A nonlinear time series model known as Markov Switching Autoregressive Model proposed by Hamilton (1989) and available in STATA (version 14) was used in modeling the movement of states (crisis or growing) of dimensions of food security in each region , transition probabilities between two states and the expected duration that one state last for each and every region. This model can be used for time series that are in transition over a set of finite states. States are unobserved and the process can switch among states throughout the sample. The time of transition between states and the duration in a particular state are both random. Such a Markov switching model uses the idea of the Markov process (Hamilton, 2008).

Results and Discussion

Outcome of Markov Switching Autoregressive Model

Estimated means (The average growth rates) of two states Markov Switching Auto regressive model are given in Table 2. The lower p-value reported in the test implied that two states were significant for all the regions except the state two in Europe region. All the regions showed low mean for state one than the mean of state two (Table 2). Hence, state one was termed as the 'crisis' state while state two was named as the 'success' state.

Table 2. The Average Growth Rates of Two States Obtained From Markov Switching Auto Regressive Model

Region	Food Availability		Accessibility to Food		Utilization of Food		Stability of Other Dimensions	
	Mean		Mean		Mean		Mean	
	S_1 Crisis	S_2 Success	S_1 Crisis	S_2 Success	S_1 Crisis	S_2 Success	S_1 Crisis	S_2 Success
Africa	-0.54*	0.24*	-16.9*	163.1*	0.65*	1.10*	0.01*	0.06*
America	-0.52*	0.42*	405.6*	394.6*	0.45*	0.53*	0.02*	0.102*
Asia	-1.19*	0.38*	57.2*	2299*	0.26 *	0.55*	-1.50*	0.112*
Europe	-0.54*	0.49*	269.3*	5509.5*	0.07 *	0.01*	-0.04*	0.105
Oceania	-0.55*	1.03*	349.7*	211.64*	0.15*	1.92*	0.006*	0.06*
South Asia	-0.01 *	0.01 *	23.19*	211.69*	0.79 *	0.90*	0.38*	0.02*

**Significant at 5%*

Availability of Food

The average growth rate of crisis state in food availability was negative and it is positive in the success state for all regions (Table 2). The lowest average growth rate of the crisis state (-1.19) of food availability was seen in the Asian region and the highest growth rate (-0.52) was in the American region. It implied that growth rate of food availability was high in developing regions like Asian and African than developed regions like America.

African and Oceania regions showed high probability of being in the crisis state in the next period of food availability (Table 3) and the estimated duration of crisis period was 22 and two years respectively (Table 3). Meanwhile, the duration of the success state is one year. The American, Asian, and South Asian regions showed a high probability of being in the success state in the next period and the estimated durations were 15, 2.7, and 1.2 years respectively. In the European region, the probability of being in both crisis (0.38) and success state (0.34) in next period was high, so both states were persistent. The estimated duration was two years. Therefore when compared with the other regions, African region showed longest period in the crisis state in food availability.

Accessibility to Food

With respect to accessibility of food, both the lowest average growth rate of being in crisis state (-16.9) and success state (163.1) was shown in the African region and highest average growth rate of crisis state (405.6) was shown in the American region (Table 2). And highest growth rate of success state (5509.5) was shown in the European region. So for African, Asian and South Asian regions, although the growth rate of crisis state of GDP was decreased the growth rate of the success state has not improved. It implied that these regions have to face fluctuations in accessibility to food. For America, Europe and Oceania regions growth rates of both states have improved. All six regions showed high probability of being in the crisis state in the next period and estimated durations were eight, 19, 19, 16, 12 and 20 years respectively. Therefore according to the results America, Asia, and South Asian regions showed longest time period in crisis state (Table 3.).

Table 3. Transition Probabilities and Expected Duration

Region	Food Availability		Accessibility to Food		Utilization of Food		Stability of Other Dimensions	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
Africa								
Probability	0.95	10^{-8}	0.88	0.75	0.95	10^{-8}	0.98	0.005
Duration	1.2	1	8	4	20	1	48	1
America								
Probability	10^{-8}	0.93	0.95	0.64	10^{-8}	0.49	0.96	0.83
Duration	1	15	19	2	1	2	23.5	1.5
Asia								
Probability	10^{-8}	0.64	0.95	0.49	0.91	0.47	10^{-8}	0.97
Duration	1	2.7	19	1	11.2	1.9	1	49
Europe								
Probability	0.38	0.34	0.94	0.69	0.82	0.68	0.97	0.97
Duration	2	2	16	3	5.8	3.2	35	36
Oceania								
Probability	0.31	10^{-8}	0.92	0.38	0.90	10^{-8}	0.98	10^{-8}
Duration	2	1	12	1	10	2	11	1
South Asia								
Probability	0.12	0.17	0.95	0.32	0.34	0.28	0.98	10^{-8}
Duration	1.14	1.2	20	1	1.5	1.4	40	1

S_1- Crisis State, S_2-Success State

Utilization of Food

The lowest average growth rate of crisis state (0.07) in utilization of food was shown by European region, and the highest (0.79) was shown by South Asian region. The highest average growth rate of success state (1.92) was shown by Oceania region. For American region, average growth rate of both states showed a moderate value. The utilization in South Asian region was in a low state and high state in European region. Except for American region, other regions showed high probability of being in the crisis state in the next period was and the estimated duration of crisis period was 20, 10, 1.5 years respectively. For American region the probability of being in the success state in the next period was higher and the estimated duration of crisis period was two years. Though the estimated probability of being in the crisis state was high, it will not last for a longer time in the American region.

Stability of Other Dimensions

Asia and Europe regions showed the lowest (negative) average growth rate of crisis state and that of the state of success was positive for all regions. South Asia showed the highest growth rate of crisis state (0.38) in stability and Asia showed lowest growth rate (-1.5). Because that, the growth rate of success state is higher in Asian region than other regions, it showed the highest stability in other three dimensions of food security. Except for Asian and European, other regions showed high probability in the crisis state in the next period. Africa and Oceania regions showed longest period in crisis state. It implied that Africa and Oceania regions have to face critical problems in the aspect of utilization of food.

Conclusions

Outcome of the Markov Switching Auto Regressive Model revealed that there are diverse regimes in the dimensions of food security (Crisis State and Success State) as identified by the predicted regimes. Therefore, as believed, food insecurity is a recurring problem rather than reducing over time.

In the African region, although the availability of food has slightly increased, stability of other dimensions will be in a crisis for a long time. Therefore, all four dimensions of food security will remain on the crisis state for a longer period when compared with other regions. Consequently, Africa will have to face a critical problem in food security (Chronic food insecurity) and food aid and assistance should be prioritized as a concern of all four dimensions. In the American and the Oceania regions, food availability is not a big problem. But there is concern on other dimensions. So America should put more emphasis on accessibility, utilization of food and stability of other dimensions.

For Asian and European regions most critical problem is the accessibility to food. Thus, the assistance should be prioritized on increasing economic and physical access to food. South Asian region also face problems in accessibility and, utilization of food and also stability of other dimensions.

To improve food availability, increasing domestic food production and import capacity may be some options. To improve physical access, transport and market

structure can be improved. To improve stability of supply and access, price fluctuations and political instability should be minimized. To improve food utilization, options would be improving food safety and hygiene in manufacturing practices applied and increasing dietary diversity. The options for food insecurity which has long term effects maybe limiting global warming, develop climate- friendly agricultural production systems and land-use policies which helps to mitigate climate change and raise awareness of the pressures of increasing population growth and consumption patterns.

Finally, food security is a multi-dimensional phenomenon, where, all four dimensions have to be in a favorable state to eradicate insecurity. Therefore, all four dimensions should be considered and by understanding, which dimension is critical in each region, a proper mechanism to eradicate food insecurity can be put in place.

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