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Food Security Models

by
Samir Jrad
Bashar Nahas
Hajar Baghasa

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Summary

This policy brief reviews the various literature related to food security comprising: studies related to food security in Syria, studies related to food security in general and other references in order to propose a methodology for the analysis of food security in Syria. In this regard, past surveys are also presented. Hence, several approaches, considering their mixed application, are used to assess the state of food security. The first approach is indicator-based emphasizing the indicators focusing on food security dimensions such as food availability, food accessibility and variability, and those based on FIVIMS[1]. The second approach relies on general equilibrium point of view using the Social Accounting Matrix (SAM) and the 1-2-3[2] Simple Computational General Equilibrium Model (SCGE) to make policy simulations. The third approach focuses on the econometric estimation of consumer demand by applying the Linear Expenditure System (LES) and the Almost Ideal Demand System (AIDS) to assess elasticities, nutrition related measures and welfare indicators.

1. Background

The objective of food security, as defined by the Food and Agriculture Organization of the United Nations (FAO), is to assure that 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[3]. This has to be achieved at three levels simultaneously: individual, household, and national/regional levels. This definition implies that there is the need not only to have adequate supplies of food available, but also to maximize their stability and to secure their access[4]. It also indicates 5 dimensions for food security: availability, accessibility, stability of supply and access, utilization/nutrition and food & nutrition safety[5].

Relying on above, Chart A1[6] shows different levels of food security and the main analysis approach. This methodology focuses on comparing supply, demand and consumption with needs. In addition, Chart A2 illustrates the conceptual framework to assess the state of food insecurity by food security dimensions indicating both the dependencies between the macro-environment and food security concepts and the interrelationships among the food security measures. Hence, the socio-economic and political environment has a substantial impact on the food security elements and the state of food security. Thomson and Metz (1997) and Siam (2008) formulated several frameworks to identify the impacts of various policies comprising monetary, financial, trade, self-sufficiency, production, pricing, marketing, distribution and stock policies. Table 1 illustrates the impacts of selected policies on food security.

Table 1. Impacts of selected policies on food security dimensions

Item	Availability	Accessibility	Sustainability
Support policy	Producers support	Consumers support	
Production policy	Self-sufficiency and self-reliance		
Strategic stocks policy			Sustainable availability
Trade policy	Relaxing food import constraints		Stocking through imports

Source: Elaborated from Siam (2008).

[1] "Food Insecurity and Vulnerability Information and Mapping Systems".
[2] One country, two sectors and three commodities.
[3] Goettingen University (2009) and FAO, SOFA (2005).
[4] Thomson, Anne and Metz, Manfred (1997) and NAPC, SOFAS 2007.
[5] Goettingen University (2009).
[6] Chart A1: Annex Chart 1.

Chart A3 traces the impacts of structural adjustment programmes on agricultural production, prices and marketing. Chart A4 shows the correlation between macro policies and food security. Chart A5 indicates the relationships among agricultural policies and food availability and access. Chart A6 identifies the impacts of liberalization of agricultural world trade on the state of food security in food importing countries. To quantify the impacts of such policies on the state of food security different approaches and models are used. However, before explaining the nature of such methods, a literature review is conducted to show the various applications of these methodologies and to choose the methodology for conducting the current food security study of the NAPC[7].

2. Literature review

This section reviews various studies and past surveys related to food security in Syria and other food security studies and references, which are useful to propose a methodology for the food security study of the NAPC.

2.1. Studies and past surveys related to food security in Syria

A study was conducted in 2000 by the NAPC about *food security* under the supervision of the international consultant Hamdi Salem. The organization of the main report followed the formal definition adopted by FAO for food security: production of adequate food supplies, maximization of the stability of supplies and secured access to available supplies on the part of those who need them. The report analyzes closely the different factors affecting developments within these three dimensions, with a view to reaching specific policy recommendations and suggesting a number of projects that would ensure sustainability of food security over time.

A second study was executed by the UNDP in 2004 about *macroeconomic policies for poverty reduction in Syria* under the supervision of Mahmoud Abdel Fadil and several authors. This report adopted a general approach that focuses on fostering growth with equity. Dealing with inequalities, such as regional inequalities, is integral to this effort. Inequalities can be reduced, the report argues, through general microeconomic policies, such as those that provide farmers with more secure access to land and credit or stimulate their production through price supports. The report also gives high priority to reducing unemployment and underemployment. Allocating funds to the unemployed is part of the solution. But employment generation depends fundamentally on whether growth is rapid and broad-based. General macroeconomic and adjustment policies are decisive in determining such an outcome.

Another study in 2004 was implemented by Ghosh about *poverty, household food availability and nutritional well-being of children in north-west Syria* under the supervision of the Department of Nutrition of the University of Massachusetts Amherst. As a result, rural women and children suffer the most from poverty and its physical and social deprivations. The study compares differences in child growth and nutrition in three rural livelihood groups related to Aleppo Province in Syria: a barley–livestock' group, an 'olive/fruit tree' group and an irrigation group. Informal interviews, food card sorts' exercise, key informant socioeconomic evaluation, household food frequency and portion size questionnaires, health questionnaires, and anthropometry were conducted. Independent sample t-tests, one-way analysis of variance, GLM[8] univariate analysis of variance and linear regression analysis were used.

A *food security study and survey* focusing on the Arab world comprising Syria were executed by the Arab Organization for Agricultural Development (AOAD) in 2007. The report consists of two parts. The first section assesses the indicators of food security considering food supplies, accessibility, nutrients, gap and self-sufficiency. The second one investigates the main issues related to food security at both international and Arab levels. The study indicates an adequate

[7] NAPC = National Agricultural Policy Center.
[8] Generalized Least Squares Method.

development in 2007 regarding food supplies, availability and consumption of plant and animal products leading to better nutritional levels and food self-sufficiency ratios as well as to reduction of food gap in spite of the increasing rate of international food prices. The most important issues related to food security explained by the report are the development of international food prices, food safety nets, use of food products for bio-fuel, changes in food stocks and the impacts of such variables on the livelihood of people. The research discussed also the state of food security in the context of the Arab Sustainable Agricultural Development Strategy in the forthcoming two decades. The AOAD focuses on the cooperation with Arab countries to execute projects in the fields of the enhancement of food production and consumption, establishment of national food stocks and foundation of regional stocks especially cereals.

A technical report about *income distribution and poverty: impact of selected policies in Syria* was published by the NAPC in 2008. The general aim was to strengthen the capacity of NAPC staff in addressing policy issues for rural areas, as poverty alleviation and internal rural to urban migration, using quantitative tools of analysis. A detailed Social Accounting Matrix (SAM) of Syrian economy was built for 2004. The matrix includes accounts for 51 commodities, 41 production activities, 2 factors of production and 22 institutions. A high degree of disaggregation has been included for agriculture (31 commodities and 28 activities) and food sector (15 commodities and 8 activities). The households sector has been disaggregated by income level (deciles of equivalent per capita expenditure) and by regional location (urban vs. rural). The estimated SAM has been used to carry out an analysis of income distribution and poverty in Syria. A SAM based "fixed price" model has been used to conduct a structural analysis of distributive features of Syrian economy. The results highlight the existence of structural asymmetries in income distribution. On the whole richer and urban households are favored by multiplier effects, improving their relative position in income distribution in presence of exogenous increases in final demand. The model has been also used to simulate the impact of selected policy options for agriculture and food industries. Nine policy scenarios have been defined combining in different ways the suppression of three current policies for food and agriculture (subsidies to agricultural production activities, price support for strategic crops, support of food consumption through the Price Stabilization Fund) with alternative uses of financial resources set free for the Government budget (deficit reduction, Government expenditure increase, transfer to households increase).

A good reference about the food security situation in Syria is the *Strategy of Nutrition of the Ministry of Health*, which describes the food security status in Syria relying on the results of the Multiple Indicators Cluster Survey2006 conducted by the Central Bureau of Statistics (CBS) in cooperation with the United Nations Children's Fund (UNICEF) and published in 2008. The strategy describes the nutrition conditions relying on anthropometric, biochemical, clinical and dietary measures and includes the reference intakes of macro and micro nutrients by age groups. In addition, the Household Expenditure Survey conducted by the CBS in 2003-2004 and 2006-2007 represents an adequate data base for applying several methodologies to assess the circumstances of food security in Syria.

A recent Rapid Rural Appraisal conducted by the MAAR in 2009 focuses on exploring the food security situation in the villages underlying severe poverty according to the poverty map of Syria to formulate a national programme for food security in order to reduce poverty complying with the millennium goals of food security proposed by the World Food Summit. The number of surveyed villages amounted to 17 representing 114 villages. It studies deliberately the villages considering all dimensions of food security and showed the existence of food security problems especially concerning the acquired income, nutrients deficiency and malnutrition.

In 2008 a case study about *the impact of soaring international food prices on the Near East and North Africa Region (NENA)* was performed under the supervision of the FAO Regional Office for the Near East relying on survey data from the participated countries. Accordingly,

Syria was impacted moderately by the increase of food prices and the number of the undernourished augmented slightly because of the fair government policies towards food security. Another study in 2008 was conducted by the AOAD on the same topic considering Arab countries including Syria. The study indicates that there are simultaneously positive and negative impacts on the food security situation in these countries. The impacted variables are supplies of food stuffs, resource reallocation, cropping structure, demand for and consumption of food products, food expenditure, food quality, income level, poverty level, trade balance and others.

Finally, according to the Syria Drought Response Plan (2009), Syria has been affected by drought since 2006. While the 2007-2008 droughts were very severe and had a wider geographical reach, the current drought has again affected a population that was already suffering from the impacts of previous drought spells. According to the Government of Syria and UN assessment missions1, some 1.3 million inhabitants of eastern Syria have been affected by this disaster, out of which 803,000 people have lost almost all of their livelihoods and faced extreme hardship. According to this UN Needs Assessment Mission, up to 80% of those severely affected live on a diet consisting of bread and sugared tea, which only covers on average some 50% of both caloric and protein requirements. These families are not able to sustain or restore their livelihood without emergency support including food aid, farming inputs, and animal feeds, supplemented by other types of assistance.

2.2. Other references related to food security assessment

Beyer and Walter (1977) illustrated the use of mathematical-statistical methods for the quantitative analysis of economic phenomena comprising output and inputs measures. They used *index numbers* (Paacshe and Laspeyres) to quantify the impacts of the factors underlying these indicators. Hoy et al. (2001) explained the methodology of *comparative statics equilibrium analysis* to study the impacts of the changes in exogenous variables on endogenous variables in economic models such as the Simple Keynsian Model of Income Distribution by assessing the income multiplier. Both aforementioned methods can be used to analyze the dynamic of the SAM accounts.

Johnson, Hassan and Green (1984) explained the application of various demand systems both static and dynamic to assess consumer demand for major foods in Canada. Accordingly, consumption behavior is the focus of continuing emphasis in applied economic research; aspects of consumption behavior that have attracted the attention of economists include consumer demand, Engel curve analysis and consumption functions in more aggregated contexts. The static demand systems are the LES, the Rotterdam Model and the Indirect Addilog System. The dynamic demand systems are the dynamic LES and the State Adjustment Model. Perali (2003) illustrated the use of various demand estimation models including Engel curves' analysis to study consumers' behaviors and to conduct welfare analysis. Extending this analysis, Pomboza and Mbaga (2007) used a modified AIDS model to estimate demand elasticities for food in the same country. Mittal (2006) indicated that the knowledge of demand structure and consumer behavior is essential for a wide range of development policy questions like improvement in nutritional status, food subsidy, sector and macroeconomic policy analysis, etc. An analysis of food consumption patterns and how they are likely to shift as a result of changes in income and relative prices is required to assess the food security-related policy issues. He used a quadratic AIDS model to estimate the price and income elasticities in India and to project demand for major food groups using household consumption expenditure data. On the same topic, Ecker and Qaim (2008)[9] used a quadratic AIDS model to estimate income and price elasticities of food, calorie and micronutrients consumption in Malawi. Hence, given multiple nutrient deficiencies, income-related policies are better suited than price policies to improve nutrition.

[9] Goettingen University (2009).

Robinson (1989) illustrated the typologies of models and their uses comprising input-output and social accounting as well as CGE[10] models. Sadoulet and de Janvry (1995) gave an idea about a number of monetary measures of change in welfare comprising consumer surplus, compensated and equivalent variation, and real income. Both sources also explained the assessment of Gini coefficient as an indicator of income distribution and dimensions of food security and their variability using total availabilities, per capita availability, self-sufficiency and import dependency ratios, and coefficient of variation. Furthermore, they illustrated the estimation of LES and AIDS models and their application to assess nutrition elasticities as well as the implementation of the SAM and the CGE in various countries. The University of Pretoria examined the 1993/1994 SAM of Botswana to make policy simulations on food security using fixed-price income multiplier and price multiplier analysis. Francois and Reinert (1997) explained the use of a simple CGE model incorporating one country, two sectors and three goods (1-2-3 model). The State of Food and Agriculture 2005 published by the FAO traces the impacts of trade liberalization on food security and poverty, indicates the effects of trade by the means of a CGE model and explains the key features of using such a model.

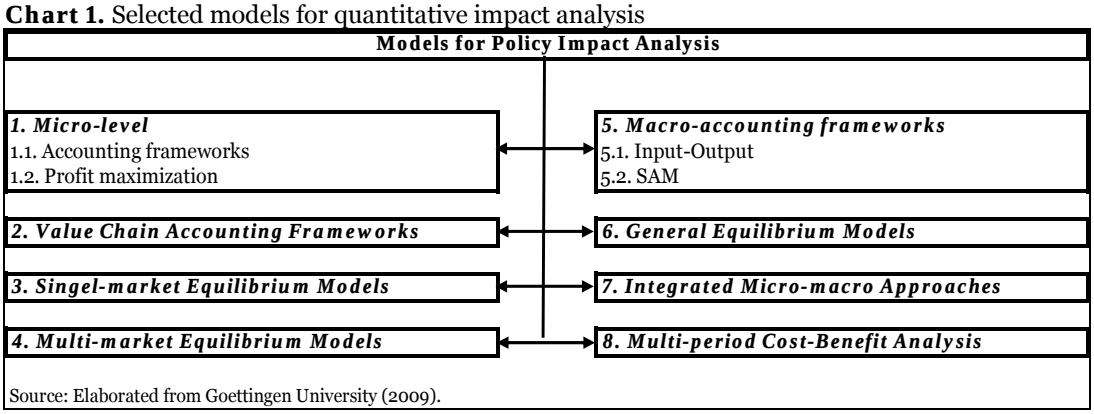
Bickel et al. (2000), USDA[11], present a guide to measuring household food security comprising a questionnaire composed of 16 questions and a food security scaling procedure, which can be adopted by measuring the state of food security in Syria.

The Department of Agricultural Economics and Rural Development of Goettingen University in Germany conducted a training course for NAPC staff about food security in 2009. The course comprises the following topics: definition and measurement of food security, survey methods to assess food insecurity, analysis of policy impacts on food security, relevance and usefulness of various models for food security analysis and applied policy analysis. Hence, five principal components of food security are of interest namely: availability, access, stability of supply and access, utilization/nutrition and food safety. The course also traces the factors impacting these domains relying on various literatures. In this context, indicators have been chosen to assess the state of food security at national and household level relying on FIVIMS[12] (Table A1). FIVIMS has identified 15 information domains as relevant for the agreed Conceptual Framework for Understanding the Possible Causes of Low Food Consumption and Poor Nutritional Status (Table A1 and Chart A7). Table A1 illustrates the selected indicators for National FIVIMS comprising FIVIMS-related indicators and United Nations System Lists. It has been also distinguished between macro and micro assessment using various economic models (Chart 1).

Devereux et al. (2004) published a policy paper focusing on best practice in the use of livelihoods analysis in influencing policy issues related to food security and the measurement of hunger. In addition, World Health Organization (WHO) Report (2007), which arises from the Joint WHO/FAO/UNU Expert Consultation on Protein and Amino Acid Requirements in Human Nutrition, represents a good reference to analyze protein intakes and food security issues. Also, FAO published a paper in 2008, which investigates deriving food security information from national household budget surveys. The document is a compilation of papers from 11 countries in Asia, Africa and Eastern Europe and facilitates a better understanding of food security indicators in terms of their production and use for policy analysis as well as their limitations.

[10] Computational General Equilibrium Model.
[11] United States Department of Agriculture.
[12] "Food Insecurity and Vulnerability Information and Mapping Systems".

Chart 1. Selected models for quantitative impact analysis



Source: Elaborated from Goettingen University (2009).

Qaim (2009)[13] gave an idea about the *economics of micronutrient malnutrition* comprising definition and international overview, assessment of micronutrient status, integration of micronutrients in policy impact assessments and micronutrient intervention. He explained the impacts of micronutrient deficiency and the methods applicable to avoid the shortage of micronutrients, the use of econometrics to assess the level of nutrient intakes given several independent variables such as income and home garden and the application of the AIDS model to estimate various elasticities (price, income and nutrients).

Finally, comparing Syrian food security indicators with international ones is a useful tool to trace the performance of the Syrian economy concerning food security issues. FAO Food Outlook published in 2009 about global market analysis, FAO database and AOAD database serve such an aim.

3. Choice of methodology

According to the previously mentioned literature, the methodology focuses on two approaches to assess the food security situation in Syria and to make policy simulations namely: macro assessment and micro evaluation.

The macro analysis is conducted relying on selected FIVIMS indicators that are used to investigate the food security situations on national/sub-national levels (Table 1, Table A1 and charts presented in Annex) as well as SAM assessment to trace the impacts of exogenous shocks on food security (Chart 1).

Sum selected FIVIMS measures are food availability, food access, stability of food supply and access, food acquisition and food safety considering the policies affecting those. Food availability is measured by the assessment of total availability and the per caput availability taking into account the domestic supply compared with domestic consumption and international indicators; food accessibility is analysed using measures of income such as real GDP, food prices and food price indexes; stability of supply and access is illustrated by using the coefficient of variation; food acquisition is assessed in the form of macro and micro nutrients compared with international measures; food safety is estimated using health and sanitation indications; see chart A2. The changes in the aforementioned measures and those underlying factors are also presented using the average annual growth rate (AAGR) and index numbers' analysis.

Total availability = domestic supply + import – export – non-food uses – wastage & losses ± changes in stock

Per caput availability = total availability/population

CV = standard deviation of $(y_i-\tilde{y}_i)/\tilde{y}_i * 100$

[13] Goettingen University.

Where:

CV- Coefficient of variation measured in percent;

y_i- The current value;

$\tilde{y}i$- The trend value.

Average change% = ((average last three years – average first three years)/average first three years)*100

AAGR = (Power (average of the last three years/average of the first three years, 1/N)-1)*100

Where:

AAGR- Average annual growth rate measured in percent;

N- Number of years-1

Change% = $(y_i-y_o)/y_o * 100$

Where:

y_i- The current value;

y_o- The base value.

In addition to the aforementioned indicators, it is useful to assess welfare and inequality measures.

A financial measure of the welfare change comprises the changes in real income (y) and consumer surplus (ΔCS) due to price change between the states (p^o, y^o) and (p^1, y^1) according to the following equation:

$S = y^1-y^o + \Delta CS$

Where:

S – change in welfare;

y^1 – current income;

y^o – income in base year;

p^o – price of the base year;

p^1 – price of the current year;

ΔCS – change in consumer surplus;

Δ - change.

The change in real income can be expressed as follows:

$\Delta \text{real } y/\text{real } y = \Delta y/y - \Delta p/p$

Where, p denotes the price.

In this regard, the definition of a true price index (P) is necessary to achieve a constant level of utility. Such a price index can be assessed as the ratio of the minimum expenditure required in current period 1 and base period 0. Typical candidates are the Laspeyres Price Index P_L and the Paasche Price Index P_P. To avoid the drawbacks of both indices, the Fisher's Ideal Price Index P_F is also calculated.

$P_L = \sum q_i^o p_i^1/\sum q_i^o p_i^o$

$P_P = \sum q_i^1 p_i^1/\sum q_i^1 p_i^o$

$P_F = \sqrt{\sum q_i^o p_i^1 \sum q_i^1 p_i^1/ \sum q_i^o p_i^o \sum q_i^1 p_i^o}$

Where, I is assigned for commodity, q denotes quantity and √ is the square root.

Index numbers can also be used to separate the impact of various factors on an indicator. For example, the total expenditure is composed of the quantities consumed and the prices paid by the consumer. To split the impact of quantities and prices on the total expenditure between the current period and the base period, the following formula can be useful:

$I_E = I_q I_p$

Or:

$\sum q_i^1 p_i^1 / \sum q_i^0 p_i^0 = \sum q_i^1 p_i^0 / \sum q_i^0 p_i^0 * \sum q_i^1 p_i^1 / \sum q_i^1 p_i^0$

Where:

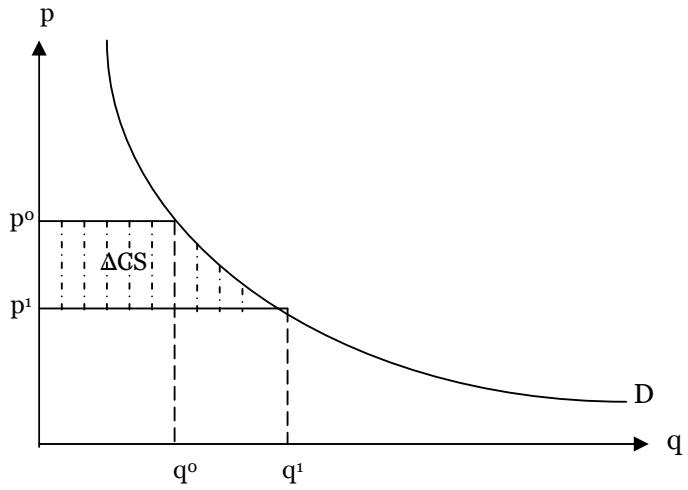
$I_E = \sum q_i^1 p_i^1 / \sum q_i^0 p_i^0$ – Index of total expenditure, which traces the impact of both quantities and prices on total expenditure;

$I_q = \sum q_i^1 p_i^0 / \sum q_i^0 p_i^0$ – Index of quantity, which indicates the effect of quantities on total expenditure holding prices constant;

$I_p = \sum q_i^1 p_i^1 / \sum q_i^1 p_i^0$ – Index of price, which assesses the influence of prices on total expenditure keeping quantities fixed.

The consumer surplus is an attractive measure of consumer benefits from price change because it represents the excess willingness to pay over what is actually paid (Figure 1 and formula).

Figure 1. Consumer surplus



Source: Elaborated by the author.

$\Delta CS = q^1 (p^0 - p^1) + 0.5 (q^1 - q^0) (p^0 - p^1)$

D – Demand curve.

A simple statistical indicator of income inequality is the coefficient of variation of income cv(y), which is the ratio of the standard deviation of income σ(y) to mean income ỹ. A more accurate measure is to calculate the cv(y) considering the trend line.

Analysis of the interaction among sectors is crucial to identify the role of agriculture and other sectors in the development process considering food security aspects. Such linkages are the focus of a Social Accounting Matrix (SAM). "A SAM is a square matrix in which each trans-actor or account has its own row and column. The payments (expenditures) are listed in columns and the receipts in rows. As each account must balance, the corresponding row and column totals are equal. There are six types of accounts in the SAM: the activities, commodities, and factors (labor and capital) accounts; the current accounts of the domestic institutions, divided into households, firms, and the government; the capital account; and the rest of the world account

(ROW)."[14] The composition of these accounts can be presented as indicated in Annex, Table A2 and Table A3. The SAM is also used to make policy simulations. Therefore, it's divided into endogenous and exogenous accounts. The account is called endogenous when changes in the level of expenditure follow directly any change in income, while by exogenous accounts the expenditures are set independently of income. The relationship between endogenous and exogenous accounts can be illustrated as indicated in Table 2. Y is the vector of total income or expenditure of the endogenous accounts, F the vector sum of the expenditures of the exogenous accounts, L the column vector of the income of the exogenous accounts, M the square matrix (n x n) of coefficients of the endogenous accounts and B the rectangular matrix (m x n) of the coefficients with exogenous accounts.

Table 2. Relationship between endogenous and exogenous accounts of the SAM

Item	Endogenous accounts (n)	Sum of exogenous accounts (1)	Total
Endogenous accounts (n)	MY	F	Y
Exogenous accounts (m)	BY	L	
Total	Y		

Source: Elaborated from Sadoulet and de Janvry (1995).

If Δ denotes the change, one may define:

The matrix of multipliers	$(I-M)^{-1}$
The vector of shocks	ΔF
The vector of impacts	$\Delta Y = (I-M)^{-1}\ \Delta F$
The leakages	$\Delta L = B\ \Delta Y$

A shock, or "injection", is induced by a change in elements of the exogenous accounts. The model solves for the equilibrium level of all the endogenous accounts. Multipliers are completely demand driven. The matrix M of technical coefficients (a_{ij}) is imputed as the ratio of the corresponding cell of the SAM matrix to the column total. Inverting the block (I-M) gives the SAM multipliers, which represent the direct impacts on production (sectors) and income (factors) of an increase in exogenous demand. This process is called the problem of comparative-static equilibrium analysis or comparative statics (see Annex, The Simple Keynesian Model of Income Determination)[15]. In addition to comparative statics, index number analysis can also be used to analyse the dynamic of SAM accounts.

Furthermore, a concise SAM can be useful to a apply general equilibrium analysis for the purpose of making policy simulations considering prices[16]. Such SAM is presented in Table 3. Hence, the variables are: X = output (GDP), C = household consumption, G = government consumption, Z = investment, E = exports, Y = income (value added), T^h = household taxes, S^h = household savings, S^g = government savings, B = balance of trade and M = imports; the microeconomic identities are: Y = X (domestic income = domestic product), X + M = C + G + Z + E (aggregate supply = aggregate demand), $Y = C + S^h + T^h$ (household income = expenditure), $S^g = T^h - G$ (government savings = taxes – expenditure), $Z = S^h + S^g + B$ (investment = savings) and B = M – E (balance of trade = foreign savings).

Relying on the aforementioned SAM, the Basic 1-2-3 Simple Computational General Equilibrium Model (CGE) can be applied. The model assumes one country, two producing sectors and three goods: an export good E, which is sold to foreigners and not demanded domestically, a domestic good D, which is only sold domestically, and an import good M, which is not produced domestically. There is one consumer who receives all income. The country is

[14] For more details, see Sadoulet and de Janvry (1995) and NAPC (2008).

[15] Also, see Hoy et al. (2001).

[16] Chenery and Srinivasan (1989).

small in world markets, facing fixed world prices for exports and imports. The equation system is presented in Table 4. The model can also be solved as programming problem (see annex).

The above-mentioned approaches can be applied at micro level or household level considering both the distributional effects among households and household characteristics. In addition, an extension is needed in the fields of income distribution

Table 3. A macroeconomic SAM

Receipts	Expenditures						Total
	Activities	Commodities	Households	Government	Capital account	ROW	
Activities		X					GDP
Commodities			C	G	Z	E	Demand
Households	Y						Income
Government			T^h				taxes
Capital account			S^h	S^g		B	Savings
Rest of the world (ROW)		M					Imports
Total	Domestic income	Supply	Expenditures			Foreign exchange	

Source: Elaborated from Chenery and Srinivasan (1989).

Table 4. The basic 1-2-3 CGE model

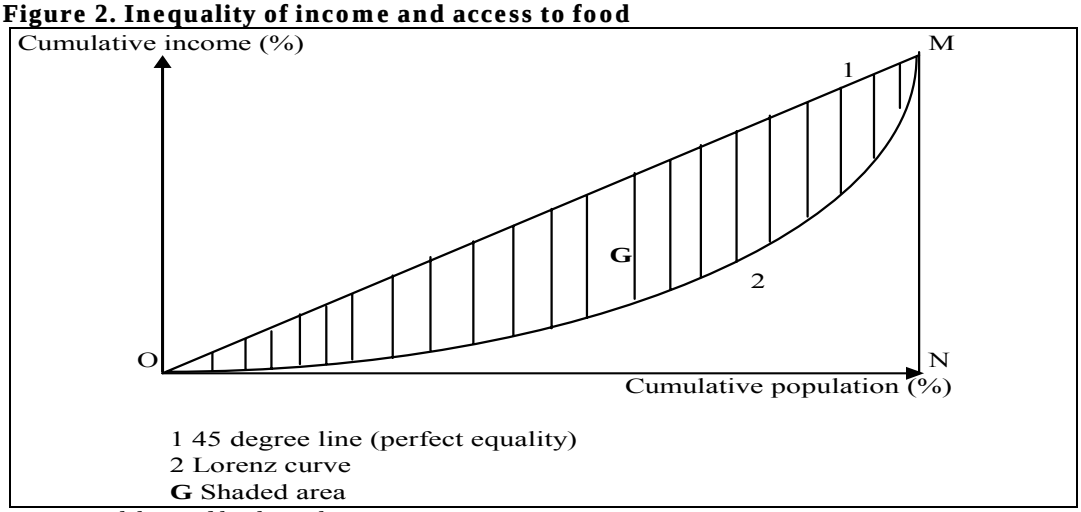
Flows	Prices	Equilibrium conditions	Identities	Endogenous variables	Exogenous variables
$X = G(E, D^s; \Omega)$	$P^m = R\ pw^m$	$D^D = D^s$	$P^x \bar{X} = p^e E + p^d D^s$	E: Export good	Pw^e: World price of export good
$Q^s = F(M, D^D; \sigma)$	$P^e = R\ pw^e$	$Q^D = Q^s$	$P^q Q^s = p^m M + p^d D^D$	M: Import good	pw^m: World price of import good
$Q^D = Y/p^q$	$P^x = g_1(p^e, p^d)$	$Pw^m M - pw^e E = \bar{B}$	$Y = p^q Q^D$	D^s: Supply of domestic good	$\bar{B}$: Balance of trade
$E/D^s = g_2(p^e, p^d)$	$P^q = f_1(p^m, p^d)$			D^D: Demand for domestic good	σ: Import substitution elasticity
$M/D^D = f_2(p^m, p^d)$	$R = 1$			Q^s: Supply of composite good	Ω: Export transformation elasticity
$Y = p^x \bar{X} + R \bar{B}$				Q^D: Demand for composite good	
				Y: Total income	
				p^e: Domestic price of export good	
				P^m: Domestic price of import good	
				P^d: Domestic price of domestic good	
				P^x: Price of aggregate output	
				P^q: Price of composite good	
				R: Exchange rate	
				$\bar{X}$: Fixed aggregate production (real GDP)	

Source: Elaborated from Francois and Reinert (1997).

(Gini) and demand estimation to calculate demand elasticities, nutrition elasticities and consumer surplus.

A more complete way to analyse income distribution is accomplished by constructing the Lorenz Curve, which traces the relationship between the cumulative income and cumulative population, and estimating the Gini Coefficient (Figure 2 and formula).

Figure 2. Inequality of income and access to food



Source: Elaborated by the author.

Gini = area G/area OMN

The Gini coefficient[17] varies from 0 (perfect equality) to 1 (perfect inequality).

To assess consumer demand, there are various approaches: single equation and demand systems, which are characterized by advantages and disadvantages; hence, the focus is here on Engel curve estimation, the Linear Expenditure System (LES) and the Almost Ideal Demand System (AIDS).

By the Single Equation Approach, the demand functions will be estimated in a pragmatic fashion without recourse to the economic theory. Thus, these ad hoc models or single equation models can not represent preferences for all goods we buy, so the total expenditure function and utility based on the consumption of the complete basket can not be derived. However, such models can be implemented in the context of a welfare analysis where a great accuracy is not required like the one achieved by estimating a system of demand equations. A typical situation, for instance, is to estimate from time series data the income and price elasticities for a commodity in a constant elasticity demand equation such as:

$$\ln Q_i = \alpha_i + \sum E_{ij} \ln P_j/P + \eta_i \ln y/P + \sum b_{ik} \ln z_k$$

Where: Q_i = Quantity purchased of good i per capita, P_j = Prices of good i and of selected other commodities j which are close substitutes or complement, y = Total expenditure per capita, P = Consumer price index, E_{ij} = Direct and cross price elasticities, η_i = Expenditure elasticity, z_k = Household characteristics, time (to account for steady changes in tastes, in the distribution of income, and in the quality of products), and other exogenous variables, b_{ik} = Elasticities of demand with respect to z_k; see Perali (2003), Sadoulet and de Janvry (1995), and Oezcan, Tan and Dellal (Ankara, Turky).

The use of relative prices (P_i/P) and real income (y/P) as exogenous variables makes the demand equations homogenous of degree zero in prices and income. This insures that there is no "money illusion" in demand in the sense that it is not affected by a proportional increase in

[17] For more details, see Sadoulet and de Janvry (1995).

all prices and income. Moreover, this approach is designed to answer policy questions that are specific to a particular commodity or commodity group.

The drawbacks of this approach can be summarized as follows:

- The choice of functional forms for the demand equations and of the variables to be included is arbitrary (combination of common sense, interest in specific elasticities, computational convenience, and goodness of fit criteria).
- The log functional form used above assumes constant elasticities over all values of the exogenous variables. This is true only over a short range of prices and income (because of switching between luxuries and necessities as income increases).
- Predictions relying on this approach may not satisfy the budget constraint.

More flexibility to the model can be introduced in the case of nonlinearities by adding a quadratic term (income, price, and demographic). For example, when the model is non-linear in income, the model can be written as follows; see, Perali (2003) and Raunikar and Huang (1984).

$\text{Ln } Q = a_o + a_1 \ln d + a_2 \ln p + a_3 \ln y + a_4 \ln y^2$

Where: a_o, a_1, a_2, a_3, a_4 are parameters to be estimated, d = demographic variable, p = price, y = income.

Holding prices constant is considered a link to study the relationship between the consumption of food and income, which is expressed through Engel laws and Engel curves (Table 5), see Binger and Hoffman (1998) and Perali (2003).

Table 5. Engel's curves

Engel's curve	Mathematical formula	Income elasticity
Linear	$q = a + b*y$	$\eta_i = b*y/(a + b*y)$
Double-logarithmic	$\ln q = a + b*\ln y$	$\eta_i = b$
Semi-logarithmic (semi-log)	$q = a + b*\ln y$	$\eta_i = b/q = b/(a + b*\ln y)$
Logarithmic reciprocal	$\ln q = a - b/y$	$\eta_i = b/y = a - \ln q$
Working – Leser (WL) Engel curve (semi-log)	$w = a + b \ln (y/N)$**	$\eta_i = b/w + 1$
WL Engel curve with demographic	$w = a + b \ln d + c \ln (y/N)$	
WL Engel curve with prices	$w = a + b \ln p + c \ln(y/N)$	
WL Engel curve with prices and demographic	$w = a + b \ln d + c \ln p + d \ln$	

Source: Elaborated from Sadoulet and de Janvry (1995) and Perali (2003)
**$y^* = y/N$.

***First Engel Law*:** As the log of income increases, the food share decreases.

***Second Engel Law*:** As family size increases, the share of expenditure allocated to food also increases.

The estimated Engel curves should have several qualities (Sadoulet and de Janvry, 1995):

- They should satisfy the budget constraints. The predicted expenditure for each commodity should add up to the total expenditure.
- They should be able to represent luxuries, necessities, and inferior goods.
- They should have variable income elasticities due to the empirical fact that income elasticities tend to decline as income increases.

- The consumption of many commodities should reach a saturation point as income increases.

The Demand Systems Approach uses a complete system of demand equations relying on the economic theory. This system of equations aims at taking into account consistently the mutual interdependence of large numbers of commodities based on the structure of relative prices, real income, and a set of individual characteristics and demographic variables such as age, education, professional status, type of household, and rural versus urban population. The estimation results can be used to study behavior (forecasting) and to conduct welfare analysis; see Perali (2003).

Study of behavior:

- Demand for goods (wheat, nutrients, etc.).
- Analysis of structural changes: habits, heterogeneity of tastes.
- Demand for quality characteristics.

Welfare analysis:

- Estimation of the expenditure function and utility in order to derive the compensating variation which is an exact measure of consumer surplus.
- Poverty and inequality.
- Consumer Surplus (CS).
- Demand and optimal taxation.

The microeconomic theory of consumer behavior postulates that a consumer's choice can be described as deriving from utility maximization subject to a budget constraint. Thus, the objective of the theory is to explain how a rational consumer chooses what to consume when confronted with various prices and a limited income. Consequently, the solution to this maximization problem is a system of demand equations (first order conditions) restricted to several homogeneity and aggregation conditions.

Sadoulet and Janvry (1995), Johnson, Hassan, and Green (1984), and Perali (2003) illustrated the theory of consumers behaviors and the restrictions imposed on the system of equations. Accordingly, the consumer maximization problem can be described as follows:

Max L = u(q,z) + λ (y – p' q) subject to λ and q

Where: L – The consumer objective function, u(q, z) – Utility function of the consumer,

q- Vector of quantities of n commodities on which a consumption decision must be made, z- Individual characteristics, λ - Langrange multiplier, y – The amount of income which can be spent, p' – N – dimensional vector of prices, y = p'q.

The solution to the aforementioned maximization problem is a set of demand equations $q_i = q_i$ (p, y, z) with i = 1… n. The n equations include n income slopes $\partial q_i/\partial y$ (partial derivative) or income elasticities $\eta_i = \partial q_i/\partial y * y/q_i$ and n^2 price slopes $\partial q_i/\partial p_j$ or price elasticities $E_{ij} = \partial q_i/\partial p_j * p_j/q_i$. According to the signs and magnitudes of these elasticities the goods are classified as follows:

Own-Price Elasticity

- Non-Giffen good: $E_{ii} < 0$ ($E_{ii} < -1$ elastic; $E_{ii} > -1$ inelastic).
- Giffen good: $E_{ii} > 0$ (see Binger and Hoffman (1998)).

Cross-Price Elasticity

- Gross substitutes: $E_{ij} > 0$.
- Gross complements: $E_{ij} < 0$.

Income Elasticity

- Normal good: $\eta_i > 0$ ($\eta_i > 1$ luxury; $\eta_i < 1$ necessity).
- Neutral good: $\eta_i = 0$.
- Inferior good: $\eta_i < 0$.

The parameters of the demand equations must satisfy the following constraints:

1. The Engel aggregation equation derived from the budget constraint:

$\Sigma\, p_i\, \partial q_i/\partial y = 1$ or $\Sigma\, w_i\, \eta_i = 1$, where $w_i = p_i\, q_i/y$ is the budget shares.

2. The n Cournot equations derived also from budget constraint:

$\Sigma\, p_i\, \partial q_i/\partial p_j = -\, q_j$ or $\Sigma\, w_i\, E_{ij} = -\, w_j$, for j = 1, …, n.

The two sets of equations together lead to the n Euler equations (not additional restrictions) which represent the homogeneity conditions ($\Sigma\, E_{ij} + \eta_i = 0$; i = 1, …, n). These conditions state that demand functions are homogeneous of degree zero in prices and income. In other words, if all prices and income increase in the same proportion, demand remains unchanged.

3. The n (n-1)/2 Slutsky equations that express symmetry in substitution effects:

$E_{ij} = w_j/w_i * E_{ji} + w_j\, (\eta_j - \eta_i)$, for $i \neq j = 1, \ldots, n$.

Consequently, several demand systems approaches have been evolved to solve this maximization problem, the most important of which are the Linear Expenditure System (LES), the Almost Ideal Demand System (AIDS), and the Generalized Almost Ideal Demand System (GAIDS); see, Sadoulet and Javry (1995) and Perali (2003), Raunikar and Huang (1984), Johnson, Hassan, and Green (1984), and Little (1985). It is worth to note that demand systems are used when accuracy is required in demand estimation.

The advantages and disadvantages of applying a demand systems approach can be summarized as follows:

- It delivers more reliable estimates.
- It uses the theory of demand as a guideline for the choice of functional forms and variables to be included.
- It imposes constraints on demand parameters.
- However, it requires data on individual consumer (which are not easily available).

The research at hand investigates the LES and AIDS.

The Linear Expenditure System (LES):

The demand equations of the LES are derived from maximizing the Stone-Geary utility function ($u = \sum b_i \ln(q_i - c_i)$ subject to a budget constraint (Sadoulet and de Janvry, 1995). Where the symbols denote the following:

u- Utility.

b_i – Constant greater than zero ($0<b_i<1$) and $\sum b_i = 1$.

$q_i - c_i > 0$ – Where q_i is quantity consumed and c_i is the subsistence quantity below which consumption cannot fall.

The derived demand functions are estimated from the following equations:

$p_i q_i = c_i p_i + b_i (y - \sum c_j p_j)$, i = 1, …, n.

Where:

p_i – The price of the commodity.

p_j – The price of the other commodities.

c_i, c_j – Parameters to be estimated.

bi - The marginal budget shares ($\partial pq/\partial y$) telling how expenditure on each commodity changes as income varies.

$\sum c_j p_j$ – The subsistence expenditure.

y – The total expenditure.

$y - \sum c_j p_j$ – The "uncommitted" income which is spent in fixed proportions bi between the commodities.

The price and income elasticities are calculated as follows:

$E_{ii} = -1 + (1 - b_i)\, c_i/q_i$, $E_{ij} = - b_i c_j p_j / p_i q_i$, $\eta_i = b_i/w_i$,

where E_{ii} = Own-price elasticity, E_{ij} = Cross-price elasticity, η_i = Income elasticity and w_i = The budget share of commodity i.

The following characteristics underlie the LES:

- It doesn't allow for inferior goods since $b_i > 0$.
- It assumes linear Engel functions. So, it can be used only for short-term predictions.
- It is better applied to large categories of expenditure than to individual commodities.
- It postulates that all goods are gross complements ($E_{ij} < 0$).

The Almost Ideal Demand System (AIDS):

The AIDS derives from a utility function specified as a second-order approximation to any utility function. The demand functions are derived in budget share form as:

$p_i q_i/y \sim w_i = a_i + \sum b_{ij} \ln p_j + c_i \ln y/P$;

where w_i is the budget share, P is a price index defined as:

$\ln P = a_o + \sum a_k \ln p_k + \frac{1}{2} \sum \sum b_{ik} \ln p_k \ln p_j$;

and the parameters are subject to the following restrictions:

$\sum a_i = 1$, $\sum b_{ij} = 0$, $\sum c_i = 0$ and $b_{ij} = b_{ji}$.

Deaton and Muellbauer (1980) suggest approximating the price index P by the Stone geometric price index:

$\ln P^* = \sum w_i \ln p_i$.

This linear approximation is all the better if there is collinearity in prices over time. The equation to be estimated is thus:

$w_i = a_i^* + \sum b_{ij} p_j + c_i \ln y/P^*$;

where $a_i^* = ai - ci \ln Ø$ and $P = Ø\ P^*$is the approximation to P. The price and income elasticities can be derived from the parameter estimates as:

$E_{ii} = -1 + b_{ij}/w_i - c_i$, $E_{ij} = b_{ij}/w_i$ and $\eta_i = 1 + c_i/w_i$.

Ordinary Least Squares (OLS) is used to estimate the parameters of the single demand equations. Then, Seemingly Unrelated Regressions (SUR) procedure is applied to solve the demand system equations simultaneously and to correct the standard errors.

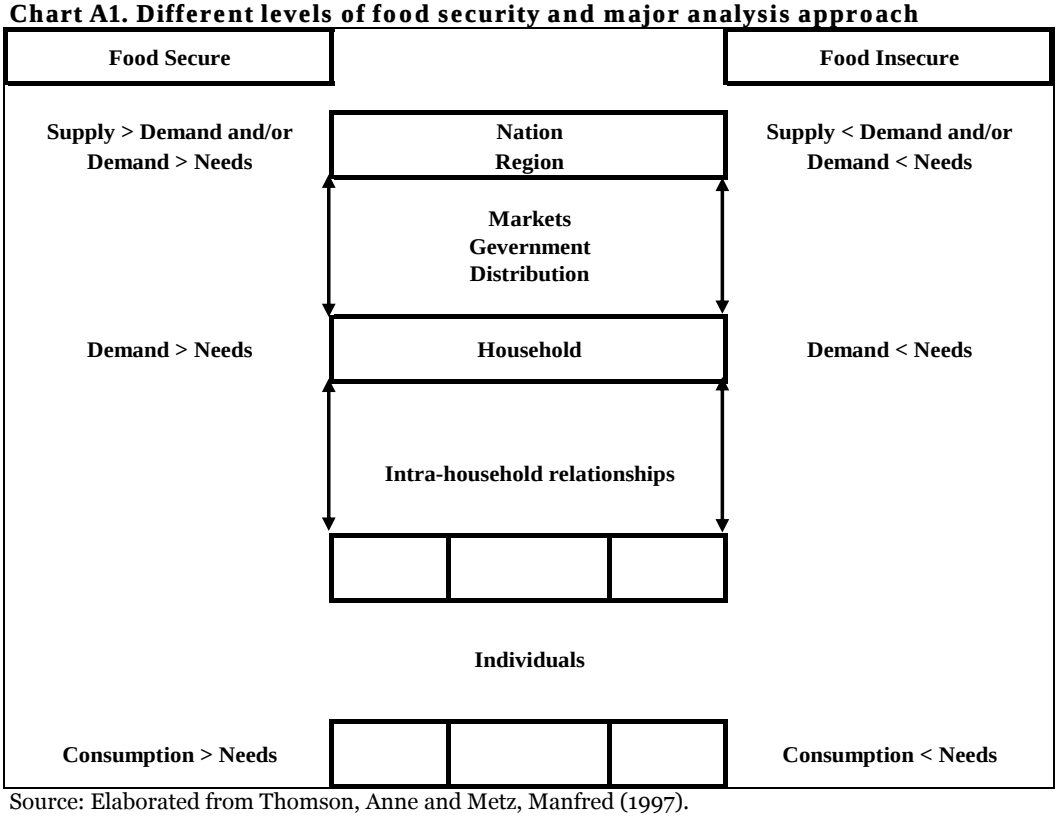
The nutrient elasticities are derived directly from the price and income elasticities for food items considering the technical coefficients measuring the nutrient content (a_{ni}). For example, given the technical coefficient for calorie (a_{ci}), the calorie elasticities can be calculated as follows:

$E_{ci} = (dc/c)/(dp_i/p_i) = \sum a_{cj} q_j E_{ji}/\sum a_{cj} q_j$, and $\eta_{cy} = (dc/c)/(dy/y) = \sum a_{cj} q_j \eta_j/\sum a_{cj} q_j$, where E_{ci} denotes the price elasticity of calorie, η_{cy} is the income elasticity of calorie and d indicates difference.

Finally, Qaim and Ecker (2008) applied a quadratic AIDS model using a quadratic income term within three-stage budgeting process to estimate food demand and its determinants in Malawi.

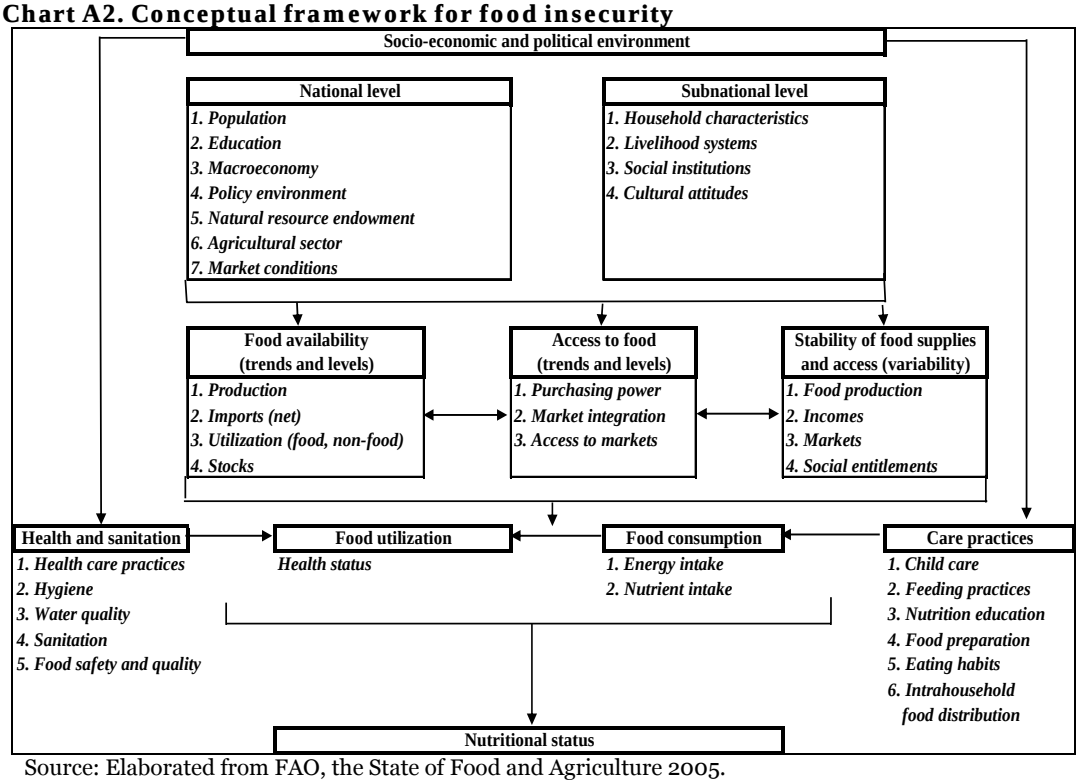
Annex

Chart A1. Different levels of food security and major analysis approach



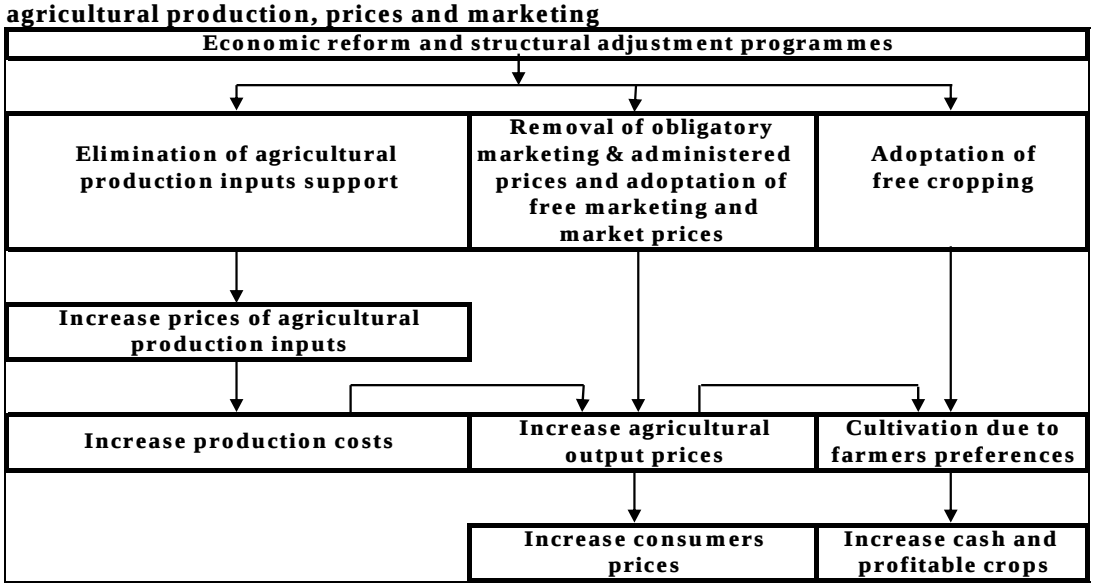
Source: Elaborated from Thomson, Anne and Metz, Manfred (1997).

Chart A2. Conceptual framework for food insecurity



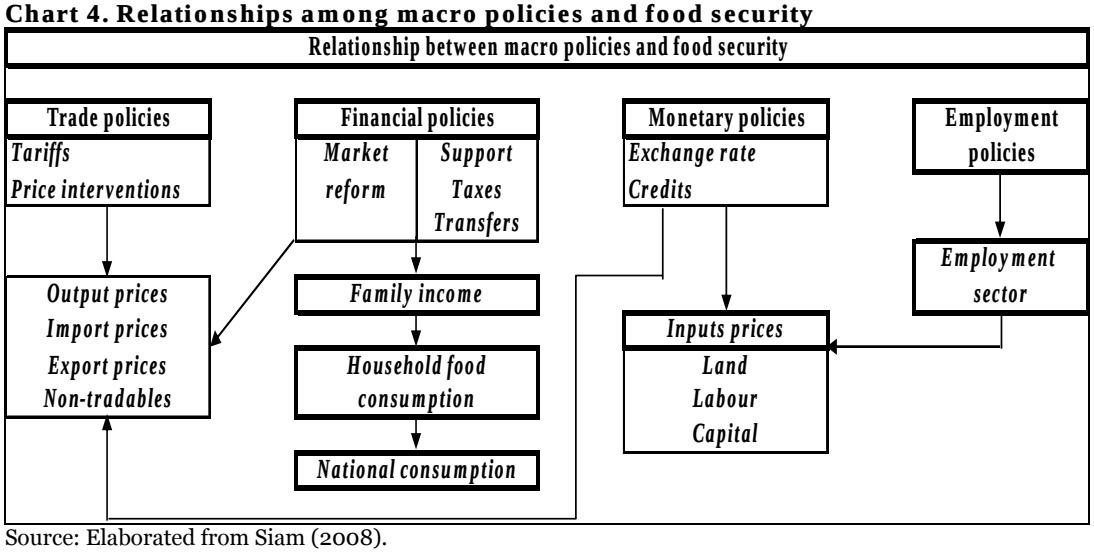
Source: Elaborated from FAO, the State of Food and Agriculture 2005.

Chart A3. Impact of economic reform and structural adjustment programmes on agricultural production, prices and marketing



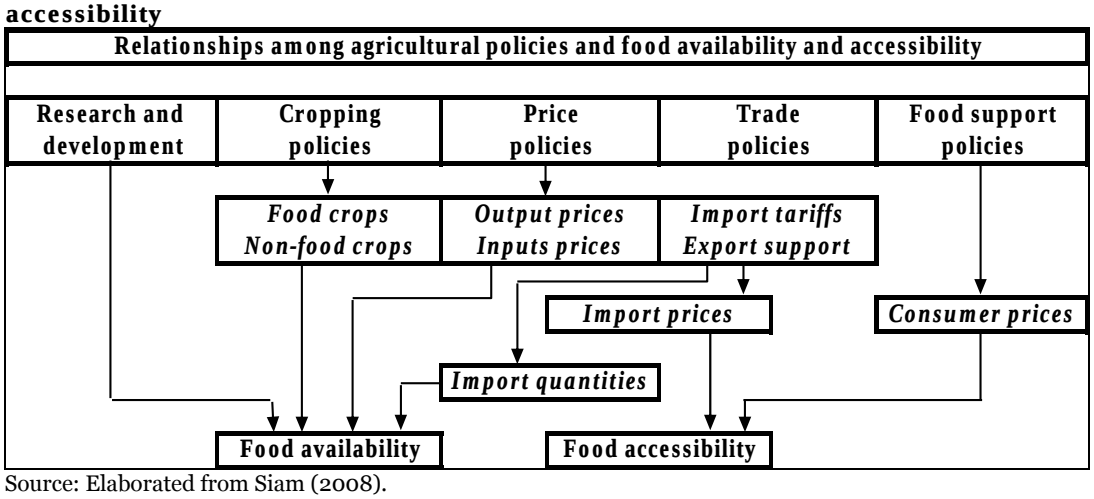
Source: Elaborated from Siam (2008).

Chart 4. Relationships among macro policies and food security



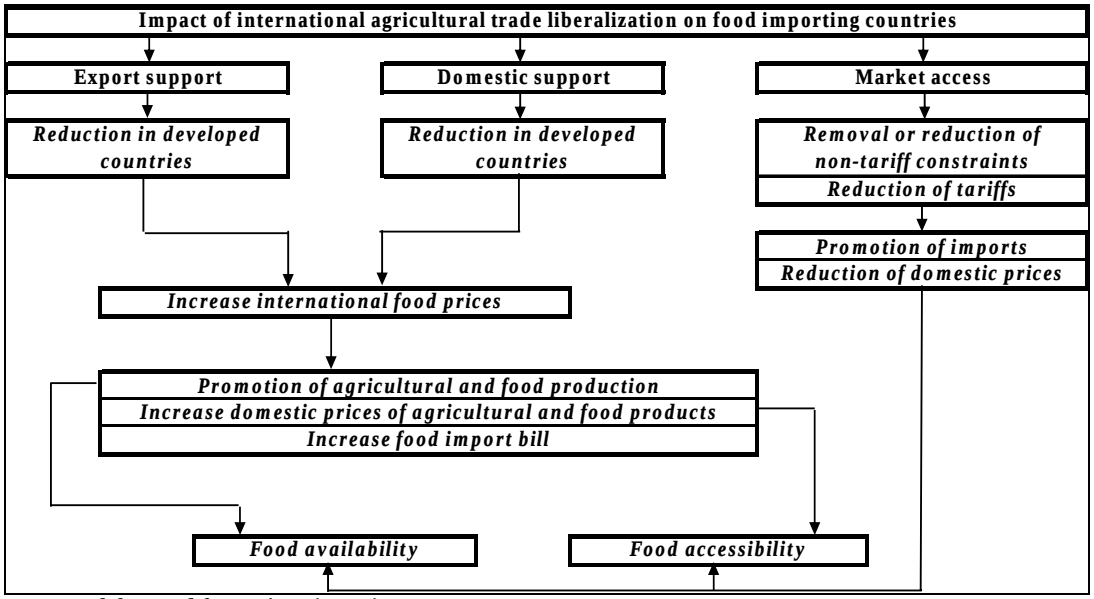
Source: Elaborated from Siam (2008).

Chart A5. Relationships among agricultural policies and food availability and accessibility



Source: Elaborated from Siam (2008).

Chart A6. Impact of international agricultural trade liberalization on food importing countries



Source: Elaborated from Siam (2008).

Table A1. National FIVIMS indicators

Indicator	FIVIMS-related indicators					UN-system lists	
	CFS	FAOS	FAOFSR	ANDI	Asia KIDS	OECD IDGs	UN CCA
Food security and nutrition outcomes							
Food Consumption Status							
Average per person dietary energy supply (DES)	x	x	x	x	x		
Cereals, roots and tubers as % of DES		x			x		
Percentage of population undernourished	x	x	x	x	x		x
Health Status							
Life expectancy at birth	x	x			x	x	
Maternal mortality rate (%)		x			x	x	x
Under-5 mortality rate (%)	x	x			x	x	x
Infant mortality rate (%)		x			x	x	
Prevalence of anaemia		x					
Prevalence of cholera		x					
Prevalence of acute respiratory infections				x			
Prevalence of diarrhea				x			
Prevalence of HIV		x	x				
Prevalence of malaria		x					
Prevalence of tuberculosis		x					
Nutritional Status		x		x	x		
Percentage of adults with body mass index (BMI)<18.5		x	x	x	x		
Percentage of children under 0-3 exclusively breast fed (%)							
Percentage of children under 5 that are underweight (%)	x	x	x	x	x	x	x
Percentage of children under 5 that are stunted (%)	x	x	x	x	x		
Percentage of children under 5 that are wasted (%)	x	x	x	x	x		
Percentage of children under 5 affected by night blindness		x		x			
Percentage of households consuming iodized salt (%)							
Percentage of newborns with low birthweight (%)		x		x			
Outcome indicators for vulnerability factors							
Demographic Conditions							
Fertility rate (%)		x		x	x	x	
Percent of population in different age groups (%)		x		x	x		
Population growth rate (%)		x		x	x		
Urban/rural population shares (%)		x		x			
Environmental Conditions							
Arable land per person		x					x
Average annual rate of deforestation (%)		x					
Carbon dioxide emissions per person						x	x
Carrying capacity of land		x					
Countries with environmental strategies (%)						x	
Intensity of freshwater use from renewable internal sources		x				x	
Energy use in agriculture		x					
Forest area as % of total land area			x			x	
GDP per unit of energy use						x	x
Land area protected as % of total arable land						x	
Mangrove areas						x	x
Percentage of change in km^2 of forest land in the past ten years							x
Severely degraded land as % of total area		x	x				
Tree density outside forest		x					
Total human induced soil degradation		x					

Table A1. Continued

Indicator	FIVIMS-related indicators					UN-system lists	
	CFS	FAOS	FAOFSR	ANDI	Asia KIDS	OECD IDGs	UN CCA
Environmental Conditions							
Urban air pollution						x	
Economic Conditions							
Changes in cereal production	x						
Cropped area as % of total area		x					
Employment of population of working age (%)			x		x		x
Export price movements for wheat, maize and rice	x						
Growth in cereal yields		x					
Growth in GDP		x					
Growth in GNP per person	x	x					
Growth in staple food yields, by commodities		x					
Informal sector employment as % of total employment							x
Ratio of five major grain exporters' suppliers to requirements	x						
Share of agriculture in GDP (%)		x	x				x
Volume of production, food use, trade and stock changes for major food commodities							
Wages, by economic activity (real $ per year)		x					
Yield per hectare for major cereals		x			x		
Political Conditions							
Number of countries facing a conflict-related emergency		x					
Socio-Cultural Conditions							
Adult literacy/illiteracy rate		x			x	x	x
Female illiteracy rate				x	x		
Girl net enrolment rate in primary school			x	x	x		
Literacy rate of 15-24 year-olds						x	x
Net primary enrolment or attendance rate (%)			x	x	x	x	x
Percent of population with access to primary health care		x	x				
Risks, Hazards, Shocks							
National monthly rainfall index		x					
Number of countries facing food emergency	x						
Land use change		x					
Percentage of population affected by droughts and natural disasters		x			x		
Percentage of land with erosion risk		x	x				
Rate od deforestration		x					
Food availability							
Animal protein supply per person				x			
Cereals supply per person				x			
Dietary fat supply per person				x			
Dietary protein supply per person				x			
Food production index		x	x				
Food Access							
Consumer prices index		x			x		
Food prices index	x	x			x		
Gini index of income distribution	x	x			x		
GDP and GNP per person	x	x	x	x		x	
GNP per person at Purchasing Power Parity	x						
Market density (number of markets per unit area)		x					
Paved roads as % of total road mileage		x	x				
People living below national poverty line (%)	x	x	x				
People living on less than $1 a day (%)	x		x				
Percentage of household income spent on food for the poorest quintile			x				x

Table A1. Continued

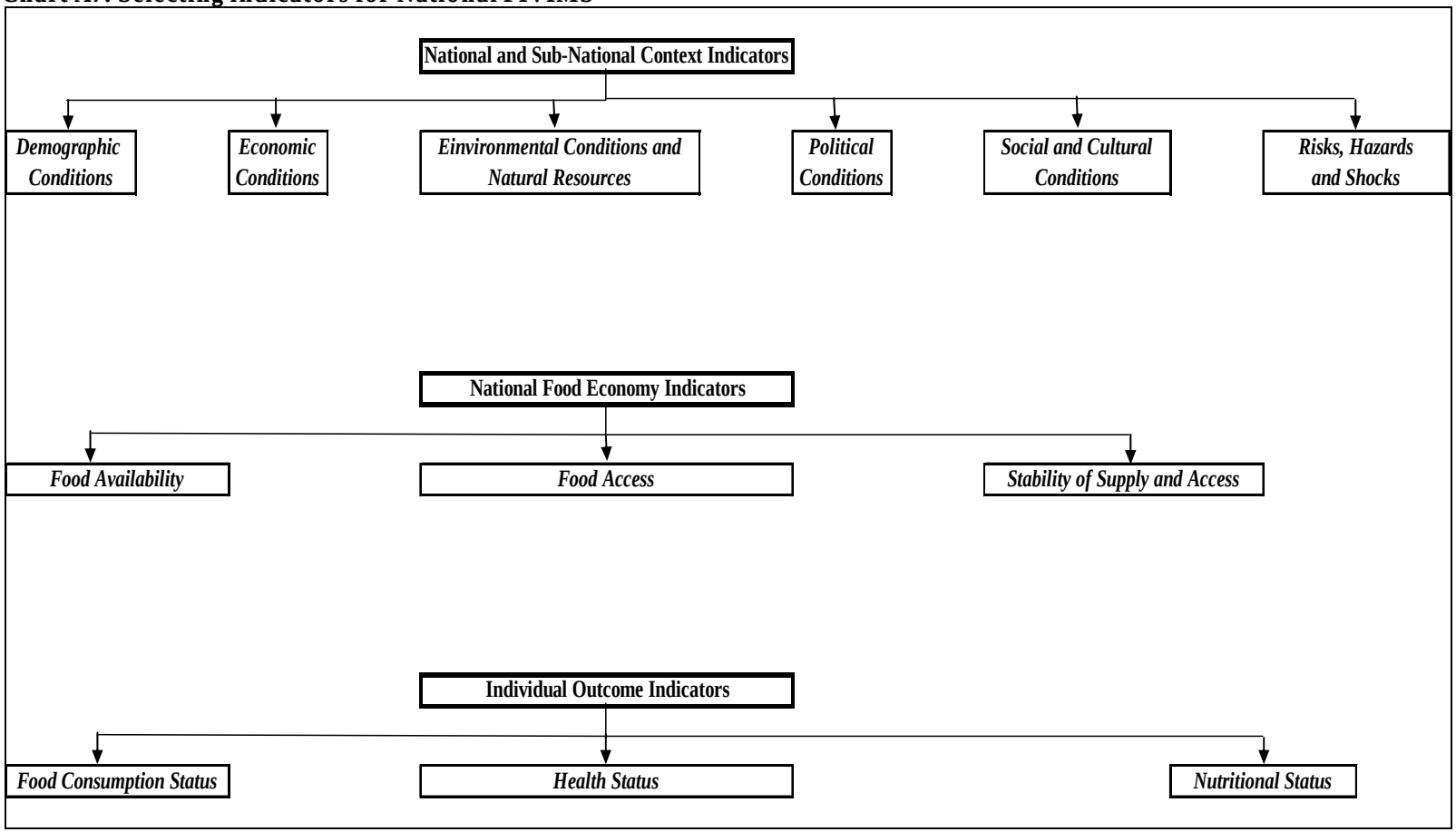
Indicator	FIVIMS-related indicators					UN-system lists	
	CFS	FAOS	FAOFSR	ANDI	Asia KIDS	OECD IDGs	UN CCA
Food Access (continued)							
Percentage of income spent on food	x	x					
Poorest fifth share of national consumption						x	x
Poverty gap ratio		x				x	x
Road density (kilometers of road per unit area)		x					
Share of national income by percentile of population		x					
Stability of Food Supplies and Access							
Cereal import dependency ratio		x			x		
Frquency of published or broadcast market information		x					
Index of variability of food production	x	x					
Months of cereal self-provisioning capacity	x	x			x		
Variability of food prices	x	x			x		
Household Characteristic							
Average household income (only urban)		x					
Average household size		x					
Number of persons per room, or average floor area per person							x
Ratio of dependants to wage-earners in average households		x					
Health and Sanitation							
Contraceptive prevalence rate (%)						x	x
Estimated HIV adult prevalence rate %)							x
HIV prevalence in pregnant women under 25 years of age (%)						x	x
Percentage of 1 year old children immunised against measles				x			x
Percentage of population with access to adequate sanitation		x	x				x
Percentage of population with access to primary health care services							x
Percentage of population with access to safe water		x	x		x	x	x
Care and Feeding Practices							
Number of meals eaten in a day		x					
Percentage of births attended by skilled health personnel						x	x
Percentage of children under 15 in the labour force							x
Weaning age		x					

Source: FAO (2002). *Making FIVIMS Work For You.*

Abbreviations:

FIVIMS: Food Insecurity and Vulnerability Information and Mapping Systems.
CFS: Committee on World Food Security.
FAOS: Food and Agriculture Organization of the United Nations Secretariat.
FAOFSR: Food and Agriculture Organization of the United Nations Food Security Report.
ANDI: African Nutrition Database Initiative.
Asia KIDS: Asia Key Indicators Data System.
OECD: Organisation for Economic Cooperation and Development.
IDGs: International Development Goals of the Millenium Summit.
UNCCA: United Nations Common Country Assessment.

Chart A7. Selecting indicators for National FIVIMS



Source: Elaborated from FAO, Making FIVIMS Work for You.

Table A2. Composition of SAM accounts 1

Incomes		Expenditures									Total
		1	2	3		4			5	6	7
				Factors		Institutions					
		Activities	Commodities	*Labour*	*Capital*	*Households*	*Firms*	*Government*	Capital account	ROW	
1	Activities		Domestic sales					Export subsidies		Exports	Production
2	Commodities	Intermediate demand				Households consumption		Government consumption	Investment		Domestic demand
3	Factors										
	Labour	Wages								Factors incomes from abroad	Gross national product at factor cost
	Capital	Rent									
4	Institutions										
	Households			Labour income	Distributed profits	Intra-household transfers, transfers		Transfers		Transfers from abroad	Households income
	Firms				Non-distributed profits	Transfers		Transfers			Firms income
	Government	Value-added taxes	Tariffs, indirect taxes	Taxes, social security	Taxes on profits	Direct taxes	Taxes				Government income
5	Capital account					Households savings	Firms savings	Government savings		Capital transfers	Total savings
6	ROW		Imports	Factor payments			Current transfers abroad				Imports
7	Total	Production	Domestic supply	Factor outlay		Households expenditures	Firms expenditures	Government expenditures	Total investment	Foreign exchange earnings	

Source: Sadoulet and de Janvry (1995).

Table A3. Composition of SAM accounts 2

Item	Commodities	Activities	Factors	Institutions	Capital	Rest of the world	Total
Commodities		Intermediate consumptions		Final consumptions	Investments	Export	Total demand for product
Activities	Domestic supply						Total output
Factors		Value added				Factor income from abroad	Total factor income receipts
Institutions	Taxes less subsidies	Taxes less subsidies	Factors income to institutions	Inter insititutional transfers		Non factor income receipts	Total institutional receipts
Capital				Savings		Capital transfers from abroad	Total in-flows of capital ac-count
Rest of the world	import		Factor payments to abbroad	Current tranfers to abroad	Capital transfers to abroad		Total inflows from ROW
Total	Total supply of products	Total output	Total factor income payments	Total institutional outlays	Total out-flows of capital ac-count	Total outflows to ROW	

Source: NAPC (2008).

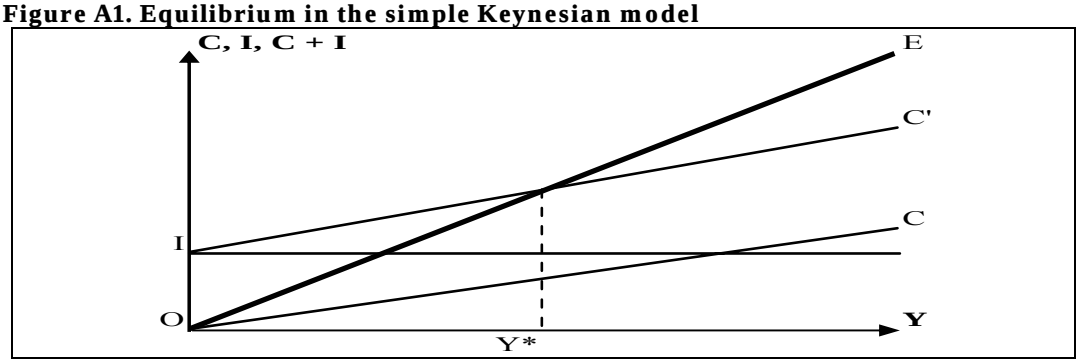
The Simple Keynesian Model of Income Determination

Economic models have two types of variables: endogenous variables, whose values the model is designed to explain, and exogenous variables, whose values are taken as given from outside the model. A central part of the analysis will often be to show how the solution values of the endogenous variables change with changes in the exogenous variables. This is the problem of *comparative-static equilibrium analysis or comparative statics*.

Let Y denote the national income. The aggregate demand for goods and services consists of two components: consumption demand C and investment demand I. I is considered exogenous, whereas C is determined by the consumption function.

C = c Y, where c is the *marginal propensity to consume* and 0< c < 1; the equilibrium condition is that aggregate supply must equal aggregate demand, or Y = C + I implying that Y* = I/(1-c), where Y* is the equilibrium income. This is illustrated in Figure A1. The 45º line OE shows the set of points at which C + I = Y or the set of equilibrium points; the line OC, with slope c, denotes the consumption function C = c Y; the horizontal line gives the exogenous investment level I; the line IC', also with slope c, is therefore the aggregate-demand function C + I = c Y + I; its intersection with the 45º line gives the equilibrium income level Y* at which aggregate demand is equal aggregate supply.

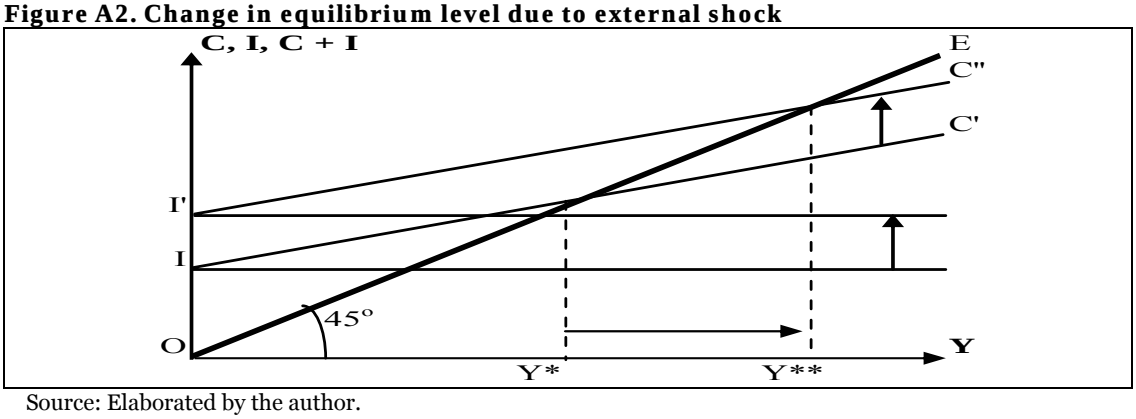
Figure A1. Equilibrium in the simple Keynesian model



Source: Elaborated by the author.

The comparative-statics question in this model is: How does a change in exogenous investment I affect the equilibrium income level Y*? Algebraically, the answer is found simply by regarding Y* as a function of I, either implicitly through the equilibrium condition (1 – c) Y* - I, or explicitly through the solution Y* = I/(1 – c). In either case by differentiation, it follows that dY*/dI = 1/(1 – c) > 0. Therefore, an increase in investment increases equilibrium national income by a multiple 1/(1 – c)-the multiplier. Diagrammatically, the comparative statics is illustrated in Figure A2.

Figure A2. Change in equilibrium level due to external shock



Source: Elaborated by the author.

Table A4. The 1-2-3 model as a programming problem

Maximize $Q = F(M, D^D; \sigma)$ with respect to: M, E, D^D and D^s (absorption)		
Subject to:		
		Shadow price:
$G(E, Ds; \Omega) \leq \bar{X}$	(technology)	$\lambda^x = p^x/p^q$
$pw^m M \leq pw^e E + B$	(balance of trade)	$\lambda^b = R/p^q$
$D^D \leq D^s$	(domestic supply and demand)	$\lambda^d = p^d/p^q$

Source: Elaborated from Francois and Reinert (1997).

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