FOOD SYSTEMS AND SOCIETY:
THE SYSTEMS EVOLUTION –
AN ALTERNATIVE APPROACH

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ABSTRACT

This article sketches a basic mathematical approach to systems evolution associated with the phenomenon of famine risk in a food-consuming society. The *main* issue is to approximate functional relations between the macroeconomic indices and factors of famine vulnerability.

In an earlier treatment, Sen *et al.* developed the groundwork of the systems evolution concerning food systems and society (entailing the three subsystem components: 1) physiography-ecology subsystem, 2) socio-economic subsystem, and 3) health-nutrition subsystem) and presented a heuristic equilibrium model to bring a famine state to a state of non-famine [1].

The present effort, an extended systems analysis on food systems and society, proposes a theoretical strategy involving the functional relationship between regional macroeconomic dynamics and indices of vulnerability to famine. The conditions are particularly applicable to famine areas in developing countries where the agricultural economy is in a "trapped" state.

ANALYSIS AND DISCUSSION

The approach formalizes the objective regularities of food consumption/ nonfood consumption of a region in a developing economy, with accepted strategies of national economy development: That is, to approximate functional relations between the dynamics of the regional (macroeconomic) indices and indices used in famine forecasting.

The regional indices constitute the components of regional income dynamics (X_1) and gross regional product dynamics (X_2, X_3). Physiographic-ecologic index (X_4) and health index (X_5) are also broadly included as components belonging to this group.

For famine forecasting, we assume the accounting and planned values of the indices $X_1, X_2, \ldots, X_5$ and food consumption characteristics $Y_1, Y_2, \ldots, Y_{13}$ from which numerical values for the functional relations between them are determined. We also assume forecast values of the regional indices (macro-economic indices) from which the food consumption forecast is obtained by functional relations.

The task is not to forecast each of the Y-values separately but as a system of interrelated variables. In addition, the dependent variables of other equations are used as independent variables of equations that stipulate the interdependency of equations. Thus, the model represents a system of interdependent regression equations.

The relations between variables (X) and (Y) have a non-linear character, that is every equation of the model is non-linear and of the form:

$$Y_{ij} = X_0 \theta_0^i + X_{j1} \theta_1^i + \ldots + X_{jm} \theta_m^i + X_{j1} X_{j2} \theta_{12}^i + X_{jm-1} X_{jm}$$

$$\theta^i(m-1)m + Y_{jk_1} \theta_{mm}^i + \ldots + Y_{jk_1-1} \theta_p^i = \sum_{\gamma=0}^{m} X_{j\gamma} \theta_\gamma^i + \sum_{\gamma \leqslant k}^{m} X_{j\gamma} X_{jk}$$

$$\theta_{\gamma k}^i + \sum_{\gamma \neq i}^{l-1} r_{j\gamma} \theta_\gamma^i \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where,

    $i = 1, 2, \ldots, 1$ is the number of values of the forecast variable Y;

    $j = 1, 2, \ldots, n$ is the number of realizations of the values X and Y;

    $m =$ the quantity of regional indices (macroeconomic) X;

    $p = C_{m+2} - m + 1 - 1$ is the number of times in equation (1), and

    $\theta =$ an estimation of parameters in equation (1).

This type of polynomial is chosen because the second order polynomials describe many complex economic processes with sufficient precision and a more objective analysis of the economic phenomena and forecast results. In this case, however, it is necessary to have an efficiency estimate only of paired interactions between regional (macroeconomic) indices (variables X), since higher order interactions may not be described.

Mathematically, the problem centers around a search for relations over time between dependent (endogenous) and independent (exogenous) variables. These can be described in general by some function:

$$Y/X = \eta(x) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where $Y^T = [Y_1, Y_2, \ldots, Y_1]$

is a vector of correlated endogenous variables with the values of exogenous variables determined by the vector coordinates X; the function, $\eta(x)$ depends on the unknown parameters $\theta_1, \theta_2, \ldots, \theta_p$. Moreover, every vector Y_t and $Y \epsilon \gamma$ of the set is uniquely compared with the $X_t (X \epsilon X)$, namely,

$$X_t \sim Y_t, \ (t = 1, 2, \ldots, n) \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ (3)$$

where, $\sim$ is the sign of conformity.

The procedure for searching for the *least* linear estimations of equations of the type (1) is:

Supposing that the relation between endogenous and exogenous variables can be described by some function

$$Y/X = \eta(X_1 \ \theta) = [V_1^T f(X), \ldots, V_1^T f(X)]^T \ . \ . \ . \ . \ . \ . \ . \ (4)$$

we determine the error matrix for endogenous variables $Y_1, Y_2, \ldots, Y_1$

$$D = \begin{vmatrix} \sigma_{11}^2 & \sigma_{12} & \cdots\cdots & \sigma_{11} \\ \sigma_{21} & \sigma_{22} & \cdots\cdots & \sigma_{21} \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ \sigma_{11} & \sigma_{12} & \cdots\cdots & \sigma_{11}^2 \end{vmatrix} \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ (5)$$

We then consider the so-called structural matrix of dimension n x p:

$$A = \begin{vmatrix} 1 & Z_{12} & Z_{12} & \cdots\cdots & Z_{1p} \\ 1 & Z_{21} & Z_{22} & \cdots\cdots & Z_{2p} \\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots \\ 1 & Z_{n1} & Z_{n2} & \cdots\cdots & Z_{np} \end{vmatrix} \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ (6)$$

the elements of which are, exogenous variables $X_1, X_2, \ldots,$ and their paired interactions $X_1 X_2, X_1 X_3, \ldots$ (Equation 1), reduced to the normalized form.

It is now assumed that we have a block-diagonal matrix S of dimension (n x 1) x (p x 1):

$$S = \begin{vmatrix} A & & 0 \\ & A_2 & \\ 0 & & A_1 \end{vmatrix} \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ (7)$$

and matrices L of dimension (n x 1) x (p x 1):

$$
L = \begin{vmatrix} \sigma_{11}^2 I & \sigma_{21} I & \dots\dots & \sigma_{21} I \\ \sigma_{21} I & \sigma_{22}^2 I & \dots\dots & \sigma_{21} I \\ \dots\dots\dots\dots\dots\dots\dots\dots \\ \sigma_{11} I & \sigma_{12} I & \dots\dots & \sigma_{11}^2 I \end{vmatrix} \qquad \dots\dots\dots\dots\dots \quad (8)
$$

where I is the unit matrix of dimension (n x n) and σ_{ij} are elements of matrix D.

If the introduced notation and structural properties of the matrices S and L are taken into account, approximate estimates of the coefficients in equations of type (1) can be obtained by the formula:

$$
\theta = M^{-1} U \qquad \dots\dots\dots\dots\dots\dots\dots \quad (9)
$$

where matrix M^{-1} is non-singular,

$$
M^{-1} = [S_L^T - {}^1 S]^{-1} \qquad \dots\dots\dots\dots\dots\dots \quad (10)
$$

and
$$
U = [S_L^T - {}^1 Y] \qquad \dots\dots\dots\dots\dots\dots \quad (11)
$$

In order to obtain the best estimates, an iterative process of specifying their values until they are consistent, unbiased and efficient is organized. For example, unbiased estimators $\widetilde{\theta}$ are effective in the case of inequality:

$$
D (\widetilde{\theta}) \leqslant D (\widetilde{\widetilde{\theta}}), \qquad \dots\dots\dots\dots\dots\dots\dots \quad (12)
$$

where $D (\widetilde{\theta})$ is a variance matrix of the estimators $\widetilde{\theta}$ and $D (\widetilde{\widetilde{\theta}})$ is a variance matrix of any other unbiased estimators $\widetilde{\widetilde{\theta}}$. In expression (12), the variance matrix of the estimators $\widetilde{\theta}$ is:

$$
D (\widetilde{\theta}) = M^{-1}. \qquad \dots\dots\dots\dots\dots\dots\dots \quad (13)
$$

Conditions of equation (12) can be satisfied if instead of the matrix D at the first iteration, we may use its estimation:

$$
d(\theta) = n^{-1} \sum_{i=1}^{n} [Y_i - V_i^T f(x)] [Y_i - V_i^T f(X)^T] \qquad \dots\dots\dots\dots \quad (14)
$$

All subsequent iterations can also be realized, with account taken of expression (14).

There are still ambiguities and anomalies in the boundary conditions which may be resolved or the model otherwise refined through further analysis with the input of real-life (field) data.

ACKNOWLEDGMENT

REFERENCE

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