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Khan, Haider

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**Haider A. Khan**
**GSIS**
**University of Denver, USA**
**hkhan@du.edu**

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## Abstract

The main purpose of this paper is to clarify some crucial links between the important ecological systems concept of Emergy and its physio-social accounting dialectically via a consistent interdependent System of  Social Accounting. It is hoped that a brief but historically accurate background and description of Emergy, SAM, SAM-based and Emergy-based dialectically formulated fixed price multiplier models will be helpful to the increasing number of ecological systems researchers who are interested in using SAMs for both FPM and other types of socially and ecologically relevant modeling.

Keywords: Dialectics of Abstract and Concrete, Emergy, Disequilibrium Dynamics, Dialectical SAM, Dialectical EmSAM, Socio-economic ecological accounting, EmSAM-based modeling

## 1.Introduction

The main purpose of this paper is to explore some important links between the ecological systems concept of emergy and a rigorously formulated physio-social systems framework. I illustrate these links by using a Social Accounting Matrix and Fixed Price Multiplier(FPM) Model based on a SAM. The emergy concept was proposed in the 1980s and justified by its proponents on the ground that like the classical theories of value, it offered an objective basis of valuation.

However, without further analytical foundation in social relations specifications, there is a danger of emergy being reductionist by proposing a simplistic solar energetic metric.I try to show that it is possible to avoid this danger by making emergy a physico-social concept and specifying the dialectics. It is then possible to further specify the emergy-based dialectical social-ecological accounting procedure.

For ease of reference I call such an emergy-based social system framework Emergy Social Accounting Matrix, or EmSAM. I hope that a brief but historically accurate background and description of SAM and SAM-based fixed price multiplier models will be helpful to the increasing number of ecological systems thinkers and researchers who are interested in using SAMs for understanding Emergy in a socioeconomic system

The roots of SAM go back to the pioneering work in social accounting by Gregory King in 1681. However, modern social accounting is largely inspired by the work of Stone in connection with the Cambridge growth model in the 1950s and 60s. Stone's work with the UN SNA project gave further impetus to developing a disaggregated household sector description. In the 1970s Pyatt, Round and Thorbecke advanced the work to apply the idea of a SAM to developing countries. The work done in the 1980s at Cornell by Thorbecke, Khan and others led to disaggregation of technologies and the inclusion of the informal sector separately within a SAM.

## 2.The concept of Emergy

The concept of emergy was the result of joint work by Odum and Scienceman in the 1980s based fundamentally on the former's earlier study Systems Ecology. Odum himself credits Scienceman with the invention of the term:

> In 1983, the term EMERGY, spelled with an "M", was suggested by David Scienceman for our concept [of embodied energy] and emjoule or emcalorie as the unit… EMERGY is defined as the energy of one kind required directly or indirectly to produce a service or product.[1]

Emergy was intended to clear up some confusions surrounding Odum's earlier term "embodied energy" which was used for a time in the early 1980s to refer to energy

[1] Odum(1996) and Odum(1983) , and Odum in Hall(1995):318.See also the references to Clark and coauthors, and Foster and coauthors in the references section.

quality differences .But the term embodied energy was also used by others in senses quite different from Odum's intended meaning. More important is to look at Emergy dialectically in a non-reductionist manner.

On the positive side, the idea of emergy is to capture an objective (solar) energetic basis of valuation. With the added idea of transformity and the algorithm for computing the solar emjoules for each activity producing goods and services, the ecological accounting basis seems to exist.

However, one must be careful here. The social embeddedness of any economy-energy system is reflected in dynamic social relations. Therefore, the ecological accounting must also be social in an objective sense. The social relations must be captured in both abstract conceptual terms and concrete mappings among goods and services and emergy. This is what a social accounting system when formulated dialectically, can do.[2]

Even from this very brief description above, it is clear that the dialectically formulated input-output structures of societies are needed to capture interrelated aspects of emergy. These structures need to be captured in detailed social and physical terms.

Even if the economic data come in monetary units, these need to be converted by using the price data that are consistent across time periods and reflect approximately correct valuations based on cost of production. On the demand side, the household demands(i.e. disaggregated final demand structure) can also be expressed by following a similar methodology in the derivation of physical units of energy in productive activities.

Since a SAM can integrate both monetary and physical data consistently across space and time, for emergy analysis it could serve as a natural socio-economic-physical framework. We now turn to a brief analysis of SAM. With the careful social conversion into physical units, we get EmSAMs which can be used for ecological systems based socio-economic analysis. In the following discussion, we present the theoretical-conceptual aspects and some computational procedures. A future paper with concrete applications has been planned.

## 3. Emergy-based Social Accounting Matrices (EmSAMs) as Dialectically Consistent Economy wide Data Bases and Fixed Price Multipliers

In this section the Emergy-based Social Accounting Matrix is presented as a dialectical data gathering framework as well as an analytical tool for studying the effects of various macroeconomic policies as well as the impact of sectoral growth on poverty alleviation. As mentioned before,the origins of social accounting can be traced as far back as Gregory King's efforts in 1681, but more recent work stems from the attempts by Richard Stone, Graham Pyatt, Erik Thorbecke and others. [2]

In the methodological framework of application to FPM and Computable Dynamic models, the EmSAM can be viewed as a tool for mapping production and distribution at the

[2] See the references for Khan, James and Khan, and Khan and Thorbecke, and Taylor in the reference section for details of social accounting and modeling. See also Shaikh(2016) and Saito(2017;2023).See also the items by Sen and Deaton in the references.

economy wide level. In this section, first a general EmSAM is described. Then it is shown how the method for studying the short-run effects of economic growth within this framework follows logically from its structure.

The model used is a simple version of a class of EmSAM-based general dis/equilibrium models.[3] It summarizes succinctly the interdependence between productive activities, factor shares, household income distribution, balance of payments, capital accounts, etc. for the economy as a whole at a point in time. Given the technical conditions of production the value added is distributed to the factors in a determinate fashion. The value added accrued by the factors is further received by households according to their ownership of assets and the prevailing wage structure. In

[2] For a description of SAM as a data gathering device, see G. Pyatt and E. Thorbecke, *Planning Techniques for a Better Future* (Geneva: ILO, 1976).

[3] In Walrasian general equilibrium models the flexible price vector determines the equilibrium. In a Keynesian (dis)equilibrium model in the short-run the quantities vary while the price vector remains fixed.

the matrix form the EmSAM consists of rows and columns representing receipts and expenditures, respectively. As an accounting constraint receipts must equal expenditures.

As is elaborated further in Khan and Thorbecke (1988), the EmSAM framework can be used to depict a set of linear relationships in a fixed coefficient model. For deciding the question of determination, the accounts need to be divided into exogenous and endogenous ones. For instance, in the South African SAM used by Khan(1989) to analyze the impact of economic sanctions on the South African economy, there are three endogenous accounts. These are factors, households and production activities, leaving the government, capital and the rest of the world accounts as exogenous.[4]

In examining the poverty and energy/emergy profiles in any country, one particular set of accounts assume special importance. These are the household accounts. The proper flow of income and expenditures need to be recorded for these accounts if an accurate picture of poverty as inadequate income/ consumption is to emerge out of a given EmSAM. For this reason, the classification of households needs special care. There are at least six aspects that need careful attention.

These six aspects are:

(1) to classify households by socio-economic characteristics;
(2) to understand the income generation process by which the households receive their incomes;
(3) to pinpoint the distributional mechanisms;
(4) to understand the household consumption patterns;
(5) to link household income and consumption to social capabilities and functionings; and
(6) to estimate the resource generating capacity and resource absorbing capacity of the households.

If items 1-6 can be investigated systematically by combining economic and social modes of inquiry in an EmSAM, proper policy intervention for poverty reduction will become a more tractable exercise than it is at present. In particular, if disaggregated EmSAMs can be constructed at the local, sub -national levels, then intervention at the local levels may be much more effective than it has been historically in many cases. This is yet to be realized, but clearly is an important goal to pursue. I now turn to a discussion of another particular strength of the EmSAM framework for data gathering. SAMs have the consistency features that one needs in capturing economic flows for use in a general equilibrium framework which can be used also to study dynamic departures from equilibrium .

[4] See Khan and Thorbecke, op.cit., Ch. III. The presentations here follow the cited work closely.

The following tables illustrate in the aggregate the consistency requirements for building a SAM.

TABLE 1. SAM-FORMAT OF SNA-AGGREGATES, KENYA, 1982

(in KE million pounds)

| | FACTORS OF PRODUCTION | INSTITUTIONS | PRODUCTION ACTIVITIES | CAPITAL ACCOUNT | INDIRECT TAXES | REST OF THE WORLD (NET) | TOTAL |
|---|---|---|---|---|---|---|---|
| FACTORS OF PRODCUTION | | | G.D.P. at factor cost (2931.87) | | | Net Factor Income from Abroad (-133.80) | Domestic Factor Inocme (2798.07) |
| INSITUTIONS | G.D.P. at factor cost (2798.07) | | | | Net Indirect Taxes (467.59) | Net Non-Factor Income from Abroad (38.80) | Disposable National Income (3304.46) |
| PRODUCTION ACTIVITIES | | Total Final Consumption (2793.15) | | Gross Investments (764.71) | | Trade Balance (158.40) | Net Final Demand (3399.46) |
| CAPTIAL ACCOUNT | | Domestic Savings (511.31) | | | | Balance of Payments Deficits (253.40) | Total Savings (764.71) |
| INDIRECT TAXES | | | Net Indirect Taxes (467.59) | | | | Net Indirect Taxes (467.59) |
| TOTAL | Domestic Factor Income (2798.07) | Total Expenditure at Market pr. (3304.46) | G.D.P. at market prices (3399.46) | Total Gross Investments (764.71) | Net Indirect Taxes (467.59) | ---------- | |

TABLE 2. MODULAR COMPOSITION OF THE SAM

| | FACTORS OF PRODUCTION | INSTITUTIONS | PRODUCTION ACTIVITIES | CAPITAL ACCOUNT | INDIRECT TAXES | REST OF THE WORLD | TOTAL |
|---|---|---|---|---|---|---|---|
| FACTORS OF PRODCUTION | | | Income Generation Module | | | Factor Income Received from Abroad | Total Factor Income Received |
| INSITUTIONS | Income Distribution Module | Income Redistribution Module | | | Total Net Indirect Taxes | Transfers Received from Abroad | Total Disposable National Income |
| PRODUCTION ACTIVITIES | | Domestic Consumption Module | Industrial Transactions Module | Domestic Investment Module | | Exports | Total Demand |
| CAPTIAL ACCOUNT | | Domestic Savings Module | | | | Balance of Payments Deficits | Total Savings |
| INDIRECT TAXES | | Indirect Taxes on Final Consumption | Indirect Taxes on Intermediate Consumption | Indirect Taxes on Investment Goods | | | Total Net Indirect Taxes |
| REST OF THE WORLD | Factor Income Paid Abroad | Imports of Final Consumer Goods | Imports of Intermediate Consumer Goods | Imports Investment Goods | | | Total Payments Abroad |
| TOTAL | Total Factor Income Paid | Total Expenditure of the Institutions | Total Supply | Total Gross Investments | Total Net Indirect Taxes | Total Receipts from Abroad | |

In terms of the usefulness of the EmSAM information base, one can argue that not only is the National EmSAM a tool for the overall poverty reduction and energy use analysis, perhaps even more importantly, the building of local and regional EmSAMs will help the field-worker to understand the interrelations between households characteristics, the immediate causes of poverty and energy consumption and the best way to help specific types of households out of poverty. I now turn to the discussion of a particular type of modelling exercise that can be carried out with both the national and regional EmSAMs.

## 4.Fixed Price Multipliers for National and Regional EmSAMs

In what follows, a national framework with distinct regions where the poor may be located is assumed. Suppose there are n regions indexed by i = 1, 2, .....,n. For each region i, there are intra-regional transactions as well as inter -regional transactions. Then, the national SAM can be disaggregated into 'n' Regional or RSAMs. The typical RSAM for region i can be schematically described as in table 3. Table 4 divides up the regional accounts according to whether these are endogenous or exogenous for the purpose of modelling.

TABLE 3. SIMPLIFIED SCHEMATIC EMERGY-BASED SOCIAL ACCOUNTING MATRIX

| | | | | Expenditures | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Endogenous accounts | | | Exogenous | Totals |
| | | | | Factors | Households | Technology production activities | Sum of other accounts | |
| | | | | 1 | 2 | 3 | 4 | 5 |
| Receipts | Endogenous accounts | Factors | 1 | 0 | 0 | $T_{1.3}$ | $x_1$ | $y_1$ |
| | | Households | 2 | $T_{2.1}$ | $T_{2.2}$ | 0 | $x_2$ | $y_2$ |
| | | Production Activities | 3 | 0 | $T_{3.2}$ | $T_{3.3}$ | $x_3$ | $y_3$ |
| | Exog. | Sum. of other accounts | 4 | $1^1_1$ | $1^1_2$ | $1^1_3$ | t | $y_x$ |
| | | Totals | 5 | $y^1_1$ | $y^1_2$ | $y^1_3$ | $y^1_x$ | |

The above SAM framework can be used to depict a set of linear relationships in a fixed coefficient model. This is the essential point behind fixed price multiplier modelling approach based on a SAM. For deciding the question of determination of the equilibrium quantities, the accounts need to be divided into exogenous and endogenous ones as in table 4 below.

TABLE 4. SCHEMATIC REPRESENTATION OF ENDOGENOUS AND EXOGENOUS ACCOUNTS IN AN EMSAM

| | | Expenditures | | | | Totals |
|---|---|---|---|---|---|---|
| | | Endogenous | Sum | Exogenous | Sum | |
| Receipts | Endogenous | $T_{nn}$ | n | Injections $T_{nx}$ | x | $y_n$ |
| | Exogenous | Leakages $T_{xn}$ | 1 | Residual Balances $T_{xx}$ | t | $y_x$ |
| Totals | | $y_n'$ | | $y_x'$ | | |

**Source:** H.A. Khan and E. Thorbecke, *Macroeconomic Effects and Diffusion of Alternative Technologies Within a Social Accounting Matrix* (Aldershott, U.K.,: Gower Publishing Co., 1988).

Essentially the regional income EmSAM above describes the circular process in which production activities generate household incomes (via the aggregation of factorial income per household category), and household expenditures which generate the demand for output. Other related variables such as government spending, imports and exports, transfers, etc. are linked to this core process where necessary. Transfers to the households from various other institutions including other household are also important for income determination and poverty analysis.

The 1978 income SAM for South Africa which is used by Khan (1999) for poverty analysis, for example, contains 28 separate productive activities. There is clearly enough detail here on the production side. The value added generated in these productive activities is distributed among landowners, capitalists, and forty occupation-by-race groupings. The realism of the classifications captures the nature of the past apartheid regime by indicating the determination of many occupational categories by racial factors. Finally, there are seven groups of households within each of the four racial groups. These are stratified by income. Therefore, both racial and economic stratification are embodied here. For the purpose of studying the relationship between growth and poverty the households are separated into rural and urban types in this paper. Further, within urban and rural areas, households are classified as high, middle and low according to economic status. This six-fold classification is more relevant for exploring questions related to poverty than the aggregated (i.e. urban and rural combined) approach of the original SAM and extended EmSAM. The justification for reducing the household types to three within the urban or rural categories is that the original household classification was somewhat arbitrary. The top three household categories could be aggregated as high income. The remaining six could be reclassified according to the information provided by the household expenditures survey data into low and middle categories.

The starting point for an analysis based on this EmSAM is the exogenous nature of the increased demand leading to sectoral output increase. The set of fixed price multipliers can then be used to ascertain the impact of this increase in output on the incomes of specific household groups.

Looking at tables 3 and 4, which represent an EmSAM, we can see immediately that

$$y = n + x \quad (1)$$
$$y = 1 + t \quad (2)$$

Now if we divide the entries in the matrix Tnn by the corresponding total income (i.e. Yn), we can define a corresponding matrix of average expenditure propensities. Let us call this matrix A. We now have:

$$y = n + x = Ay + x \quad (2.1)$$
$$y = (1 - A)^{-1}x = Mx \quad (2.2)$$

M can be called the matrix of *accounting* multipliers. for these multipliers, when computed, can account for the results (e.g. income, consumption, etc.) obtained in the SAM without explaining the process that led to them. Let us now partition the matrix A in the following way.

$$A = \begin{pmatrix} 0 & 0 & A_{1.3} \\ A_{2.1} & A_{2.2} & 0 \\ 0 & A_{3.2} & A_{3.3} \end{pmatrix}$$

Given the accounts factors, household and the production activities, now we see that the income levels of these accounts (call them $y_1$ , $y_2$ , and $y_3$ respectively) are determined as functions of the exogenous demand of all other accounts. In this respect, what we have is a reduced-form model which can be consistent with a number of structural forms. This is quite satisfactory as far as tracing the effects of a certain injection in the economy is concerned or for prediction purposes when the structural coefficients are more or less unchanged.

One limitation of the accounting multiplier matrix M as derived in equation (2.2) is that it implies unitary expenditure elasticities (the prevailing average expenditure propensities in A are assumed to apply to any incremental injection). A more realistic alternative is to specify a matrix of marginal expenditure propensities ($C_n$ below) corresponding to the observed income and expenditure that prices remain fixed. Expressing the changes in income (dy) resulting from changes in injections (dx), one obtains,

$$dy_n = C_n dy_n + dx$$
$$= (I - C_n)^{-1} dx = M_c dx$$

$M_C$ can be termed a fixed price multiplier matrix and its advantage is that it allows any nonnegative income and expenditure elasticities to be reflected in $M_C$. In particular, in exploring the macroeconomic effects of exogenous changes in the output of different product-cum-technologies on other macroeconomic variables, it would be very unrealistic to assume that consumers react to any given proportional change in their incomes by increasing expenditures on the different commodities by exactly that same proportion (i.e. assuming that the income elasticities of demand of the various socioeconomic household groups for the various commodities were all unitary). Since the expenditure (income) elasticity is equal to the ratio of the marginal expenditure propensity ($MEP_i$) to the average expenditure propensity ($APE_i$) for any given good i, it follows that the marginal expenditure propensity can be readily obtained once the expenditure elasticity and the average expenditure propensities are known, i.e.,

$$Ey_i = \frac{MEP_i}{AEP_i}$$ , *where Eyi is the income elasticity for*

$$MEP_i = E\,y_i . AEP_i$$

Thus, given the matrix $A_{32}$ of average expenditure propensities, and the corresponding expenditure elasticities of demand, $y_i$ the corresponding marginal expenditure propensities matrix $C_{32}$ could easily be derived.

As a further example, one can mention the use of SAMs for poverty analysis.For analyzing poverty both at the national and the subnational levels these multipliers can be further decomposed in terms of their effects on poor households incomes Tracing out these effects can be computationally demanding, but under assumptions of distributional neutrality of growth, the pure effects of growth on poverty have been estimated by Thorbecke and Jung(1996) for Indonesia and by Khan(1999) for South Africa. The latter used the South African EmSAM described above and found that the lack of human capital and more generally, basic capabilities in Sen's framework, was the main reason why growth left out the rural Black poor in particular.

**5. Conclusions:**

The main purpose of this note has been to find links between emergy in a social ecological system and the model of socio-economic systems across time with energy receiving the attention it deserves. I have sketched out some preliminary links explicitly in a consistent social theoretical and accounting framework.

I have also tried to clarify very briefly some important links between the Emergybased *Social* Accounting Matrix and Fixed Price Multiplier(FPM) Models. I hope that this brief but historically accurate background and description of Emergybased SAM and EmSAM-based fixed price multiplier models will be helpful to the increasing number of researchers who are interested in constructing and using EmSAMs for both FPM and Computable Dynamic Disequilibrium modeling.

The examples given here could be multiplied easily since the already large literature is growing apace. Instead of surveying all the applications, the focus here has been on the dialectical grounding of emergy in social relations in a Marxian sense, and the exposition of a few significant aspects of dialectical EmSAMs for modeling purposes.

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