Paper submitted for the
Thirteenth International Conference on
Input-Output Techniques
And for Leontief Memorial Prize

Macerata, Italy
August 21-25, 2000

Social and Ecological Accounting Matrix: an Empirical Study for China*

Xiaoming PAN
Institute of Systems Science
Chinese Academy of Sciences (Academia Sinica)
Beijing 100080, P.R. China

January, 2000

Abstract

The basis of sustainability planning is how to correctly assess the status of sustainability in a certain nation or a region. Based upon Input-Output Analysis, System of National Accounts and Social Accounting Matrix, this paper presents a Social and Ecological Accounting Matrix (SEAM) for sustainability planning. It is demonstrated that SEAM can establish a concrete base for sustainability planning and an operable framework for sustainable development indicators. An empirical study for China is attached as a necessary approach assessment.

Key words: Sustainability, Input-Output Analysis, System of National Accounts, Social Accounting Matrix, Social and Ecological Accounting Matrix

JEL classification: C67, O21, O53, Q20, Q30.

* This paper is supported by Alliance for Global Sustainability (AGS) and National Natural Science Foundation of China (NSFC).

Social and Ecological Accounting Matrix: an Empirical Study for China

I Introduction

The concept of Sustainable Development has been worldwidely recognized since United Nations Conference on the Environment and Development, Rio de Janeiro, 1992. Sustainability planning, as a policy instrument to achieve sustainable development**,** therefore has to first correctly assess the status of sustainability in a certain nation or a region. Since sustainable development not only comprises comprehensive issues related with population, economy, society, resources and environment, but also links complicated problem of inter-generation equity, it is indispensable to integrate all components at a consolidated basis for sustainability planning.

So far available systematic accounting approaches follow:

1. Input-Output Analysis

Input-Output Analysis (IO) studies the interindustry linkages and relations between inputs and outputs in an economic system (Leontief, 1951, 1986). Through the following open static model (see Table1), the total input coefficients, both direct and indirect ones, can be derived by the well-known Leontief Inverse:

$$B = (I - A)^{-1} - I \qquad (1)$$

here B: matrix of total input coefficient $\{b_{ij}\}_{nxn}$

A: matrix of direct input coefficient $\{a_{ij}\}_{nxn}$

$a_{ij} = X_{ij} / X_j$ input of sector i for unit output of sector j

Table 1 Open Static Input-Output Model

Outputs / Inputs	Sector	Intermediate Demands	Final Demands	Total
		1 … n	C G I (E-M)	Outputs
Interme-diate Inputs	1	X_{11} … X_{1n}	Y_1	X_1
	…	…	…	…
	n	X_{n1} … X_{nn}	Y_n	X_n
Primary Inputs **(VA)**	Depreciation	D_1 … D_n		
	Wages & Salaries	V_1 … V_n		
	Taxes & Profits	M_1 … M_n		
Total Inputs		X_1 … X_n		

The final demand is classified, as the same as in national accounts, by consumption (household and government), investment and net export:

$$Y \text{ (VA, or GDP)} = C + I + G + E - M \quad (2)$$

Here C: household consumption;

I: investment;

G: government expenditure;

E: export; and

M: import.

It is found, however, that Input-Output is analysis too simple for sustainability planning, though Leontief first modified input-output model to study environment pollution issues (Leontief, 1970), and Chen first extended Input-Output analysis to Input-Occupancy-Output Analysis (IOO) focusing on not only the flow items of inputs and outputs, but also the stock items, called occupancies, of resources (Chen, 1990).

2. System for integrated Environmental and Economic Accounting

As a response to UN Rio Summit, the System of National Accounts (SNA) 1993 included System for integrated Environmental and Economic Accounting (SEEA) to deal with the environment issues which were not treated in previous SNA versions (United Nations, 1993). Needlessly to say, Input-Output tables are basic components of all issued SNA versions. Since SEEA is a satellite system attached to SNA, not integrated into SNA, various reversions have been suggested in recent years, such as the National Accounting Matrix including Environmental Accounts (NAMEA) (De Haan, Mark and Steven J.Keuning, 1996). However, the biggest shortcoming of SEEA is not accounting for social items such as income generation and distribution, which are decisive factors influencing the status of sustainable development.

3. Social Accounting Matrix

For social items, particularly income generation and distribution, a powerful analysis tool, Social Accounting Matrix (SAM) has been implemented in last two decades (Pyatt, G. and J. Round, 1985). Although the structure and size of a SAM varies on the availability of data and the purpose for which it is constructed, the basic framework of SAM follows (see Table 2):

Table 2. Basic Framework of SAM

	Supply	Household	Capital	Government	Trade
Supply	AX	C	I	G	E
Household	Y				
Capital		S^H		S^G	F
Government		T			
Trade	M				

here S^H: household saving;

S^G: government saving;

F: foreign investment; and

T: net tax.

Through the balance of each column and row, the fundamental equations of SAM can be deduced as follows:

$$Y = C + I + G + E - M \quad (3)$$

$$Y = C + S^H + T \quad (4)$$

$$I = S^H + S^G + F \quad (5)$$

$$T = G + S^G \quad (S^G = T - G) \quad (6)$$

$$M = E + F \quad (F = M - E) \quad (7)$$

However, it is obvious that because SAM does not incorporate resource and environment accounts, it is also unsuitable for sustainability planning.

II Social and Ecological Accounting Matrix

Here I presents the Social and Ecological Accounting Matrix (SEAM) for sustainability planning, in which population, economy and society are incorporated into the **Social** system, and resources and environment are placed into the **Ecological** system. The basic Structure of SEAM as follows (see Table 3):

Table 3. Basic Structure of SEAM

	Supply	Household	Capital	Government	Trade	Resource	Environment
Supply	AX	C	I	G	E	V	Z
Household	Y					V_H	Z_H
Capital		S^H		S^G	F		
Government		T					
Trade	M						
Resource	N						
Environment	K						

Here V: recovered resources by industrial activity,

Z: recovered environment assets by industrial activity,

V_H: final demand of resources,

Z_H: final demand of environment assets,

N: input of resources

K: input of environment assets.

According to the balance of each column and row, the key equations of SEAM can be concluded as follows:

$$Y = C + I + G + (E - M) - (N - V) - (K - Z) \quad (8)$$

$$Y = C + S^H + T - V_H - Z_H \quad (9)$$

$$I = S^H + S^G + F \quad (10)$$

$$T = G + S^G \quad (11)$$

$$M = E + F \quad (12)$$

$$N = V + V_H \quad (V_H = N - V) \quad (13)$$

$$K = Z + Z_H \quad (Z_H = K - Z) \quad (14)$$

Here Y: Ecological Domestic Products (or Environmentally adjusted net Domestic Products), EDP.

The above equations infer that the classical aggregate index GDP, Gross Domestic Products, or Y in equation (2) and (3) is reduced from its nominal value if resource losses and environment degradation are taken into account. The new aggregate index EDP, Ecological Domestic Products, therefore, more accurately depicts the situation. It is much more important that, as shown by equations (13) and

(14), the net losses of resources and environment finally transfer to households, the end-consumers, and why human being is solely responsible for the global sustainability.

Based upon SEAM, the general definition of Social and Ecological Accounts (SEA) follows:

I Goods & Services

- Ecological goods & services
- Other goods & services

II Income Distribution

- Household
- Government

III Accumulation

- Financial assets
- Human capitals
- Natural resources
  - Cropland
  - Freshwater
  - Ores
  - Others (biological varieties, etc.)
- Environmental assets
  - Air (greenhouse gases, CFO, SO_2, NO_x, TSP, etc.)
  - Water (BOD, COD, etc.)
  - Solid wastes (toxic, hazardous and radioactive wastes, etc.)
  - Others (natural and cultural relics, etc.)

As for the source and destination of accounts, it can be regionally classified by national, international and global breakdowns according to specific considerations.

Following is Indicators of Sustainable Development by SEAM and SEA:*

Demographic	**Scale**	**Population**
		Net growth rate
	Structure	Ratio of urban population
		Ratio of working-age population
		Ratio of senile population
		Adult illiteracy rate
		Adult high-educated rate
		Ratio of poverty population
Economic	**Scale**	**GDP** (gross and per capita)
		EDP (gross and per capita)
		Grain output (gross and per capita)
	Structure	Ratio of service sectors in GDP
		Ratio of information sectors in GDP
		Foreign trade rate ((E +M) / GDP)
		Regional disparity rate
	Performance	Gross labor productivity (GDP / total labors)
		Intermediate input rate
		Ratio of financial income
		Inflation rate
	Finance	Saving rate
		Investment rate
		Ratio of foreign investment (FI / GDP)
		Foreign direct investment rate (FDI / FI)
		Ratio of foreign debts (Debt / GDP)
	Science & Education	**Ratio of research & development** (R&D / GDP)
		Ratio of education expenditure (EE / GDP)
		Patents per capita
Social	**Employment**	**Unemployment rate**
	Living	Engel index (Urban vs. Rural)
		Gini index (Urban vs. Rural)
		Floor area per capita (m^2)
		Road intensity (km / km^2)
		Telephone lines per hundred households
	Health	Medical service rate (doctors per thousand citizens)
	Security	**Social security coverage rate**

Resource	**Water**	Freshwater occupancy per capita (m^3)
		Usage efficiency of freshwater (Urban vs. Rural)
		Ratio of underground water exploitation
	Land	**Arable land per capita** (hectare)
		Multicropping index
	Forest	Forestry coverage rate
		Wood occupancy per capita (m^3)
	Ocean	Ratio of breed aquatics
		Fishing aquatics rate
	Pasture	Pasture per capita (hectare)
	Ore	Mining efficiency of ores
		Ratio of mined ores
	Energy	**Energy intensity index**
		Ratio of clean energy
	Waste	Ratio of waste recycling
Environment	**Water**	**Water pollution index**
	Land	Ratio of deserting land
		Ratio of water and soil erosion
	Air	**Air pollution index**
	Waste	Industrial waste treatment rate
		Urban garbage treatment rate
	Noise	Urban noise index
	Biodiversity	Ratio of threatened species
	Protection	Urban greenbelt per capita (m^2)
		Ratio of "green" products

* The bold indicators are kernel ones.

Generally speaking, the SEAM indicators of sustainable development, only with 13 kernel and 60 total indicators, are much easier to use than the "Indicators of Sustainable Development" issued by United Nations' Commission on Sustainable Development (UNCSD) in April 1996, which is too complicated to be adopted even by the developed countries, needlessly to say to the developing countries that have fragile statistical bases even for economic accounts.

III An Empirical Study for China

China is a large developing country in a state of rapid economic growth. Its status of sustainability, therefore, influences not only East Asian but also global sustainability. Based upon the Social and Ecological Accounting Matrix, China Sustainability is identified as follows (see Table 4):[i]

Table 4. China Sustainability Identification by SEAM

Indicator	Unit	1978	1997
Population	million	962.59	1236.26
net growth rate	%	1.20	1.01
ratio of urban residents	%	17.92	29.92
GDP (current RMB)	billion Yuan	362.41	7345.25
index	(constant price)	100.00	582.40
ratio of tertiary	%	23.70	32.10
GDP per capita (current RMB)	Yuan	379.00	6079.00
index	(constant price)	100.00	459.60
Total exports & imports	billion Yuan	35.50	2695.86
Foreign trade reliability[1]	%	9.80	36.70
Inflation rate[2]	%	0.70	0.80
Total foreign investment	billion US $		64.41
ratio of FI[3]	%		7.27
foreign direct investment	billion US $		45.26
ratio of FDI[4]	%		70.27
Balance of foreign debts	billion US $		130.96
Liability ratio[5]	%		14.80
ratio of long-term debts	%		86.10
R&D expenditure	billion Yuan		50.21
ratio of R&D[6]	%		0.68
Unemployment rate[7]	%		7.00
Social security coverage	million		112.40
ratio of social security[8]	%		9.09
Cropland per capita[9]	hectare	0.13	0.10
Total energy consumption	million ton of SCE	571.44	1420.00
energy intensity[10]	kg/Yuan	1.58	1.13
Water pollution index[11]		II	III
Air pollution index[11]		II	III
EDP reduction[12]	billion Yuan		250.00
ratio of EDP reduction[13]	%		3.40
EDP (current RMB)[14]	billion Yuan		7095.25

Data sources:China Statistical Yearbook 1998,China Environment Yearbook 1998

1 Total exports & imports / GDP X 100%

2 General retail price index

3 Total foreign investment / GDP X 100%

4 Foreign direct investment / Total foreign investment X 100%

5 Balance of foreign debts / GDP X 100%

6 R&D expenditure / GDP X 100%

7 The registered unemployment rate was 3.1%

8 Social security coverage /population X 100%
(unemployment insurance, medical insurance and pension system)

9 Calculated by State Land Administrative Bureau data

10 Total energy consumption / GDP

11 Water and air quality grade by CEPA

12 Estimated net losses of natural resources and environment assets

13 EDP reduction / GDP X 100%

The most important findings follow:

- China's 1.2 billion massive **population has been, and will continue to be, the major constraint of her sustainability in the foreseeable future**, though the annual net growth rate has been decreased to 1%. One of the good demographic changes is that the ratio of urban residents now is about 30% and will keep rising along with her urbanization and modernization, which is helpful to effectively implement the family planning policy.[ii]
- It is anticipated that China GDP and GDP per capita will still increase at reasonable high speed in next decades, thus strengthening the solid bases for her sustainability. A good signal is that the ratio of **tertiary industry**--that is less ecological intensive than the primary and secondary industry--now is over 30% and will also keep rising, which is beneficial to China sustainability.
- Although China experienced high rates of **inflation** in the later 1980s and middle 1990s, now inflation is very low. Of course it is good for further social and economic development.[iii]
- Compared to the countries troubled by financial crisis, **China's states of foreign trade, and international income and expenditure are still favorable**. Now the foreign trade reliability is near 40%, the ratios of foreign investment, foreign direct investment and liability ratio are all, and will be, maintained in safety levels, which are basis for China in the globlizing economy.

- However, the main obstacles of China sustainability are the low ratio of **Research & Development** expenditure,[iv] increasing **unemployment** rate caused by the transition from planning economic system to free market system, limited coverage of **social security** system,[v] shortage of **cropland** to further supply China grain production, still rather low **energy efficiency**,[vi] and the worsening air, water and solid waste **pollution** in rapid industrialization and urbanization.
- The most notable indicator derived from SEAM, Ecological Domestic Products (EDP) calculated for China implies that, if considering the net losses of natural resources and environmental assets, **China's GDP has to be reduced at least 3.4%**[vii]. This is just a demonstration of why EDP aggregate should be adopted.

IV Conclusion

By integrating all components of sustainable development, the social and ecological accounting matrix, which is an evolution from input-output table, system of national accounts and social accounting matrix, therefore establishes a concrete base for sustainability planning and an operable framework for sustainable development indicators. For example, ecological domestic products (EDP) is a better index than the traditional gross domestic products (GDP).

The attached empirical study for China found that, if considering the net losses of natural resources and environmental assets, **China's GDP has to be reduced at least 3.4%**. This implies that, while devoting efforts to social and economic development and to meeting the basic needs of the people's lives, China should act in accordance with the UNCED consensus to regard "environmental protection as an integral part of the development process", and to refrain from following the developed countries' patterns of production and environmental protection, characterized by "pollute first, treat later". China, therefore, should accord with her national conditions, give overall consideration to the elements of population, economy, society, resources, production, consumption, and environmental protection so as to embark steadily on the road of sustainable development.

Endnotes

[i] The full scale China Social and Ecological Accounting Matrix (CSEAM) is still in compiling, partly waiting for State Statistical Bureau (SSB) to publish the 1997 Input-Output Table of China. The reported results, therefore, are interim and integrated ones for brief review.

[ii] So far the main difficulty for China to implement family planning is in rural areas, where China farmers still incline to traditional culture of "more children, more happiness", nonetheless the cost of raising Child in countryside is extremely lower than in city in China.

[iii] In 1998, China even faced the first deflation since opening-up and reform, partly because of the Asian Currency Crisis and international market recession.

[iv] China's ratio of R&D expenditure is not only lower than the developed countries such as USA's 2.9%, but even lower than some developing countries such as India's 1.0%.

[v] So far very few rural residents in China can be received basic social security such as medical insurance and pension, even certain part of urban residents has difficulties to access social security system because of the bankruptcy or poor management of enterprises that has increasingly laid off labors year by year.

[vi] Although China energy intensity has been decreased dramatically in last two decades, it still rather high compared to international advanced standards, especially for some industrial products, the input intensities of China are tens or even hundreds folds of that of Japan, USA, etc (McElory, Michael et al., 1998).

[vii] Word Bank estimated China pollution cost at US $ 50 billion per year, or 7.12% of GDP, based upon annual premature death, morbidity, restricted activity, chronic bronchitis, and other health effects (Word Bank, 1997). The EDP reduction presented here is estimated from cost of natural resource and environment protection. For example, small coal miner usually wastes three tons of coal resource while producing coal per ton. China small miners produced about 0.3 billion tons of coal in 1997, thus the cost of wasted resource = 100 Yuan / ton X 0.3 billion tons X 3 = 90 billion Yuan. The other items include environment protection investment, economic losses of pollution accidents and medical expenses for occupational diseases.

References

Chen, Xikang (1990), Input-Occupancy-Output Analysis and Its Application in China, in M. Chatterji and K.E. Kuenne eds., *Dynamic and Conflict in Regional Structural Change*, Macmillan, London.

De Haan, Mark and Steven J.Keuning (1996), Taking the Environment into Account: the NAMEA Approach, *The Review of Income and Wealth*, 42(2), 131-148.

Leontief, Wassily (1951), The Structure of American Economy 1919-1939 (2nd ed.), Oxford University Press, New York.

Leontief, Wassily (1970), Environmental Repercussions and the Economic Structure: An Input-Output Approach, *Review of Economics and Statistics*, 52(3), 262-271.

Leontief, Wassily (1986), Input-Output Economics, Oxford University Press, New York.

McElroy, Michael, et al. (1998), Energizing China—reconciling environmental protection and economic growth, Harvard University Press, Boston.

Pyatt, G. and J. Round (1985), Social Accounting Matrix: a basis for planning, The World Bank, Washington D.C.

United Nations (1993), Handbook of National Accounting: Integrated Environmental and Economic Accounting, Interim Version, United Nations (ST/ESA/STAT/ SER.F/61).

World Bank (1997), Clear Water, Blue Skies: China's environment in the new century, Washington, DC.