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TO RESEARCH THE METHODOLOGIES FOR MEASURING ENVIRONMENTS AND RESOURCES IN A POPULATION AND IN THE INDUSTRIAL PRODUCTION – BASED ON THE FRAME OF THE SYSTEM OF NATIONAL ACCOUNTS

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Abstract. *The System of National Accounts (SNA) and Integrated Environmental and Economic Accounting (SEEA) published by the UN are the programmatic documents of national economic accounting theory, and can be deemed as the criteria by theoretical and practical workers in the national economic accounting all over the world. This paper deals with the methodologies or methods to measure environments and resources in an accounting population and in the activities of industrial production, and probes into the general formula of the key matrix, comprehensive matrix, and the calculating model for measuring resources in the process of industrial production. The paper examines the usefulness of the methodologies designed by the empirical application, so as to enrich the accounting theory of environmental-economic and guide the accounting practice in China.*
Keywords: Measuring methodologies, Environments and resources, Industrial production

1. **Introduction.** In the early times, the Statistics Committee of United Nations and relevant institutions have recommended 4 accounting systems to all countries around the world: System of National Accounts (SNA) [1], System of Material Products and Balances (MPS) [2], System of Social Demographic Statistics (SSDS) [3], Handbook of National Accounting – Integrated Environmental and Economic Accounting 2003 (SEEA) to instruct the economic accounting, social accounting and the environmental accounting in the global countries. The four great accounting systems have played an important role in coordinating accounting results for all countries, and promoting the international comparisons of statistical data and economic analysis data in the world.

In the developmental history of the national economic accounting, the earliest accounting system released by the Economic and Social Affairs Statistic Committee of United Nations in 1953, called SNA1953, was created by a group of statistic experts with the chief being professor Richard Stone, a famous British statistician, based on the previous accounting theories methods and practices. After SNA1953, the Statistics Committee of UN provided a revised SNA in line with various statistical accounting practices in

1968, namely SNA1968, to meet the accounting demand for the countries with different development levels and the different economic institutions in the world. After 25 years, the Statistics Committee of UN jointly rolled out another revised edition of SNA, named SNA1993. However, the development of SNA still has not come to an end. After 15 years, the United Nations, together with another five international organizations, once again published the updated version of SNA in 2008, named SNA2008 [4]. In fact, in order to guide and coordinate the accounting activities of environment and economy worldwide, the Statistics Committee of UN has issued The Handbook of National Accounting – Integrated Environmental and Economic Accounting in 2003 (SEEA) [5] to stress the accounting of environments and resources. With the rapid growth of the global economy, humankind is more inclined to keep a watchful eye on the environments and resources. This paper will focus on the methodologies for measuring environments and resources in a population (region or country) and in the activity of industrial production in accordance with the SNA and SEEA.

This paper is organized as follows. Section 1 is the introduction and the review of the system of national accounts. Section 2 is to design methodologies for measuring the environments and resources in a population. Section 3 is to design indices and models for measuring the consumption of the environments and resources and the optimal drain of pollutants and wastes in the activities of industrial production. Section 4 is empirical application of cases to demonstrate feasibility of the designed matrices and models, and the last section is conclusion and further study.

2. To Design the Methodologies for Measuring the Environments and Resources in a Population.

From SNA and SEEA, the major methodology for measuring the environments and resources in a population is accounts and matrices, so we will start with designing the accounts of environments and resources on the basis of SNA and SEEA.

2.1. The theoretical base of design.

Similar to SNA, SEEA has also been warmly worshiped by economists and statisticians all over the world as a benchmark in the field of national accounting theory. A number of countries imitate it as a model to construct their system of environmental and economic accounting to meet their own conditions. Based on the theory, some scholars, for example, Repetto [6], Hartwick [7], Uno and Bartelmus [8], respectively explored the accounts and matrices to measure the environments and resources. Now we research a kind of key accounts and key matrix for describing the environments and resources in a population.

2.2. To design the key account.

It is well-known that the accounting item of any individual account is aimed at a specific population, so it is crucial to define a "population" as the first step. We use "beginning of period" and "ending of period" to delimit timeline of the population, and use "inside the region" and "outside the region" to define its limit of space. It means that the location of the accounting items in any accounts is an environmental phenomenon emerging between the "beginning" and "ending" timeline in

Table 1. The general formula of a key account for environments and resources

Coming from	Going direction
The stock of the beginning The inflow of increase in the accounting period	The inflow of decrease in the accounting period The stock of the ending
Total of the stock and inflow comes from	Total of the stock and inflow goes direction

a specific "region" or a country. Furthermore, in keeping with the structural principles of economic accounts, the accounts of environments and resources have "debtors" and "creditors" and stocks and flows, as well as "increasing" on the one side and "decreasing" on the other side.

Thus, a general formula of a key account of environments and resources can be designed as Table 1.

Table 1 is a key account: its left side is the source of the environments and resources, the right side is the usage of the environments and resources, and there is an equation between them as below:

The stock of the beginning + the inflow of increase in the accounting period – the inflow of decrease in the accounting period = the stock of the ending

A series of related items could be estimated by the equation above, and a lot of accounts based on Table 1 could be transformed by the classification of environments and resources in a population, so it is called the general formula of the key accounts.

2.3. **To design the key matrix.** The matrix is another kind of effective tool to measure environments and resources. Huang et al. [9] studied a clustering method to analyze structural changes, and Kang et al. [10] proposed a methodology to measure the risk level in real-time for business activity monitoring. These studies give us a helpful idea for reference. Therefore, key matrix designed for a population in the light of its conditions and accounting principles is as below (Table 2).

TABLE 2. The general formula of a key matrix of environments and resources

Beginning of period / Ending of period		Inflow	Inside region				Stock of ending of period
			State 1	State 2	...	State n	
outflow		a	b_1	b_2	$\cdots$	b_n	
Inside region	State 1	c_1	x_{11}	x_{12}	$\cdots$	x_{1n}	T_1
	State 2	c_2	x_{21}	x_{22}	$\cdots$	x_{2n}	T_2
	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\cdots$	$\vdots$	$\vdots$
	State n	c_n	x_{n1}	x_{n2}	$\cdots$	x_{nn}	T_n
Stock of beginning of period			S_1	S_2	$\cdots$	S_n	–

In Table 2, the columns represent inflow of environmental assets or resources, and the rows represent outflow of environmental assets or resources. Thus, the sum of the last row shows the stock of beginning of period and the sum of the last column shows the stock of ending of period.

Here, a is a constant which represents the amount entering into the accounting population and leaving the population in the accounting period, and it belongs to neither the stock of beginning of period nor the stock of ending of period in the population.

$\mathbf{B}$ is a row vector, $\mathbf{B} = (b_1, b_2, \ldots, b_n)$. It is the amount of inflowing into or entering into the population in the various states in the accounting period, which is included in the stock of the beginning of period, but not in the stock of the ending of period.

$\mathbf{C}$ is a column vector, $\mathbf{C} = (c_1, c_2, \ldots, c_n)'$. It is the amount of outflow of the population in the various states in the accounting period, which is included in the stock of the ending of period, but not in the stock of the beginning of period.

$\mathbf{X}$ is a square matrix.

$$\mathbf{X} = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nn} \end{pmatrix}$$

It represents the transforming amount from one kind of the state to another kind of the state in the population during the whole accounting period, and being a flow matrix, the amount is included in the stock of the beginning of period and also in the stock of the ending of period.

S is a row vector, $\mathbf{S} = (\mathrm{S}_1, \mathrm{S}_2, \ldots, \mathrm{S}_n)$. It is the stock of environmental assets or resources in various states on the beginning of period.

T is a column vector, $\mathbf{T} = (\mathrm{T}_1, \mathrm{T}_2, \ldots, \mathrm{T}_n)'$. It is the stock of environmental assets or resources in various states on the ending of period.

Here are some equations as follows:

The amount of outflow of the environmental assets or resources in the accounting period + The flow during accounting period = The stock of beginning of period

$$\begin{cases} b_1 + x_{11} + x_{21} + \ldots + x_{n1} = \mathrm{S}_1 \\ b_2 + x_{12} + x_{22} + \ldots + x_{n2} = \mathrm{S}_2 \\ \qquad\qquad\qquad \vdots \qquad\qquad \vdots \\ b_n + x_{1n} + x_{2n} + \ldots + x_{nn} = \mathrm{S}_n \end{cases} \tag{1}$$

The amount of inflow of the environmental assets or resources in the accounting period + the inflow during accounting period = the stock of end of period

$$\begin{cases} c_1 + x_{11} + x_{12} + \ldots + x_{1n} = \mathrm{T}_1 \\ c_2 + x_{21} + x_{22} + \ldots + x_{2n} = \mathrm{T}_2 \\ \qquad\qquad\qquad \vdots \qquad\qquad \vdots \\ c_n + x_{n1} + x_{n2} + \ldots + x_{nn} = \mathrm{T}_n \end{cases} \tag{2}$$

This general formula of the key matrix organically combines the stocks, flows, inflows (increasing) and outflow (decreasing), and achieves a unity of static descriptions and dynamic descriptions.

2.4. **To design the comprehensive matrix.** As we know above, a lot of specific accounts or matrixes for environments and resources could be generated by the general formula of a key account or a key matrix. Bearing in mind environmental factors' special features and accounting contents, we have constructed general formula of a comprehensive matrix for environments and resources as follows (Table 3).

Table 3 is that of a kind of chessboard in this formula. It can offer, being organically integrated of the different key accounts and different key matrixes, a quite complete and comprehensive description of stocks, flows and transforms for many different environmental and resource factors in a specific population (region) in the accounting period, meanwhile provide ideas and data support or the constructing analytical models of environments and resources.

Here "resource factors" refers to a number of accounting factors of environments or resources in a specific population in the accounting period. Each factor can be divided into different items, being expressed as F_j $(j = 1, 2, \ldots, n)$.

Vectors $\mathbf{k}^0$ and $\mathbf{k}^1$ are respectively the stock of various resources or environmental factors in the beginning of period and end of period, which provide, being indices of time point, a static description for resource or environmental factors.

Vector **E** and vector **H** are respectively the amounts of inflow and outflow of various resource or environmental factors in the accounting period, which provide, being indices of time period, a dynamic description of resource or environmental factors.

Vector **B** and vector **C** are respectively the amounts of various resources or environmental factors, naturally regenerated and naturally exhausted in the accounting period, being

Table 3. The general formula of a comprehensive matrix for environments and resources

			Resource factor 1				$\ldots$	Resource factor M			
			F_{11}	F_{12}	$\ldots$	F_{1n}	$\ldots$	F_{m1}	F_{m2}	$\ldots$	F_{mn}
Stock of beginning of period $\mathbf{k}^0$			k_{11}^0	k_{12}^0	$\ldots$	k_{1n}^0	$\ldots$	k_{m1}^0	k_{m2}^0	$\ldots$	k_{mn}^0
The amount of inflow in the period $\mathbf{E}$			e_{11}	e_{12}	$\ldots$	e_{1n}	$\ldots$	e_{m1}	e_{m2}	$\ldots$	e_{mn}
The amount regenerated in the period $\mathbf{B}$			b_{11}	b_{12}	$\ldots$	b_{1n}	$\ldots$	b_{m1}	b_{m2}	$\ldots$	b_{mn}
Flow in the period	Resource factor 1	F_{11}	$P_{(11,11)}$				$\ldots$				
		F_{12}		$P_{(12,12)}$		$P_{(1j,1j)}$	$\ldots$				
		$\ldots$			$\ldots$		$\ldots$				
		F_{1n}		$P_{(1j,1j)}$		$P_{(1n,1n)}$	$\ldots$				
	$\vdots$		$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\ldots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
	Resource factor N	F_{m1}					$\ldots$	$P_{(m1,m1)}$			
		F_{m2}					$\ldots$		$P_{(m2,m2)}$		$P_{(mj,mj)}$
		$\vdots$					$\ldots$			$\vdots$	
		F_{mn}					$\ldots$		$P_{(mj,mj)}$		$P_{(mn,mn)}$
The amount exhausted in the period $\mathbf{C}$			c_{11}	c_{12}		c_{1n}	$\ldots$	c_{m1}	c_{m2}		c_{mn}
The amount of outflow in the period $\mathbf{H}$			h_{11}	h_{12}	$\ldots$	h_{1n}	$\ldots$	h_{m1}	h_{m2}	$\ldots$	h_{mn}
Stock of ending of period $\mathbf{k}^1$			k_{11}^1	k_{12}^1	$\ldots$	k_{1n}^1	$\ldots$	k_{m1}^1	k_{m2}^1	$\ldots$	k_{mn}^1

Note: the period means accounting period.

indices of time period, which provide a dynamic description of resource or environmental factors.

$\mathbf{P}$ is the flowing matrix in the accounting period.

The values $p_{(mi,mi)}$ of $\mathbf{P}$, on the diagonal line, represent the flow of various resource factors in the accounting period; and the values $p_{(mi,mj)}$, on the non-diagonal line, represent the transforming quantity from one kind of resource factor into another kind of resource factor.

$$\mathbf{P} = \begin{pmatrix} p_{(m1,m1)} & p_{(m1,m2)} & \cdots & p_{(m1,mn)} \\ p_{(m2,m1)} & p_{(m2,m2)} & \cdots & p_{(m2,mn)} \\ \vdots & \vdots & \cdots & \vdots \\ p_{(mn,m1)} & p_{(mn,m2)} & \cdots & p_{(mn,mn)} \end{pmatrix} \tag{3}$$

The various data can be obtained through statistical calculation or be transferred from other individual accounts, and the relational equations come from the comprehensive matrix as follows:

The stock of end of period = The stock of beginning of period + Inflow in the period + The amount regenerated in the period − The amount exhausted in the period − Outflow in the period

$$k_{ij}^1 = k_{ij}^0 + e_{ij} + b_{ij} + p_{(mi,mj)} - h_{ij} - c_{ij} \quad (i = 1, 2, \ldots, M; j = 1, 2, \ldots, N) \tag{4}$$

The other comprehensive matrices could be transformed by changing the accounting contents and forms through the general formula above.

3. To Design the Methodology for Measuring the Environments and Resources in the Activities of Industrial Production.

It is also the vital part of tasks to measure the environments and resources in the activities of industrial production.

3.1. The theoretical base of the design.

The accounts of environmental input-output mainly describe the efficiency of input-output in the activity of industrial production, including accounts for the effects of environmental activity and for the value of input-output in environmental protection. On the consumption of environments and resources, Hubacek [11] studied the methods of measuring input-output of environments and resources; Vaughn [12] also explored the environment-economic accounting methodology and indices of environmental protection activities; M. R. Partidário [13], S. E. Serafy [14] were also engaged in the analogous research. The theoretical base to study the environments and resources in the activity of industrial production is the theory of circulating economy. Circulating economy is concerned with process to implement comprehensive utilization of resources and their wastes in the production activities in accordance with the cleaner production methods, and is also a modern civilized behavior to protect the earth's resources and the ecological environment.

3.2. To design the methodology for measuring the efficiency of consumption of environments and resources.

Based on the foregoing theory, circulating economy is to maximize the save resources, and to realize the sustainable utilization of resources. Therefore, it is the most important target to measure resources conservation and sustainable utilization in the activities of industrial production. To solve this issue, the feasible idea is to construct a loose input-output matrix, and to calculate a coefficient of resources consumption $\rho_{\cdot j}$ to estimate the consumption and saving of resource factors.

To assume two finite sets: the production department set Ω and resource factors set Φ, respectively be defined as $\Omega = (\omega_1, \omega_2, \ldots, \omega_n)$ and $\Phi = (\varphi_1, \varphi_2, \ldots, \varphi_m)$.

Assumption 1: the whole products of each production department ω_i in the set Ω all exhaust the various kinds of resources factors φ_i in the set Φ.

Assumption 2: the technical contacts among the production departments are relatively stable in a closed recycling economy system in a certain period, and the consumption rate of resources in production activities is not changed.

Assumption 3: the amount of consumption for resource factors shows in the value forms.

Then, the relationship between set Φ and set Ω could be described by the matrix as follows (Table 4) [15].

Table 4. Consumption matrix of resource factors (in valued form)

		Production departments				Total of consumption of resources
		ω_1	ω_2	$\cdots$	ω_n	
Resource factors of consumption	φ_1	g_{11}	g_{12}	$\cdots$	g_{1n}	$g_{1\cdot}$
	φ_2	g_{21}	g_{22}	$\cdots$	g_{2n}	$g_{2\cdot}$
	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
	φ_m	g_{m1}	g_{m2}	$\cdots$	g_{mn}	$g_{m\cdot}$
Total of resources consumption		$g_{\cdot 1}$	$g_{\cdot 2}$	$\cdots$	$g_{\cdot n}$	$\sum g_{i\cdot}$
The added amount of output of production department		Δy_1	Δy_2	$\cdots$	Δy_n	$\sum \Delta y_i$

In Table 4, the subject columns are the classification of the resource factors exhausted, the object columns are the classification of production departments.

The matrix G, g_{ij} $(i = 1, 2, \ldots, m; j = 1, 2, \ldots, n)$ is the amount of consumption in each production department (or enterprise) for the all kinds of resources; $g_{.j}$ is the total consumption of resource factors in the each production departments; $g_{i.}$ is the total amount of all kinds of resources factors.

If order: the added amount of each unit of output for each production department in the certain period is Δy_j, then the consumption coefficient of resources factors for added amount of each unit could be defined:

$$\rho_{ij} = \frac{g_{ij}}{\Delta y_j} \quad (i = 1, 2, \ldots, m; j = 1, 2, \ldots, n) \tag{5}$$

So the matrix of consumption coefficient of resources factors is:

$$\tilde{\mathrm{P}} = \begin{pmatrix} \rho_{11} & \rho_{12} & \cdots & \rho_{1n} \\ \rho_{21} & \rho_{22} & \cdots & \rho_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \rho_{m1} & \rho_{m2} & \cdots & \rho_{mn} \end{pmatrix}$$

Two statistics can be calculated by $\tilde{\mathrm{P}}$ as follows:

$$\rho_{i.} = \sum_{j=1}^{n} \rho_{ij}; \quad \rho_{.j} = \sum_{i=1}^{m} \rho_{ij} \quad (j = 1, 2, \ldots, n) \tag{6}$$

Here: $\rho_{i.}$ is the whole consuming amount for the kind i of resources factors when each production department provides an unit added value; $\rho_{.j}$ is the total consuming amount of all kinds of resource factors when the kind j of production department provides an unit added value.

Based on the matrix $\tilde{\mathrm{P}}$, a forecast model for the consumption of resource factors can be constructed as follows.

$$\because g_{ij} = \rho_{ij} \cdot \Delta y_j \quad (i = 1, 2, \ldots, m; j = 1, 2, \ldots, n) \tag{7}$$

Then, $\tilde{\mathrm{G}} = \tilde{\mathrm{P}} \cdot \Delta\tilde{\mathrm{Y}}$, i.e.,

$$\begin{pmatrix} g_{11} & g_{12} & \cdots & g_{1n} \\ g_{21} & g_{22} & \cdots & g_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ g_{m1} & g_{m2} & \cdots & g_{mn} \end{pmatrix} = \begin{pmatrix} \rho_{11} & \rho_{12} & \cdots & \rho_{1n} \\ \rho_{21} & \rho_{22} & \cdots & \rho_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \rho_{m1} & \rho_{m2} & \cdots & \rho_{mn} \end{pmatrix} \begin{pmatrix} \Delta y_1 & & \cdots & 0 \\ & \Delta y_2 & & \vdots \\ \vdots & & \cdots & \\ 0 & \cdots & & \Delta y_n \end{pmatrix} \tag{8}$$

Namely the consumption matrix of resource factors is the product between the coefficient matrix of resource factors consumption and the diagonal incremental matrix of department output.

From the equation above, then:

$$\hat{g}_{.j}^{(t)} = \sum_{i=1}^{m} \rho_{ij} \cdot \Delta\hat{y}_j^{(t)} = \rho_{.j} \Delta\hat{y}_j^{(t)} \quad (j = 1, 2, \ldots, n) \tag{9}$$

Here: $\rho_{.j}$ is the consumption coefficient of resources factors for the kind j of production department; $\Delta\hat{y}_j^{(t)}$ is the added amount of output for the kind j of production department in the period t; $\hat{g}_{.j}^{(t)}$ is the amount of consumption of resources factors for the kind j of production department in the period t.

So a forecast model for the consumption of resource factors has been constructed.

The circulating economy requires resources reused, and achieves the minimization of resource factors consumed in the industrial production. Therefore, the consumption coefficient of resource factors should be theoretically declined gradually in a closed system of circulating economy. If the coefficient η $(0 < \eta < 1)$ is gradient, then the predicated amount of the consumption of resources factors for the kind j of production department in the period t will be

$$\hat{g}_{.j}^{(t)} = (1-\eta)^t \sum_{i=1}^{m} \rho_{ij} \cdot \Delta y_j^{(t)} = (1-\eta)^t \cdot \rho_{.j} \cdot \Delta y_j^{(t)} \quad (j = 1, 2, \ldots, n) \tag{10}$$

$(1-\eta)^t$ is a gradient operator to the consumption coefficient of the resources factors.

Write the equation above in the form of matrix, then

$$\begin{pmatrix} \hat{g}_{.1}^{(t)} \\ \hat{g}_{.2}^{(t)} \\ \vdots \\ \hat{g}_{.n}^{(t)} \end{pmatrix} = (1-\eta)^t \begin{pmatrix} \rho_{.1} & & \cdots & 0 \\ & \rho_{.2} & & \\ \vdots & & \cdots & \vdots \\ 0 & & \cdots & \rho_{.n} \end{pmatrix} \begin{pmatrix} \Delta y_1^{(t)} \\ \Delta y_2^{(t)} \\ \vdots \\ \Delta y_n^{(t)} \end{pmatrix} \tag{11}$$

In turn, the deformation of the equation above is

$$\begin{pmatrix} \Delta \hat{y}_1^{(t)} \\ \Delta \hat{y}_2^{(t)} \\ \vdots \\ \Delta \hat{y}_n^{(t)} \end{pmatrix} = \frac{1}{(1-\eta)^t} \begin{pmatrix} 1/\rho_{.1} & & & 0 \\ & 1/\rho_{.2} & & \\ & & \cdots & \\ 0 & & & 1/\rho_{.n} \end{pmatrix} \begin{pmatrix} \hat{g}_{.1}^{(t)} \\ \hat{g}_{.2}^{(t)} \\ \vdots \\ \hat{g}_{.n}^{(t)} \end{pmatrix} \tag{12}$$

With the help of this equation or model, the added output of each production department could be calculated.

3.3. **To design the methodology for measuring the optimal consumption of environments and resources.** The drain of pollutants and wastes in the industrial production should be measured in the accounting environments and resources in SNA and SEEA because the production of circulating economy requires the maximization of resource utilization and also the minimization of drain of wastes. Therefore, it is of huge significance in theory and practice to measure the drain of pollutants and wastes in the industrial production. Here, we will construct a model to measure the optimal consumption of environments and resources.

3.3.1. *The identification of objective function.* The amount of drain of pollutants and wastes in the production process in the different periods is the impacting factor for the total amount of the drain in a closed circulating economy system, so we can set the total objective function of drain as V [16].

$$\mathrm{V} = \psi[\psi(t), \psi(t+\Delta t), \psi(t+2\Delta t), \ldots] \tag{13}$$

The economic meaning of the equation above is the total target value V of drain of pollutants and wastes is the function of target value $\psi_i(t)$ for the future period.

Hereby requesting the drain of pollutants and wastes is gradually descended being in the future periods, we use time factor α $(0 < \alpha < 1)$ and gradient factor of the drain of pollutants and wastes as weights to weigh the target value of each period in the future, and then the total target value V can be expressed as the equation as follows:

$$\mathrm{V} = \psi\{\alpha(t)[\psi(t)]^{\beta(t)} + \alpha(t+\Delta t)[\psi(t+\Delta t)]^{\beta(t+\Delta t)} + \alpha(t+2\Delta t)\psi[t+2\Delta t]^{\beta(t+2\Delta t)}, \ldots\} \tag{14}$$

Order a time period $\Delta t = 1$, when the change of Δt is enough small for function $\psi(t)$ relatively, then this equation can be converted into a continuous function:

$$\mathrm{V} = \int_t^\infty \psi(t)dt \tag{15}$$

So the optical goal requires:

$$\min \mathrm{V} = \min \int_t^\infty \psi(t)dt \tag{16}$$

3.3.2. *The design of the model.* Suppose: the amount of drain pollutants and wastes in the time t is L, the coefficient of environment self-purification is θ, then the function between the cumulative drain of pollutants and wastes S and the drain of pollutants and wastes L can be expressed in the time t as follows:

$$\frac{ds}{dt} = \mathrm{L} - \theta \mathrm{S} \quad (0\angle\theta\angle 1) \tag{17}$$

Here θ shows the capacity of self-purification of environments.

According to the idea of circulating economy, the drain of pollutants and wastes in the natural world must be less than that of generating in the production process. Now assuming the input of fixed assets is G, the input of current assets is J, the amount of pollutants and wastes in the production process is O, then L is the function of G, J, O, i.e.,

$$\mathrm{L} = \psi_{(1)}(\mathrm{G}, \mathrm{J}, \mathrm{O}) \tag{18}$$

Additionally, the gross of output U determines the drain of pollutants and wastes in the production process, therefore:

$$\mathrm{O} = \psi_{(2)}(\mathrm{U}) \tag{19}$$

Similarly gross of output U is the function to the amount being exhausted of the regenerated resources X_1, non-regenerated resources X_2, fixed assets Z_1, current assets Z_2, labor assets H in the production process, i.e.,

$$\mathrm{U} = \psi_{(3)}(\mathrm{X}_1, \mathrm{X}_2, \mathrm{Z}_1, \mathrm{Z}_2, \mathrm{H}) \tag{20}$$

Again there is a function between regenerated resources X_1 and economic activity population P, the store of resources factors Z:

$$\mathrm{X}_1 = \psi_{(4)}(\mathrm{P}, \mathrm{Z}) \tag{21}$$

Further analysis, the gross output (U) of the production process could be decomposed into 6 parts: the first part is U_1 to be used in the production input for expanded reproduction; the second part is U_2 to be used in environment cleaning and declining drain pollutants and wastes; the third part is U_3 to be used in producing the regenerated resources, the fourth part is U_4 to be used in protecting regenerated resources, the fifth part is U_5 to be used in residents living consumption, and the sixth part is U_6 to be used in saving, i.e.,

$$\mathrm{U} = \mathrm{U}_1 + \mathrm{U}_2 + \mathrm{U}_3 + \mathrm{U}_4 + \mathrm{U}_5 + \mathrm{U}_6 \tag{22}$$

Order the input coefficient of reproduction is φ_1, then:

$$\mathrm{U}_1 = \varphi_1 \times \mathrm{U} \tag{23}$$

Order the input coefficient of environment cleaning and declining drain is φ_2, then:

$$\mathrm{U}_2 = \varphi_2 \times [(1 - \varphi_1) \times \mathrm{U}] \tag{24}$$

Order the input coefficient of the regenerated resources production is φ_3, then:

$$\mathrm{U}_3 = \varphi_3 \times [(1 - \varphi_1 - \varphi_2) \times \mathrm{U}] \tag{25}$$

Order the input coefficient of the un-regenerated resources protect is φ_4, then:

$$U_4 = \varphi_4 \times [(1 - \varphi_1 - \varphi_2 - \varphi_3) \times U] \tag{26}$$

Order the consumption coefficient of residents living is φ_5, then:

$$U_5 = \varphi_5 \times [(1 - \varphi_1 - \varphi_2 - \varphi_3 - \varphi_4) \times U] \tag{27}$$

Order the saving coefficient of residents living is φ_6, then:

$$U_6 = \varphi_6 \times [(1 - \varphi_1 - \varphi_2 - \varphi_3 - \varphi_4 - \varphi_5) \times U] \tag{28}$$

Accordingly, the total input of the social fixed assets W at least can be divided into five parts: the first part is W_1 to be used in expanded reproduction; the second part is W_2 to be used in environmental cleaning; the third part is W_3 to be used in the production of regenerated resources; the fourth part is W_4 to be used in the protection of un-regenerated resources, and the fifth part is W_5 to be used in other side of fixed assets, i.e.,

$$W = W_1 + W_2 + W_3 + W_4 + W_5 \tag{29}$$

So the relationship between U_i $(i = 1, 2, 3, 4, 5, 6)$ and W_k $(k = 1, 2, 3, 4, 5)$ can be expressed as follows:

$$\frac{dW_1}{dt} = U_1 - \lambda_1 W_1 \tag{30}$$

$$\frac{dW_2}{dt} = U_2 - \lambda_2 W_2 \tag{31}$$

$$\frac{dW_3}{dt} = U_3 - \lambda_3 W_3 \tag{32}$$

$$\frac{dW_4}{dt} = U_4 - \lambda_4 W_4 \tag{33}$$

$$\frac{dW_5}{dt} = U_5 - \lambda_5 W_5 \tag{34}$$

Here: λ_1 is the rate of depreciation for fixed assets of expanded reproduction; λ_2 is the rate of depreciation for fixed assets of environmental cleaning; λ_3 is the rate of depreciation for fixed assets of production of regenerated resources; λ_4 is the rate of depreciation for fixed assets of the protection of un-regenerated resources; λ_5 is the rate of depreciation for fixed assets of other side.

Therefore, the model can be provided for measuring the optimal drain of pollutants and wastes in a closed circulating economic system as follows:

$$\begin{array}{ll}
\left\{\begin{array}{l} \min V \\ 0 < \varphi_1 < 1; \quad 0 < \varphi_2 < 1 \\ 0 < \varphi_3 < 1; \quad 0 < \varphi_4 < 1 \\ 0 < \varphi_5 < 1; \quad 0 < \varphi_6 < 1 \end{array}\right. & \\
U_1 = \varphi_1 \times U; & U_2 = \varphi_2 \times [(1 - \varphi_1) \times U] \\
U_3 = \varphi_3 \times [(1 - \varphi_1 - \varphi_2) \times U]; & U_4 = \varphi_4 \times [(1 - \varphi_1 - \varphi_2 - \varphi_3) \times U] \\
U_5 = \varphi_5 \times [(1 - \varphi_1 - \varphi_2 - \varphi_3 - \varphi_4) \times U]; & U_6 = \varphi_6 \times [(1 - \varphi_1 - \varphi_2 - \varphi_3 - \varphi_4 - \varphi_5) \times U] \\
\dfrac{dW_1}{dt} = U_1 - \lambda_1 W_1; & \dfrac{dW_2}{dt} = U_2 - \lambda_2 W_2 \\
\dfrac{dW_3}{dt} = U_3 - \lambda_3 W_3; & \dfrac{dW_4}{dt} = U_4 - \lambda_4 W_4 \\
\dfrac{dW_5}{dt} = U_5 - \lambda_5 W_5 &
\end{array} \tag{35}$$

The model above, being a theoretical model, offers an optimal pathway to realize the minimum of drain of pollutants and wastes in the activity of the industrial production. Its solution provides the optimal mode of environments and resources for the operation of circulating economic system.

4. **Empirical Applications.**

In order to test and verify the feasibility of the key matrix, comprehensive matrix and models abovethere are empirical applications provided as follows.

4.1. **The empirical application of the key matrix.**

Based on the Thematic Database for Human-earth System, we selected the data of the natural resources from a region, then the key matrix to describe and analyze the dynamic change of the natural resources in the region could be constituted (Table 5).

TABLE 5. A key matrix of natural resources in a region Unit: 10000 Acre

Beginning of period / Ending of period		Inflow	Inside region								Stock of ending of period
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
outflow		0	863	140	726	49	107	−106	78	13	
Inside region	(1)	−494	6981	126							6613
	(2)	−1180		6380							5200
	(3)	−323			8351	265					8293
	(4)	364				7522					7886
	(5)	−336					5208	166			5038
	(6)	−24						2893			2869
	(7)	78							1217	13	1308
	(8)	570								609	1179
Stock of beginning of period			7844	6646	9077	7836	5315	2953	1295	635	–

Note: The data comes from *Thematic Database for Human-earth System* (www. data. ac. cn), but it is adjusted and replenished as required for just only illustrating the practicability of the key matrix.

In Table 5 the data are collected from province in China and can be adjusted for easily demonstrating the application of the key matrix. The Arabic numerals with parenthesis, i.e., (1), (2), ..., (8), respectively represent the arable acreage, cultivated area, area of suitable forest, area of forest, area of available grassland, area of cultivated grassland, area of suitable breeding freshwater, area of cultivated breeding freshwater. It simultaneously demonstrates the inflows, stocks and variations of various natural resources in the accounting periods in the province.

The factor on the diagonal of T respectively represents the proportion of keeping same state for all kinds of natural resources in the accounting period, and the factor on the non-diagonal of T respectively represents the transforming proportion of various natural resources from one state to another state in the accounting period. So we can analyze the changing and utilizing condition of natural resources in this region (province) in the accounting period by Table 5.

4.2. **The empirical application of the comprehensive matrix.**

Similarly we can design a comprehensive matrix to describe the static condition and dynamic change of the natural resources based on the data of environment and natural resources in Hubei province in China as follows (Table 6).

We select three kinds of natural resources to demonstrate the applications of the comprehensive matrix in Table 6.

Table 6. The comprehensive matrix of resources to a province in China

		Land (10000 mu)		Forest (10000 mu)		Water (10000 kilowatt)	
		cultivable land	cultivated land	Usable forest	Used forest	developable reserve	Developed reserves
Stock of beginning of period		6330.09	6076.89	11905.13	10833.82	3554.05	2509.03
The amount of inflow in the period		73.29	18.16	182.11	46.51	26.33	78.31
The amount regenerated in the period		36.31	9.35	25.91	23.71	11.19	16.69
land	cultivable land	6267.06	96.27				
	cultivated land	19.10	6003.28				
forest	Usable forest			11071.77	353.69		
	Used forest			20.08	10779.23		
water	developable reserve					3538.11	361.77
	Developed reserves					27.09	2493.10
The amount exhausted in the period		35.38	25.07	27.34	39.22	9.39	56.33
The amount of outflow in the period		26.76	8.73	219.35	55.59	21.44	66.20
Stock of ending of period		6396.65	6166.87	11886.54	11162.92	3587.83	2843.27

Note: The data comes from the *Communique of Land and Resources of Hubei province* in 2009, but it is adjusted and replenished as required for just only illustrating the application of the comprehensive matrix.

Obviously Table 3, as the tool or methodology to describe and analyze, realizes the combination of static description and dynamic description.

4.3. **The empirical application of the methodology for measuring the efficiency of consumption of environments and resources.** As mentioned above, the methodology designed could measure the efficiency of consumption of resources. In addition, we could also examine the practical applicability. We select the 8 kinds of manufacturing industrial in China to calculate the consumption coefficient of resources and set analysis model for convenient operating; then the coefficient matrix of resource consumption is

$$\tilde{\mathrm{P}} = \begin{pmatrix} 0.003029 & 0.006390 & 0.006954 & 0.001141 & 0.005558 & 0.001357 & 0.005083 & 0.018905 \\ 0.000001 & 0 & 0.000003 & 0 & 0.000001 & 0.000004 & 0.000006 & 0.000005 \\ 0.001540 & 0.001998 & 0.001734 & 0.009367 & 0.005525 & 0.001404 & 0.003678 & 0.006461 \end{pmatrix}$$

$$\rho_{i.} = \sum_{j=1}^{n} \rho_{ij} = (0.048598, 0.000020, 0.023277)$$

$$\rho_{.j} = \sum_{i=1}^{m} \rho_{ij} = (0.004750, 0.008390, 0.008692, 0.002077, 0.0110845, 0.002765, 0.008707, 0.002537)'$$

Then there are

$$\tilde{G} = \tilde{P} \cdot \Delta\tilde{Y}$$

$$= \tilde{P} \begin{pmatrix} 279610300 & & & & & & \cdots & 0 \\ & 92192400 & & & & & & \\ & & 74650300 & & & & & \\ \vdots & & & 49249700 & & & & \vdots \\ & & & & 229713800 & & & \\ & & & & & 104448000 & & \\ & & & & & & 57596000 & \\ 0 & & \cdots & & & & & 82643600 \end{pmatrix}$$

$$= \begin{pmatrix} 897498 & 589122 & 519120 & 56109 & 1276758 & 141840 & 292761 & 1562319 \\ 126 & 0 & 261 & 0 & 261 & 423 & 360 & 459 \\ 430632 & 184212 & 129447 & 46134 & 1269252 & 146610 & 211851 & 533952 \end{pmatrix}$$

So the forecast model is

$$\begin{pmatrix} \hat{g}_{.1}^{(t)} \\ \hat{g}_{.2}^{(t)} \\ \vdots \\ \hat{g}_{.n}^{(t)} \end{pmatrix} = (1-\eta)^t \begin{pmatrix} 0.004750 & & & \cdots & & & & 0 \\ & 0.008390 & & & & & & \\ & & 0.008692 & & & & & \\ \vdots & & & 0.002077 & & & & \vdots \\ & & & & 0.011085 & & & \\ & & & & & 0.002765 & & \\ & & & & & & 0.008707 & \\ 0 & & & \cdots & & & & 0.002537 \end{pmatrix} \begin{pmatrix} \Delta y_1^{(t)} \\ \Delta y_2^{(t)} \\ \Delta y_3^{(t)} \\ \Delta y_4^{(t)} \\ \Delta y_5^{(t)} \\ \Delta y_6^{(t)} \\ \Delta y_7^{(t)} \\ \Delta y_8^{(t)} \end{pmatrix}$$

Assume that 3 years later, the gross value-output of these 8 industries are respectively 28000, 9300, 7500, 5100, 23000, 11000, 5800, 8300 one hundred million yuan, if order the $\eta = 0.011$

$$= (1-0.011)^3 \begin{pmatrix} 133 \\ 78.03 \\ 65.19 \\ 10.59 \\ 271.52 \\ 30.42 \\ 50.50 \\ 21.06 \end{pmatrix} = \begin{pmatrix} 128.65 \\ 75.48 \\ 63.06 \\ 10.24 \\ 262.64 \\ 29.43 \\ 48.85 \\ 20.73 \end{pmatrix}$$

The data above comes from *China Yearbook of Energy statistics in 2010*. The motivation of the practical case used is to demonstrate the feasibility of the methodologies for measuring the environments and resources in the activities of industrial production. The process and results shows that it is successful.

5. **Conclusions and Further Study.** This paper has explored the design of accounts of matrices to measure the inflow and the stock of environments and resources, and construct the model to measure the optimal consumption of environments and resources, and the optimal drain of pollutants and wastes in the industrial production. The factual proof shows that the achievement is feasible and pregnant.

Compared with other similar existing results in the international and domestic fields, the biggest advantages and innovations of this paper with the methodologies for comprehensively describing and analyzing environment and natural resources in a population and the processing or activities of industrial production, and supply of the techniques to achieve the integrated analyzing of static and dynamic in one model. This is our biggest contribution and innovation since great early researches are all unilateral functions, even in SNA and SEEA.

As for the further direction, the study should be focused on the methodology to describe and analyze environments and natural resources based on the available data, and draw econometric models and methods into the accounting fields.

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