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天然資源、エネルギー、経済、環境の結合モデルの設計と分析

―投入・産出分析―

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概　要

投入産出法による線形モデルを使って、天然資源、エネルギー、経済、環境保全の関連をモデル化することと、連関表の解析を行う手法について述べる。紹介する内容は７つである。

１．モデル作成に必要な基本的なアイデアと方法の紹介

ここでは人間の経済活動が、天然資源や環境との間に負のフィードバック関係があることと、人間の資源や環境の修復活動モデル。

２．追加機会コストという新概念の導入

製造コストと人間の活動のプロセスを加味したコストの導入の考え方。

３．新しい投入産出表の設計

通常の産業連関表に資源の修復と公害防止のための支出の欄、および資源の消費や公害物質の排出についての項目を追加した表の設計。

４．モデルの設計

連関表を計算するための数式についての考察。

５．中国における応用例

1992 年の産業連関表を使って、CO_2 や SO_2 などの排出と除去の費用などを評価。

６．応用の考え方

グリーンＧＤＰや価格変化を取り入れた中国の例を具体的な数値で表現し、対応シナリオを 2020 年のＧＤＰをベースにして４ケース考え、その結果を紹介。

７．結論と今後の課題

以下、英文資料を添付する。

Linkage Model Design & Analysis
for
Natural Resources-Energy-Economy-Environmental

—— Input-output Analysis

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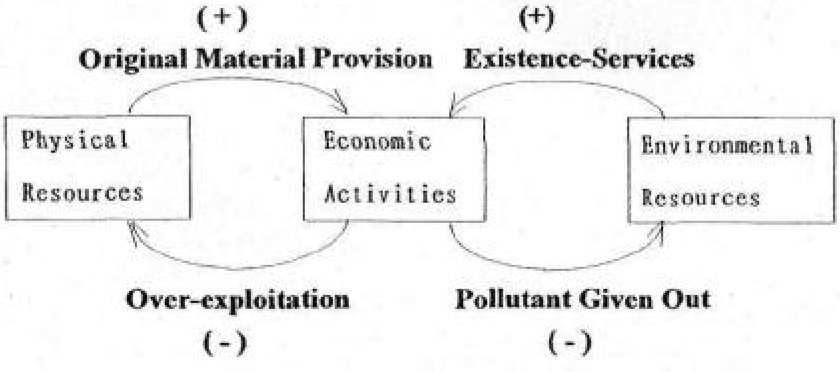
1 Basic Analysis

1.1 Negative Feedback System

Negative feedback system between human economy activities and natural resource and environmental



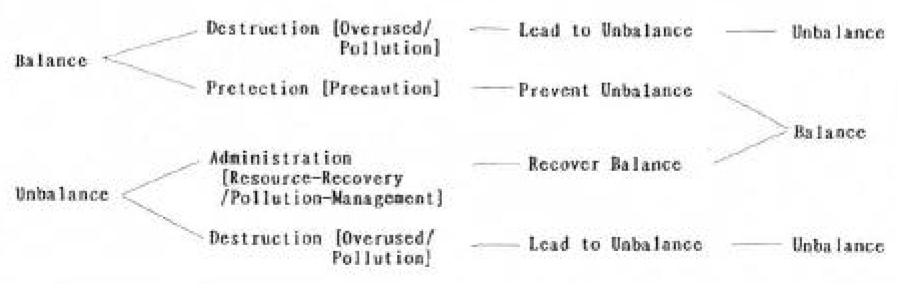
The cost of any kind of human economy activities not only contains the consumption of all production factors (labor, capital etc.), but also the cost resulted from external diseconomy caused by human activities

1.2 Human Action on Protecting Environmental

1) Resource Recovery/Resource Reproduction, aim at keeping natural resource (physical) renewed and accumulated sustainablly by recovering resources exhausted (reproduction) (e.g., widely investigation and exploration of mineral, land amelioration, recovery of cultivated land, forest breeding, grass breeding, grows seedlings for aquatic product, investigation and exploration of the sea, etc.)

2) Environmental Protection/Pollution Disposing, aim at maintaining the environmental service quality with high efficiency by eliminating pollutant

Conditions of Resource/Environmental	Human Being's Activities Relating to Resource/Environmental	Effect on Resource/Environmental	Conditions of Resource/Environmental



2 Marginal Opportunity Cost (MOC)

Marginal opportunity cost refers to the costs not only the production cost but all costs formed in the process of human activities

MOC=MPC+MEC+MUC

3 Input-Output Table Design

Output / Input	Resources Recovery Dept.	Primary Energy Dept.	Second Energy Dept.	Other Prod. Dept.	Pollution Abatement Dept.	Final Prod.	Total Output
Resource Used	u^{e}_{ij}	u^{p1}_{ij}	u^{p2}_{ij}	u^{p3}_{ij}	u^{w}_{ij}	Y^{e}_{i}	X^{e}_{i}
Primary Energy Products	q^{e1}_{ij}	q^{p11}_{ij}	q^{p12}_{ij}	q^{p13}_{ij}	q^{w1}_{ij}	Y^{p1}_{i}	X^{p1}_{i}
Second Energy Products	q^{e2}_{ij}	q^{p21}_{ij}	q^{p22}_{ij}	q^{p23}_{ij}	q^{w2}_{ij}	Y^{p2}_{i}	X^{p2}_{i}
Others Products.	q^{e3}_{ij}	q^{p31}_{ij}	q^{p32}_{ij}	q^{p23}_{ij}	q^{w3}_{ij}	Y^{p3}_{i}	X^{p3}_{i}
Pollution Emitted	e^{e}_{ij}	e^{p1}_{ij}	e^{p2}_{ij}	e^{p3}_{ij}	e^{w}_{ij}	Y^{w}_{i}	X^{w}_{i}
Value-added	N^{e}_{j}	N^{p1}_{j}	N^{p2}_{j}	N^{p3}_{j}	N^{w}_{j}		
Total Input	Z^{e}_{j}	Z^{p1}_{j}	Z^{p2}_{j}	Z^{p3}_{j}	Z^{w}_{j}		

(where u^e_{ij} -- the amount of resource i consumed by resource recovering department j; q^{ek}_{ij} -- the amount of products of k'th (k= primary energy products, second energy products, and the others products) production-department i consumed by resource recovering department j; e^e_{ij} -- the amount of pollution i emitted by resource recovering department j; N^e_j--the value-added (labor wage, net social income, etc.) created by recovering department j (including the depreciation in fixed assets); Y^e_i -- the amount of consumption of resource i in final products; X^e_i -- the total amount of consumption of resource i; Z^e_j -- the total amount of resource j recoveried; u^{pk}_{ij} -- the amount of resource i consumed by k'th (k= primary energy products, second energy products, and the others products) production-department j to produce corresponding k'th product; q^{pkl}_{ij} -- the amount of products of k'th (k= primary energy products, second energy products, and the others products) production-department i consumed by k'th (k= primary energy products, second energy products, and the others products) production-department j; e^{pk}_{ij} -- the amount of pollution i emitted by k'th (k= primary energy products, second energy products, and the others products) production-department j to produce corresponding k'th product; N^{pk}_j -- the value-added created by k'th (k= primary energy products, second energy products, and the others products) production-department i; Y^{pk}_i -- the final product of k'th (k= primary energy products, second energy products, and the others products) production-department i; X^{pk}_i -- the total product of k'th (k= primary energy products, second energy products, and the others products) production-department i; Z^{pk}_j -- the total consumption by production-department j, equals to X^{pk}_j in values; u^w_{ij} -- the amount of resource i consumed by pollution abatement department j; q^{wk}_{ij} -- the amount of products of k'th (k= primary energy products, second energy products, and the others products) production-department i consumed by pollution abatement department j; e^w_{ij} -- the amount of pollution i emitted by pollution abatement department j; N^w_j -- the value-added created by pollution abatement department j; Y^w_i -- the amount of emission of pollutant i in the final products; X^w_i -- the total emission of pollutant i; Z^w_j -- the total amount of pollutant j eliminated)

4 Input-Output Model

4.1 Physical Model

$$G^e \underline{\alpha}\, X^e + G^{p1} X^{p1} + G^{p2}X^{p2} + G^{p3}X^{p3} + G^w \underline{\beta} X^w + Y^e = X^e$$

$$A^{e1}\underline{\alpha}X^{e1} + A^{p11}X^{p11} + A^{p12}X^{p12} + A^{p13}X^{p13} + A^{w1}\underline{\beta}X^{w1} + Y^{p1} = X^{p1}$$

$$A^{e2}\underline{\alpha}X^{e2} + A^{p21}X^{p21} + A^{p22}X^{p22} + A^{p23}X^{p23} + A^{w2}\underline{\beta}X^{w2} + Y^{p2} = X^{p2}$$

$$A^{e3}\underline{\alpha}X^{e3} + A^{p31}X^{p31} + A^{p32}X^{p32} + A^{p33}X^{p33} + A^{w3}\underline{\beta}X^{w3} + Y^{p3} = X^{p3}$$

$$F^e \underline{\alpha}\, X^e + F^{p1} X^{p1} + F^{p2} X^{p2} + F^{p3} X^{p3} + F^w \underline{\beta}\, X^w + Y^w = X^w$$

where, $G^{*} = (g^{*}_{ij})^{T}$, $A^{*} = (a^{*}_{ij})^{T}$, $F^{*} = (f^{*}_{ij})^{T}$, $X^{e} = \underline{\alpha}^{-1} Z^{e}$, $X^{w} = \underline{\beta}^{-1} Z^{w}$, $Z^{p} = X^{p}$, $Z^{*} = (Z^{*}_{1}, Z^{*}_{2}, \ldots, Z^{*}_{k})^{T}$, $Y^{*} = (Y^{*}_{1}, Y^{*}_{2}, \ldots, Y^{*}_{k})^{T}$, $X^{*} = (X^{*}_{1}, X^{*}_{2}, \ldots, X^{*}_{k})^{T}$ (for * as e, p**(**= primary energy products, second energy products, and the others products), w, k = L, N, M, and " T" indicates transferred matrix), $\underline{\alpha} = \mathrm{diag}(\alpha_1, \alpha_2, \ldots, \alpha_L)$, $\underline{\beta} = \mathrm{diag}(\beta_1, \beta_2, \ldots, \beta_N)$, $g^{e}_{ij} = U^{e}_{ij} / Z^{e}_{j}$, $g^{p}_{ij} = U^{p}_{ij} / Z^{p}_{j}$, $g^{w}_{ij} = U^{w}_{ij} / Z^{w}_{j}$, $a^{e}_{ij} = q^{e}_{ij} / Z^{e}_{j}$, $a^{p}_{ij} = q^{p}_{ij} / Z^{p}_{j}$, $a^{w}_{ij} = q^{w}_{ij} / Z^{w}_{j}$, $f^{e}_{ij} = c^{e}_{ij} / Z^{e}_{j}$, $f^{p}_{ij} = e^{p}_{ij} / Z^{p}_{j}$, $f^{w}_{ij} = e^{w}_{ij} / Z^{w}_{j}$, $\alpha_i = Z^{e}_{i} / X^{e}_{i}$, $\beta_i = Z^{w}_{i} / X^{w}_{i}$.

4.2 Value-Model

$$P^{e} = G^{e} P^{e} + A^{e1} P^{p1} + A^{e2} P^{p2} + A^{e3} P^{p3} + F^{e} P^{w} + B^{e}$$

$$P^{p1} = G^{p1} P^{e} + A^{p11} P^{p1} + A^{p12} P^{p2} + A^{p13} P^{p3} + F^{p1} P^{w} + B^{p1}$$

$$P^{p2} = G^{p2} P^{e} + A^{p21} P^{p1} + A^{p22} P^{p2} + A^{p23} P^{p3} + F^{p2} P^{w} + B^{p2}$$

$$P^{p3} = G^{p3} P^{e} + A^{p31} P^{p1} + A^{p32} P^{p2} + A^{p33} P^{p3} + F^{p3} P^{w} + B^{p3}$$

$$P^{w} = G^{w} P^{e} + A^{w1} P^{p1} + A^{w2} P^{p3} + A^{w3} P^{p3} + F^{w} P^{w} + B^{w}$$

where $P^{*} = (p^{*}_{1}, p^{*}_{2}, \ldots, p^{*}_{k})^{T}$, $B^{*} = (b^{*}_{1}, b^{*}_{2}, \ldots, b^{*}_{k})^{T}$(for * as e, p**(**= primary energy products second energy products, and the others products), w, and k = L, N, M), $b^{e}_{j} = N^{e}_{j} / Z^{e}_{j}$, $b^{p}_{j} = N^{p}_{j} / Z^{p}_{j} = N^{p}_{j} / X^{p}_{j}$, $b^{w}_{j} = N^{w}_{j} / Z^{w}_{j}$, P^{e}_{i} be the resource tax imposed on for using per unit resource i (here refers to the recovering cost of per unit resource i); P^{p}_{i} be the price of product i; P^{w}_{i} be the emissive cost imposed on for emitting pollutant i (here refers to the cost consumed by managing per unit pollutant i)

5 Chinese Input-Output Table (92)

Based on Chinese 1992 Input-Output Table and Chinese Statistics Year Book(1993), we set up one concrete Energy-Economy-Environmental Input-Output Table (Appendix Basic Input-Output Table), in light of the above theoretical Energy-Economy-Environmental Input-Output Table .In this new I-O table, there are

i) three kinds of natural resources, that is, Coal, Petroleum and Natural gas (Units: 10000 ton);

ii) five energy production sectors, that is, Coal mining and processing, Petroleum and natural gas extraction, Power generation 、 steam and hot water production and supply, Petroleum processing, Coking 、 gas and coal-related products (Units: million tons of oil equivalent);

iii) thirteen non-energy production sectors, that is, Farming 、 forestry 、 animal husbandry 、 fishery and water conservancy, Food 、 beverage and tobacco, Textiles, Paper-making and paper products, Chemicals and allied products, Building materials and other, Smelting and pressing of metals, Machine building 、 electric and electronic equipment, The others manufacturing, Construction, Transportation 、 post and telecommunications services, Commerce 、 food services 、 materials supply and marketing and storage, Nonmaterial (the others services) production sectors (Units: 10000 RMB ￥);

iv) two kinds of pollution, that is, SO_2, CO_2 (Units: 10000 ton);

are included, but the natural resources recovery sectors and the pollution abatement sectors are not considered because of lacking of the relevant data.

6. Application Analysis

6.1 Green GDP

(unit： 10000RMB Yuan)

	Gross Prod.	Green G. P.	Change%	GDP	Green GDP	Change%
1	684639769	683153536.4	-0.2171	2.66E+08	264956600.4	-0.55781
2	684639769	684062884.3	-0.0843	2.66E+08	265865948.3	-0.21651

1. There are 0.21% over-evaluated in Gross Product and 0.558% over-evaluated in GDP in light of the above first assumption, in other words, there are 0.21% of Chinese Gross Product and 0.558% of Chinese GDP were produced by destroying the equivalent amount of natural resources and environmental

2. There are 0.084% and 0.217% over-evaluated in Gross Product and GDP respectively, or in other words, there are 0.084% of Chinese Gross Product and 0.217% of Chinese GDP were produced by destroying the equivalent amount of natural resources and environmental in 1992

6.2 Price Change

	Agri.	Mining	Other Indu	Constru.	Transp.	Commer.	Other Serv.
%	0.30657	26.14955	1.23398458	0.798655	0.70712	0.5331	0.55041503

1. The theoretical production price of agriculture, coal mining and processing, others industry, construction, transportation, commercial and the others services will be increase 0.31%,26.15%,1.23%,0.80%,0.71%,0.53% and 0.55% in 1992 respectively by taking into the compensation fee of coal resource used and the tax of SO2 emission under the above first assumption.

	Agri.	Mining	Other Indu	Constru.	Transp.	Commer.	Other Serv.
%	0.069829	3.360554	0.27765635	0.17905	0.15223	0.11608	0.118338112

2. The theoretical production price of agriculture, coal mining and processing, others industry, construction, transportation, commercial and the others services will be increase 0.07%,3.36%,0.27%,0.18%,0.15%,0.12% and 0.12% in 1992 respectively by taking into the compensation fee of coal resource used and the tax of SO2 emission under the above second assumption

6.3 Scenarios Analysis

1) Basic Scenario

i) In 2020, gross production of coal in China is about 2323.52 million ton but the total used of coal in the production process will be about 7122.4 million ton ;

ii) Till 2020, total energy consumption will be 9209.566 million TOE, in which coal will be million TOE, petroleum & natural gas will be 1002.565 million TOE, power will be 47.8574 million TOE, petroleum refinery products will be 486.2151 million TOE, coke will be 399.419 million TOE.

iii) The structure of total energy consumption are changed with the proportion of coal against total energy consumption is changed from 1992's 0.688403 to 2020's 0.663072, power's changes from 0.007696 to 0.008329, petroleum refinery products' from 0.07829 to 0.084615. Meanwhile, The structure of energy final consumption are also changed, in which the proportion of coal against total energy final consumption is changed greatly from 1992's 0.965027 to 2020's 0.921428, power's changes from 0.007696 to 0.008329, natural gas and petroleum refinery products' change greatly too, from 0.000261 to 0.002237, 0.015733 to 0.032188, respectively.

iv) Total SO_2 and CO_2 emission will be 210.68 million tons, 422.172 million tons, respectively in 2020, and per GDP SO_2 and CO_2 emission will be decrease from 1992's 6.93 (tons/100000US$) and 136.4 (tons/100000US$) to 2020's 6.08 (tons/100000US$) and 121.9 (tons/100000US$).

2) Scenario I

Chinese coal resources used accompany with coal exploitation will be decrease about 2480.33 million ton, decrease 34.8%, comparing with the Basic Scenario's keeping the 1992's the coal re-exploitation rate unchangeable in 2020

3) Scenario II

Total coal consumption of China will be decrease 1.0644% in 2020, and SO_2, CO_2 emission will decrease 1.0644% and 1.016% in 2020,respectively, comparing with the Basic Scenario's keeping the 1992's final demand structure of non-energy sectors unchangeable in 2020

4) Scenario III

Total SO_2, CO_2 emission will decrease 3.6878% and 3.1096% in 2020, respectively, comparing with the Basic Scenario's keeping the 1992's energy consumption structure in Power Generation unchangeable in 2020

5) Scenario IV

Total coal consumption of China will be decrease 4.714% in 2020, and SO_2, CO_2 emission will decrease 4.714% and 4.09% in 2020,respectively, comparing with the Basic Scenario's keeping the 1992's final demand structure of non-energy sectors unchangeable and the 1992's energy consumption structure in Power Generation unchangeable in 2020

7. Conclusion & Suggestion

1) The low coal re-exploitation rate in China is one key factor which results in the low efficiency and high waste in Chinese current subsoil energy resources e.p. coal exploitation process.
2) It's the necessary way to protect Chinese natural resources by promoting the re-exploitation rate of subsoil energy resources e.p. coal and reducing the waste in the resources exploitation process.
3) Coal used, especially, coal used in power generation is main cause of SO_2 and CO_2 emitted in today's and future's China.
4) Change the energy consumption structure in power generation, by means of raise the efficiency of energy transformation, increasing hydropower and nuclear power and decreasing firepower, is an effective way to reduce SO_2 and CO_2 emission.
5) Changing the final demand structure, by decreasing the proportion of Chemicals and allied products and increasing the proportion of the third industrial products and services in final demands, is also an effective way to reduce SO_2 and CO_2 emission.