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An extended input–output table for environmental and resources accounting

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Environmentally Extended Input–Output (EEIO) tables have become a powerful element in supporting information-based environmental and economic policies. National- and provincial-level IO tables are currently published by the National Bureau of Statistics of the People's Republic of China according to well-defined conventions. However, county-level IO tables are not provided as a rule by official statistics organizations. This paper conducts an overview of compiling EEIO tables for environmental and resources accounting at the county level and then answers several questions: First, what kind of data should be prepared for the compilation of county-level EEIO tables? Second, how can we set up comprehensive EEIO tables at the county level? Third, regarding the survey methods and the indirect modeling, which one should be chosen to build EEIO tables at the county level? Finally, what policy questions could such a table answer? EEIO tables at the county level can be used to predict the economic impacts of environmental policies and to perform trend and scenario analysis.

Keywords: county-level input–output table; accounting; influence coefficients

1. Introduction

The Input–Output (IO) table measures the total input and output of national production in principle, which can provide a comprehensive overview of the national economy. The development of IO tables has greatly facilitated economic analysis, providing planners and policy-makers with more detailed information on economic structures towards a more effective and specific development plan and program for economic transformation. On the one hand, economic accounting measures economic performance on the basis of market transactions; on the other hand, economic performance benefits considerably from the services provided by the natural environment, which are not transacted in markets and consequently are not captured by the gross domestic product (GDP) or other conventional indicators (Peskin & Angeles 2001). In addition, some researches indicate that the unbalanced development of regional economies has become a very serious problem in China (Fan & Zheng 2003; Zhang & Zhao 2006). How to improve the economic conditions of the undeveloped regions has aroused much concern among both policy-makers and scholars. The single IO table ignores the interdependence among regions and cannot reflect the interregional spillovers and feedback effects. Therefore it is necessary to build the extended IO table for environmental and resource accounting at the county level so as to expose interregional differences for small-scale researches (Isard 1951; Leontief & Strout 1963; Giesecke 2002). More specifically, the IO table should answer two questions: First, what is the output of the economy – its size, its composition, or its use? Second, what is the economic process or mechanism through which the output is produced and distributed?

The theoretical development of input–output analysis took place from the 1930s to the 1950s, with Wassily Leontief playing a key role, having first developed the IO framework (Leontief 1951). Then the EEIO table was developed (Leontief 1970). In addition, the international standardization of monetary IO analysis was started in the OECD (Stone 1961), followed by the UN (UNSD 2005). In brief, the monetary IO tables can give insights into the value of economic transactions between different sectors in an economy entity, including output for exports, capital formation and final government and private consumption. Besides, monetary IO tables can be used to calculate the added value in each sector that contributes to the final output, and further such IO tables can be extended with environment- and resources-related information for each sector. For example, Leontief added a row vector of pollution to represent the quantity of pollution discharged by each economic sector. And the delivery of pollution to the final demand is the level of pollutants that households are willing to accept. In order to balance the table, Leontief added an "anti-pollution" column which accounts for the total eliminated emissions from pollution abatement industries. These environmental externalities may be well

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expressed in monetary terms. Standardization of environmental extensions has taken place in the UN. EEIO tables and models have become a powerful element in assisting the formulation of information-based environmental and economic policies (Xia et al. 2010). What's more, such EEIO tables can be integrated in broader models such as computable general equilibrium (CGE) models.

Compilation of county-level EEIO tables using non-survey methods has become the most common approach (Zhong et al. 1993; Jackson & Murray 2004; Hou 2006). It is neither possible nor desirable to produce a table every year since the compilation of IO tables requires considerable manpower, resources and time. For example, compilation of county-level EEIO tables started in the early 1980s in China (Luan 1985), but the process was then interrupted. As a result, the compilation of EEIO tables remains ongoing at the national, provincial and municipal levels in China. Lack of historical and large-scale data have proven a major hindrance to the compilation and application of county-level EEIO tables and SAM and CGE models.

This paper aims to answer the following questions. First, what kind of data should be prepared for the compilation of county-level EEIO tables? Second, how can we set up a comprehensive EEIO table at the county level? Third, in order to build EEIO tables at the county level, which method should be chosen from among the survey methods and indirect modeling for the data sources? Finally, what policy questions could such a table answer?

2. Procedures for the compilation of EEIO tables

Current IO tables are generally compiled at the national, provincial and municipal levels, but are scarcely compiled at the county level. With county-level economy developing rapidly, it has been increasingly recognized that the county-level IO table is an important data source for the analysis of regional economic performance. Currently, researchers who have to compile county-level IO tables by themselves must collect the statistical data and select the enterprises for investigation at different scales according to the national standard. This work generally follows the rules formulated for national economic account by the national accounting institution.

Complication of EEIO tables begins with requesting data in accordance with a harmonious industry structure based on the International Standard Industrial Classification of all Economic Activities. The statistical basis of monetary EEIO tables is transactions between sectors, which are recorded by sales and purchases, incomes and expenditures. These sectors have no reason to classify by themselves or to specify their transactions in terms of the standard industrial classification. In order to compile standardized EEIO tables, a classification has to be carried out that groups these sectors into specific classifications such as sector and product classifications. It is necessary to apply standardized classification in the complication of EEIO tables at different scales such as national, provincial, municipality and county. Then, the structure of production of each sector must be clarified. This process should also be carried out with the income and expenditure flows of specific savings, investments and expenditure on the final consumption, and imports and exports of commodities. In practice, a tiered procedure is used in which the specific data are added and updated based on surveys and coordinated by the relevant governmental institution (Table 1). Environmental effects originating from activities rather than transactions can thus be reflected. The consumption of natural resources occurs in the production process, which can also be embedded.

Generally speaking, apart from the accounting of environmental permit requirements and resource consumption, we have no systematic book-keeping as a basis for the compilation of EEIO tables at county level. Location measurement, survey methods and indirect modeling can be used to integrate the sources here for producing environmental accounts. Environmental and natural resources make a huge contribution to long-term economic

Table 1. Basic data and components of an EEIO table.

Categories	Supply table	Export table	Use table	Import table
Economic data: flows of products, (products in monetary terms)	Output by product and by sector	Products by exporting sectors (Intermediate)	Consumption by product and by sector	Products by importing sectors
Idem but additionally (kg, numbers)	Products specified in physical units	Products specified in physical units	Products specified in physical units	Products specified in physical units
Natural resource consumption data	The resource consumption by sector	Outflow by compound	Consumption by product and by sector	Natural resource per product
Environmental data: emissions and extractions (flows of compounds)	Emission by compound and by sector	Outflow by compound	Extraction or reabsorption by compound and by sector	Inflow by compound
Materials and substance flows (possibly also energy)	Materials/substances per product	Materials/substances per product	Materials/substances per product	Materials/substances per product

performance no matter whether they enter the marketplace directly or not. Therefore they should be considered as economic assets.

The EEIO table at county level can also be compiled based on the "top-down" municipal table estimation, besides the "down-top" survey method mentioned above. The municipal EEIO table is imperative for "top-down" decomposition. Data on interregional transaction are also helpful in the decomposition (Leontief 1953). Moreover, we can calculate certain information according to models such as the gravity and gray models, and these methods require fewer data than the survey method. The direct consumption coefficient matrix is the most important component of the EEIO tables. The gray GM (1, 1) model can be used as a prediction tool to compile the direct consumption coefficient matrix. Some researches have shown that the prediction error may be less if the high cost and lag issues of building the EEIO table were to be solved. This will provide a platform for advanced research such as the adjustment of industrial structure and the theory of economic development. Besides the input- or output-oriented indicators, various indicators are applicable to analyze the effect of adjustment and economic development (i.e., consumption indicators, balance or trade indicators and efficiency indicators). For example, efficiency indictors are relevant to economic performance and are also related to material losses from the environment.

3. Steps in the compilation of IO tables

Measuring production in an economy system is essential to the calculation of GDP. Vast amounts of information are needed to clarify the process through which the input of labor, capital, goods and services produces the output of goods and services. Statisticians and economists organize the relevant information under a statistical and analytical framework termed the supply, use and IO tables. In the compilation of EEIO tables, the data for inputs are usually acquired from industries in which these were used rather than the products for which the inputs were used. An industry is a collection of establishments that share a common principal product. However, besides the principal product, a number of secondary products may be produced in the process. Products must come within the standard industries classification, so the inputs are designated by what the products were rather than which industry produced them. Similarly, the data of final demands such as exports and personal consumption expenditures are acquired from products exported or consumed rather than the industries that produced them. Therefore, the input–output matrices usually appear in two parts. The first part, called the Use matrix, has products in its rows and industries in its columns of entries to show the use of each product (in the rows) in each industry (in the columns). The second, called the Make matrix, has industries in the rows and products in the columns of entries to show how much of each product was made in each industry.

The process of compiling an EEIO table depends on the rudimentary structure (Figure 1). The typical process of transformation is as follows:

- Supply and use tables at purchase prices. Convert the use table to basic prices. Using available supplementary information (e.g., finance ministry sources for tax rates, such as value added tax, VAT) or standard assumptions, we remove taxes and subsidies from products included in the intermediate consumption and final demand and re-allocate these to a separate row. Again, using available supplementary information, or standard assumptions, we remove the trade margins (transport and distribution) from the intermediate consumption and final demand cells and re-allocate these to the appropriate industry. Typically these standard assumptions assume that all consumers pay or receive the same rates of taxes or subsidies and pay the same rates of distribution margins, and these assumptions can be refined, according to the available information. For example, if the tax column in the Supply matrix shows different taxes separately, it is possible to ensure that VAT is only removed from those consumers that have paid VAT. Similarly it is possible to ensure that all, or most of the retail margins (as opposed to wholesale) are removed from the Household Final Consumption (HHFC) column.
- Supply and use tables at basic prices. Convert the use table to the domestic use table and import use table, using either a straightforward proportionality assumption or information on import use structures from earlier years (using the proportionality assumption if these were not derived from themselves), which is constrained to total of the latest year using either Rivest-Shamir-Adleman (RSA) techniques or the information provided by commodity-by-commodity import tables.
- Supply and domestic use tables at basic prices. Convert the supply and domestic use tables to the symmetric industry-by-industry tables using the "fixed product sales structures".
- Symmetric industry-by-industry tables (domestic and total). Aggregate the industries shown using the national classification systems so as to standardize them to the required industry level. For many counties, it is necessary to keep a balance between input–output and supply–use.

EEIO tables can be compiled on the basis of the rudimentary IO table using the following steps. First, gather the basic data for the region. Second, combine basic data in

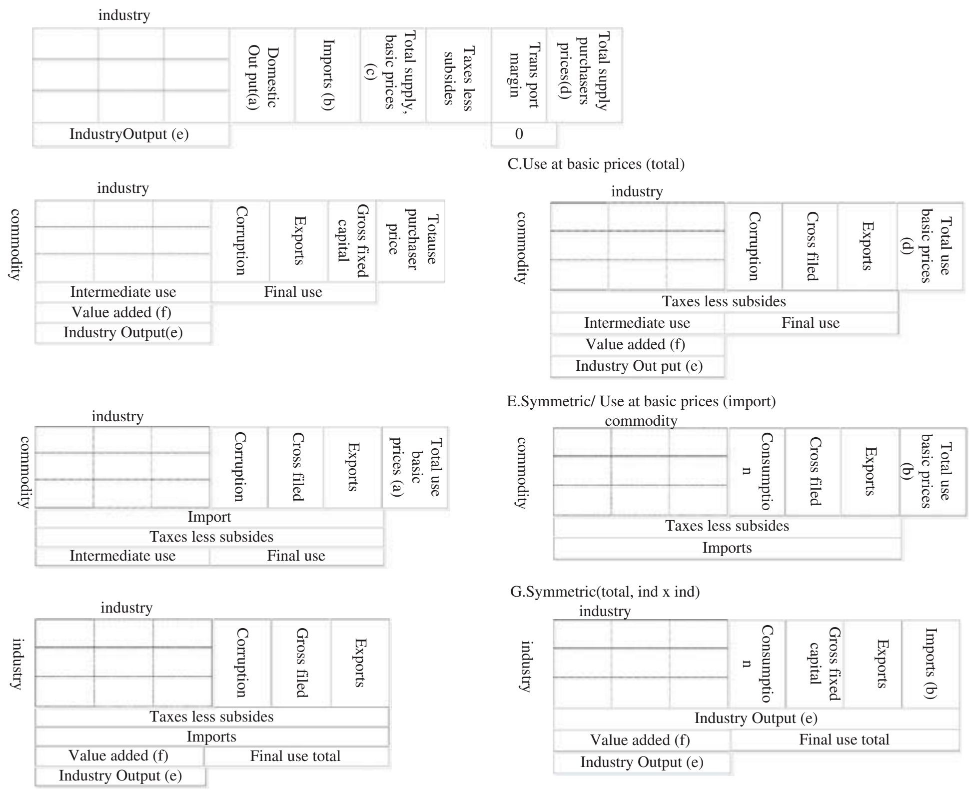

Figure 1. Rudimentary structure of IO tables.

accounts – the supply and use tables. The third step can be further divided into three procedures. To begin with, allocate multi-product sectors to the single-product sector in the supply table. Then, adjust the monetary use table to the sector structure of the allocated monetary supply table. Next, adjust environmental flows in the environmental supply and use the table according to the method from the previous procedure. In the fourth step, combine the allocated (symmetric) supply table and adjusted (symmetric) use table into the symmetric input–output tables with environmental extensions. In the fifth step, transform the allocated supply and adjusted use table into the material flow and substance flow tables. Finally, relate the regional table to other regions.

Environmental extensions have two basic forms, with one linking to the sectors (for emissions and resource extraction in EEIO tables) and the other linking to physical products (including installations and capital goods). First, relate monetary flows to physical product flows and next relate physically defined products to their composition in terms of materials (for Material Flow Accounting, MFA) and substances (Substance Flow Accounting, SFA), and the two main variants of physical input–output tables differ only in level of aggregation of the flows concerned. MFA is a method for physical accounting (Finnveden & Moberg 2005) that accounts for physical units of inputs and outputs (e.g., substances, raw materials, waste, and emissions to air and water which are involved in the production, processing, consumption and recycling of materials). It aims to build volume indicators to assess the environmental resource extraction (input side) or the emission of waste (output side). The GDP in the EEIO table is limited to deductions for natural resource depletion and environmental degradation. Although consistent with the economic literature on appropriate environmental and resource adjustment to GDP, the theories suggest that limiting the adjustments to natural resource depletion and environmental degradation does not go far enough.

4. Applications of EEIO tables

EEIO tables and CGE models based on EEIO tables are mainly applied in the support of environmental and other policy purposes (Hawdona & Pearson 1995; Zheng & Fan 1999). The following options for applications are described.

4.1. *Assessment of environmental crisis*

Assessment of environmental crisis involves analysis of the nature and causes of environmental problems, and is related to relevant policies for resource use and emissions. The most important application of EEIO tables is in life cycle environmental impact assessment. Traditional economic analysis rarely takes natural resources into account and thus water is seldom recognized as a factor of production. But in reality, water is a direct or indirect primary input to all goods and services. The available quantity and quality can affect the outputs of goods and services, and thus influence economic development, especially in those societies transforming from an agricultural-based economy to an industrialized and modern economy, such as China, where the water problem has been a critical issue for a variety of reasons.

China suffers from serious water scarcity, with an available amount per capita of 2300 m^3, which is less than 1/3 of the global average. Besides, water resources are unevenly distributed: WThose distributed on the North China Plain account for only about 20% of total water resources in China, yet support more than half of the country's population (Table 2). An appropriate and efficient water accounting method plays a vital role in assisting policy-making in economic and social development, and is of great importance in analyzing interdependences within the production system of an economy and identifying the main factors affecting water resource exhaustion and polluters of the aquatic ecosystem.

The traditional IO table is an $n \times n$ matrix, describing the flows of goods between economic sectors in monetary units. We extend the matrix to $(n + m) \times (n + m)$ by adding the water sectors in physical units. The hydro-economic water accounting framework is further developed based on the economic-ecological model so as to represent the interrelationship between economic activities and hydrological processes using the EEIO table (Table 3).

Matrix A ($n \times n$) represents the technical coefficients in the production sectors. Matrix F ($m \times n$) represents the primary water inputs (e.g., surface water, ground water and rainfall) into the production sectors. Matrix R ($n \times m$) quantifies the outputs of each economic sector to the water resources (e.g., pollution). Matrix B ($m \times m$) captures hydrological changes after production wastewater is discharged.

The coefficients of direct water consumption vary greatly among sectors in China. The Chinese Input–Output Association published the water resource consumption and water input coefficient of national economic sectors using the EEIO in 2002. According to this account, we find that the sectors of agriculture, electricity, steam and hot water production and supply and chemicals consumed most of the water resource, and their coefficients of direct water consumption varied greatly. For example, the total direct water consumption coefficient of the agricultural sector ranked highest, reaching 0.1307 m^3/Yuan while that of the instrumentation and cultural office machinery manufacturing industry was only 7×10^{-5} m^3/Yuan. The direct fresh water consumption coefficient of the agricultural sector also ranked highest, and that of instrumentation and cultural office machinery manufacturing the lowest, with the difference between the two sectors being over 4000-fold.

In regard to both water and fresh water, the direct water consumption coefficients of most sectors are relatively low. There are 21 sectors with a direct coefficient of total water less than 0.003 m^3/Yuan, accounting for more than 50% of the total number of sectors, while there are 28 sectors having a direct coefficient of fresh water of less than 0.003 m^3/Yuan, accounting for more than 75% of total number of sectors. Besides, the total water input coefficients also vary greatly among various sectors, but

Table 2. Availability of water resources in China.

Region	Total fresh water resource (10^8 m^3)	Population in 2000 (×1000)	Per capita water (m^3)
North	843.5	311,100	271.1
Northeast	1529	106,334	1437.9
East	1926.2	198,149	972.1
Central	2761.2	167,256	1650.9
South	5190.8	129,942	3994.7
Southwest	6389.8	243,414	2625.1
Northwest	2115.6	111,128	1903.8
China average			2271.0
Global average			6981.0

Table 3. Extended hydro-economy input–output table.

Units in "( )"		Activities intermediate demand	Final demand: Household & governments	Final demand: Exports	Total output	Hydrological system: Surface water	Hydrological system: Ground water	Hydrological system: Natural losses
Economic activities Primary inputs Imports		x_{ij} (RMB) s_{ij} (RMB)	y_{ij} (RMB) Matrix **A**	w_{ij} (RMB)	x_i(RMB)	h_{il} (m^3)	Matrix **R**	
Total inputs		x_j (RMB)				h_l (m^3)		
Water inputs	Surface water Ground water Rainfall	g_{kj} (m^3)	Matrix **F**		g_k (m^3)	d_{kl} (m^3)	Matrix **B**	

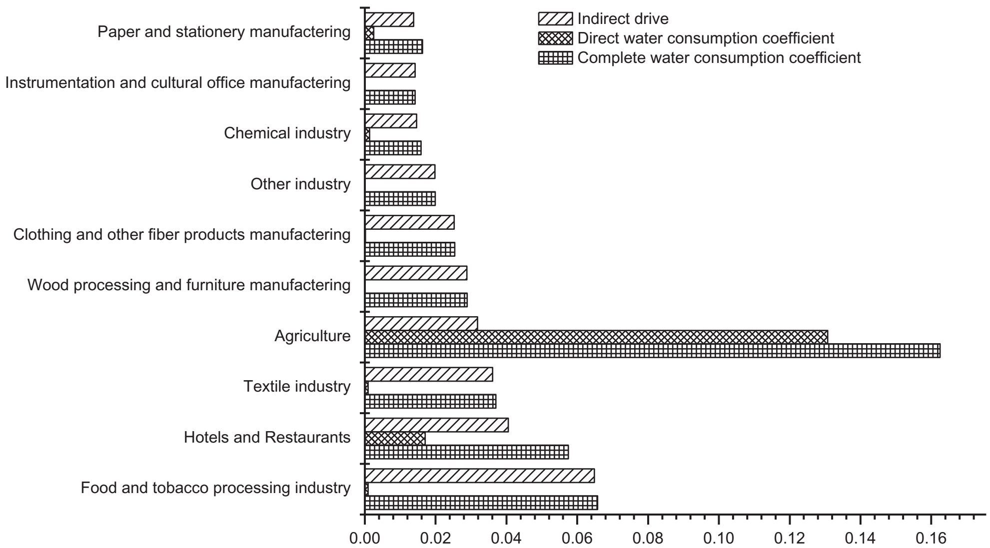

Figure 2. Water use coefficients of important sectors.

the gap is smaller than that of the direct water coefficient. In addition, the maximum value of the total water input coefficient for total water was 0.1659 m^3/Yuan, while the minimum was only 0.0066 m^3/Yuan, with a difference of up to 25-fold. What's more, the sectors of agriculture and instrumentation/real estate had the maximum and minimum fresh water input coefficients, respectively, with a difference of nearly 40-fold.

The discrepancy between the direct water consumption coefficient and total water consumption coefficient also varied greatly among sectors. Taking the difference between the direct and total coefficients of fresh water as an example, the total water input coefficient was 1.24-fold of the direct water input coefficient in the agricultural sector, and 1.19-fold for the electricity, heat production and supply industries. These differences are highly significant in the sectors of wood processing and furniture manufacture, instrumentation and cultural office machinery manufacture, clothing, shoes, feather and other fiber product manufacture and other industries, being 384-, 331-, 164- and 147-fold, respectively.

In the input–output analysis, backward sector linkage (also known as complete pulling power) is the unit of final demand arising from direct and indirect pulling power in all sectors. Direct pulling power is the sector's direct consumption of water resources in the production processes, while indirect pulling power is other sectors' consumption in order to meet the demand for water in the production processes. By calculating the direct and total water consumption coefficients in various sectors, we found that the former value in some sectors was low, leading to error in calculation of water consumption. The total water consumption coefficient is fairly high in these sectors, which is mainly due to the indirect pulling power from other sectors. For example, the high total water consumption coefficient for the food manufacturing and tobacco processing industry is mainly due to indirect pulling power. We calculated the coefficient of indirect stimulating factors, and listed the 10 sectors with the largest indirect pulling power (Figure 2).

4.2. *Evaluation of policy implementation*

The evaluation of policy implementation involves the extended prediction of the effects of policy measures and may include trend and scenario analysis. EEIO tables can be used to evaluate the effects caused by the implementation of public policies based on a set of parameters included therein. China is a large country with a rapidly growing economy, but regional imbalance in development is a significant problem. The ecological environment is very fragile in Western China, and at present China continues to implement western development policies such as industrial transfer and eco-compensation, which not only influences sustainable development but also increases the external cost of economic development in that region. We used EEIO tables to analyze environmental cost and pollution risk caused by industrial transfer in Qinghai Province.

This study suggests that the developmental pace of the agriculture, forestry, animal husbandry and fishery sectors in Qinghai Province was approximately equal to the national average level. However, the output value of the primary industry of Qinghai Province increased by 74.42% from 2002 to 2007, indicating that the local primary industry still developed very quickly compared with that in 2002 (Figure 3).

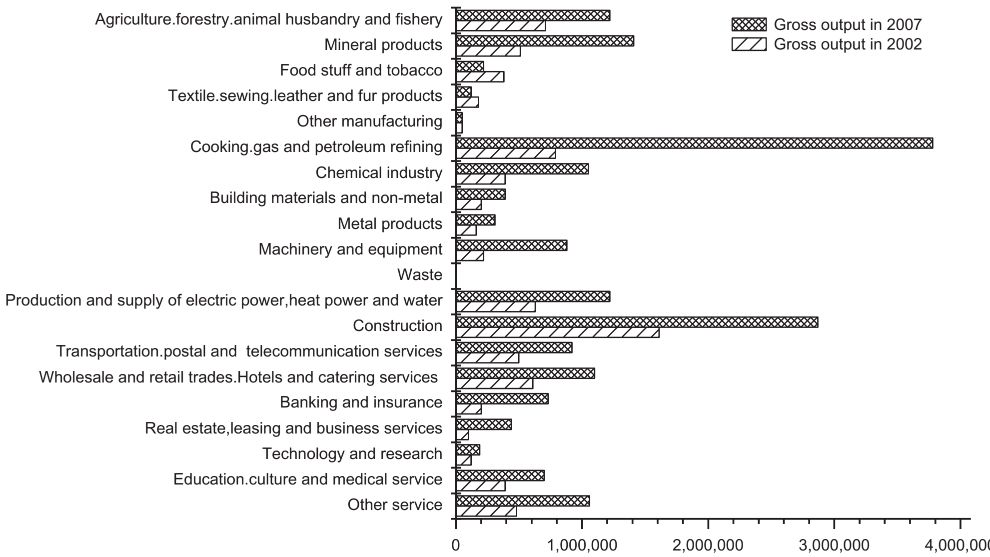

Figure 3. Gross output in 2002 and 2007 in Qinghai Province.

The percentages of the output values of most sectors in Qinghai Province that account for the national total output value of each sector increased, except in the coking, gas and petroleum refining, machinery and equipment and waste sectors. The national total output value of the foodstuffs and tobacco and construction sectors decreased most, by 0.116% and 0.114%, respectively. The development of these two sectors is closely related with the urbanization level and local living standards. The economic development of Qinghai Province was very slow, as was the urbanization level, which consequently led to much slower development than the national average. Besides, the percentages of the output value of the sectors of production and supply of electric power, heat power and water and metal products, which account for total national output value, also decreased by 0.086% and 0.061%, respectively. Both sectors are energy-intensive and heavily polluting, their transformed mode of production reduces the pollution to some degree. In addition, the percentages of the sectors of mineral products, textile, sewing, leather and fur products, building materials and non-metals also decreased to some degree. What's more, although there was some increase in the percentages of output value of the sectors of coking, gas and petroleum refining, machinery and equipment and waste, their growth rates were marginal at only 0.034%, 0.014% and 0.004%, respectively. On the whole, the percentages of output value of secondary industry in Qinghai Province that account for the national total output value in 2007 were lower than in 2002, indicating that the development of secondary industry in Qinghai Province was still relatively slow compared with other areas of China, although it had developed more rapidly than primary and tertiary industry.

The levels of waste water from 20 sectors in Qinghai Province were estimated on the basis of the statistical data of waste discharge and total output value of each sector in 2007. The total amount of pollutants discharged by each sector was further estimated on the basis of EEIO tables. The waste water discharged by the machinery and equipment sector increased greatly, by 402 million tons, due to the adjustment of industrial structure during the period 2002–2007 (Table 4). Waste water discharged by the sectors of real estate, leasing and business services and wholesale and retail trades, hotels and catering services increased by 96 and 46 million tons, respectively. Besides, there was a slight increase in the level of waste water discharged by the sectors of waste and coking, gas and petroleum refining.

Waste water discharged by the construction sector decreased by 1.8337 million tons, mainly due to the adjustment of industrial structure. Waste water discharged by the sectors of textiles sewing, leather and fur products and metal products decreased by 0.08316 and 0.03411 million tons, respectively, while there was only a slight decrease in waste water discharged by other sectors.

Qinghai Province is experiencing a period of rapid economic development, in parallel with the current speed of economic growth. The level of pollutant discharge will increase with economic growth, and consequently pollution consequent to economic growth will still be very serious. This, in a sense, highlights the necessity and urgency to optimize environmental and development strategy and encourage green development.

Table 4. Changes in pollutant discharge due to adjustment of industrial structure (units: 10,000 tons)

Sectors	Discharge of waste water
Agriculture, forestry, animal husbandry and fisheries	−194.5
Mineral products	−4027.9
Foodstuffs and tobacco	−126670.7
Textile, sewing, leather and fur products	−831559.8
Other manufacturing	−359
Coking, gas and petroleum refining	60.4
Chemical industry	−2381
Building materials and non-metal	−54173.6
Metal products	−341107.6
Machinery and equipment	40224.1
Waste	117.7
Production and supply of electric power, heat power and water	−1899.5
Construction	−1833658.7
Transportation, postal and telecommunication services	−32867.3
Banking and insurance	9590.4
Real estate, leasing and business services	0
Technology and research	22558.6
Education, culture and medical services	−6862.3
Other services	−2907.6

5. Conclusions

The county is an essential unit in the integration of urban and rural economies and fulfills a vital function in the Chinese society and economy. The county economy is an important component of the regional economy. Input–output models at the national or regional level are known as a fundamental tool for economic analysis, while county-level EEIO tables can be used to study interregional economic relationships and commodity flows. However, in order to use such models, researchers must have access to the corresponding input–output tables. National- and provincial-level tables are currently published by the national statistical offices according to well-defined conventions, but the situation is quite different in regard to EEIO tables at the county level, the conventions of which have not been provided by official statistics organizations. Since the data cannot be obtained directly, it is not easy to compile EEIO tables. And the most critical procedure during the entire process of compiling EEIO tables is to investigate interregional commodity flow. As a result, a key aspect of input–output research is still dedicated to the study of techniques in gathering data for input–output tables.

There are no records of survey-based interregional trade data in most counties. But in order to make the gravity model succeed in capturing spillover and feedback effects caused by interregional linkages, a minimum amount of data on interregional trade is still necessary even when some simplified assumptions are used in the model. With the county-level EEIO tables we have compiled we calculate various coefficients, including influence, sensitivity and commodity flow coefficients, which can reflect interregional linkages. EEIO tables at county level can predict the economic impacts of environmental policy measures and may develop the trends and scenario analysis of environmental planning.

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