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Socio-economic impacts of algae-derived biodiesel industrial development in China: An input–output analysis

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ABSTRACT

The economic and employment impacts of algae-derived biodiesel industrial development in China are analyzed based on an input–output (I–O) model in this work. The results show that the algae-derived biodiesel industry has a significant impact on promoting regional economic and employment growth. In China, due to the development of algae-derived biodiesel with an annual production of 0.2 million t, the economic growth can reach from 5.08 billion to 17.87 billion CNY, while employment growth can be from 39,200 to 104,000 jobs. However, because of the differences in the regional industrial structure, product distribution and marginal consumption propensity, the regional economic and employment impacts vary significantly in China. For example, the biggest economic and employment impacts of the algae-derived biodiesel industry are seen in Yunnan followed by Guangxi, Hubei and Henan, with the smallest being in Hunan. A sensitivity analysis shows that certain social-economic parameters, including the post-factory price of biodiesel, marginal consumption propensity, production scale and production taxes, are more sensitive to economic impact than others. Furthermore, certain technical parameters, including biomass productivity, lipid content, running time, lipid extraction rate and lipid conversion rate, have a susceptible impact on employment than others. To achieve the maximum socio-economic benefit of algae-derived biodiesel development, areas should be chosen that have a large potential and a high socio-economic impact multiplier, taking full account of the conditions relating to the regional climate, marginal land, and socio-economic factors.

1. Introduction

Microalga is a photosynthetic organism, which is widely presented in nature, and known for its high photosynthesis efficiency, short growth cycle, high biomass yield and appreciable lipid content when compared with terrestrial energy plants [14,15]. The microalgae-derived biofuel, which provides a link between energy production and wastewater purification with a carbon emission reduction, can improve the environment as well as provide high-value energy and other high-value products. As a result, there is a rising interest in algae-derived biofuel in both industrial and academic fields [6]. However, since a large amount of inputs, including electricity, nutrients, and chemical reagents, is involved in algae culture as algae-derived fuel becomes widely commercialized, it will undoubtedly have a remarkable impact on regional environment, including natural, social and economic conditions [16,23]. Many researchers have been aware of this phenomenon and have carried out a number of studies [16,18]. In extant studies, more attention has been paid to the environmental impact assessment (EIA), and less to social and economic impact (SEI). With gradually improving technology and an increasing number of development projects in China, the possibility of algae-derived biofuel commercialization is growing, and an SEI assessment is urgently needed to formulate the planning of algae-derived fuel development, particularly location choice. Input–output (I–O) analysis is a popular method to evaluate the social and economic impacts of demand changed of one industry to other sectors, particularly the energy industrial development; for example, four electric power sectors in an exogenous sector have a great influence on the inputs and outputs of other individual sectors [9]. To date, only few empirical studies are performed on algae-derived biofuel that use an I–O analysis, because the level of algae-derived biofuel technology is still at an early stage and the scale of the market is small. In this study, an I–O model is introduced to assess the SEI of algae-derived biofuel. A developed I–O table, including the algae-derived biofuel sector, is generated, and the SEI of algae-derived biofuel commercialization is discussed using a related example.

2. Methodology

2.1. An input–output analysis

An I–O analysis is an appropriate methodology for examining the impact of changes in expenditures, such as general expenses and

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investments, in each sector using I–O tables [5]. It not only quantifies the direct effect that an investment-intensive industry has on the economy, but also describes its indirect effect on the demand for products and services in other sectors, which are affected by changes in the initial sector [20].

The I–O tables consist of total gross inputs (X) and total gross outputs (X, the value of the total inputs is equal to the total outputs). Total gross inputs (X) are divided into the intermediate inputs (Z) and added value (V), such as labor or capital inputs. Total gross outputs (X) include intermediate outputs (Z) and final demands (F) such as capital or consumption goods [12]. If the final demand for goods or services in a sector changes, the effect of the change on all industries can be obtained by the direct or indirect interdependent relations among the industries [9], this can be expressed as Eqs. (1)–(4):

$$I = I_d + I_i + I_c \tag{1}$$

$$I_d = G \times \Delta f = V/X \times \Delta f \tag{2}$$

$$I_i = I_d \times \left[(I-A)^{-1} - I\right] = I_d \times \left[(I-Z/X)^{-1} - I\right] \tag{3}$$

$$I_c = \frac{I_d + I_i}{1-c} \tag{4}$$

where I, I_d, I_i and I_c represent the total, direct, indirect and induced impacts, respectively; Δf indicates the changing value of final demand; c is the marginal propensity to consume ($0 < c < 1$); G and A represent the matrixes of the added value coefficient and input coefficient, respectively; I is a unit matrix; and $(I - A)^{-1}$ is the Leontief inverse matrix.

Moreover, a comparative analysis of the social-economic impact benefits of industrial development is often conducted between different regions. The normalization index is an economic impact multiplier, which reflects the impact benefits by unit output, and can be calculated as follows:

$$IM_n = I_n/X \tag{5}$$

where: IM_n represents the multiplier of impact n; I_n is the benefit value of impact n and in unit of 10,000 CNY; X is the total output and in unit of 10,000 CNY.

2.2. The I–O tables for algae-derived biodiesel in China

China's regional I–O tables have been published every five years since 1987. The last regional I–O tables were published at the end of 2011 using the economic data from 2007 [19]. Because of its small scale, the algae-derived biodiesel sector is not included in the extant I–O tables; a developed I–O table should be constructed firstly.

In this study, the China's I–O tables with 42-sectors from 2007 are used to examine the influence of an exogenous sector, i.e., the algae-derived biodiesel sector on other sectors, and some researchers from the Joint Research Laboratory for Sustainable Aviation Biofuels,

Table 1
Sectors in Chinese I–O table.

Number	The sectors in Chinese I–O table	The sectors in Statistical Yearbook	Number
1	Agriculture animal husbandry and fishery	Agriculture animal husbandry and fishery	1
2	Coal mining and dressing	Mining	2
3	Petroleum and natural gas extraction		
4	Metal mining and dressing		
5	Non-metallic mineral and other mineral mining		
6	Food production and tobacco processing	Manufacturing	3
7	Textile industry		
8	Textile, clothing, shoes, hats, leather and its products		
9	Timber processing and furniture manufacturing		
10	Paper printing and stationery and sporting goods manufacturing industry		
11	Oil processing and coking and nuclear fuel processing		
12	Chemical industry		
13	Manufacture of non-metallic mineral products		
14	Metal smelting and rolling processing industry		
15	Manufacture of metal products		
16	General and special equipment manufacturing (boiler, pump)		
17	Transportation equipment manufacturing industry		
18	Electric equipment and machinery manufacturing		
19	Communication equipment, computers and other electronic equipment manufacturing industry		
20	Instrumentation and cultural office machinery manufacturing		
21	Handicraft article and other manufacturing		
22	Scrap waste treatment industry		
23	Electricity, heat production and supply industry	Electricity, gas and water production and supply industry	4
24	Gas production and supply		
25	Water production and supply		
26	Building industry	Building industry	5
27	Transportation and warehousing	Transportation, warehousing and post-industry	6
28	Post-industry		
29	Information transmission, computer services and software	Information transmission, computer services and software	7
30	Wholesale and retail trade	Wholesale and retail trade	8
31	Hotel and restaurants	Hotel and restaurants	9
32	Finance	Finance	10
33	Realty business	Realty business	11
34	Leasing and business service	Leasing and business service	12
35	Research and experimental development industry	Research and technical services	13
36	Polytechnical services		
37	Water resources, environment and public facilities management	Water resources, environment and public facilities management	14
38	Resident services & other services	Resident services & other services	15
39	Education	Education	16
40	Health, social security and social welfare	Health, social security and social welfare	17
41	Culture, sports and entertainment	Culture, sports and entertainment	18
42	Public management and social organization	Public management and social organization	19