Economic Impact Assessment of Laos-China Hydropower Projects Using the Entropy Method

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Abstract

Given that Laos is rich in water resources, it attracts many Chinese companies to invest in the construction of hydropower stations in Laos and has made great contributions to the economic development of Laos. Evaluating the economic impact of Lao-China hydropower projects is of importance for improving Laos' social and economic development. This quantitative study aimed to construct an evaluation system to evaluate economic impacts of the Lao-Chinese transnational hydropower projects and to describe key factors to provide theoretical support for improving its economic benefits.This article designed an Economic Impact Assessment (EIA) system of hydropower projects from three aspects: economic growth, economic structure, and economic quality, taking Laos' hydropower projects in the Nam Ou river basinas a sample. The data were analyzed by the entropy method to examine its impacts on the Lao economy. The results showed that the construction of cascade hydropower stations in the Nam Ou river basin has played a crucial role in enhancing Lao economic development. After the completion of the projects, Lao economic benefits have been significantly increased; the adjustment and optimization of the economic structure of hydropower projects area major force for economic development. Meanwhile, the unemployment rate has been reduced during the construction and operation stages. The urbanization rate and people’s income have also increased to a certain extent, which has also promoted economic development.

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Introduction

With population growth, accelerated industrialization process, and sustained economic and social development, countries from every corner of the world are successively facing the real problem of a power supply shortage. Because of its low price, hydropower has become a large-scale commercial application of renewable energy. According to the report of the International Hydropower Association (IHA) in 2020, the current global hydropower development accounts for about 27.3% of the technological volume. There is still a large development space for hydropower resources as a whole in all regions. The Lancang-Mekong River is the largest river in Southeast Asia and one of the longest international rivers. It is known as "the Danube of the East", which originated in China's Qinghai-Tibet Plateau and flows through China, Myanmar, Laos, Thailand, Cambodia, and Vietnam. Laos is the country with the most abundant hydropower resources on the lower Mekong River. Besides, Laos also contains the Nam Ou River and many other rivers with a flow of more than 200 kilometers, which provide abundant hydropower reserves and favorable hydropower conditions for the construction of hydropower projects.

Recently, with the gradual advancement of China’s Belt and Road initiative and the Lanmei Cooperation, China’s investment in Laos has increased year by year. In 2016, the investment was US$1.26 billion, making it the largest foreign investor in Laos. To date, most of China's investment in Laos is concentrated in hydropower, mining, and other sectors. Nine hydropower plants have been put into operation. Hydropower projects have gradually become the main carrier of China's direct investment in Laos.

Not only does direct investment in these hydropower projects brings new opportunities for Laos in its local hydropower advantages, but it also promotes Laos’s domestic infrastructure, increases employment and power trade, and greatly enhances Laos’s economic development. Considering economic impacts, the long construction period, large investment scale, related stakeholders, and a wide range of influence, the Laos-

China hydropower projects are scientifically and rationally economical which the impact evaluation is of great significance.

Literature review

The related literature is mainly expanded from two dimensions. The first is to focus on potential problems that are common in multinational engineering projects. The researchers usually started from the potential problems of investment decision (Meng, et al., 2016) project management (Zhu, 2010), risk management and control (Tuo, Y., Duan, Z., Disse, M., & Chiogna, G., 2016). conflicts among stakeholders (Martin, F. & Bolliger, D.U., 2018) performance evaluation (Adenfelt, 2010), impact evaluation (Yang, et al., 2007), and other potential issues. Many researchers have studied the impact of multinational engineering projects on different aspects: economy (Hu, et al., 2012) society (Jia, 2013) and nature (Huang, 2018) It can be seen that it has various impacts on the projects' bases. As a complex economic activity, the projects showed a profound impact on the economic system of an invested area. The researchers believed that the economic impact assessment of multinational engineering projects mainly included financial evaluation and national economic evaluation (Liu and Yuan ,2015; Liu Liangzhong, 2016) pointed out that scientific analysis and evaluation of the regional economic impact is a prerequisite for engineering decision-making, and by comparing the economic benefits before and after the project construction, the economic impact of the cross-sea channel project is systematically evaluated. (Tu Su, 2016) stated that transnational projects have a huge effect on economic development and poverty reduction in the project area.

Secondly, some studies focused on specific types of transnational engineering projects. Due to the different types of multinational engineering projects and some conditions of a host country, they conducted in-depth research on specific types including water conservancy and hydropower (Li, et al., 2016), oil and gas pipelines (Peng, 2017), railway construction (Wang, et al., 2018) architectural design (Chen & Song, 2012) and other studies related to engineering projects. Currently, there are few studies on multinational water conservancy and hydropower investing projects, mainly focusing on an environmental assessment of hydropower systems (Berkun, 2011) supply chain

management (Shen, 2009) and risk prevention in hydropower projects (Jaafari, 2001) On the whole, little research on the economic impact assessment of transnational water conservancy and hydropower investment projects has been conducted.

Therefore, this article chooses the Laos-China transnational hydropower projects as a sample by analyzing and evaluating their impacts on the Lao economy based of three economic aspects.

Research Methodology

Speaking of national economic evaluation, the impacts of the construction of Laos-China transnational hydropower projects on the economic system is mainly manifested in three aspects: economic growth, economic structure, and economic quality. Therefore, indicators are selected around these three aspects to measure the impact of the projects on the local economic system.

1.1) Economic growth refers to the continuous increase in a country's per capita level over a long period. The level of economic growth reflects the growth rate of a country's total economic volume at a certain time. It also measures the overall economic strength of a country or region. This article selects growth rates of GDP, GDP per capita, and Gross National Income per capita as economic growth evaluation indicators.

1.2) Economic structure refers to the spatial relationship between various elements in the economic system. The economic structure is an important yardstick for measuring the level of national and regional economic development. A reasonable economic structure can push a country to its advantages. Countries and regions with different economic systems and different economic development trends have very different economic structures. This paper selects the proportion of the primary industry, the primary industry employees, the proportion of the secondary industry, the secondary industry employees, the proportion ofthe tertiary industry, and the tertiary industry employees as economic structure evaluation indicators.

1.3) Economic quality refers to the measurement of the value of resources consumed by people to obtain quality. This paper selects labor productivity, unemployment rate, and urbanization rate as economic quality evaluation indicators.

The data used in this study derived from the Statistical Yearbook and the World Bank's WDI database merely from 2012 to 2019 as an evaluation sample of economic benefits to evaluate the impact of Laos' cascade hydropower projects in the Nam Ou river basin towards the Lao economy. The collected data were analyzed by using the Entropy method. The term "Entropy" is coined by Rudolph Clausius in 1856, expressing changes in the measurement capacity of energy failure in a material system in the theory of thermodynamics (Gu & Li, 2009) By 1948, Claude Shannon established the theory of information through unremitting study. He called the uncertainty of information sources in the communication process "the information entropy". According to Shannon's definition, information is used to measure the degree of order, and entropy is used to measure the degree of disorder in a system. The main theoretical basis of the entropy method is the smaller the value of the information entropy of the evaluation index, the greater the amount of information provided by this index, the greater the role it plays in the evaluation, and the greater its weight it has.

Brief introduction of cascade hydropower projects in Nam Ou river basin

The Laos cascade hydropower stations in the Nam Ou River Basin is the first overseas project that Chinese enterprises have gone overseas based on the overall river basin planning and Build-Operate-Transfer (BOT) investment and development. It is also the first project invested and constructed by Power China in the whole industry chain integration model. As a key project of Laos' national energy strategy, the power station is constructed in two phases with a total installed capacity of 1272 MW and an average annual power generation of about 5 billion kWh. In January 2021, the 7-level hydropower station projects passed the water storage inspection and gained acceptance. The first phase of the Nan Ou projects is generating greater comprehensive economic and social benefits, allowing the integrated advantage of the entire industrial chain of power construction to be fully demonstrated in international competition, becoming a bright spot in the practice of China's Belt and Road initiatives. It represents a new model of China-Laos power and energy cooperation. After the completion of the cascade hydropower stations in the Nam Ou river basin, they will provide stable and high-quality electric energy, guarantee 12% of the electricity supply in Laos, and promote the upgrade of the

northern power grid and transmission interconnection. The project will help Laos become the "Battery of Southeast Asia" and accelerate the process of Laos's electricity export and regional integration of electricity. The seven power stations transform the rich water resources of the Nam Ou River into a source of economic and social development.

Research Findings

According to the entropy method, the collected 12 evaluation indicators and 96 raw data were processed to obtain the information entropy, difference coefficient, and weight of each indicator (see Table 2).

Table 1: The economic index of Lao economic weights

Index		Information entropy	Coefficient of difference	Weights	Total weight
First level	Second level				
Economic Growth	GDP growth rate (X_1)	0.9214	0.0786	0.0585	0.2115
	GDP per capita growth rate(X_2)	0.9254	0.0746	0.0555	
	GNI per capita (X_3)	0.8691	0.1309	0.0975	
Economic structure	The proportion of the primary industry (Y_1)	0.9119	0.0881	0.0656	0.5013
	The proportion of employees in the primary industry(Y_2)	0.8797	0.1203	0.0896	
	The proportion of the secondary industry(Y_3)	0.8933	0.1067	0.0794	
	Employees in the secondary industry(Y_4)	0.8860	0.1140	0.0848	
	The proportion of tertiary industry(Y_5)	0.8853	0.1147	0.0854	
	Employees in the tertiary industry(Y_6)	0.8703	0.1297	0.0965	
Economic quality	Labor productivity(Z_1)	0.9303	0.0697	0.0519	0.2872
	Unemployment rate(Z_2)	0.8152	0.1848	0.1375	
	Urbanization rate(Z_3)	0.8686	0.1314	0.0978	

The data were further processed to obtain the period data and the cumulative score of economic benefits (see Table 3).

Table 2: The evaluation scores of Lao economic benefits from 2012 to 2019

Index		2012	2013	2014	2015	2016	2017	2018	2019
First level	Second Level								
Economic Growth	X_1	0.0540	0.0585	0.0433	0.0357	0.0360	0.0342	0.0281	0.0000
	X_2	0.0502	0.0555	0.0393	0.0344	0.0398	0.0344	0.0296	0.0000
	X_3	0.0000	0.0135	0.0247	0.0525	0.0637	0.0727	0.0892	0.0975
Economic structure	Y_1	0.0282	0.0409	0.0432	0.0000	0.0486	0.0224	0.0494	0.0656
	Y_2	0.0000	0.0161	0.0297	0.0436	0.0434	0.0664	0.0786	0.0896
	Y_3	0.0616	0.0355	0.0147	0.0000	0.0794	0.0418	0.0498	0.0418
	Y_4	0.0000	0.0157	0.0302	0.0436	0.0587	0.0649	0.0758	0.0848
	Y_5	0.0148	0.0558	0.0852	0.0854	0.0000	0.0390	0.0404	0.0587
	Y_6	0.0000	0.0169	0.0305	0.0454	0.0336	0.0700	0.0837	0.0965
Economic quality	Z_1	0.0502	0.0519	0.0466	0.0435	0.0412	0.0409	0.0308	0.0000
	Z_2	0.0076	0.0000	0.0227	0.0378	0.0559	0.0862	0.1149	0.1375
	Z_3	0.0000	0.0136	0.0274	0.0412	0.0552	0.0693	0.0833	0.0978
Total		0.2664	0.3740	0.4375	0.4631	0.5556	0.6422	0.7536	0.7697

It is found that the four most weighted indicators are the unemployment rate, urbanization rate, GNI per capita, and the proportion of employees in the tertiary industry. That is, the construction of Laos-China transnational hydropower projects can effectively enhance regional development and improve overall economic benefits. Besides, the total weights of the three first-level indicators are 0.2115, 0.5031, and 0.2872, respectively, indicating that the adjustment of the industrial structure has the most significant impact on economic benefits, while the growth of GDP and GNI and other indicators have less impact on economic benefits.

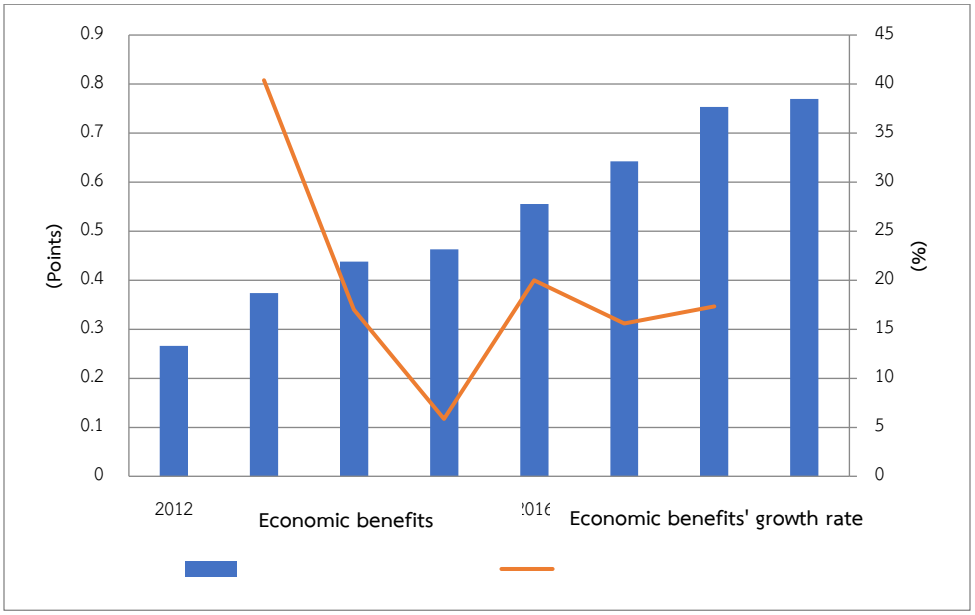

Figure 1: Changes in Laos' Economic Benefits from 2012 to 2019

In Figure 1, the economic benefit evaluation scores of Laos have been increasing year by year from 2012 to 2019. The score growth rate in 2015 has a V-shaped characteristic, meaning that the score changes significantly around the year. Specifically, the score in 2015 increased by only 5.85% compared with the previous year, while the increase in 2016-2018 compared with the previous years was 19.97%, 15.59%, and 17.35%, which increased significantly. In May 2016, all nine hydropower plants of the first phase in the Nam Ou river basin were put into operation for power generation. The evaluation results show that the project has a greater effect on improving economic benefits.

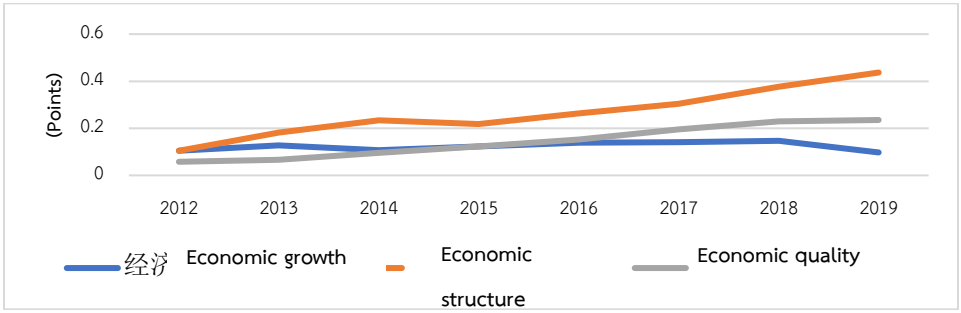

Figure 2: Changes in Laos' economic growth, economic structure, and economic quality from 2012 to 2019

In Figure 2, the score of economic structure indicatorshas long been higher than the scores of economic growth and economic quality indicators. It can be seen that the scores of economic structure and economic quality indicators were increasing, while economic growth indicators have developed slowly. Therefore, the economic impact of cascade hydropower projects in the Nam Ou river basin is generally reflected in the optimization of the economic structure and the enhancement of the economic quality growth. The adjustment and optimization of the economic structure is the major driving force for the economic development of Laos, and the construction and operation of hydropower stations have shown a significant growthrate.

Conclusion and Discussion

The development and construction of Laos-China transnational hydropower projects have an impact on the employment, income, and industrial development of residents. The purpose of economic benefit evaluation is to analyze and predict the possible economic impact of the project implementation on the region. This paper establishes the economic impact assessment indicating system of Lao-China transnational hydropower projects, taking hydropower plants in Laos' Nam Ou river basin as a sample; the impacts of the first phase of the project towards the Lao economy before and after the completion of the project were analyzed using the entropy method. The conclusion is the following:

First, after the completion of hydropower projects, the increase in economic benefits in Laos is significantly higher, indicating that the project has contributed to the economic development of Laos.

Second, a scientific and reasonable evaluation index system can objectively reflect the economic impact of transnational hydropower projects to a certain extent. From the three aspects, economic growth, economic structure, and economic quality, the economic structure indicators have the greatest impact on economic benefits, reflecting the optimization of industrial structure of hydropower stations, which are the main driving force for economic development and can greatly improve the overall economic benefits. In addition, there are many factors affecting the economy. The weight results show that the construction and operation of the project mainly promote

regional economic development by reducing the unemployment rate, increasing the urbanization rate and the people's income level.

Third, the entropy method determines the index weight according to the amount of information provided by the observation value of each index, which can intuitively reflect the degree of influence of each index on the economic system, and at the same time, it is convenient to determine the comprehensive index of each year, so as to illustrate the economic impact of the project before and after completion.

Transnational hydropower projects generally have the characteristics of diverse stakeholders, diverse influencing factors, and complex problems. Not only will those said characteristics have a huge impact on the natural ecosystem, but also affect the socio-economic system due to environmental pollution and subject conflicts. This study only explored the economic impact of multinational hydropower project investment projects, and failed to conduct a comprehensive evaluation of its social and environmental impacts. From the perspective of the social-economic-natural composite ecosystem, it is of further investigation to explore the impact of the Laos-China transnational hydropower projects towards the social-economic-natural system and its risks based on the degree of system coordination.

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