Energy 108 (2016) 74–85

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

An externality evaluation model for hydropower projects: A case study of the Three Gorges Project

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ARTICLE INFO

Article history:
Received 14 January 2015
Received in revised form
23 October 2015
Accepted 25 October 2015
Available online 14 November 2015

Keywords:
Hydropower exploitation
Externality
Three Gorges Project
Reservoir migration

ABSTRACT

Hydropower has become an important method for relieving energy tensions and facilitating energy structure adjustments in China. However, the development of hydropower has been restricted due to issues related to migration, ecology, and benefit sharing. The key is to establish a reasonable and scientifically based benefit sharing system that considers all input and output factors in a project's life cycle. Most of the studies performed in this field to date have focused on the direct costs and benefits of hydropower projects; however, the systematic identification and integral assessment of externalities is seriously lacking. Therefore, this paper 1) identifies a hydropower project's externalities using the Externality Theory based on analysis of input and output factors; 2) chooses or designs a specific calculation method for each externality and subsequently establishes an externality evaluation model for hydropower projects; and 3) calculates and analyses the externalities of the TGP (Three Gorges Project). The results show that the TGP has several considerable positive externalities, whose monetary value is approximately five times that of the negative externalities. Additionally, there are so many externalities that should not be ignored that it is necessary to include externalities in the evaluation of hydropower projects. These results lay a foundation for establishing a scientific and reasonable benefit-sharing system and provide the public with important and quantitative information to objectively understand the TGP.

1. Introduction

1.1. Conditions of Chinese hydropower exploitation

China produces and consumes large amounts of energy. Energy consumption and demand in China have been increasing in recent decades [22]. Both the promise to decrease the proportion of fossil fuel energy in energy generation portfolio and the pressure for carbon emission reductions have encouraged the Chinese government to rapidly adjust the energy generation infrastructure and to develop renewable energy resources in China [17,18]. Hydropower, as a kind of clean renewable energy, is becoming increasingly important in addressing the energy shortage situation [42]. However, the problems of migration, ecology, and benefit sharing currently represent negative effects of hydropower exploitation. According to published statistics, the number of reservoir migrants in China totaled 19.3 million over the period from the founding of China to 2008, and in recent years, the annual mass disturbances resulting from land requisition and demolition have increased to approximately ten or hundreds of thousands times the historic rates [46]. A scientific and reasonable benefit-sharing system is urgently required, and the key to solving hydropower-related problems is to build a comprehensive hydropower project evaluation system. This paper identifies the externalities of hydropower projects based on analysis of input and output factors and subsequently chooses or designs a specific calculation method for each externality to establish an externality evaluation model for hydropower projects. This framework will lay a theoretical foundation for a reasonable benefit-sharing system.

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http://dx.doi.org/10.1016/j.energy.2015.10.116
0360-5442/

The TGP (Three Gorges Project) is the largest engineering project in China to date, and it is also the largest hydropower station in the world, with a total installed capacity of 22.5 GW and an annual power generation of approximately 100 TW h [12]. The impacts of the project have been controversial both domestically and abroad since the idea of building the dam reemerged. After decades of investigation and discussion, the National People's Congress approved the plan in 1992, and construction began in December 1994. The construction of the dam was completed in 2008, at which point all of the generation units were fully operational; this phase of the project was completed one year earlier than expected. Furthermore, the dam had achieved the goal of raising the water level in the reservoir to 175 m (574 ft) above sea level yearly from 2010 to 2013. Currently, the completion approval process of the TGP is underway. Wang Yang, Vice Premier of the State Council, has taken the lead in the approval and has organized approximately 30 academics and other related experts for the evaluation committee. An important and complex component of the approval review is evaluating externalities. This paper calculates the impact of the externalities of the TGP with the externality evaluation model, which lays a theoretical foundation for approval and provides support for scientific and objective evaluation of the TGP.

1.2. Literature review

In previously published literature, evaluation of hydropower projects has been performed from two perspectives: input factors and output factors. Input factors refer to the cost of a project and include negative effects that occur during the process of construction and operation. Output factors are the benefits derived from hydropower projects. The evaluation methods of a hydropower project's direct costs and benefits have been universally accepted. An increasing number of researchers have begun to focus on indirect impacts, termed externalities, for which various achievements have been made.

The values of several output factors, especially the externalities, of hydropower projects are not well recognized and have not been well evaluated in China. Hydropower resources in China are mainly distributed in the western region of the country, while market demand is higher in the eastern region [5]; therefore, hydroelectricity is transmitted from the west to the east. People in the eastern region enjoy a fairly lower electrovalence than average according to the current pricing policy of the cost plus profit system in China [20]. As noted by Lu Youmei, the former general manager of the China Three Gorges Corporation, the western region of China is entitled to share the benefits as it contributes hydropower resources to the hydropower projects; currently, the eastern region is the only region that benefits from the low-cost hydropower [10]. Quantitative research focusing on calculating the value of water resources is drawing increasing attention; payments for hydropower resources are being more extensively accepted and supported [10,25]. However, the social security functions of people who previously owned the land are typically ignored, resulting in flaws in the scope of compensations; therefore, the real value of the land is not reflected [30]. Immigration experts of the World Bank who have conducted research on reservoir migration have declared that the costs of migration, especially the invisible losses that migrants experience, are significantly underestimated [3,4,23]. This problem is particularly relevant in China. Additionally, there is a consensus that hydropower projects have various negative effects on the environment. Possible negative impacts of hydropower projects include land salinization, geological disasters, and species extinction [29,35].

There is no doubt that hydropower projects produce tremendous benefits because they contribute significantly to, for example, power generation, flood control, navigation, and irrigation. Trice, Knetsch and Southgate separately analyzed tourism benefits derived from hydropower projects, improvements in land's economic value and soil and water conservation benefits and established corresponding calculation models [31,32]. The concept of "to construct a dam, to drive the economy" adequately reflects the regional economic benefits and social development stimulated by a hydropower project. Meanwhile, a hydropower project also contributes to reducing greenhouse gas emissions because it presents an alternative to thermal power in the energy structure of China [21,33,34]. Recent research also shows that the construction of a reservoir can improve the quality of regional environment to some extent [44].

In conclusion, 1) current research on hydropower resources and land usage mainly focuses on policy limitations, thus resulting in a relative lack of solid theoretical foundations and an absence of recognized calculation methods; 2) quantitative analyses on certain elements, including migrants' invisible losses, are still in an exploratory stage; and 3) the externalities of hydropower projects have attracted increasing attention, but most of the research has focused on a single factor, while a systematic study with a comprehensive point of view is missing. Therefore, this paper establishes the externality evaluation model for hydropower projects based on analysis of input and output factors and subsequently uses the TGP as an example to calculate the externalities.

2. Method

According to Samuelson's definition, an externality is an unexpected cost or benefit brought about by a body (e.g., project or action) to others or effects that cannot be fully explained using prices or market trading [26]. Positive externalities correspond to additional benefits, and negative externalities correspond to additional costs. In this paper, the basis for identifying externalities using the Externality Theory is the determination of whether anyone benefited from the project but did not pay for the benefits and whether anyone suffered losses without being paid by the developer of the hydropower project. The benefits and costs are considered to be externalities if one of these criteria is met.

This study is one step of a research project on input–output model for hydropower projects. First, it builds an input–output analysis model for a hydropower project (see Fig. 1), as the input and output factors were identified in previous studies and directly used herein [6,24,44]. Second, it analyzes all the factors with the Externality Theory to identify externalities and establishes an externality model of hydropower projects in Section 3 (see Fig. 2).

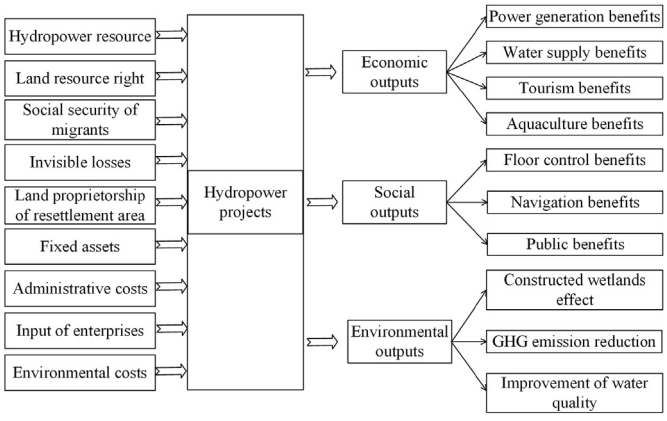

Fig. 1. The input–output analysis model of hydropower projects.