

Discussion

Supply–Demand Coupling Mechanisms for Policy Design

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Abstract: Ecosystem services are important for sustaining human survival and sustainable socio-economic development. For the past two decades, ecosystem services studies have greatly promoted the application of ecosystem services science in conservation. As a scientific method to integrate multi-regional and multi-scale ecosystem service providers and beneficiaries, ecosystem service supply and demand coupling mechanisms and payments for ecosystem services programs are closely linked. In this paper, we first provide an overview of the payments for ecosystem services concept and an evaluation of its effectiveness in implementation. We then analyze the correlation between payments for ecosystem services and supply–demand coupling mechanisms and propose a framework to link these two ideas. China’s practice in implementing ecological redline policy and institutional reforms for protected area management will provide a good experimental platform for comprehensive payments for ecosystem service design and effectiveness evaluation within China and beyond.

Keywords: ecosystem services; supply and demand; cost and benefit; payments for ecosystem services

1. Introduction

Ecosystem services (ESs) are the top policy-related issue in ecosystem management research and are considered an important approach to address sustainability challenges [1]. With the deepening of the concept and theory of ESs, ES research has gradually shifted from theoretical framework and value assessment to integrated mapping, trade-off analysis, and supply–demand coupling mechanisms, and has gradually reached a new height of policy design and management applications [2,3]. Defining the process of ecosystem service delivery and its impact on the temporal dynamics of costs/benefits of stakeholders is not only key to scientific policy design and management applications in countries around the world but is also a challenge for countries in assessing the effectiveness of policy implementation [4,5].

Payments for ESs (PES) is an effective way to link ecosystem service providers and beneficiaries to coordinate stakeholders and integrate ecosystem conservation and socioeconomic development [6]. It also represents a recent ES-based policy instrument with often very different programs operating at various scales (e.g., local, regional and national) which aims to realign and coordinate the costs/benefits among different stakeholders [7,8]. PES has been widely implemented across the world [9–13] as a promising tool to reconcile the long-term conflicts between socioeconomic development and

ecosystem conservation [8]. Recent decades have witnessed over 550 active programs around the world and an estimated 36–42 billion USD in annual payments [14]. The published articles in scientific journals also reflect the breath of the research on this topic [14]. The central idea of PES is that beneficiaries outside the conservation areas should compensate the costs borne by communities in target areas [8] to simultaneously facilitate ecosystem conservation and socioeconomic development in target areas [4,6,15]. Therefore, passing a benefit–cost test is a precursor for a successful PES programs [16]. A limited number of studies have evaluated the effects of PES programs on environmental and socioeconomic outcomes [4,6,8,12,13,16,17]. In a recent review titled “China’s response to a national land-system sustainability emergency”, Byran et al. [13] reviewed 16 sustainability programs in China and found that these programs overwhelmingly improved the sustainability of China’s rural land systems. Motivating voluntary participation was a common objective of these programs, and PES was widely used to simultaneously improve local livelihoods and conservation ecosystems [4,6]. The central government of China has also included PES in China’s 11th Five-Year Plan (2006–2010), 12th Five-Year Plan (2011–2015), and 13th Five-Year Plan (2016–2020). China’s ecological redline policy also requires consulting local stakeholders to reach agreement and the establishment of horizontal PES mechanisms between the conservation and beneficiary areas. These all suggest the importance of incorporating PES policies into sustainability programs. However, due to data gaps and information gaps, it is often difficult to link ecosystem suppliers and beneficiaries to create PES programs. This might lead to many problems such as insufficient stakeholder participation, difficulty in determining compensation payers and recipients, and a lack of a scientific basis for determining compensation standards [7]. Thus, the application of ES research in policy design and management decision-making is still subject to certain constraints [1,18], especially in effectively regulating key factors and identifying strategies affecting ESs to improve ESs and reduce unwanted trade-offs [19].

Research on ecosystem service supply–demand coupling mechanisms can quantitatively reveal the spatial distribution characteristics of the ecosystem service provision and benefiting areas. This can be used to help determine the stakeholders/participants and compensation standards. By integrating the linkages among PES programs, the benefits and costs of ecosystem service suppliers, and beneficiaries, we propose a framework for creating PES programs based on ecosystem service supply–demand coupling mechanisms. In this way, we can demonstrate the operationalization of this framework to analyze the effectiveness of PES programs on the benefits and costs of multiscale stakeholders and provide recommendations to adjust PES mechanisms to improve the participation attitude and willingness of stakeholders in specific study areas and beyond.

2. PES Concept and Its Implementation Effectiveness Evaluation

Although PES has been defined differently by various scholars, it is consistently agreed that PES is an incentive mechanism rather than a punishment mechanism [20,21]. Based on these definitions, Salzman et al. [14] further defined PES as the exchange of value for intended land management practices or ensured ESs and grouped PES mechanisms into three broad categories: user-financed PES, government-financed PES, and compliance PES.

PES is an important environmental policy instrument that seeks to create market incentives for ecosystem conservation areas that ensure ES provision [8,14]. It is an effective way to link ecosystem service providers and beneficiaries to coordinate stakeholders, ecosystem conservation and socioeconomic development. In recent decades, PES programs have been practiced at the local, regional and national levels around the globe [8,14]. Salzman et al. [14] provided an assessment of the trends and current status of PES mechanisms across the domains of water, biodiversity, and forest and land-use carbon around the world and found a growth in the number of programs, geographical spread and dollar value over the past decade.

The success of PES programs depends on the participation and cost–benefit effectiveness of multi-scale stakeholders. Scholars worldwide have carried out numerous theoretical discussions and preliminary research on the implementation of PES programs [7], and a limited number of

studies have assessed the cost–benefit effectiveness of PES programs [4,6,8,9,12,13,16,22] and the causal mechanisms [8,17,23]. However, as there have been few efforts to analyze the cost–benefit of PES programs [16,24], it is often difficult to determine the effectiveness of the vast majority of PES programs [25,26]. This could mainly be because we have often lacked baseline data, control areas, or randomized designs to compare the differences in effectiveness with and without a program [26,27] or across programs [16]. Currently, we lack empirical studies that systematically connect the program design with multi-stakeholder cost–benefit evaluation to provide a more comprehensive perspective for further optimization.

3. Supply–Demand Coupling Mechanisms and Their Correlation with PES Program Design and Effectiveness Evaluation

3.1. Supply–Demand Coupling Mechanisms

Ecosystem service suppliers can establish a coupling relationship with demanders through specific spatial locations [28,29]. The coupling mechanisms between ecosystem service supply and demand include in-situ, omnidirectional, and directional mechanisms, according to the spatial characteristics [28]. The importance of research into the coupling mechanisms of ecosystem service supply–demand can be mainly concluded to be (1) identifying the hotspots of ecological conservation areas and the geographical scope of the ecological spatial planning units [18,30,31]; (2) determining land spatial planning and development strategies by identifying the trade-offs and coupling mechanisms between ecosystem service providers and beneficiaries under different land use patterns and management scenarios [32–39], and (3) evaluating the cost–benefit of ecosystem suppliers and beneficiaries to promote the establishment of a horizontal ecological compensation system to avoid the short-term economic behavior that might damage ecosystems. Currently, scholars have carried out a great deal of research on the connotation, scale relationship, and coupling pathway of ecosystem service providers and beneficiaries [34,36–41]. The scientific progress in this field provides important support for the in-depth analysis of the spatial coupling mechanisms between ecosystem service providers and beneficiaries to promote a PES program and the cost–benefit effectiveness analysis of multi-stakeholders.

3.2. Supply–Demand Coupling Mechanisms Inform PES Program Design and Effectiveness Evaluation

The PES program seeks to create market transactions between ecosystem service providers and beneficiaries to internalize the positive externalities generated by natural ecosystems [14]. The kernel of PES is that beneficiaries of ESs should compensate the costs borne by communities for maintaining and conserving ESs in target areas to achieve a win–win goal in both the target areas and benefiting area [8]. The success of the PES program depends to a large extent on the degree of stakeholder participation [42]. Therefore, solving the problem of “who should provide compensation”, “who should be compensated” and “how much compensation is needed” is necessary to establish a PES mechanism that coordinates environmental and socioeconomic outcomes to achieve sustainability goals [8,14]. We need to understand the coupling mechanisms between ES providers and beneficiaries to estimate the biophysical and social extent of the program and the cost–benefit associated with the ecological infrastructure investment to inform PES program design and effectiveness evaluation.

First, we need to solve the key issues of “who should provide compensation”, “who should be compensated”, and “how much compensation is required” in designing a PES program. The gains of conservation are often shared across various scales [8,15]; therefore, we could solve the issue of “who should provide compensation” by determining the spatial distribution and extent of the beneficiaries. Determining “who should be compensated” is comparatively easier since the opportunity costs of maintaining or conserving ESs are mostly borne by local communities [8,15]. The feasibility of designing a PES program mainly depends on whether the gains of beneficiaries can compensate the cost borne by communities from a PES program, since a PES program aims to simultaneously facilitate ecosystem conservation and socioeconomic development in target areas.

Therefore, measuring the costs incurred by and evaluating the benefits gained by maintaining and conserving ESs requires an understanding of the ES supply–demand coupling mechanism. We need to determine how ecosystems need to be maintained or conserved to produce the service and estimate the opportunity cost of maintaining or conserving the ESs from the supply side. We also need to measure the benefits of maintaining or conserving those ESs from the demand side. Finally, benefits and costs could be connected to encourage the participation of providers and beneficiaries in designing a PES program (e.g., user-financed PES, government-financed PES, or compliance PES) [14].

Second, we need to evaluate the effectiveness of PES programs in achieving the goal of conserving ecosystems while facilitating socioeconomic development [8]. Although the design of PES programs also depends on a cost–benefit comparison, this is mostly based on hypothetical scenarios regarding the way that the development or conservation of an ecosystem might change the cost–benefit relationship. In comparison, the effectiveness evaluation mainly depends on the status quo after the implementation of the PES program. The real difference between the cost–benefit analysis of PES program design and the effectiveness evaluation is whether the aim of conserving ecosystems while facilitating socioeconomic development criterion could be satisfied or was satisfied. The main steps of effectiveness evaluation could be concluded to be as follows [16]: (1) comparing the opportunity cost of maintaining or conserving ecosystems with the compensation fund from beneficiaries to determine whether ecosystem service providers were a winner in the PES program; (2) comparing the marginal benefits of maintaining or conserving ESs with the compensation fund to determine whether ecosystem service beneficiaries were a winner in the PES program; (3) determining the effectiveness of the PES program; and (4) considering whether alternative ecosystem conservation strategies could improve the effectiveness of the PES program. These also require an understanding of the ES supply–demand coupling mechanism.

4. Framework Linking Supply–Demand Coupling Mechanism with PES Program Design

Based on the relationships between PES program design, effectiveness evaluation and supply–demand coupling mechanisms, and the limitations of studying supply–demand coupling mechanisms and PES, this study proposes a framework to link supply–demand coupling mechanism with PES program design and effectiveness evaluation. The framework mainly includes three aspects: the PES program design, integrated ES evaluation and PES program effectiveness evaluation, PES program layout optimization, and references for its application beyond this framework (Figure 1).

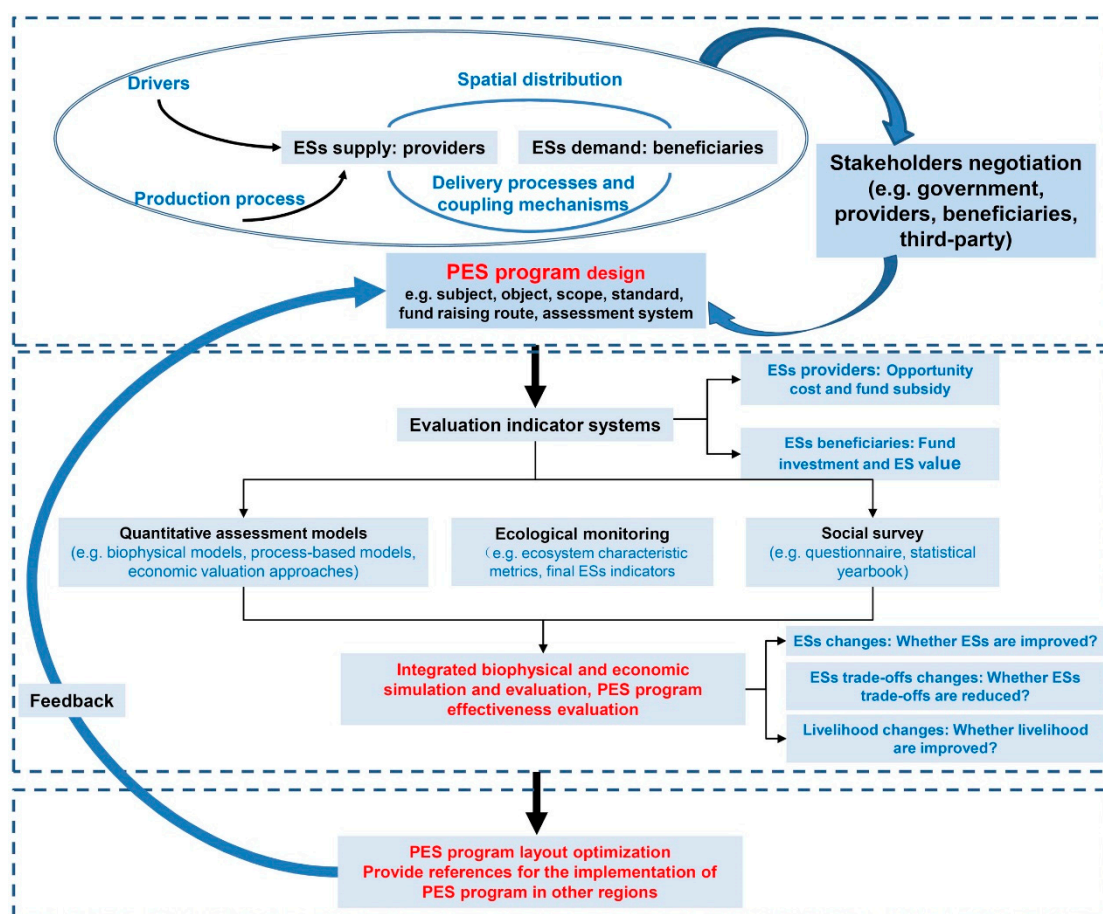


Figure 1. Framework linking the supply–demand coupling mechanism with the payments for ecosystem services (PES) program design. ESs: ecosystem services.

(1) PES program policy design: Clarifying the characteristics of the spatial distribution, delivery processes, coupling mechanisms, and main driving factors of ES providers and beneficiaries, and conducting a multi-round negotiation with multi-scale stakeholders to determine the subject, object, scope, standard, methods and routes, financing channels and assessment system of the PES program. Considering the fact that the internal and mutual coupling mechanisms between ES suppliers are complex and are not easily decomposable from the whole, it is necessary to analyze the main eco-environmental problems and determine the ESs that need priority protection when conducting a PES program for a specific region. The ecosystems also should be managed as a whole that guarantees that the priority ES can be protected.

(2) Integrated ES evaluation and PES program effectiveness evaluation: First, we should select important ES indicators and establish a PES program effectiveness evaluation system based on the PES program target. Then, we can link ecological monitoring, social survey and quantitative evaluation models (e.g., biophysical models, process-based models, and ecological valuation approaches) to carry out an integrated biophysical quantification and economic valuation of ESs and the opportunity cost. Finally, the dynamic changes of ESs and their trade-offs, and changes in ES suppliers' livelihoods before and after the implementation of PES program can be analyzed, which can help us to clarify the following questions: Are ESs improved? Are ESs trade-offs reduced or even transformed into synergies? Are ESs providers' livelihoods improved?

(3) PES program layout optimization and references for other applications: The PES program layout (e.g., scope, standard, methods and routes, financing channels, and guarantee mechanisms) can be optimized based on the effectiveness evaluation of the PES program. In turn, this will improve the

satisfaction and participation of multi-scale ES stakeholders, and the overall value of regional ESs, which can then result in an operational model, policy-making tool, and PES program system that can be used and promoted in other regions.

Currently, China's practice in implementing ecological redline policy [31] and institutional reforms for protected area management [43] will provide a good experimental platform for PES program design, evaluation effectiveness, and layout optimization. These efforts should substantially move China forwards in achieving the top design goal of ecological civilization [43] and provide recommendations to conserve ecosystems and improve socioeconomic outcomes beyond this framework [8].

5. Conclusions

PES programs seek to internalize the positive externalities generated by natural ecosystems. Currently, we lack systematical studies connecting PES program design with effectiveness evaluation analysis for further optimization. This paper first provides an overview of the PES concept and its implementation effectiveness evaluation; then, we analyzed the correlation between supply–demand coupling mechanisms and PES program design and effectiveness evaluation. Lastly, we propose a framework to link these two aspects for future PES program design, effectiveness evaluation, and layout optimization. China's practices in implementing ecological redline and institution reforms for protected area management will provide a good experimental platform for comprehensive PES design and effectiveness evaluation within China and beyond.

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