

Index Insurance in a Changing Climate: The Dual Role in Economic Efficiency and Social Equity in Developing Countries

Yuhang Li

*School of Economics and Finance, Shanghai International Studies University, Shanghai, China
ariel.li13627673442@outlook.com*

Abstract. This study explores the utility impact of index insurance in developing countries under the background of climate change through a literature review, with a focus on analyzing from two dimensions: economic effects and social equity effects. In terms of economic effects, index insurance significantly reduces transaction costs, enhances the efficiency of claims settlement, and effectively curbs moral hazard. The social equity effect is reflected in its risk protection for highly vulnerable groups and its balancing role against downside risks. The research also points out that there are still limitations in these two aspects, such as insufficient coverage and universal accessibility issues. Finally, this paper proposes suggestions such as being courageous in technological innovation, enhancing cooperation among systems, and improving product design to enhance the practicality and fairness of index insurance in addressing climate risks. The innovation of this study lies in systematically integrating the dual utility of index insurance in the economic and fairness dimensions, and comprehensively analyzing its limitations and applicable conditions based on literature, providing theoretical references and practical directions for subsequent empirical research and the formulation of climate-adaptive insurance policies.

Keywords: Index Insurance, Developing Country, Climate Change, Economic Effectiveness, Social Distribution

1. Introduction

Global climate change is showing a trend of "increasing frequency, intensifying intensity and expanding impact range", posing a systemic threat to the survival and development of developing countries. According to the sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC) of the United Nations, the global average temperature from 2011 to 2020 rose by approximately 1.09°C compared with the pre-industrial level. Developing countries, especially those in low latitudes, have become "hotspots of climate vulnerability" due to their insufficient geographical location, economic structure and adaptability. The probability of extreme weather events in these regions has increased by 30% to 50%, compared with the end of the 20th century [1]. Moreover, according to the Global Assessment Report, which was published in 2022 by the United Nations Office for Disaster Risk Reduction (UNDRR), the impact of disasters on developing

countries is disproportionate, and the poorest people in developing countries also suffer the greatest losses. On average, these countries lose 1% of their GDP each year due to disasters, while the loss rate for developed countries is 0.1% to 0.3%. Among them, the Asia-Pacific region has the highest cost, with an average annual loss of 1.6% of its GDP due to disasters.

Facing the risks posed by climate change, traditional indemnity insurance could have served as a central instrument for risk management in developing countries. However, in practice, it has encountered a predicament characterized by “inadequate supply and constrained demand” due to a multitude of structural contradictions, ultimately resulting in a significant “insurance gap”. From UNDRR, only 40% of disaster-related losses are insured, while the insurance coverage rate in developing countries is often less than 10%, and sometimes even close to zero. Against the backdrop of traditional insurance struggling to overcome these limitations, index insurance has gradually emerged as an important avenue for exploration in developing countries’ efforts to adapt to climate change. The operational logic of index insurance is completely different from that of traditional insurance: It pre-sets “trigger Indexs” highly related to disaster losses. When the monitoring data reaches the preset threshold, the insurance company does not need to verify the actual losses and directly pays the compensation to the policyholder - this mechanism fundamentally solves the core pain point of traditional insurance [2]. On the one hand, index insurance provides protection against systemic risks, and with its low administrative cost, it is also a complementary tool for traditional indemnity-insurance products. On the other hand, index insurance generally is not prone to the moral hazard and adverse selection problems, which are considered to impede the development of insurance.

In this essay, we concern about whether index insurance can truly become an effective tool for developing countries to adapt to climate change, mainly focusing on its performance on economic effectiveness and social distribution. As some insurance studies in developing countries, insurance has been proven to effectively reduce the financial risks faced by vulnerable families. What’s more, it also makes positive contributions to local economic growth and financial independence, which confirms the economic value of insurance tools [3]. Index insurance, through its unique mechanism, is expected to achieve the above-mentioned economic goals with higher efficiency. Theoretically, index insurance has the potential to become a universal risk management tool. However, if its design and implementation ignore the dimension of social equity, it will fail to help the poor and also pose a higher risk of exacerbating social inequality and excluding the poorest farmers [4]. While it is often asserted that index insurance is a product born of the pursuit of fairness, does it actually embody fairness in terms of its coverage and target groups. Therefore, for this study, fairness and effectiveness are indispensable cornerstones for evaluating the overall effectiveness of index insurance.

2. Methodology

2.1. Research questions

This study centers on the core proposition of “whether index insurance is effective in promoting the adaptation of developing countries to climate change”, and conducts a systematic exploration by combining the dual dimensions of economic effectiveness and social distribution.

Previous studies have focused on the practical application of index insurance in developing countries, mainly exploring its role in the affordability and sustainability directions for the poor in developing countries [2,5]. It has become an outstanding method for managing climate vulnerability in the most vulnerable regions such as South Africa. However, there are still problems such as low

demand and inaccurate loss compensation [6]. Some have already paid attention to the feasibility of index insurance in mitigating the impacts of climate change, involving the role of weather insurance and other insurances as climate insurance risk management tools for vulnerable agricultural communities [7]. The research mainly focuses on the environmental effects, while another part pays attention to the impact of agricultural index insurance on farmers' perceptions of benefit and equity in developing countries [5]. This aligns closely with my research direction, though it emphasizes more on farmers' willingness to pay a risk premium rather than the effectiveness of existing index-based insurance products.

Firstly, from the perspective of economic efficacy, it is essential to critically examine the substantive role of index insurance within climate risk response frameworks in developing countries. Key inquiries include: Does index insurance demonstrate a statistically significant advantage over traditional indemnity-based insurance in mitigating transaction costs, moral hazard, and adverse selection? Furthermore, does its rapid loss-assessment and payment mechanism substantively shorten post-disaster recovery cycles for agricultural producers and micro-enterprises, thereby reducing disaster-induced poverty vulnerability and stabilizing long-term production expectations? Another crucial dimension involves evaluating whether the market-driven risk transfer inherent in index insurance effectively alleviates fiscal pressure on governments and enhances allocative efficiency in climate adaptation, thereby circumventing the inefficiencies associated with conventional post-disaster fiscal interventions.

Secondly, regarding social distributive outcomes, this research assesses the capacity of index insurance to ameliorate disparities in climate risk burden across vulnerable populations. Central to this inquiry is whether the product's structural features, such as lower premium costs and simplified underwriting, enable extended coverage to traditionally excluded groups, including low-income households, smallholder farmers in remote regions, and rural women, thereby advancing inclusive risk protection. Empirical investigation is needed to determine whether payouts are effectively directed toward high-vulnerability groups, improving their loss-compensation ratios and mitigating the regressive effects of climate risk. Additionally, the study must confront operational challenges such as basis risk and limited consumer awareness, analyzing the extent to which these factors undermine both economic performance and distributive equity, and consequently, the overall feasibility of index insurance in developing economies.

2.2. Research approach

This paper reviewed the recently published empirical evidence on the application practice of index insurance in developing countries. This intervention measure was selected as the research subject because it aims to transfer climate risks through market mechanisms and enhance the resilience of small-scale agricultural systems. Moreover, it has become a key innovative tool that international development agencies, academia, and the insurance industry continuously focus on, invest in, and evaluate in the field of climate adaptation. Our analysis of the evidence mainly considers studies published in both Chinese and English within the last fifteen years (2008-2023), which must meet the following requirements: (a) Directly explore the economic or social impact paths of index insurance, (b) provide empirical evidence based on original analysis (quantitative or qualitative), and (c) clearly target the agricultural sector or low-income groups in developing countries. Candidate literature is determined through the following methods: Combine systematic keyword search (using terms such as "Index insurance", "economic effectiveness", and "social equity" in databases such as Web of Science, Scopus, and CNKI), retrospective search of known key literature, and the author's continuous tracking of research trends in related fields.

Based on the analytical framework established in this study - that is, to evaluate the effectiveness of index insurance from the two core dimensions of “economic effectiveness” and “social distribution”, we map the evidence extracted from each study that meets the inclusion criteria to the following specific categories:

In the dimension of economic effectiveness, we focus on: (a) the advantages over traditional insurance in reducing transaction costs and alleviating governmental fiscal pressure; (b) Shortening the post-disaster recovery period and reducing the poverty rate caused by disasters; (c) The effect of mitigating moral hazard and adverse selection. In the dimension of social distribution, we focus on: (a) the coverage of low-income and highly vulnerable groups (inclusiveness); (b) The fairness of the distribution of compensation results among different groups (such as the loss compensation rate); (c) The mitigating effect on the traditional phenomenon of unfair risk allocation.

We simultaneously identified the countries and regions involved in each study, the types of agricultural systems, and the main challenges faced (such as basis risk and cognitive threshold). We systematically summarized the number and distribution of studies reporting the above-mentioned types of evidence, and conducted an overall subjective assessment of the strength of evidence in each dimension.

3. Economic effectiveness of index insurance

3.1. Reduced costs

Claim settlement was a bottleneck in the underdeveloped stage of the insurance market because there were not enough skilled and experienced experts to handle claims settlement for traditional compensation insurance, such as specific or multi-disaster crop insurance. Breakthroughs in satellite technology have expanded its key application scenarios - insurance companies have been able to break through geographical limitations and assess disaster damage in remote islands, mountainous areas and other regions where traditional loss assessment is difficult to cover, significantly enhancing the geographical accessibility of climate risk protection. However, the cost of assessing risks in traditional compensatory insurance is higher than that in index insurance. This is because traditional insurance requires an on-site loss assessment for individual farmers after each disaster, while index insurance only relies on objective and pre-agreed environmental indices for compensation, without the need for post-event investigations, thereby significantly reducing transaction and operational costs. In recent years, both public and private sectors in Asian countries have begun to pilot insurance to reduce the risks faced by vulnerable rice farmers. Among them, the index insurance projects in Kenya and Ethiopia have passed the conceptual and pilot stages. Marketing, supervision, design and application is underway, can provide a lot of information for review and discussion [8]. The spirit of index-based insurance is transparency, where the underwriting company offers the same policy in a certain area. The losses are calculated based on Index, so the cost of claim settlement can be significantly reduced. Take the production of dry beans in Honduras as an example. Rainfall index insurance has effectively reduced transaction costs, overcome management costs, decreased farm losses, and helped small-scale farmers manage drought risks effectively [9]. Take Thai sugarcane as an example. In the rainfall index insurance, the insurance pays compensation based on the rainfall amount according to the standards stipulated in the contract, simplifying the compensation process. Therefore, the compensation amount is not related to the actual loss of the individual, effectively reducing the cost of disaster investigation [10].

3.2. Enhanced payout efficiency

The development of index insurance provides an important foundation for the innovation of predictive insurance models. By associating specific climate or environmental indices with the high risk of future natural disasters, index insurance can trigger the compensation mechanism before the disaster actually occurs. This forward-looking compensation method benefits policyholders, especially farmers. Small and micro enterprises and local governments can obtain financial support before disasters strike, thus taking protective measures in advance and reducing potential property and economic losses [11]. Prompt access to funds is especially needed in developing countries where low-income farmers are vulnerable to short-term liquidity gaps. Omar and other scholars have pointed out that agricultural supply chains are inherently vulnerable to natural disasters such as earthquakes and floods. To address this vulnerability, they proposed a crop index insurance framework based on private blockchains. This plan is expected to significantly shorten the processing time of insurance claims, reduce transaction costs, and at the same time enhance the transparency and trust relationship between farmers and insurance companies [12].

3.3. Alleviated moral hazard and adverse selection

Index insurance, based on its compensation mechanism, fundamentally curbs moral hazard and adverse selection. Farmers cannot manipulate the actual amount of loss because the compensation is based on an independent index rather than the actual loss of crop yield, relying on an open, transparent, and non-manipulable independent index by individuals. Combining credit with index insurance policies is an effective way to access the credit market for small-scale farmers in developing countries nowadays. This study proves that index insurance bundled with loan contracts can reduce moral hazard and improve the welfare of borrowing [13]. In alleviating the problem of adverse selection, traditional insurance often encounters an adverse selection predicament where high-risk groups actively participate while low-risk groups are reluctant to do so due to information asymmetry. Index insurance, however, breaks this deadlock through the design of unified index and unified premium and all policyholders within the same area are subject to the same trigger index and premium standards. Regardless of individual risk differences, the compensation rules are completely transparent and uncontrollable. This de-differentiation mechanism enables high-risk and low-risk groups to be included in the same insurance pool, avoiding excessive concentration of risk groups, effectively balancing the risk structure, and providing a foundation for stable premiums [14].

3.4. Limitations, controversies, and neutral outcomes

The long-term financial feasibility of index-based insurance is facing widespread skepticism from industry experts, with the core contradiction stemming from the fact that the pace of climate risk escalation far exceeds expectations: The frequency of current extreme weather events has far exceeded the prediction models of ten years ago, directly leading to a persistently high payout frequency of index insurance, which in turn has triggered a chain reaction of passively pushing up premiums. As a result, some early practice projects have fallen into an unsustainable predicament. According to World Economic Forum, a typical example is the Kenya Livestock Insurance Plan, which paid out a total of 1.2 billion Kenyan shillings (approximately 8.8 million US dollars) to drought-stricken herders from 2015 to 2021. However, the total premium income during the same period was only 1.1 billion Kenyan shillings (approximately 8.1 million US dollars), remaining in a

long-term loss-making state. It was eventually replaced this year by a new plan that integrates insurance and financial savings functions, becoming a direct example of financial unsustainability.

From the current development pattern, index insurance plans in developing countries still highly rely on external subsidies from non-profit organizations, their own governments or high-income countries. Although most projects expect to achieve the sustainable goal of “policyholders bear the majority or even all of the premiums themselves”, the continuous deterioration of extreme weather is gradually deviating this vision from reality. As Viktor Roezer, a resilience researcher at the London School of Economics and Political Science, pointed out, escalating climate risks may make it difficult for such insurance plans to break away from their reliance on subsidies and eventually turn them into “disguised aid projects”. Against this backdrop, the expert group began to re-examine the core operational mechanism of index insurance - including appropriate implementing agents, precise risk definition and dispersion paths, and the logic of risk pool construction, etc. Even though index insurance has been attempted to be incorporated into a broader welfare security and humanitarian intervention system, aiming to enhance stability by expanding coverage, the current largest risk pool still faces operational difficulties. This phenomenon profoundly reveals: If the core conditions for providing protection to global climate risk reverse selectors cannot be fundamentally adjusted, the goal of “risk democratization” pursued by index insurance may be difficult to truly achieve [6].

4. Social distribution of index insurance

4.1. Targeted subsidies for high-vulnerability groups

Index insurance can effectively expand the coverage of risk protection, incorporating groups that were previously excluded due to the “high cost and high threshold” of traditional insurance into the protection system. It fills the gap in risk protection for rural vulnerable groups and provides a reliable barrier for them to resist agricultural disaster risks. In the field of agricultural risk management, researchers conducted a series of in-depth field trials on a total of 344 households in Heilongjiang Province in Northeast China and Jiangsu Province in East China. These experiments provide key empirical evidence for revealing the risk management behaviors of farmers in different regions. As detailed in relevant studies, the research results clearly show that farmers in the two regions are more inclined to choose weather index insurance rather than rely on informal risk management strategies [15]. This research further confirmed the significant correlation between the influence of farmers' characteristics on the choice of risk management strategies. Factors such as the area of cultivated land, the diversity of crop cultivation, and the ability to access credit of farmers will all affect their choice of risk management tools. Among them, small-scale farmers, as a typical vulnerable group, often face more obstacles in the traditional risk management model due to limited resource reserves and narrow information acquisition channels - such as high premiums and complex terms of traditional agricultural insurance, which are difficult for small-scale farmers to afford or understand. Index insurance, with its characteristics of low cost and standardization, provides such groups with more accessible and cost-effective risk solutions. Singh's study pointed out that WII has emerged as a critical risk management tool for agricultural communities in vulnerable regions. By providing a financial safety net against climate-related shocks, WII enhances farmers' ability to cope with droughts, floods, or other extreme weather events, thereby supporting livelihood stability and food security. Particularly in low-income region, where traditional insurance is often inaccessible because of high costs and operational complexities, WII offers a more feasible

alternative, and it also links payouts to predefined environmental index rather than individual loss assessments [7].

4.2. Rebalanced risk allocation

The effectiveness of index insurance in rebalancing risk allocation has been verified in multiple empirical studies. The core of this rebalancing lies in effectively transferring and diversifying the climate and production risks, which highly concentrated on individual farmers through financial tools. And it can greatly enhance the overall resilience of the agricultural system. In the field of crop production, the value of index insurance is particularly reflected in its synergy with other agricultural intervention measures. Research indicates that, in developing countries, when index insurance is implemented in conjunction with irrigation facilities, a dual protection mechanism for infrastructure security and financial risk hedging is formed. Crop insurance, which not only effectively increases farm income, but also significantly reduces the downside income risk. Also, it ensures the stability of farmers' livelihoods [16]. Similarly, in the livestock industry, the scale-up of index insurance is a key factor in balancing risk distribution. Research has confirmed that policies and investments aimed at promoting the scale-up of index livestock insurance can significantly improve climate risk management in sub-Saharan Africa. When the insurance coverage rate reaches a certain scale, it effectively promotes the overall improvement of the welfare level in the region by stabilizing the income of herdsman and reducing the downside risks brought by shocks such as drought [17]. The increase in its coverage rate can effectively reduce the negative impact that many families suffer from major drought shocks. Moreover, it can significantly lower the downside risk to their income and wealth, enabling more farmers to have stronger buffering and recovery capabilities facing climate uncertainties.

4.3. Limitations, controversies, and neutral outcomes

Although index insurance has great potential in rebalancing risk allocation, its design and implementation still have some limitations and unintended consequences, especially when facing some severe challenges in terms of fairness, social dynamics and technical defects.

First of all, based on Indexed Livestock Insurance (IBLI) and Agricultural Climate Risk Enterprise Take products like Africa (ACRE), there may be a deep gap between the inclusive goal of index insurance and its actual effect, and can raise serious fairness questions. Although they are designed to cover vulnerable small-scale farmers, who are excluded by traditional insurance, empirical research shows that the distribution of their benefits is not balanced. As a risk management tool, IBLI is targeted at the poorest groups. Herders with the meager assets benefit the least, as their extremely low payment capacity and high tolerance for basis risk result in a low participation rate. On the contrary, this tool provides more effective protection for wealthier herders with more assets and stronger risk tolerance [4]. This paradox highlights the difficult trade-offs policymakers face when integrating social equity, business sustainability and climate risk management goals, and there is no simple solution.

Moreover, beyond financial mechanisms, the introduction of index insurance can inadvertently undermine social security. Research based on field experimental data from the Tigray region in northern Ethiopia, indicates that the purchase of WII may have a negative impact on social capital, when farmers turn to relying on formal insurance products to manage risks. And it may also weaken the traditional risk-sharing mechanism and informal mutual assistance behaviors within the

community, which can potentially undermine the social network that acts as the foundation of resilience in poor rural communities [18].

Finally, the inherent limitations of index insurance fundamentally hinder their development. The biggest challenge is Basis Risk, which means the index measurement does not match the policyholder's actual loss. This risk directly limits how much insurance can reduce risk, which may also seriously hurt farmers' trust in insurance products. In addition, standard index insurance only covers weather-related Covariate risks and does not cover the specific risks of individual farms. Research indicates that this may introduce compensation differences within communities: adjacent farms encountering the same weather event may receive vastly different compensation results due to different satellite pixels. This phenomenon, which is regarded as unfair, may trigger social conflicts and further dampen insurance demand [19,20].

5. Conclusions

Based on the findings of this study, to maximize the effectiveness of index insurance in promoting climate change adaptation, I propose the following three core suggestions. This paper aims to conduct my suggestions and conclusions from three dimensions: technical precision, implementation model, and product design.

First of all, favorable policies should be strengthened, and investment in this area should also be increased, to better support the integration of cutting-edge data science and technology into insurance product design. Nowadays, some advanced studies have proposed a novel risk assessment methodology based on data-driven methods, such as SVD technology and POERs risk indicators. They combine subsidies, which are provided by the public and private sectors, with close farmer partnerships. This method has jointly led to the better development and wider application of index insurance. Furthermore, applying artificial intelligence technologies to optimize the design of insurance contracts, such as Neural Networks, can also capture the complex non-linear relationship between weather and losses. The application of Neural Networks in pricing has promoted the process of premium pricing and reduced the costs for farmers to some extent. At the same time, index insurance based on satellite remote sensing, has gradually come into view in recent years. Compared with traditional index insurance, it can provide higher-resolution data, which more accurately indicates the risk level, and performs better, especially for some perennial crops.

The success of index insurance does not rely solely on the insurance company. It is also necessary to cultivate a diversified cooperation network, which encompasses the public sector, private enterprises, technology providers (TSPS), aggregators, agricultural extension agencies, agricultural product distributors and non-governmental organizations. In the ecosystem, the public sector can catalyze the market by providing initial subsidies and data support, and some private enterprises, such as seed and acquisition companies, can bundle insurance with their core products and services to reduce distribution costs. Also, some technical institutions, indispensable parts of the ecosystem, provide data optimization and platform support. This complete ecosystem model can efficiently integrate resources and naturally optimize farmers' cultivation and production decisions.

Product design must be based on a profound understanding of human nature and social dynamics. Some studies have shown that more comprehensive insurance coverage not only better protects farmers' livelihoods, but also enhances their perception of fairness. It can effectively enhance their willingness to pay and avoid social conflicts caused by differences in neighborhood compensation. Therefore, product design should be committed to expanding the scope of risk coverage and provide targeted coverage of vulnerable areas. Additionally, it is also significant to minimize basis risk as much as possible within the limits of technology, and maintain a high degree of transparency in

terms and compensation rules. Undoubtedly, when an index insurance product is well-designed and can avoid information asymmetry, it could be a highly feasible risk management tool.

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