The Market Equilibrium Model of Weather Index Insurance

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Abstract: Changes in weather patterns, an increase in the frequency of extreme weather events, and other effects of climate change pose significant threats to farmers' ability to sustain their livelihoods in the agricultural sector. Crop insurance has emerged as an efficient and valuable tool for farmers, with Weather Index Insurance (WII) schemes gaining popularity in rural areas as a cost-effective means of managing risks such as production losses due to adverse weather conditions. WII facilitates quicker recovery from crop losses and reduces the risk of loan defaults by providing timely and accurate payouts in response to weather events. Despite the numerous advantages of WII, access remains inadequate due to unaffordable premiums and the non-receipt of expected compensation, leading to lower insurance uptake among farmers. This study proposes a utility-based equilibrium model for WII, analyzing the supply, demand, and risk preferences of farmers and insurers. Additionally, the study explores the effects of premium subsidies on market dynamics.

Keywords: *Equilibrium Model, Premium Subsidies, Risk Aversion Coefficient, Weather Index Insurance.*

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I. INTRODUCTION

Agriculture is the backbone of the economy for millions of people across the globe, particularly in rural areas of developing countries. Many of these individuals rely on farming as their primary source of income and food security. However, the agricultural sector is inherently vulnerable to various risks, making it difficult for farmers to maintain stable livelihoods. As Blome [1] points out, these risks originate from multiple sources, including natural disasters, fluctuations in market demand, supply chain disruptions, legal or regulatory changes, and broader economic downturns. Each of these factors can have profound consequences for farmers and agribusinesses, requiring strategic planning and risk management to minimize adverse effects. One of the most pressing challenges for modern agriculture is climate change. The shifting patterns of temperature, precipitation, and seasonal variability pose serious threats to farming operations. Additionally, the frequency and intensity of extreme weather events—such as droughts, floods, hurricanes, and heatwaves have increased in recent years. These environmental disruptions can reduce crop yields, damage infrastructure, and lead to significant financial losses for farmers.

Furthermore, climate change exacerbates existing vulnerabilities by influencing pest outbreaks, soil degradation, and water scarcity. In regions already prone to resource limitations, these issues can make agricultural activities even more precarious. Without effective adaptation strategies, farmers may struggle to sustain their production levels, leading to food shortages, economic instability, and increased poverty. Apart from environmental risks, market-related uncertainties also impact the agricultural sector. Sudden changes in consumer demand, price volatility, and competition from large-scale agribusinesses can reduce small farmers' profitability. Supply chain disruptions, whether due to logistical failures, political instability, or pandemics, can further hinder farmers' ability to sell their products and obtain necessary inputs such seeds, fertilizers, and machinery. Crop insurance serves as an efficient and useful tool for farmers in this situation. [3]

Crop insurance tries to protect farmers from financial losses caused by numerous natural variables such as weather events and pest infestations that reduce crop output. The World Bank [3] and the Food and Agriculture Organization (FAO) (2011) [4] have identified two main types of crop insurance: traditional insurance and index insurance. Traditional insurance, particularly in agriculture, tends to have a sophisticated personal risk analysis for purposes of determining coverage and premiums. This approach has several drawbacks, including high administrative costs, limited coverage options, and a lack of flexibility to meet the needs of farmers. Index-based microinsurance is an affordable risk management tool for small-holder farmers with limited government involvement [5]. In recent years, index-based

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insurance has gained popularity as an effective risk management tool in various industries. As highlighted by Shen and Odening [6], index-based insurance has become more popular recently since it may be a useful tool for risk management across a wide range of businesses. Using an index to determine the events that trigger coverage, index-based insurance can reduce transaction costs associated with traditional insurance, which is often based on individual risk assessments. [6], this type of insurance leverages an index to identify events that trigger coverage, thus streamlining the process and reducing the transaction costs typically associated with traditional insurance, which relies on individual risk assessments.

WII is an innovative financial tool designed to help farmers manage the risks associated with weather related uncertainties. Unlike traditional insurance, where payouts are determined based on an assessment of actual crop damage, WII relies on objective weather indices, such as rainfall levels, temperature fluctuations, or drought conditions to trigger compensation. This approach eliminates the need for costly and time-consuming damage assessments, allowing for quicker and more transparent claim settlements. One of the key benefits of WII is its ability to provide farmers with a financial safety net in the face of unpredictable weather events. By ensuring timely and accurate payouts, WII enables farmers to recover more quickly from crop failures, maintain their livelihoods, and reinvest in the next planting season. This financial stability helps to reduce the likelihood of loan defaults, making it easier for farmers to access credit from financial institutions. Additionally, WII encourages the adoption of modern agricultural practices, as farmers are more willing to invest in improved seeds, fertilizers, and irrigation systems when they have a reliable risk management mechanism in place. Furthermore, WII can play a crucial role in enhancing food security and economic resilience in rural communities. When farmers are better protected against weather-related losses, they can sustain agricultural production levels, reducing the risk of supply shortages and food price volatility. This stability benefits not only individual farmers but also the broader economy, as agriculture is often a major contributor to GDP in developing countries.

However, despite these advantages, WII has some challenges, one of the most significant being basis risk. Basis risk arises when the weather index used to determine payouts does not perfectly match the actual losses experienced by the farmer. This can happen due to several reasons, such as the distance between the farmer’s field and the weather station or the use of general weather data that may not accurately capture localized conditions. As a result, a farmer may experience severe crop losses but receive no payout if the weather index does not trigger a claim, or conversely, receive a payout despite minimal or no actual damage. This misalignment can reduce farmers’ trust in WII and discourage participation in the program. In addition, existing studies indicate that access to WII remains limited due to factors such as high premium costs, lack of awareness, and dissatisfaction with claim settlements. Many farmers, particularly smallholders, perceive the premiums as unaffordable, leading to lower adoption rates. Concerns about the accuracy of weather indices and the non-receipt of expected compensation further hinder trust in the system.

While much research has focused on the demand for WII, there has been relatively little attention paid to the supply side. Understanding the challenges faced by insurance providers such as pricing strategies, risk modeling, and government policy support is essential for expanding WII coverage and improving its effectiveness. Addressing both the demand and supply aspects, along with strategies to reduce basis risk, can help bridge the gap between farmers and insurers, ultimately making WII a more accessible and impactful tool for agricultural risk management. Therefore, it is essential to introduce an equilibrium model for the WII. The term "equilibrium point" refers to the point at which the insurance’s expected payout and premium cost are equal, allowing both farmers and insurance companies to continue to make a profit while, the insurance offers an adequate level of protection against weather-related risks.

The interactions between farmers, insurers, and markets can be considered by the equilibrium model to determine the best design and cost of WII. This can support the effective distribution of risk in the agricultural sector and help to ensure that insurance is both financially viable for insurers and affordable for farmers. By analyzing how insurance influences farmers’ investment and decision-making behavior, the equilibrium model can be used to evaluate the effect of WII on agricultural productivity. The equilibrium model can be used to understand the role of WII in poverty reduction and rural development by analyzing how insurance can be used to stabilize farmers’ incomes and encourage investment in agricultural activities. Further by providing premium subsidies, governments or other entities can make WII more accessible to farmers, thereby increasing the likelihood that they will purchase the insurance and ultimately reducing their financial vulnerability to weather-related risks.

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purchase the insurance and ultimately reducing their financial vulnerability to weather-related risks.

II. LITERATURE REVIEW

Agricultural insurance has been a critical tool for managing risks in the agricultural sector. Various studies have explored different aspects of agricultural insurance, including its implementation, challenges, and innovations. Blome [1] provides a foundational understanding of insurance principles, which is essential for comprehending more complex insurance mechanisms. Singh [2] discusses the specific context of crop insurance in India, highlighting the challenges and opportunities in implementing such schemes in a developing country.

Clarke [27] presented a model of rational demand for indexed products. This study provided a numerical example indicating that the overall level and pattern of demand for weather derivatives among poor farmers may align with a rational demand model. This finding helps explain two key empirical puzzles without relying on behavioral preferences or credit constraints. Gebre [28] examines the willingness to pay for weather index insurance in rural Ethiopia. The study utilized data from the 2009 Ethiopian Rural Household Survey conducted by the International Food Policy Research Institute. The findings indicated that households with lower risk aversion are more willing to pay for the insurance compared to highly risk-averse households. However, this trend does not hold consistently across all risk categories.

The implementation of index-based crop insurance is often challenged by the presence of systemic risk associated with insured losses. The [6] evaluated two approaches to managing systemic risk: regional diversification and securitization through catastrophe (CAT) bonds. The analysis is conducted within an equilibrium pricing framework, which determines the optimal insurance price, and the number of contracts traded. Additionally, the study examined the impact of basis risk and the risk aversion of market participants. The model is applied to a hypothetical area yield insurance scheme for rice farmers in northeast China. The findings suggest that when yields in two regions are positively correlated, expanding the insured area results in higher insurance premiums. However, unless capital market investors exhibit high risk aversion, a CAT bond linked to an area yield index proves more effective than regional diversification in enhancing the certainty equivalents for both farmers and insurers.

A weather index insurance (WII) product was designed, priced and evaluated for beans and maize farmers of the Brazilian semiarid region by Lavorato [29]. The analyzed municipalities were chosen according to the results obtained in the previous study in order to mitigate the hazard of basis risk, being later divided in three groups according to geographical proximity. Sass and Seifried [30] analyzed the effects of mandatory unisex tariffs in insurance contracts, such as those required by a recent ruling of the European Court of Justice, on equilibrium insurance premia and equilibrium welfare. In a unified framework, the study provided a quantitative analysis of the associated insurance market equilibria in both monopolistic and competitive insurance markets. Additionally, the study investigated the welfare loss caused by regulatory adverse selection and showed that unisex tariffs may cause market distortions that significantly reduce overall social welfare.

III. METHODOLOGY

➢ *Theoretical Framework*

We consider the insurance market characterized by N number of farmers living in the same region on the demand side and a single insurance company on the supply side and, assume a two-period economy. The described approach consists of a two-period model in which agents (farmers and insurance company) make optimal portfolio choices at t=0 based on the expected utility of terminal wealth. At t = 0, agents buy and sell endogenous quantities of index- based insurance to maximize their expected utility. At t = 1, the value of the index, the yield of the crop, and the payout are all realized, and agents cannot sell the insurance contracts they bought because there is no liquid secondary market for the contracts. The absence of a secondary market means that the agent’s portfolio choice at t = 0 has long-run effects on its wealth. The method aims to identify participants’ optimal portfolio choices that maximize the expected return on their terminal assets.

In this model, the revenue is composed of the yield of the crop, which is the income generated from selling the crops, and the benefit payment from the WII, which is the payout received from the insurance company. The premium is the cost of the insurance, and the interest rate is the rate at which the premium is compounded over time. A ith farmer’s revenue R in a particular region at t = 1 is defined as follows:

$$R_i = Y_i + \alpha_i\theta(I) - \pi(1+l) ----(1)$$

Where Y_i denotes the yield of i^{th} farmer, α_i is the amount of insurance to be purchased at price π. $\theta(I)$ is Stochastic payoff based on index I and l is the interest rate.

The Profit of the insurance company is defined as follows:

$$S = \beta\pi(1+l) - \beta\theta(I) ----(2)$$

β is the number of insurance contracts the insurer is willing to supply.

The primary objective of this model is to identify the market equilibrium for WII. Therefore, farmers must determine the best portfolio options to maximize the expected utility of their income while considering market limits. In this model, it is considered that all farmers are non-homogeneous, and everyone has unique characteristics, preferences, and behavioral patterns. These

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variations may be attributed to things such as farm size, the crops raised, risk tolerance, financial status, and insurance requirements. Since we focus on production risk, the output price is assumed to be constant and normalized to unity. Product diversification of farmers for different income sources is not considered.

The expected utility maximization problem of i^{th} farmer is then given by,

$$max_{\alpha_i} \geq \left[E\left(-exp^{-\lambda_f\left(Y_i+\ \alpha_i\theta(I)-\pi(1+l)\right)}\right)\right]----(3)$$

λ_f= risk aversion coefficient of farmer

The expected utility maximization problem of the insurer is then given by,

$$max\left[E\left(-exp^{-\lambda_s\left(\beta\pi(1+l)-\ \beta\theta(I)\right)}\right)\right]----(4)$$

λ_s= risk aversion coefficient of the insurer

By maximizing the expected utility of the farmer and the insurer, the model predicts the optimal demand for the WII and the price of insurance that insurers will charge based on expected weather conditions and expected premiums. Since the revenue of farmers and the profit of the insurance company is normally distributed, maximizing the expected utility is equivalent to maximizing the linear certainty equivalent (CE) which is,

$$CE = E(R) - \frac{\lambda}{2}\sigma^2_{\theta(I)}$$

E(R) denotes expected value of the Revenue and $\sigma^2(R)$ denotes the variance of the Revenue.

In this equilibrium model, the farmers' preference for risk is modeled by the certainty equivalent function. It symbolizes the lowest amount of anticipated return for which farmers are willing to accept particular hazards. Given expected weather and insurance costs, a certainty equivalent function can be used to determine farmers' preferred insurance coverage. Insurance companies can then use this information to establish the optimal pricing structure for the policy and ensure it is economically viable and accessible to farmers.

- *Equilibrium pricing model*

Based on the assumption that investors are risk averse, they would prefer a portfolio with lower volatility (variance) to one with higher volatility, given that both portfolios have the same expected return. The mean-variance approach is a mathematical tool used to determine how an investment portfolio balances risk and return. This strategy can be used to simulate investor behavior even if they have various risk preferences and their returns follow different distributions because it has received wide acceptance as a good approximation under more generic utility functions and distribution assumptions.

In the mean-variance framework optimal demand of an individual farmer for purchasing WII is,

$$\alpha_i = max\left[0, \frac{E\left(\theta(I)\right) - \ \pi(1+l) - \ \lambda_f cov(Y_i, \theta(I))}{\lambda_f \sigma^2_{\theta(I)}}\right] ----(5)$$

The optimal demand of farmers increases with an increase in expected indemnities, while the optimal demand decreases with an increase in the insurance premium. Basis risk also affects the demand for insurance, which is captured by the covariance term. Since hedging is impossible, it is assumed that there is a negative correlation between compensation and revenue generation. The greater the absolute covariance, the lower the farmer's basis risk and the higher the insurance demand.
In a mean-variance framework, the optimal supply of an insurer selling WII is,

$$\beta = max\left[0, \frac{\pi(1+l) - E(\theta(I))}{\lambda_s \sigma^2_{\theta(I)}}\right]----(6)$$

Equilibrium in the insurance market requires that aggregate demand equals supply, i.e.,

$$\sum_{i=1}^{N} \alpha_i = \beta --- (7)$$

Applying the market clearing condition Eqa (7) allows us to derive the equilibrium price and quantity:

$$\pi = \frac{1}{1+l}\left[E\left(\theta(I)\right) - \frac{\lambda_f \lambda_s \sum_{i=1}^{N} cov(Y_i, \theta(I))}{\lambda_f +\ \lambda_s N}\right]--(8)$$

Demand of an individual farmer,

$$\alpha_i = \frac{\frac{\lambda_f \lambda_s \sum_{i=1}^{N} cov(Y_i, \theta(I))}{\lambda_f +\ \lambda_s N} - \ \lambda_f cov(Y_i, \theta(I))}{\lambda_f \sigma^2_{\theta(I)}}--(9)$$

Total demand for WII,

$$\beta = \frac{-\lambda_f \sum_{i=1}^{N} cov(Y_i, \theta(I))}{\lambda_f \sigma^2_{\theta(I)}}--(10)$$

The market equilibrium does not depend on all N farmers. The above equations show that it is solely dependent on farmers who purchase a positive number of insurance contracts. Eqa (8), Eqa (9) and Eqa (10) demonstrate that the equilibrium price is influenced by the covariance between production income and insurance benefit payment, as well as the risk aversion of both farmers and insurers. In turn, this raises both the equilibrium price as well as the total demand for the WII insurance.

- *Effect of Premium Subsidies to The Market Equilibrium*

In the context of WII, a "premium subsidy" is financial assistance given by the government or another organization to lower the cost of insurance for farmers. The premium subsidy's goal is to lower the cost of WII and increase access to WII for farmers, particularly those with

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low incomes or significant agricultural risk. The overall impact of premium subsidies on WII depends on factors such as market competition, the availability of alternative risk management tools, and the extent of government support.

In order to consider the effect of premium subsidy on equilibrium, one more parameter is added to the revenue function of the farmer. To represent the pro- portion of the premium that is subsidized, we introduce a subsidy rate s where, 0 <= s <= 1. If s = 0, there is no subsidy (the farmer pays the full premium). If s=1, the entire premium is subsidized (the farmer pays nothing).

Thus, the effective premium paid by the farmer becomes (1-s) π. Accordingly, at this point A i^{th} farmer's revenue R in a particular region at time t = 1 is defined as,

$$R_i = Y_i + \alpha_i \theta(I) - (1-s)\,\pi(1+l) - - - - (11)$$

The model assumes that the premium subsidy does not have any effect on the profit of the insurance company. To crate this model, all the assumptions are considered which, is used to build the equilibrium model without premium subsidies. By assuming that farmers have an exponential utility function, the expected utility maximization problem of i^{th} farmer is then given by,

$$max_{\alpha_i} \geq \left[E\left(-exp^{-\lambda_f\left(Y_i + \alpha_i \theta(I) - \pi'(1+l)\right)}\right)\right] - -(12)$$

In the mean-variance framework optimal demand of an individual farmer purchasing WII is,

$$\alpha_i = max\left[0, \frac{E\big(\theta(I)\big) - (1-s)\pi(1+l) - \lambda_f cov(Y_i, \theta(I))}{\lambda_f \sigma^2_{\theta(I)}}\right] - - - - (13)$$

Applying market clearing condition Eqa (7) allows us to derive the equilibrium price and quantity:

$$\pi^* = \frac{(\lambda_f + \lambda_s N)}{(1+l)(\lambda_f + (1-s)\lambda_s N)}\left[E\big(\theta(I)\big) - \frac{\lambda_f \lambda_s \sum_{i=1}^{N} cov(Y_i, \theta(I))}{\lambda_f + \lambda_s N}\right] - -(14)$$

Demand of an individual farmer,

$$\alpha^* = \frac{1}{\big(\lambda_f + (1-s)\lambda_s N\big)\sigma^2_{\theta(I)}}\left[sE\big(\theta(I)\big) + \lambda_s \sum_{i=1}^{N} cov\big(Y_i, \theta(I)\big) - \big(\lambda_f + (1-s)\lambda_s N\big)cov\big(Y_i, \theta(I)\big)\right] - -(15)$$

Total demand for WII,

$$\beta^* = \frac{sE\big(\theta(I)\big)N - \lambda_f \sum_{i=1}^{N} cov(Y_i, \theta(I))}{\big(\lambda_f + (1-s)\lambda_s N\big)\sigma^2_{\theta(I)}} - - - - (16)$$

In this scenario, the market equilibrium relies on all N farmers. The Eqa (14), (15), and (16) demonstrate that the equilibrium price is influenced by the covariance between production income and insurance payouts, as well as the risk aversion of both farmers and insurers. In turn, this raises both the equilibrium price as well as the demand for the insurance.

IV. RESULTS AND DISCUSSION

- *Equilibrium Model of WII*

For the practical approach, we considered 100 farmers, and to simplify the model they were grouped into 10 groups according to their characteristics such as farming practices, land quality, and crop yield assuming that each group includes farmers who have slightly equal characteristics. Eqa (9) shows that different groups have different amounts of insurance to be purchased at price π for WII. It means that the individual demand for the WII varies for the different groups. The relationship between the risk aversion coefficient of the farmer and the individual demand can be seen in Figure 1. There are 10 subplots, and each subplot belongs to a randomly selected revenue group.

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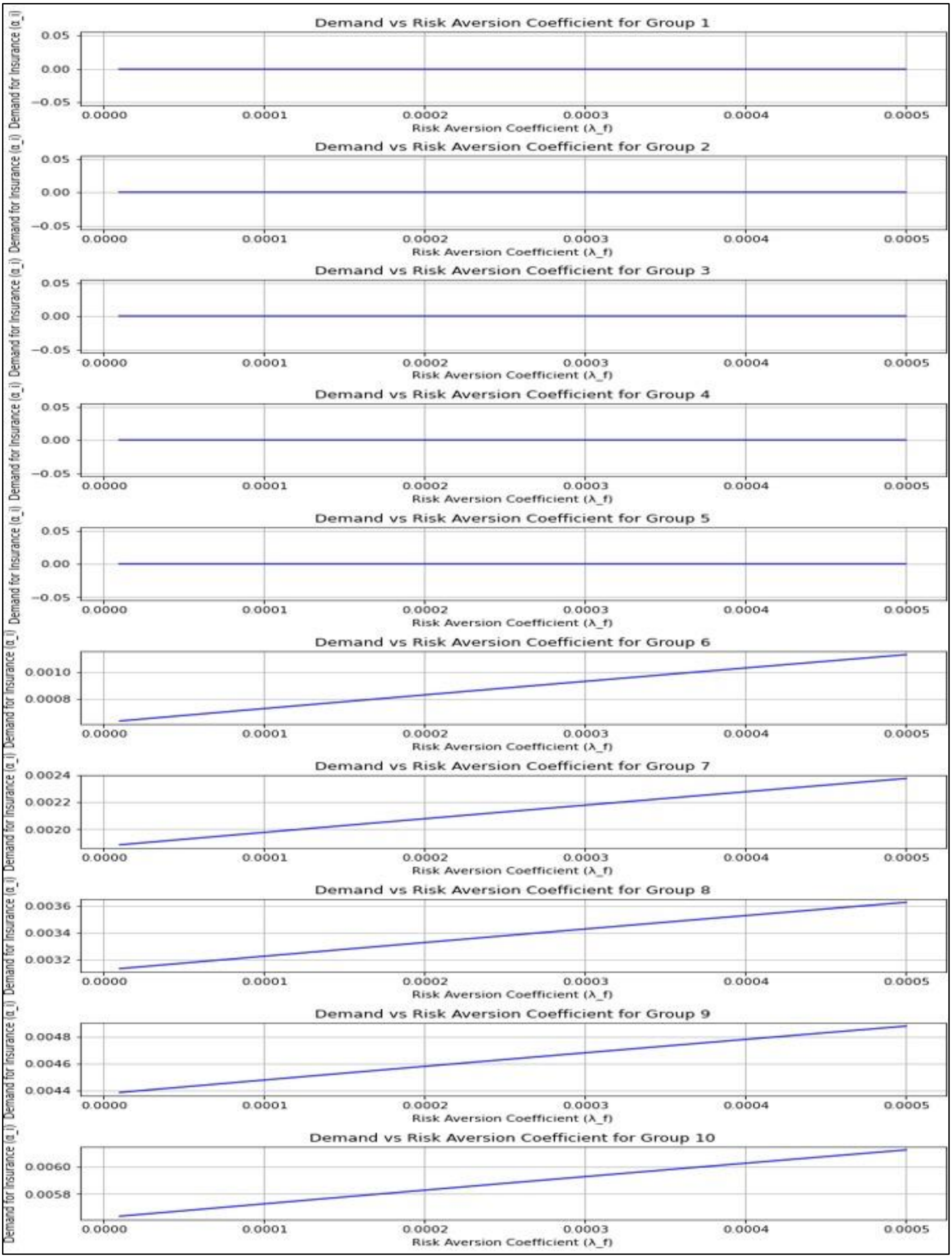

Fig 1 Individual Demand for WII

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A positive linear relationship was observed between farmers' risk-aversion coefficients and their individual demand for WII, with risk-averse farmers more likely to seek protection against weather-related losses. Farmers' risk attitudes significantly influence WII demand and should be considered by insurers in strategy development. In the WII model, farmers with varying income levels and risk aversion have different insurance demands. As shown in Figure 1, different groups of farmers exhibit diverse income streams and variability in this WII model. The equation for total demand demonstrates that market equilibrium depends solely on farmers who purchase a positive number of insurance contracts. This group, willing to pay for insurance, collectively determines the market price and quantity, as they represent the demand side of the market.

As shown in Figure 2 total demand for WII increases as farmers become more risk-averse, as they seek protection against potential weather-related losses. Conversely, an insurance company's risk aversion coefficient reflects its willingness to accept risk. A higher risk aversion coefficient leads to higher premiums and lower overall demand for WII, as farmers may turn to competitors or forgo insurance. On the other hand, a lower risk aversion coefficient indicates the insurer's greater risk tolerance, which encourages more farmers to purchase WII, boosting overall demand.

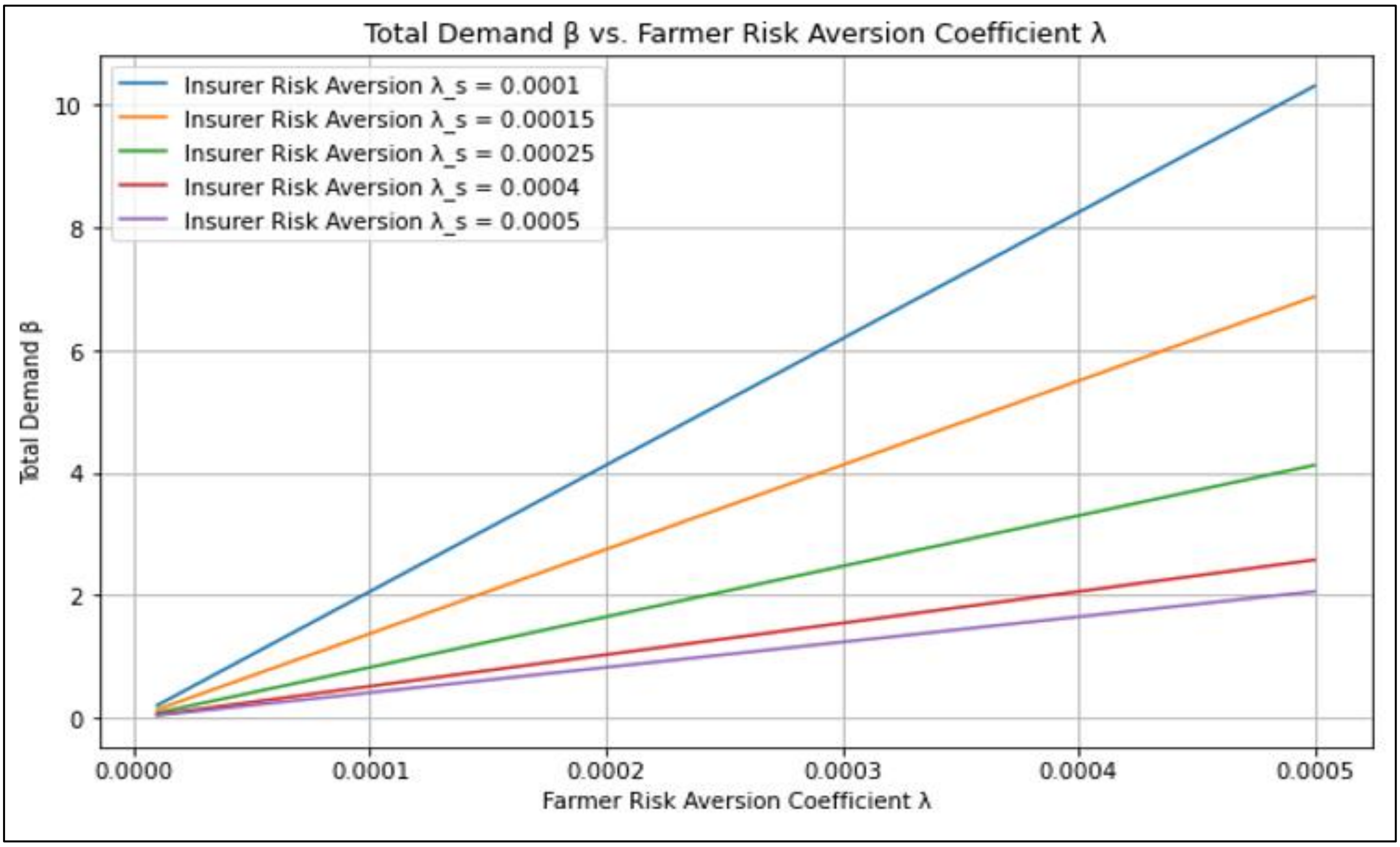

Fig 2 Total Demand for WII

- *Effect of the Premium Subsidies*

Figure 3 shows an inverse relationship between the risk aversion coefficient and individual demand for WII with premium subsidies.

Farmers with a higher risk aversion coefficient are more willing to take on the risk of adverse weather events themselves and choose to forgo purchasing insurance, as they may see it as an unnecessary expense or are willing to take a chance on the weather being favorable.

However, with the introduction of premium subsidies, the cost of purchasing WII decreases, making it more affordable for all farmers, including those who are more risk averse. These farmers may have been previously willing to forgo insurance and gamble on good weather due to the high premiums, but the subsidy makes the insurance more affordable and thus more appealing. As a result, there is an increase in the demand for insurance among farmers with low risk aversion coefficients.

The reason why the individual demand for WII with premium subsidies will never be less than the individual demand for the WII without premium subsidies is that the premium subsidy reduces the cost of insurance for all farmers, regardless of their risk aversion coefficient. Although the individual demand for insurance with premium subsidies may decrease with increasing risk aversion coefficient, it will always be higher than the individual demand for insurance without premium subsidies, since the subsidy makes the insurance more affordable and accessible to all farmers.

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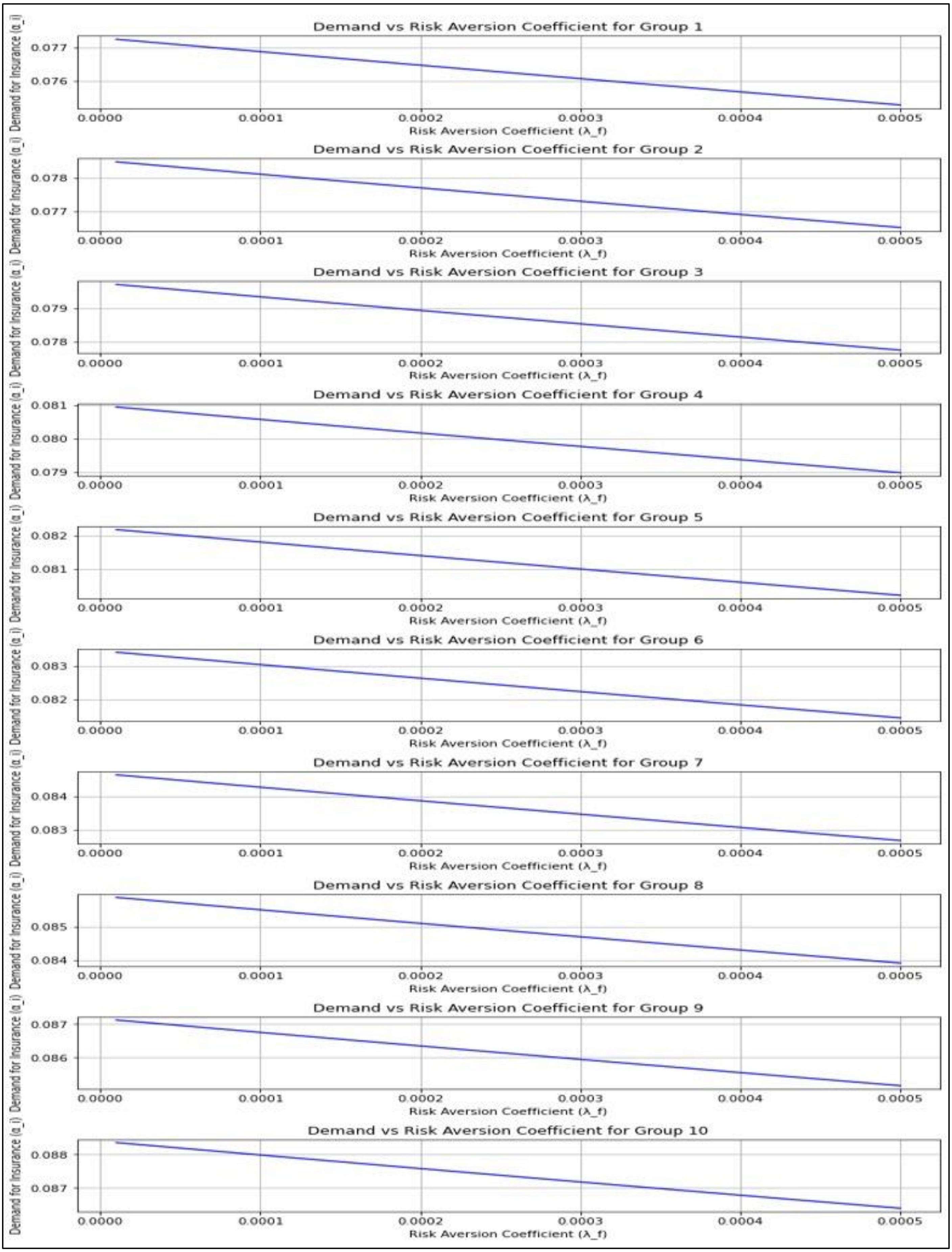

Fig 3 Individual Demand for WII with Premium Subsidies

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In the context of the equation Eqa (16), the total demand for WII with premium subsidies is higher than the demand for WII without subsidies because the subsidies reduce the cost of insurance for farmers. This in turn increases the number of farmers willing to participate in the market and purchase insurance coverage, which leads to a higher equilibrium quantity of WII.

Figure 4 shows the total demand for WII at the time of the presence of Premium subsidies. When premium subsidies are introduced, the cost of purchasing the insurance product is reduced, making it more reachable for individuals. As a result, the demand for the insurance product increases at all levels of the risk aversion coefficient. More risk-averse individuals still require a higher level of coverage to reduce their risk exposure and are willing to pay a higher premium to obtain that coverage. The premium subsidies only serve to make the insurance product more affordable but do not change the underlying risk preferences of the individuals.

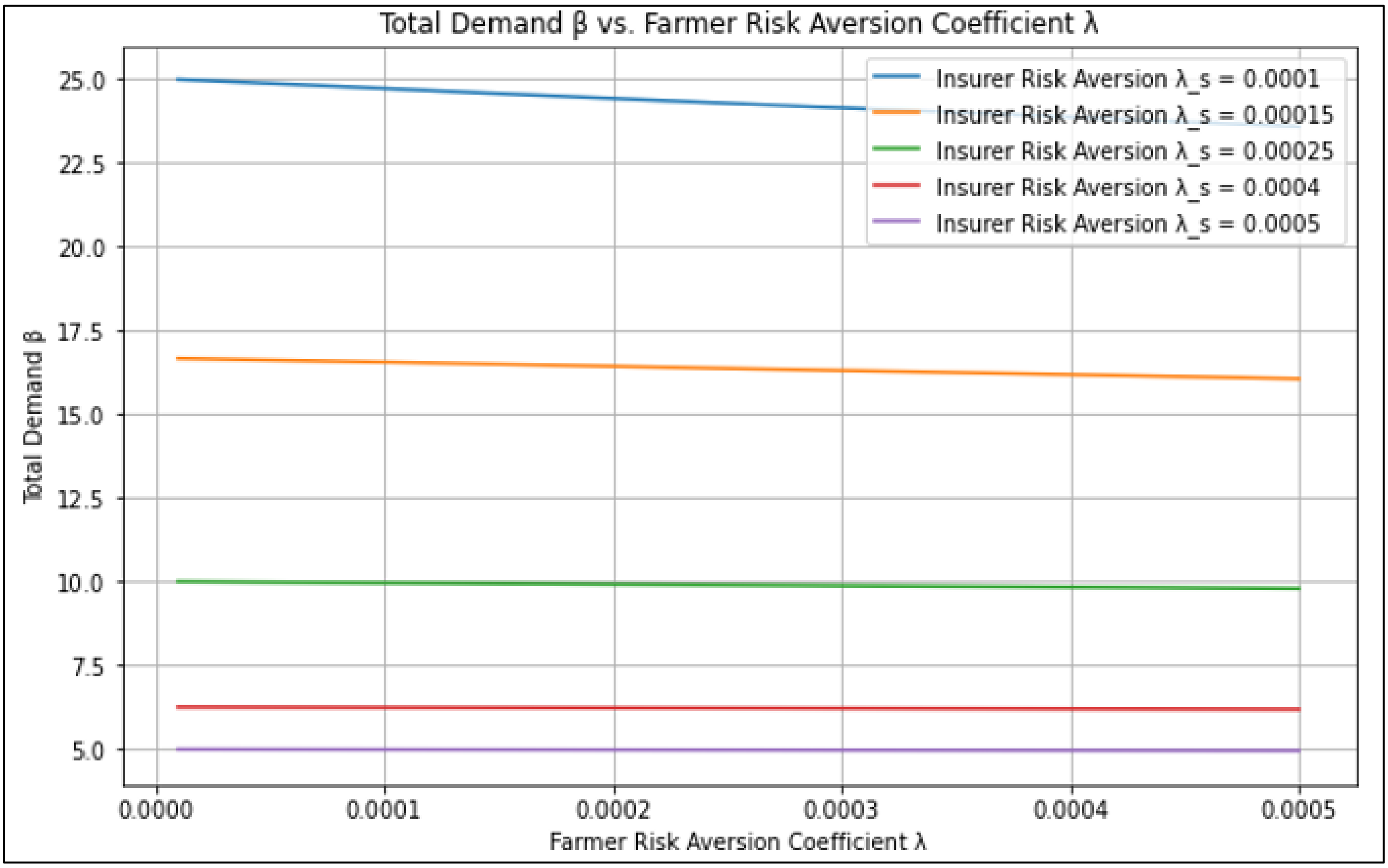

Fig 4 Total demand for WII with premium subsidies

V. CONCLUSIONS AND FUTURE WORK

Analyzing the previous research, it is revealed that there have been studies on the changes in market dynamics considering the demand side of index-based insurance in agriculture. It was also revealed that studies on both supply and demand of market fluctuations in area yield-based index insurance had been conducted. By considering both the demand and supply sides of the insurance market, this study has shown that WII can indeed be a viable option, despite the challenges posed by basis risk. The results of this study are relevant not only for insurance companies and agricultural producers but also for policymakers and researchers interested in promoting financial inclusion and resilience in the face of climate change.

Our results demonstrate that as an individual's capacity for risk-aversion coefficient increases, so does their demand. Since we considered all farmers are non-homogeneous their individual demand for WII also varies. We found that the

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market equilibrium is solely dependent on farmers who purchase a positive number of insurance contracts. The total demand rises as farmers' risk aversion coefficient increases. This emphasizes the significance of taking farmers' risk preferences into account when creating WII programs. If the insurance company has a low risk-aversion coefficient, it indicates a greater willingness to take risks, which leads to an increase in the overall demand for WII. By targeting the subset of farmers who are most likely to purchase insurance, providers can increase the demand for WII and achieve a more efficient market equilibrium.

When considering premium subsidies, the study results show that the individual demand of each farmer is influenced not only by their personal characteristics and preferences but also by the behavior of other farmers in the market. This is because aggregate demand for insurance affects the price and availability of policies, which in turn affects the benefits and costs to individual farmers of purchasing insurance. In the context of WII with premium subsidies, the behavior of other farmers in the market can have a significant impact on an individual farmer's decision to purchase insurance. As more farmers in the market purchase insurance, the demand for insurance increases. This can lead to a decrease in insurance prices and an increase in the availability of policies. These factors can make insurance more affordable and accessible to individual farmers, and therefore increase their likelihood of purchasing it.

Our model results depend on some crucial assumptions. we assume that all the farmers are nonhomogeneous, and their revenues and benefit payments are normally distributed. And considered two time periods of the economy. furthermore, we assume that there is a negative correlation between the revenue of the farmer and the compensation, and the premium subsidy does not have any effect on the profit of the insurance company. For future studies on this topic, we suggest relaxing these assumptions.

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