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“MICRO INSURANCE: A NEW WAY FORWARD”

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TABLE OF CONTENTS

Call For Papers	Page 6
Subscription Information	Page 8
<i>Introduction</i>	Page 9
Mr. H. Trent Moore Editor	
<i>Editorial</i>	Page 10
Mr. Aron Ping D'Souza Associate Editor The University of Melbourne	
<i>Stochastic Environments as Measurement Tools: A New Approach</i>	Page 13
Mr. Karl T. Muth Ms. Jennifer F. Helgeson London School of Economics and Political Science	

CALL FOR PAPERS

The field of applied economy lies at the nexus of theory and implementation, the practical and the philosophical. We must attempt to link the ivory tower of academia with the glass towers of the City and Wall Street. By understanding the theoretical foundations of global markets and economic decision making, applied economy can inform us about the role of market structures within larger analytical frameworks.

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THE JOURNAL OF APPLIED ECONOMY

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Introduction

Mr Karl T. Muth and Jennifer F. Helgeson, visionary economists and progressive leaders in the field of applied economy, charitably accepted an invitation to publish their piece, *Stochastic Environments as Measurement Tools: A New Approach* in this special edition of *The Journal of Applied Economy*.

As regular readers will know, Mr Muth is an editor of *The Journal of Applied Economy* and is a multifaceted scholar who has made many contributions to diverse areas of economic theory. Ms Helgeson is a new contributor to this journal, and we are immensely excited to showcase such groundbreaking scholarship from this partnership.

The title of this edition, will be, “Micro Insurance: A New Way Forward” reflecting the central questions of the paper.

I am confident that the Muth-Hulgeson Survey Tool is a revolutionary system and a game-changing evolution in the creation of financial instruments for low literacy demographics and for risk analysis in the developing world.

It is an exciting and rare event to have the opportunity to publish such groundbreaking scholarship. It is inevitable that *Stochastic Environments as Measurement Tools: A New Approach* will have a momentous impact in the field of applied economy, and an even greater effect on the lives of the broader populace in developing countries.

H. Trent Moore
Editor
Melbourne, Australia
1 March 2011.

Editorial: Aron D'Souza

Karl Muth and I met over dinner at Harris Manchester College in the University of Oxford. In the grandeur of the neo-gothic Arlosh Hall, Karl captivated me with accounts of his work with the Grameen Foundation. His work may have been born in the storied halls of academia, but it is special because of its relevance to the everyday lives of millions of people, particularly some of the most disadvantaged individuals in the world.

Many of the structures citizens of developed countries take advantage of are, obviously, not available in the developing world. Banks, stable currencies and insurance are three very evident examples of societal structures whose absence is a significant impediment to national development. Further complicating structural developments are educational issues, which hinder basic financial literacy. Limited literacy and numeracy has, traditionally, impeded access to financial structures, which could otherwise be a significant catalyst of growth and social progress.

The work that Karl Muth and Jennifer F. Helgeson have conducted illustrates that people who lack even basic literacy can, in some ways, be financially literate. The foremost contribution that the Muth-Helgeson Survey Tool (MHST) makes is a challenge to the attitude in the banking, insurance and finance industries that people in developing countries are not capable of interacting with complex financial instruments.

Muth and Helgeson are aware of the enormous impact that financial instruments, particularly insurance, can have in developing countries, particularly farmers. Providing farmers with long-term stability, which insurance is an essential component of, is central to building stable countries, not the least because of food-security and the importance of agriculture to sub-Saharan countries.

Although the coin and dice games may appear simple, they offer a valuable insight, which mere surveys and interviews could never achieve. Self-reported preferences, particularly in areas of risk analysis, are notoriously

unreliable, the MHST helps overcome this barrier and will make it significantly easier for insurance firms to design instruments for farmers in developing countries.

We know from the work that the Grameen bank did and continues to do with micro-finance that financial products can have a huge impact on poverty reduction. The work that Muth and Helgeson have done, in this research, will be a catalyst for similar measures in the insurance field.

It is rare that an academic journal would dedicate a whole issue to one article, and I applauded H. Trent Moore, the editor of *The Journal of Applied Economy*, for supporting Muth and Helgeson's work. Mr Moore, like myself, is confident that the Muth-Helgeson Survey Tool is a groundbreaking system and a watershed moment in the design of financial instruments for low literacy individuals and for risk analysis in developing countries.

I have not yet had the pleasure of meeting Jennifer F. Helgeson, but I know that Karl Muth is inspiring individual committed to improving our global community through informed action. I am certain that *Stochastic Environments as Measurement Tools: A New Approach* will make an important impact to the academy, but, more importantly, a broad impact in the lives of everyday people in developing countries.

Aron Ping D'Souza, Associate Editor (J. App. Econ) &
Editor (J. Jurisprudence)

**Stochastic Environments as Measurement Tools: A New
Approach**

Karl T. Muth and Jennifer F. Helgeson¹

Contents

- I. Background
- II. Purpose
- III. Microinsurance
- IV. Games, Not Simulation
- V. The Coin Game
- VI. The Coin Game: The Research Design
- VII. The Dice Game
- VIII. The Dice Game: The Research Design
 - a. The Dice Game
 - b. Complex Dice Games
 - i. Complex Dice Game 1
 - ii. Complex Dice Game 2
- Note. Rationale
- IX. The Dice Games: The Underlying Mathematics
- X. Pricing Insurance
- XI. Game Theory Topics: Classification, Analysis, and the Rational Participant
 - a. The Dice Game
 - b. Complex Dice Games
 - c. A Note About Insurance Behavior
- XII. The Future of This Research
- XIII. Conclusion

¹ Karl T. Muth, Department of International Development, The London School of Economics and Political Science. Jennifer F. Helgeson, Grantham Institute for Climate Change, The London School of Economics and Political Science. Thank you to Drs. Simon Dietz and Robert H. Wade for supporting this research. We are grateful to Ashley Cox, Pat Larsen, and Anouk Rigterink for valuable input as to earlier drafts of the survey tool. Thanks to Alex Counts, Camilla Nestor, Grameen Foundation, and Bankers Without Borders for their support of the research that led to earlier versions of the survey tool. Special thanks to Prof. Daniel Osgood of Columbia University, an expert at the forefront of agricultural microinsurance, for his advice, patience, and encouragement. Elizabeth M. Schutte contributed invaluable comments as to this Article. This work is part of the programme of the Centre for Climate Change Economics and Policy, which is funded by the UK Economic and Social Research Council (ESRC) and Munich Re.

I. Background

In early 2010, the authors joined Grameen Foundation as Consulting Economists to evaluate the agricultural microinsurance market, which comprises small policies offered to farmers in the developing world to allow them to endure droughts and other events that would otherwise prove disastrous. Traditionally, small farmers in developing countries and emerging markets have had difficulty negotiating, securing, and enforcing insurance contracts.

The research evaluated key areas related to insurance product design, such as willingness to pay (WTP) and risk tolerance, which were used to test the representativeness of the minimal historical and actuarial data available. After months of research, both authors found (as have many scholars in the area): there simply is not enough information about many markets that, at first glance, appear ripe for the introduction or improvement of agricultural microinsurance. The development of robust microinsurance tools in such markets requires a sound understanding of not only the quantitative realities of the insurance environment and the actuarial econometrics driving premiums, but also the social, market, and macro factors that may distort both policy terms and policyholder behavior.

The search for better answers to the questions surrounding microinsurance led to the development of the Muth-Helgeson Survey Tool (MHST), a tool designed to provide the information needed to better evaluate how well (or poorly) suited a market is to agricultural microinsurance. Version 1 of the MHST was first deployed in India and Uganda in September 2010 and presented in October 2010. Subsequent improvements quickly evolved, including versions with more specific metrics concerning farmer situation, behavior, and expectations. After completing their consulting project for

Grameen Foundation in October 2010, Helgeson and Muth returned to London and continued to devise new ways to measure how farmers in developing and emerging markets interact with insurance, both conceptually and practically.

risk, high consequence even farmer may draw upon support of family and friends in times of crisis	contar em momentos de dificuldades, grandes consequências, tais como seca, enchentes, etc.	s'appuyer pour faire face aux situations pour lesquelles la situation, la valeur des ressources de sa famille au sein des situations pour lesquelles de la situation, la valeur des de soutien n'ont pas été suffisantes	۱- اکثر کشاورزان محلی (یک گروه) نیاز اولیه خود را از خانواده‌های خود استفاده کرده‌اند. ما می‌پاییم
how the coping capacity was lost.	Nessa pesquisa objetivamos rural precisou pedir ajuda familiar, amigos e vizinhos	de la situation, la valeur des de soutien n'ont pas été suffisantes	۲- و سپس علاقه‌مند هستیم که بدانیم پژوهش‌گر بگوید که در ده (۱۰) سال مقداری مایل هستید برای جلوگیری از این اتفاق‌ها چقدر پول را در اختیار داشته‌اید؟
2. We are then concerned similar situation in which the farmer said that this has not happened to imagine such an event and	vizinhos, familiares ou organizações de enfrentamento de situações de emergência. Para melhor entender o caso	2. Le second objectif de cette recherche est d'examiner les situations auxquelles les agriculteurs n'ont pas fait face à une telle situation. Il serait prêt à payer pour se protéger	خواهشمندیم سئوال‌هایی زیر را در نظر بگیرید: اگر شما در این شرایط قرار بگیرید، چقدر پول را برای جلوگیری از این اتفاق‌ها می‌پردازید؟

Excerpt from the Survey Tool Version 2.1 Instructions in Various Languages

This Article describes two innovative elements of the current generation of the MHST not traditionally used in this type of research. After initial prototype testing of the MHST V.2.1 in India and Uganda during summer 2010, the MHST underwent a complete rewriting in November and December of 2010, including the development of the coin and dice games discussed in this Article. Among other improvements, the MHST now integrates these games alongside stated-preference traditional survey tools and pricing tools, such as payment ladders.

The games discussed herein are consistent with the MHST on or about December 15, 2010.

The authors will be working to implement the newest version of the MHST throughout 2011 to examine the characteristics of sub-Saharan African markets. This survey work, though supervised by Muth and Helgeson, will be primarily undertaken by Grameen's network of Community Knowledge Workers (CKWs). A CKW is a local person who is familiar with the financial, agricultural, and logistical realities of the farmer's daily life. He or

she speaks the local language or dialect and lives in-country, often on an income similar to that of the farmers with whom he or she works. Grameen is building a network of over 4,000 CKWs with a budget of approximately \$4.7MMUSD. These CKWs, equipped with smartphone technology and an application that allows the MHST data to be gathered and transmitted to a central database, are at the center of the MHST V.3 deployment.

This Article is intended to inform the academic community, economists, and practitioners about these new tools and to stimulate thought and debate about the use of similar tools in other contexts and other disciplines. While stochastic process has been part of the development of applied economics, finance, and insurance for the last century, the use of random-element games has focused primarily on simulating market events than investigating individual actors' preferences.

II. Purpose

The MHST is not merely a set of games; it also contains questions administered in the manner of a traditional stated preference survey tool. While information gathered by the stated preference questions is valuable, many questions about behavior and decision-making are difficult to resolve using orthodox interrogative techniques. Further, due to stated preference anomalies, self-reported behavioral preferences and decision-making methods may not reflect the behaviors and decisions in which the individual subsequently engages.²

To get around these difficulties, there is a growing use of combined stated and revealed preference techniques in resource and environmental economics research. To this point, the MHST encompasses stated

² IAN J. BATEMAN ET AL., ECONOMIC VALUATION WITH STATED PREFERENCE TECHNIQUES: A MANUAL (2002).

preference tools, such as WTP through payment card and ladder approaches. Yet, the hallmark of the MHST is to obtain information over the subject's revealed preferences for insurance uptake and risk aversion, which are subsequently compared to stated preferences to examine consistency.

To some extent the games presented in this Article allow the researchers to gauge farmers' revealed preferences, alleviating some level of potential self-reporting biases. However, that does not solve the issue that responses at one point in time cannot be assumed to perfectly accord with future decisions by the farmer.

To address this concern, the MHST also strives to obtain data on farmers' actualized behavior (e.g. choice over farming inputs), which usually is missing from such work. This is consistent with viewing intentions as the individual's conscious plan or self-instruction to carry out a behavior.³ Thus, where possible, the MHST assesses the extent to which expressed preference through the simple games follows through to actualized behavior under the constraints of real-world situational elements (i.e. influencing conditions), such as budget constraints. For example, if a farmer chooses a low-risk coin in the Coin Game (see the Coin Game, *infra*) but grows a high-risk crop, this result is flagged as an inconsistency between the revealed preference game and the stated preference section of the MHST.

This Article describes the design, rules, and implementation of these methods for evaluation of potential markets for agricultural microinsurance. The simple games presented in this Article allow participants to make

³ H.C. Triandis, *Values, Attitudes, and Interpersonal Behaviour*, in NEB. SYMPOSIUM ON MOTIVATION, 1979: BELIEFS, ATTITUDES AND VALUES 196-259 (H.E. Howe & M.M. Page eds., Univ. Neb. Press 1980).

choices, in addition to merely stating preferences in a survey format. The Coin Game is designed to measure risk aversion (or risk appetite) in the context of weak uncertainty.⁴ It is structured as a bounded risk preference tool.⁵

The Dice Game is designed to observe and measure non-arithmetic utility (as neither choice is statistically superior where the statistical disadvantage of the choice available exactly equals the cost of obtaining that choice) associated with insurance. The rational player would be indifferent as to whether or not to consume insurance. The game simulates three years of farming and gives the farmer the opportunity to purchase or not purchase insurance before each farming season.

Other, more complex dice games that more closely mirror that mechanisms of indexed insurance are under development, and are briefly discussed in Section X. Due to the complexity of these games and the difficulty of communicating gameplay via current mobile device technology, these complex games are used only with small samples under greater supervision.

⁴ This lineage of research begins in the late 1960's with the work of Ward Edwards and responses to uncertain outcomes. See **Ward Edwards, *Behavioral Decision Theory***, 12 ANN. REV. PSYCH. 473, 473-98 (1961). More specifically, this game descended directly from work in the late 1970's which appeared in Nobel Laureate Daniel Kahneman (with Amos Tversky)'s paper testing whether people would take a 100% return when betting on the flip of a coin. See Daniel Kahneman & Amos Tversky, *Prospect Theory: An Analysis of Decision Under Risk*, 47 ECONOMETRICA 263, 263–91 (1979).

⁵ The interpretation of risk aversion is consistent with that discussed in: JOHN VON NEUMANN & OSKAR MORGENSTERN, *THEORY OF GAMES AND ECONOMIC BEHAVIOR* (1st ed. 1944).

III. Microinsurance

Microinsurance is a relatively recent innovation of financial engineering. Microinsurance exists in many flavors, similar to commercial insurance offered by retail banks and insurance firms in the developed world: health insurance, life insurance, and so on. The authors' study focuses primarily on agricultural insurance, or insurance designed to mitigate the financial effects of catastrophic crop failure.

Poor farmers are often unable to save and live in an environment where crop failures are regional, common, and dangerous events. Social networks⁶ used to hedge risk break down in times of drought, flood, and famine; and meager savings and owed favors are either inaccessible or quickly exhausted. Because poor farmers do not have access to forward contracts, contra-behavioral instruments, or international markets, insurance is often the only asset farmers can obtain that behaves in a contrary direction during a disaster -- all other tangible indicators move in unison against the farmer's position. While many can understand the importance of insurance, far fewer can afford ideal coverage.

The most expensive insurance is actual loss insurance. As the name implies, this insurance involves coverage for the actual value of losses incurred by the insured party. Because the examination of losses involves a difficult claim and audit process, and because the information costs to all parties are high, this insurance is incredibly expensive to administer in rural areas in Africa. Few Africans can afford even actuarially fair premiums for such policies, let alone market rates (which, in Africa, are routinely far higher than what is actuarially fair).

⁶ See generally DARYL COLLINS ET AL., PORTFOLIOS OF THE POOR: HOW THE WORLD'S POOR LIVE ON \$2 A DAY (2009).

The most common insurance in Africa is index insurance. It is affordable for farmers, sometimes priced in competitive markets, and the claims process is relatively efficient. The coverage is only loosely correlated with the farmer's actual loss, however. In index insurance, rainfall is measured at a remote⁷ weather station on the premise that crop yield is a describable function of rainfall. Some weather stations are as much as 30 kilometers⁸ from the farmer whose rainfall they allegedly measure. While this is true in some cases, there are other sources of risk. For instance, in Malawi, crop failures have resulted from faulty seeds⁹ and other risks not associated with rainfall. As to these non-rainfall risks, farmers are uninsured.

IV. Games, Not Simulation

It is important to appreciate that the games contained within the MHST are not meant to simulate the precise act of farming. Rather, the games are designed to create analogous situations where the participant's in-game decisions are indicative of how the participant may make similar decisions when considering his farming in a real world context. The "outputs" from games are a record of decisions made by the player, rather than a series of replies a survey participant offers in answer to questions.

⁷ Even in high-coverage, near-optimal models of these policies, there may be a proportion of one weather station for every 350 farms. In Malawi in 2007, there were 1,710 farmers with microinsurance (the second year the microinsurance program was offered in Malawi) and five weather stations. For comparison, in the entire country of Ethiopia, there were only 26 weather stations in the same year. Erin Bryla & Joanna Syroka, *Unlocking Development Potential in Malawi*, 2 CLIMATE & SOC'Y 14 (2009).

⁸ See a copy of a tobacco farmer insurance contract from the Insurance Association of Malawi in 2007 referenced *infra* p. 15.

⁹ This seed defect occurred in the 2006 harvest season, and is referenced by Bryla, *supra* note 7, Osgood, *infra* note 13, and other authors.

These games provide a simplified environment for decision-making. Further, the authors have focused research design on minimizing cultural skew, linguistic dependency, literacy requirements, and computational requirements. The players of all games described here do not need to be able to read and need only the most basic language skills to understand the rules of the games. The players do not need any mathematical or computational ability aside from the ability to count and to recognize small integers expressed as multiple instances of a single item (rather than as Arabic digits).¹⁰

The results of the games are reported, as with the rest of the MHST, using mobile device technology. The person administering the MHST is trained both in its administration and in the use of the relay system, which uses mobile telephone technology to report MHST results in near-real-time. The use of a mobile telephone application to report MHST results not only makes the process more efficient (rather than, for instance, sending sheets of paper from Uganda to London for subsequent manual data entry), but allows fewer errors to occur and for those errors which do occur to be spotted quickly. Lastly, by removing the manual data entry step still present in much contemporary field research, an opportunity for errors in the dataset is taken out of the system.

Though the games are administered at a single point in time, the iterative nature of the games introduces some level of dynamic, rather than static, play. Thus, the MHST is able to obtain useful information about the

¹⁰ In the survey tool, numeracy is measured, as a baseline for how the individual deals with numeric calculations over risks. For a discussion on numeracy, see generally: Adrien Barton et al., *Comparing Risk Reductions: On the Dynamic Interplay of Cognitive Strategies, Numeracy, Complexity, and Format* in PROCEEDINGS OF THE 31ST ANNUAL CONFERENCE OF THE COGNITIVE SCIENCE SOCIETY 2347-52 (N. A. Taatgen & H. van Rijn eds., 2009).

learning process, or at least the changes to players' structural play decisions in response to outcomes in previous rounds. Changes in strategy or comments from participants that they revised their strategies during the games have been common in pilot sessions.

Pilot sessions are an important part of determining paths of gameplay and an integral piece of game design. The most recent test of the stochastic game elements of the MHST V.3 occurred at the London School of Economics and Political Science and involved students reading for graduate work in economics, environmental economics, and development economics. The Coin Game and the basic Dice Game were observed at less than ten minutes each to administer to the average participant, with substantial heterogeneity of response within the pilot sample. Further, people who had never encountered the games prior were able to be trained to administer the games in less than an hour. These individuals were then observed administering the games to other subjects with success.

V. The Coin Game

Supplies Provided: Five coins, instructions.

The Coin Game is a way to quickly measure the risk aversion of a single subject through binary choice iterations. The game is designed in a triple-bounded dichotomous choice structure. The subject is given two coins and told each coin represents a crop he could choose to grow in the coming season. One flip of the coin will decide the size of the harvest his crop yields. The coins are fairly weighted. The participant is allowed to examine and handle the coins, which are metal physical tokens, and then asked to choose which crop he will plant. One coin offers a yield of 5 on either side, while the other coin offers yields of 9 on one side and 3 on the reverse side. For consistency in describing administrations of the Coin Game, the former

is referred to as Alpha, while the latter coin is called Beta. The yields are expressed in arbitrary units with icons representing crops to minimize any cultural, linguistic, or literacy skew in results.

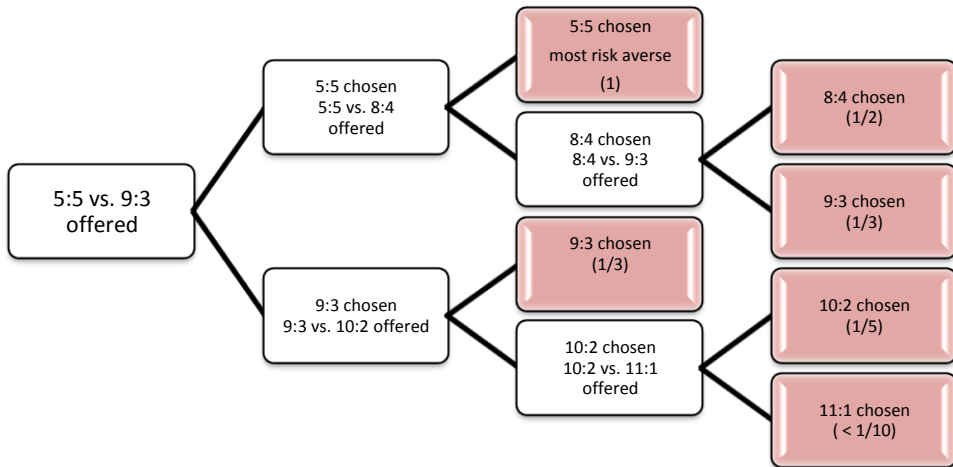


The Choices Offered in Round One of the Coin Game

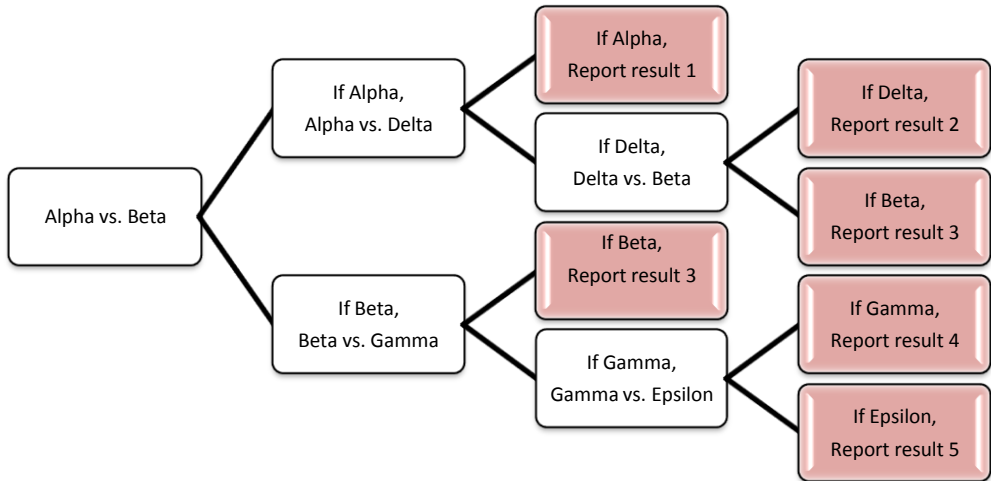
After the participant chooses a crop to plant, he is provided with two new coins from which to choose. He is told again that each coin represents a crop and that a single flip of the coin he chooses will decide the size of his harvest. If he chose the risk-free coin (Alpha) in the first round, he is provided with a choice between Alpha and Delta, a coin with yields of 8 on the obverse and 4 on the reverse. If he chose the riskier coin (Beta) in the first round, he will be presented with a choice between Beta and Gamma, a coin whose sides offer yields of 10 units and 2 units. If he chooses Beta, the game ends. If he chooses Gamma, the game continues and he is offered a

chance to compare Gamma to Epsilon, a coin with even higher variance, and to express a preference.

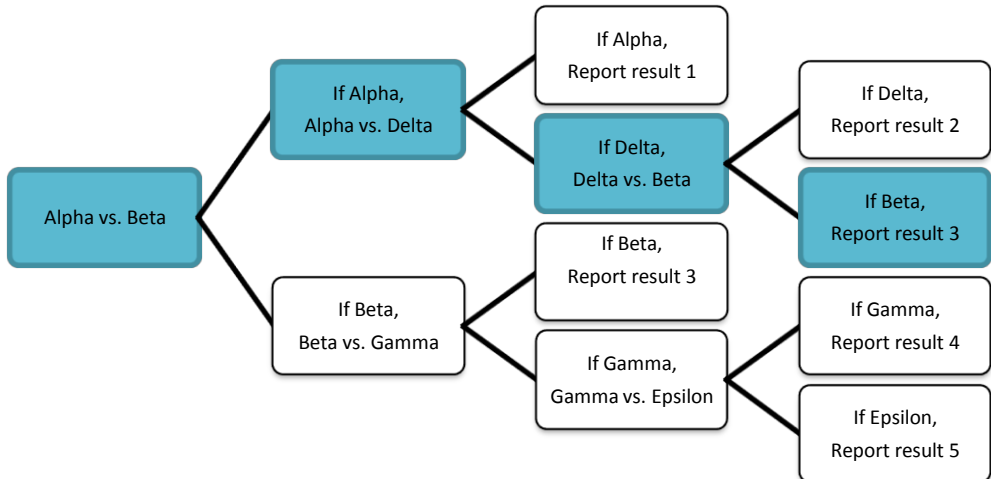
The gameplay varies according to which coin is chosen at each decision point. The following diagram illustrates the values of the two sides of the coins and the choices available to the player in each round.



The diagram below illustrates the five risk categories into which participants are grouped:



The diagram below shows one of two possible paths a player might follow to be classified in the middle risk group, 3.



VI. The Coin Game: The Research Design

The coin game is used to gauge ranges of relative risk aversion. Effectively, the a participant's choice patterns places them within a cohorts of relative risk aversion. The coin game commences by presenting a choice between zero risk and a degree of risk greater than zero. While Alpha and Beta will perform equally in long-run equilibrium, the participant can choose a crop that offers an edge over risk-free levels of performance 50% of the time. This "high variance" crop produces three units of maize on one side of the coin and nine on the other side.

In the second round of the game, regardless of which coin was chosen in the first round, the participants are given the choice of a coin that clearly outperforms Alpha in long-run equilibrium ($\bar{x} > 5$), but the more risk-averse participant is given a coin with a lower variance. By maintaining the same mean, but providing a different variance between the two groups, the coin game measures risk aversion both on an absolute index and as compared to a reference population.

Note that maize was chosen as the crop to display on the coins, as it is familiar to nearly all farmers in Uganda and is a staple crop rather than a cash crop. Hence, maize may have associated with it a "conservative" rather than "risky" set of production expectations. However, the authors felt this slight potential bias was vastly outweighed by the ability to use a recognizable agricultural yield image rather than an arbitrary symbol like a circle. Further, it is likely to produce a less biased result to use the same image reproduced at the same scale on every coin than to, for instance, use tobacco (a cash crop) as the crop on the risky coins and maize as the crop on the lower-variance coins (a staple crop), as this might cause farmers to

choose according to their preference for crops to plant, rather than their preferences in terms of risk aversion and acceptable variance in outputs.

The MHST also records results intragame, rather than simply classifying participants into a series of categories. After the participant makes a choice, he physically flips the coin and the result is recorded. This is done to ensure that, *ex post*, one might examine effects of outcome on iterative choice.

The game itself is a classic risk aversion classification exercise. Under constant relative risk aversion,

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma},$$

in other words, where the player chooses the 9:3 coin rather than the 5:5 coin in the first turn of the game, is choice is mathematically equivalent to an inequality between probabilities where the participant prefers one probability to the other. The choice of the 9:3 coin can be visualized as (standard notation):

$$5^{1-\sigma} = \frac{1}{2}(9^{1-\sigma} + 3^{1-\sigma}) \rightarrow \sigma_{9:3}$$

, and as the context of each decision is a choice between two coins and the probabilities of any given outcome at any given time are equal, this follows for all other values in the opportunity set, e.g.:

$$\therefore 5^{1-\sigma} = \frac{1}{2}(8^{1-\sigma} + 4^{1-\sigma}) \rightarrow \sigma_{8:4}$$

and

$$\therefore 5^{1-\sigma} = \frac{1}{2}(10^{1-\sigma} + 2^{1-\sigma}) \rightarrow \sigma_{10:2}$$

This method allows the player to be quickly categorized according to the variance he will tolerate with two choices at a mutual probability of 0.5. The coins represent variances of the following values (each of which represents a

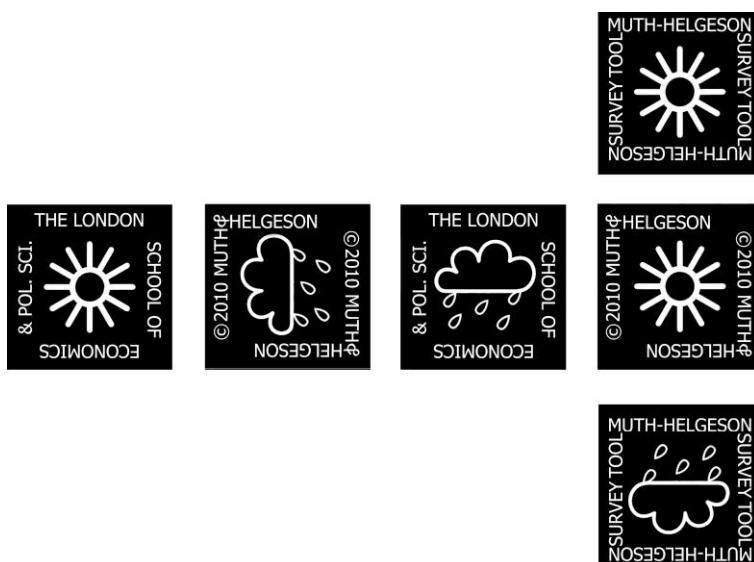
comparison of a coin's two sides expressed as a fraction): 1, 1/2, 1/3, 1/5, 1/11.

Hence, the participants are classified into five categories of risk tolerance.

VII. The Dice Game

Supplies Provided: Four dice, instructions, score recording sheets.

The sides of a die used in the Dice Games are accurately described by the diagram below:



The dice used in the Dice Games are black with three yellow “sun” sides and three blue “rain” sides.

VIII. The Dice Games: The Research Design

“The challenge is to get the formula [that is] connected to the loss.”

- Dan Osgood, Columbia University
Comments to Reuters, 24 Jun 2009

The Dice Games are meant to test the participant's preferences as to consumption, overconsumption, or non-consumption of insurance in an

environment characterized by uncertainty. There are multiple versions of the game, each to test a different aspect of insurance consumption; three of these games are described in this Article. Except in selected samples, each survey participant will play one dice game, but not more than one.¹¹ Which dice game a participant plays is not a function of any response the survey participant has given.

a. The Basic Dice Game

In the basic Dice Game, the player is provided four dice. He is given three turns to roll the dice, trying to avoid rolling all sun (drought) or all rain (flood). Alternatively, he can give up one die of the four to purchase insurance against a roll outcome of three sun dice with his remaining dice (drought), but the insurance will not protect him against a dice roll of three rain dice (floods). The player may change his choices about insurance and whether to roll three dice or four between any two turns. Players are only considered “insured” during rounds in which they roll three dice.

Players who survive for three turns without either rolling all sun or all rain if they chose to roll four dice (uninsured) or rolling all rain if they chose to roll three dice (insured) “win.” All other players “lose.”

The survey administrator records whether players choose to roll three dice or four in each turn.

¹¹ To prevent confusion among players, the authors decided to administer the coin games to all participants and then to administer one of the dice games. Because one game utilizes coins while the other involves dice, they are clearly distinct exercises. The similar but different rules of the dice games, however, are more likely to cause confusion or misunderstandings regarding the rules. Further, the amount of time to administer the MHST is limited, and hence the number of questions and games that can be administered to any given participant is limited by practical constraints.

b. Complex Dice Games

The complex dice games are structured in order to mirror more closely the functions of actual indexed insurance. The player is endowed with chips, which represent his total resources for investment during the season. This version of the dice game is under development and undergoing additional testing and refinement.

In order to be consistent with the real-world structure of indexed insurance, there are a number of design constraints the authors defined for the game:

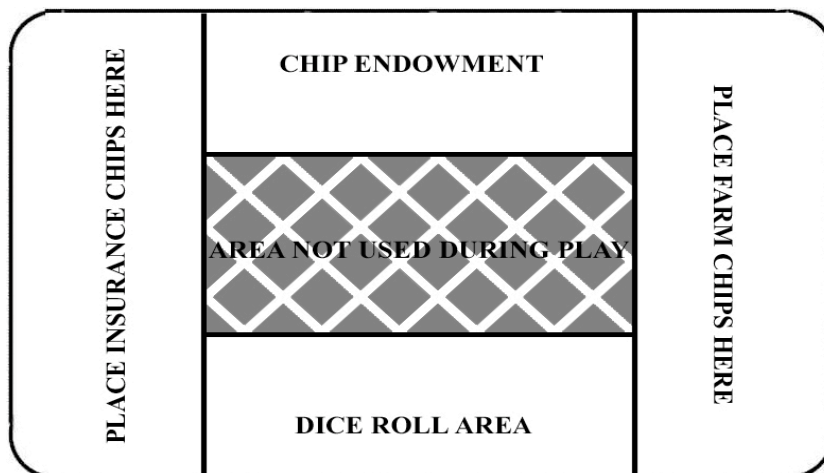
- Expected loss should not decrease in the farm size; with exogenous risk, there must be a control for consistency, or even a slightly upward sloping relationship.
- Therefore, probability of disaster should be exogenously determined. Loss in the case of disaster would be exogenous in proportional terms.
- The player's income should be restored (at least) to the level it was at the beginning of the turn without regard for appreciation or expected growth.
- Player should be unable to over-insure farm size.
- This game is played with: six-sided dice, chips, and a playing board.
Chips: The number of chips is representative of money/resources. The chips may be invested in farming activities (e.g. purchase of seeds), thereby increasing farm size. In the Basic version of the game, chips may be used to purchase insurance. In the more complex version, chips can be used to purchase insurance, but may also be allocated to the category of "mitigation activities," as defined in the game rules, below.

Supplies Provided: Three dice, playing chips, game board, instructions.

- Dice: The dice are used to exogenously determine the occurrence of a disaster event (i.e. drought or flood). Each die has either a “sun” or a “raincloud” on each side. In the basic version of the game, each die has three sides with a "sun" and three sides with a “raincloud.”



- Playing board: The game board is a simple fold-out cardboard playing mat, around the size of an A4 sheet. There is a designated area for the general chip endowment. The player can then trade chips in the general endowment for allocation to the insurance section of the board or to the farming activities section.



i. Complex Dice Game 1

In Complex Dice Game 1 the player begins with an endowment of 8 playing chips, which represents his entire wealth. The player can choose to either invest these chips in farming activities, or to purchase insurance. In each turn, all of the player's chips must be "spent" on a combination of farming activities and insurance cover. Each turn represents one year on the farm.

The player sets chips to be invested in the farm on the right side of the board. He must invest at least two chips (one half of the four-chip minimum) in his farm during each turn. This is the minimal going concern investment in the agricultural activity.

On the left side of the playing board, the player can buy insurance by paying chips to the insurance company. This payment event represents the premium for the year. The insurance company pays out when there is a drought or flood event.

The player may not ever invest more chips in insurance than in his farming activities.

The three dice determine the weather for the growing season in play. There are two main outcomes after the dice are rolled:

Outcome 1: The rolled dice display a mix of sun and rain. In which case the player gains one chip for each two chips invested in farming activities (rounded down). But, the player also loses all dice on the left side of the playing board, which were paid to the insurance company, because there was no flood or drought that year.

Outcome 2: The rolled dice display all sun (i.e. drought) or all rain (e.g. flood). In any iteration of the game, this outcome triggers the insurance mechanism. The player loses half of the chips he invested in farming. If an uneven number of chips were invested in farming, the loss is half of this number,

rounded up. Yet, if the player invested in insurance, there is a payout (gain) equal to the number of lost farming chips or the number of chips invested in insurance, whichever is less.

The next turn starts and the player once again chooses where to allocate his chips between farming and insurance, so long as the farmer controls between 4 and 25 chips.

The player wins once the number of chips in his possession is greater than 25. Note that the selection of 25 as a trigger point is selected to insure that the majority of players play at least three rounds of the game, as to allow within-sample comparisons of insurance behavior between rounds of play.

ii. Complex Dice Game 2

This version of the game is the same as above in most respects. However, basis risk is separated from weather determination at the weather station. We take basis risk in the purest form of differentiation between the index trigger weather conditions at the weather station and the actual weather experienced by the farmer.

Weather determination at the weather station is represented by the outcome of the dice roll, as in Complex Dice Game 1, above. In this version of the game, the farmer is concerned with drought and insurance cover is only available for drought events. At the initiation of each round, the player randomly selects a playing card from a total of 6 cards, which assigns a level of basis risk. In this game, there are three possible levels of basis risk:

1. Bad: indicative of greater sun (less rain) on the farm than at the weather station (Type I error).
2. Normal: indicative of a negligible difference between rainfall on the farm and at the weather station.
3. Good: indicative of less sun (more rainfall) on the farm than at the weather station (Type II error).

The six possible playing cards from which the player chooses one in each round are allocated as follows: 1 Bad, 4 Normal, and 1 Good.

The player flips over this card over only after playing the rest of the game whereby he allocates his chips between farming activities and insurance. The rules governing the game play itself are identical to the Dice Game 1, above. However, the outcome of the player's dice roll, which constitutes the weather station rainfall, is adjusted by the basis risk as defined by the playing card. Thus, when the "Bad" card is chosen, this requires that one of the rolled dice is changed from a "raincloud" outcome to the outcome of "sun." Thus, we do not force a total payout or a total loss under the conditions of good and bad, respectively, as is the case with many experiments which consider basis risk.

Our approach to basis risk game design allows the outcome of basis risk to vary each turn, making the game a closer approximation (though not a simulation) of real life. The previous game design utilized an unfairly weighted die as the basis risk source. In this proposed version, the playing card assignment of basis risk allows greater flexibility in the choice of upper and lower bounds of basis risk set by the game design in subsequent applications.

Rationale:

There has been little research describing how rural farmers deal with basis risk (and the extent to which they consider it at all) in the structure of indexed insurance purchases.¹² In this version of the game, weather is a

¹² Anthony Patt et al. *Making Index Insurance Attractive to Farmers*, 14 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 737, 737–53 (2009).

random event. The structure is such that even if the player purchases index insurance, he or she must still consider basis risk in an explicit manner.

In order to assess real world reactions to indexed insurance, we must include some simulation of basis risk. The structure of indexed insurance reduces transaction costs significantly (from reduced claims handling) and eliminating moral hazard (claims are independent of the players' practices). Yet, it introduces the problem of basis risk: when a farmer suffers a loss but receives no insurance payout¹³ In other words, index-based insurance is against events that cause loss, not against the loss itself.¹⁴

In this game, in the most basic sense we test that farmers understand that the insurance carries with it basis risk and trace their response. Thus, there is the possibility that farmers will pay more money into the insurance than they will receive in payouts. From a finance standpoint, this is expressed in that an insurance policy, even when priced actuarially-fairly, is an investment with a negative net present value.

This version of the game is easily applicable to be played in groups of farmers. In the group play format, a portion of the group is assigned "basis risk conditions," while others would not be. Ideally, for the same player conditions and decision-making between rounds when playing in a group

¹³ Barry J. Barnett & Olivier Mahul, *Weather Index Insurance for Agriculture and Rural Areas in Lower-Income Countries*, 89 AM. J. AGRIC. ECON. 1241, 1241–47 (2007). See also DANIEL OSGOOD ET AL., DESIGNING WEATHER INSURANCE CONTRACTS FOR FARMERS IN MALAWI, TANZANIA AND KENYA: FINAL REPORT TO THE COMMODITY RISK MANAGEMENT GROUP (Colum. Univ., 2007) (discussing uncompensated crop failures in Malawi).

¹⁴ Calum G. Turvey, *Weather Derivatives for Specific Event Risks in Agriculture*, 23 REV. AGRIC. ECON. 333, 333–51 (2001).

with observation of others' outcomes and gambles can be compared with his actions when playing in a single-player setting.

IX. The Dice Games: The Underlying Mathematics

Basic Dice Game:

Index insurance, the predominant type of insurance available in Africa, pays when rainfall is below a threshold amount in a given area. It does not pay when there is a flood (represented in the game by too much rain and no sun).

This game is rooted in an interesting statistical equality: the probability of rolling four dice and receiving four rain icons or four sun icons is identical to the probability of rolling three dice and receiving all rain icons.

Probability of an uninsured loss for each roll for uninsured (left) and insured (right) players:

$$\frac{2}{2^4} = \frac{1}{2^3}$$

Hence, the choice is not one of mathematical advantage, but rather purely one of consumer preference. The player who enjoys some utility from “peace of mind” being protected from drought will trade one die for insurance, even though the coverage of the insurance is imperfect. Other players will not choose to trade one die for insurance against drought.

This game tests whether the preference for insurance exists even in a scenario where the actuarial advantage of insurance is offset by additional endemic risk or, stated differently, where insurance is so expensive that it completely offsets any gains to be enjoyed from its coverage.

Complex Dice Games:

The Complex Dice Games, as of this writing are still undergoing testing and revisions as to aspects of the gameplay. Hence, mathematical descriptions of the game rules would be quickly made obsolete by later versions. It is

more helpful, however, to consider how changes in rules must be made thoughtfully and in accordance with player expectations about causality, realism, and fairness. Creating these rules is a delicate process and not one that should be undertaken quickly or lightly.

For illustration, these tables illustrate expected utility related to allocation of playing chips between farming activities and insurance, dependent upon the number of endowment chips in the first turn. We strove to find an endowment level for which the parameter of relative risk aversion would not have to be excessively high to make a game move that included purchase of some level of insurance, rather than placing all chips in farming activities.

Tables, *infra*: Expected utility estimates with different starting endowments of playing chips (i.e. resources) at the start of Complex Dice Game 1.

8 Chip Endowment

p	Act Farm	Ins.	No Disaster	Disaster	E(V)	E(U)
			0.75	0.25	eta	0.5
	8	0	12	4	10	6.196152
	7	1	10	4	8.5	5.743416
	6	2	9	5	8	5.618034
	5	3	7	5	6.5	5.086661
	4	4	6	6	6	4.898979

10 Chip Endowment

p	Act Farm	Ins.	No Disaster	Disaster	E(V)	E(U)
			0.75	0.25	eta	3
	10	0	15	5	12.5	-0.00667
	9	1	13	5	11	-0.00722
	8	2	12	6	10.5	-0.00608
	7	3	10	6	9	-0.00722
	6	4	9	7	8.5	-0.00718
	5	5	7	7	7	-0.0102

As can be seen from the two tables, even the slightest changes in rulemaking can affect not only game outcome, but gameplay and perceived game fairness (which is a function of, but not the same as, game realism), these calculations are central to the development and use of games as a measurement tool.

X. Pricing Insurance

In the context of the basic Dice Game, the premium is set to ensure that the two choices have equal net probabilities of loss. In other words, taking into account the cost of insurance (one die) and the effect of that insurance (immunity to drought), the net effect of having taken out insurance is zero.

Meanwhile, in real life, the most telling element of an insurance scheme mathematically is the method or set of factors from which its premium is derived. The analysis will first turn, then, to two competing methods for determining the premium on an agricultural insurance product with two counterparties and no substantial information disparity. If one imagines a world in which the farmer and the insurer are the only stakeholder counterparties in an insurance scheme, the farmer will want a policy that covers crop shortfalls below the anticipated agricultural net yield. This type of shortfall insurance would take the form of an insurance arrangement that guarantees a percentage (λ) of an anticipated yield (y_a). Hence, so long as $0\% \leq \lambda \leq 100\%$, in an efficient market the premium rate will resemble:

$$= P(Y < \lambda y_a)(\lambda y_a - A(Y|Y < \lambda y_a))$$

The “anticipation” operator and the probability above are a function of the conditional yield density $f_Y(y|I)$ where I represents the information shared

by the parties between the start of the pertinent datasets (T_0) and the time of the contract (T_K).¹⁵

Meanwhile, the insurer in this same relationship will want to create a far simpler system, namely, insuring against a specific condition. Where there is a fixed payout amount (W) and it is uncertain an environmental condition (C_E) is met, including a range of error for exempt-from-payout year-to-year environmental variations (E_{VAR}), in an efficient market this type of binary index insurance's premium will resemble:

$$= PW(C_E \pm E_{VAR})$$

Needless to say, these two insurance products are substantially dissimilar. It is important to understand that, particularly in the area of agricultural insurance, the needs of clients are not fully satisfied by insurers' offerings. Yet, it is not the discontinuity in offering preferences versus actual offerings that, in isolation, stifles adoption of insurance policies.

The goal of the farmer is to position himself to enjoy the proceeds of a policy when a loss is suffered, for the proceeds to be distributed in time to avert consequential losses, and for the proceeds to be in the same order of magnitude as the loss. Imagine a farmer named F with the utility function¹⁶: $u^F(w)$ and who has wealth equal to w_0 . There is some likelihood (π) that F will suffer a loss (L) of crops that she cannot prevent. There is also some likelihood ($1 - \pi$) that this loss will not occur. F is presented with the option of buying insurance that will pay I if the loss occurs, but will pay zero if the loss does not occur. The cost of the policy is q per unit of insurance, making the premium cost, qI .

¹⁵ This principle is well-known in prior art and drawn here from a simplified model offered in Jeff Racine & Alan Ker, *Rating Crop Insurance Policies with Efficient Nonparametric Estimators that Admit Mixed Data Types*, J. AGRIC. & RESOURCE ECON. April 2006, at 27-39.

¹⁶ The function described is an ordinary Bernoulli utility function.

F considers the option of buying insurance, concluding that her wealth will be $w_0 - L + I(1 - q)$ if she suffers the crop loss, but $w_0 - qL$ if her harvest is as expected. However, she does not know if the following inequality is true: $q > \pi$, making her decision difficult. Further, she is unsure whether the insurance company will pay, even if the pre-defined conditions are met.

This is the difficult calculation that faces farmers who are offered microinsurance. It is very important to understand the uncertain environment in which these decisions are made, as this drives conservative decision outcomes, low perceived marginal utility from insurance purchased, and hence low adoption rates.

Now, suppose a farmer has decided to buy insurance. What decision process would the farmer engage in to decide how much insurance to buy?

The decision to invest in insurance can be modeled as a simple nominal yield calculation...

$$Y_t = r_t + \pi_t + \varrho_t + P_{(t1, t2, t3 \dots tn)}$$

... where Y is the expected yield at a given time (t) that would motivate the client to purchase insurance. r is the real interest rate (likely low, as this capital is not readily invested in alternative instruments), while π represents the expected inflation (possibly quite high in many microinsurance markets). The variable ϱ corrects for any risk premium, which may be substantial if the farmer doubts the trustworthiness of the insurance instrument or the organization behind it (to visualize the sensitivity of this variable, if this were a yield to maturity premium in fixed income securities, this would be the liquidity premium). Unfortunately, the expected yield from the insurance investment must also cover the then-present-value (at t_n) of the premiums paid from t_1 when the policy is purchased until t_n when the insured event occurs.

If this were the entirety of the decision-making process, however, one could stop here, as nothing short of a near-certain windfall would satisfy the farmer. Instead, third-party investors are likely to be investing in insurance alongside the farmer. If this is true, one must look to the agent who is providing insurance to a portfolio of farmers with different risk profiles.

Suppose a microinsurance company writes policies in a valley in Uganda where there are elevated farmers on a hillside and valley farmers. The hillside farmers face more drought risk and, hence, are asked to pay higher premiums than the valley farmers. However, the hillside farmers also pose more risk to the insurer of a payout scenario. After consultation with the best actuarial and historical record information available, the insurer makes the following estimates, and decides the correlation coefficient between dependable and risky farmers is approximately -0.2:

Investment	Expected Return	Standard Deviation
Valley Farmer (F1)	.10	20%
Hillside Farmer (F2)	.30	60%
Safe Investment (S)	.02	0%

The company will examine this set of options and find the covariance between dependable and risky farmers :

$$\text{Cov}(r_{F1}, r_{F2}) = \rho(F1, F2) \times \sigma_{F1} \times \sigma_{F2} = -.2 \times 20 \times 60 = -240$$

Supposing that the company would rather make the risky investments and make a higher return from the farmers, rather than investing in the safe

investment, the lender would compute the optimal risky portfolio, which would contain proportions (P) of roughly 68% dependable farmers and 32% risky farmers. This conclusion is easily constructed using the following rudimentary arithmetic:

$$P_{F1} = \frac{(10 - 5)60^2 - (30 - 5)(-240)}{(10 - 5)60^2 + (30 - 5)20^2 - 30(-240)} = 68.2\%$$

$$P_{F2} = 1 - P_{F1} = 31.8\%$$

Viewed this way, one quickly realizes that companies want to make investments in portfolios composed of both low-risk and high-risk farmers. However, if the company could buy down the risk of the higher-risk farmers in his or her portfolio at a reasonable price, the company would be likely to do this so long as the NPV of returns from premiums clearly exceeds the investment necessary at a reasonable interim cost of capital (for instance, by educating farmers or subsidizing irrigation projects). While this is purely a theoretical exercise, it yields a general concept of how an insurance portfolio would need to perform in order to appear attractive to insurance companies and their investors.

XI. Game Theory Topics: Classification, Analysis, and the Rational Participant

The Coin Game

The Coin Game is the simplest species of sequential game, wherein the game's proctor proposes a choice (two coins), and the player makes a choice (one coin). Then, the proctor proposes a second choice and the player makes a choice. The Coin Game is a sequential game because the proctor's second offered choice depends upon the choice made by the player in his first choice.

In the coin game, the rational participant will choose Alpha if he is risk-averse. The two coins have exactly the same yield in equilibrium, so the assignment of a preference is isolated to a preference for variance rather than a preference for absolute yield. The second round is similar, except the coin opposite Alpha or Beta offers a one-unit yield advantage in equilibrium. The variance of this coin is adjusted according to the player's choice in the first round. This second choice has a bounding function and establishes whether the player will accept more variance in exchange for a higher expected yield. Eventually, the participant falls into one of five categories.

a. The Dice Game

The basic Dice Game is a single-player, iterative stochastic game. The beginning state is the player's possession of four dice. The player then chooses whether to "pay" one die for insurance against an outcome from rolling the remaining three dice, or to roll all four dice. Depending upon the outcome, the player receives a "payout" (being able to continue playing) or "no payout" (the game ends). The game is iterative but takes place in an arbitrary temporal bound of three iterations.

The rational player in Dice Game 1 will be indifferent between the two choices, as the cost of insurance is exactly equal to its benefit and total risk is uniform across all outcomes (e.g. all rolls of three dice have the same probability of producing the one undesirable outcome as all rolls of four dice have of producing the two undesirable outcomes). The game imposes no transaction costs; in a world where there are transaction costs associated with acquiring insurance or discontinuing an insurance policy, the rational player would remain in his initial state, either unsubscribed or subscribed to insurance, as the cost of switching from "insured" to "uninsured" or the opposite would be in excess of the marginal gain from the switch (which is zero in all cases).

b. Complex Dice Games

Each of the Complex Dice Games is a single-player extensive-form game, which can also be played in a group-setting to further analyze the effect of others' decision-making on a single player's actions. Due to the complexities of this game structure, it is likely that they will be played within the confines of focus groups. It can also be considered a Bayesian game,¹⁷ in that the player's information about the benefits or costs of his choices is generally incomplete. Rational players may disagree as to actions, much as two rational players in The Coin Game will behave differently depending upon level of risk aversion.

The idea of the more complex games is to test different aspects of player behavior, rather than to simulate the experience of farming in and of itself. The game design of the Complex Dice Games follows two general rules: 1) a player will ideally have more than one choice and will not need to have very high or very low risk aversion to consider the second choice, and 2) a player will be given choices that two rational players with different risk and utility tradeoffs would consider differently, in that the two choices must be distinguishable from each other but not so wildly different that one is dominant across all utility player considerations

A Note About Insurance Behavior

Some may argue that performance in games involving coin-flips or dice rolls has little to do with a farmer's actual behavior. While the authors concede that the MHST is not a perfect model for farming,¹⁸ it is more indicative of a

¹⁷ Though there are modern definitions of Bayesian games and specific types of Bayesian games, the definition here is the Harsanyi definition.

¹⁸ See *supra* Part IV.

farmer's preferences than a simple stated-preference survey, which has been the dominant tool deployed to understand the behavior of farmers.

Other may take issue with whether, and how much, participants should be paid to participate. The authors have debated this question and are not opposed to the use of financial incentives in this type of research, recognizing that "real money" often drives more accurate duplication of "real life" behavior. However, as Thaler and Johnson observed,¹⁹ "The ideal experiment is one in which subjects make actual choices for real money. However, an experiment in which subjects can lose money creates some ethical dilemmas." These ethical dilemmas are put into particularly harsh relief when the subjects are poor farmers living at or under the UN poverty threshold.

Lastly, many will argue (and have argued for at least two centuries) that simulated loss will never match real loss and that even real loss of a different magnitude will fail to match the psychological and social effects of real losses of other magnitudes. This is no doubt a true observation, and one the social sciences struggle to remedy in each research exercise in this area, particularly in experimental economics. While the authors concede that any simulation will be imperfect in comparison to reality, we contend that the MHST and tools like it add a type of information that has been lacking in much social science research and, in so doing, add valuable context to more traditional data gathered.

XII. The Future of This Research

To the authors' knowledge, there has not been a rigorous assessment of farmers' WTP and other relevant preferences regarding micro-insurance

¹⁹ Richard H. Thaler et al., *Gambling With the House Money and Trying to Break Even: The Effects of Prior Outcomes on Risky Choice*, 36 Mgmt. Sci. 643, 643-60 (1990).

instruments to date within a structure that considers both revealed- and stated-preferences. The MHST described in this Article, provides a mode for this type of research. To the extent possible, the sections of the MHST not explicitly described in this Article, which are stated preference and direct questioning, strive to obtain a baseline for comparison of revealed preferences obtained through the administration of the game sections. In this manner, it is possible to assess the extent to which individual attitudes and social norms (culture) affect perceptions of risk, uncertainty, insurance, and disaster.

Iterative rounds of the games describe preference formation regarding low probability, high impact risk. The data gathered is then reduced to a usable form with reference to theories of Bayesian learning and the use of heuristics in the context of bounded rationality.²⁰

Though these games are a major step in this research area, there is space for continued development. The authors' current work to improve the next generation of games includes the following areas of study:

- Accounting for mitigation strategies and alternative activities that may not be insurance instruments, particularly as the farm increases in size. Examples may include better irrigation on large farms or diversification in crop types.
- Including different types of insurance, including those that pay varying multiples of the insurance premium rather than simply returning the premium and a portion of the loss in the case of a disaster.
- Building multiplayer and competitive versions of the games.

²⁰ Herbert A. Simon, *A Behavioral Model of Rational Choice*, *Q. J. ECON.*, February 1955, at 99-188.

XIII. Conclusion

The authors hope this Article encourages others to consider using nontraditional frameworks, particularly games involving uncertainty, as measurement tools in field research. Effective measurement and information gathering require more than asking a clever question or specifying the right range of choices in a survey. While traditional surveys help frame the discussion and gather specific pieces of data, active participation by the subject reveals a range of attitudes and tendencies more objectively than traditional survey methodologies. Participatory games should be considered as both a complement to, and substitute for, many types of questions in survey design. While games require substantially more design effort and expertise, the rewards are substantial and should not be underestimated.

As of this writing, in December 2010, the MHST continues to evolve as an impartial gauge assessing the needs, preferences, and concerns of farmers in the developing world. The authors welcome comments, responses, and debates regarding this Article and its subject matter.