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How Do Time and Money Affect Agricultural Insurance Uptake? A New Approach to Farm Risk Management Analysis

Katie Farrin, Mario J. Miranda, and Erik O'Donoghue

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Errata

On August 11, 2016, a correction was made to the first sentence of the second paragraph of page 1. The original report stated the Federal Crop Insurance Reform Act (FCIRA) was passed in 1995, when, in fact, the Act was passed in 1994. While the changes to farm insurance as a result of FCIRA took effect in 1995, FCIRA became law in 1994.

Abstract

Growth in the Federal crop insurance program, as well as in the use of crop insurance in developing countries, highlights the policy importance of insurance as a risk-management tool for farmers. This report presents a new approach to the analysis of demand for crop insurance, which can better explain observed insurance coverage decisions among U.S. farmers and inform future discussion about crop insurance provisions in the Farm Bill. The findings indicate that when farmers have access to other financial mechanisms—primarily savings—their insurance decisions change. In addition, when researchers consider the element of time—for example, a farmer's consideration of many crop seasons when making production and risk management decisions—predictions about farm-level demand for crop insurance will also change. Specifically, the authors find that, with savings, relatively wealthier farmers appear to spend less on insurance and self-insure through savings, while limited-resource farmers with low farm income use savings to increase insurance coverage. The more time a farmer factors into the decisionmaking process when comparing insurance versus savings for risk management, the less important insurance becomes.

Keywords: agricultural risk management, crop insurance, Federal crop insurance, savings

Acknowledgments

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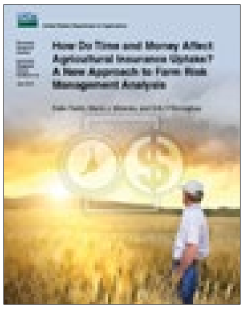

Find the full report at *www.ers.usda.gov/publications/err-economic-research-report/err212*

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What Is the Issue?

Farmers use crop insurance to protect themselves against risk—primarily against crop failure and low output prices. In the United States, the Federal crop insurance program has grown steadily since the mid-1990s and has become the single largest individual program providing support to producers under the 2014 Farm Act. The growth in crop insurance programs—both in the United States and in developing countries—appears to be driven in part by premium subsidies from governments.

This report uses a new approach to examine a farmer's risk management choices, and to look at how changes in the farmer's financial environment—particularly in savings and insurance markets—may change insurance demand. Unlike previous research on the topic, which emphasizes a farmer's attitude toward risk as the primary driver of insurance uptake, this report analyzes the relationship between wealth, savings, and insurance over time to identify alternative approaches to managing farm risk.

What Did the Study Find?

When farm households consider multiple growing seasons, insurance and savings are substitutes. Demand for insurance will fall as the interest rate on savings rises; similarly, farmers will save more and insure less as insurance premium rates increase. The exception is among farm households who are less wealthy; when wealth is low to start, additional savings complements insurance, allowing households to be able to afford to pay an insurance premium when they do not yet have enough savings to completely self-insure.

Farmer attitudes toward risk matter less when examining crop insurance demand over multiple years. Demand for crop insurance, when examined over multiple years, is primarily driven by the farmer's financial wealth rather than the farmer's attitude toward risk. Both uptake of insurance and choice of coverage levels are heavily determined by the producer's income and savings. Crop insurance is in low demand at both lower and higher levels of farm wealth—although the reasons for low purchase or coverage rates differ depending on what side of the spectrum a farm household falls. High-wealth farmers may not purchase insurance at all and may instead use savings to self-insure. By comparison, farm households with low wealth (i.e., with low incomes and little or no savings) may not purchase crop insurance because they cannot afford it.

The demand for crop insurance drops the longer the time horizon explored. Farmers do not make production decisions based solely on what would be best in the current season. Instead, they choose to manage their farms in a way that helps them earn the most value over the lifetime of the farm; this longer time period farmers consider when making their choices can span generations. An example of such behavior is crop rotation, where alternative crops are planted to maintain soil quality—even when the production value of the crop rotated in (or of fallow land) may be lower. Because farm risk management is included in farm-level production choices, planning for risk is also conducted while considering multiple seasons. Our approach takes into account a farmer's forward-thinking process. It shows that when households can save over many years, their insurance decision depends on time and is inherently dynamic; the choice is based off of a household's wealth and its history of farm income—including shocks to that income. Even among farm households with the same level of wealth, predictions about their insurance decisions will differ depending on whether the approach in the analysis considers two crop seasons or many.

Demand for crop insurance among U.S. farmers is significantly responsive to their savings and accumulated wealth. An analysis of USDA Economic Research Service and National Agricultural Statistics Service's Agricultural Resource Management Survey (ARMS) data shows that insurance and savings are substitutes, unless a household's annual farm income is relatively low. On average, savings lowers insurance demand among crop farmers in the United States. While low-income farmers are less likely to purchase insurance than those with higher gross farm income, savings among these limited-resource farmers can mitigate low insurance uptake. The study also finds that that operators with more farm debt are more likely to purchase insurance, perhaps to avoid falling farther into debt should a weather shock affect production in a given season.

How Was the Study Conducted?

The report presents a new approach to examining risk management at the farm level. The underlying analysis uses reasonable values to represent a farmer's financial and risk environment, as well as his or her risk preferences. These values can be varied to examine how farmer behavior changes under different assumptions about the environment in which the farmer lives. Thus, the new approach is valuable in that it can be used to forecast farm-level risk management behavior in a variety of settings—both in the United States and in developing countries—as it can be adapted to represent specific counties, States, growing regions, or other geographical or livelihood areas given available data. The fully dynamic approach is complex and cannot be solved by hand; a method for solving this approach on a computer is further detailed in the Appendix.

To test the empirical validity of the insights from the new approach, ARMS data are used to estimate how farm wealth changes the likelihood that a farm household will buy crop insurance.

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Introduction

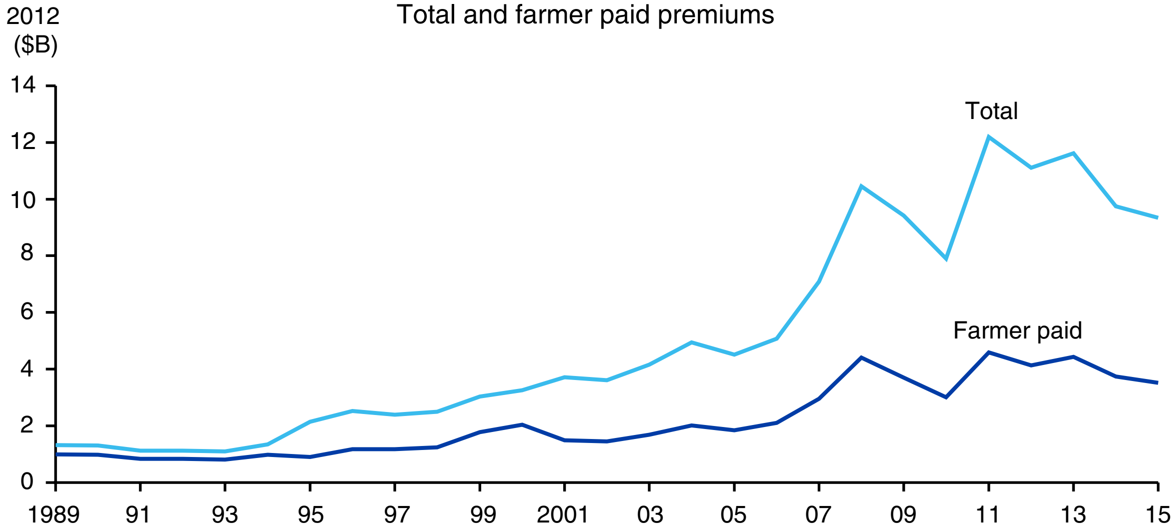
How do farmers manage production risk? The use of crop insurance programs has often been proposed as an answer to this extensively researched question.[1] In the United States, the Federal crop insurance program has grown steadily since the mid-1990s. With the 2014 Farm Act, the program has become the single largest individual program providing support to producers. The crop insurance title of the 2014 Farm Bill increased total funding for the program in the amount of $5.7 billion over 10 years, relative to projected levels that assumed no change in crop insurance policy (Shields 2015). Over the past 20 years, adoption rates have continued to rise, with more and more acres being covered by crop insurance. At the same time, farmers have also continued to increase the level of insurance coverage for their crops.

Figure 1 shows that the percentage of total U.S. cropland insured has increased since 1989, with a spike in insured acres after the Federal Crop Insurance Reform Act (FCIRA) was passed in 1994; covered acres more than doubled from 1994 to 1995, as FCIRA increased premium subsidies (including via the introduction of a fully subsidized Catastrophic Risk Protection Endorsement, or CAT, policy) and required producers to obtain insurance coverage to be eligible for other Government support. The gap between total insured acres and buy-up acres covered reflects the acres covered by fully subsidized CAT-level policies. Revenue-based insurance policies were introduced in 1996, and quickly became very popular among farmers as a risk management safety net. Seven years after introduction, farm acres insured with revenue policies outnumbered the acres insured with yield policies. By 2014, roughly 5 acres were insured to revenue policies for every 1 acre insured under a yield policy. Figure 2 depicts the shift in farm-level demand from yield- to revenue-based Federal crop insurance policies. In 2000, the Agricultural Risk Protection Act (ARPA) passed, which introduced further premium subsidies on higher levels of coverage.

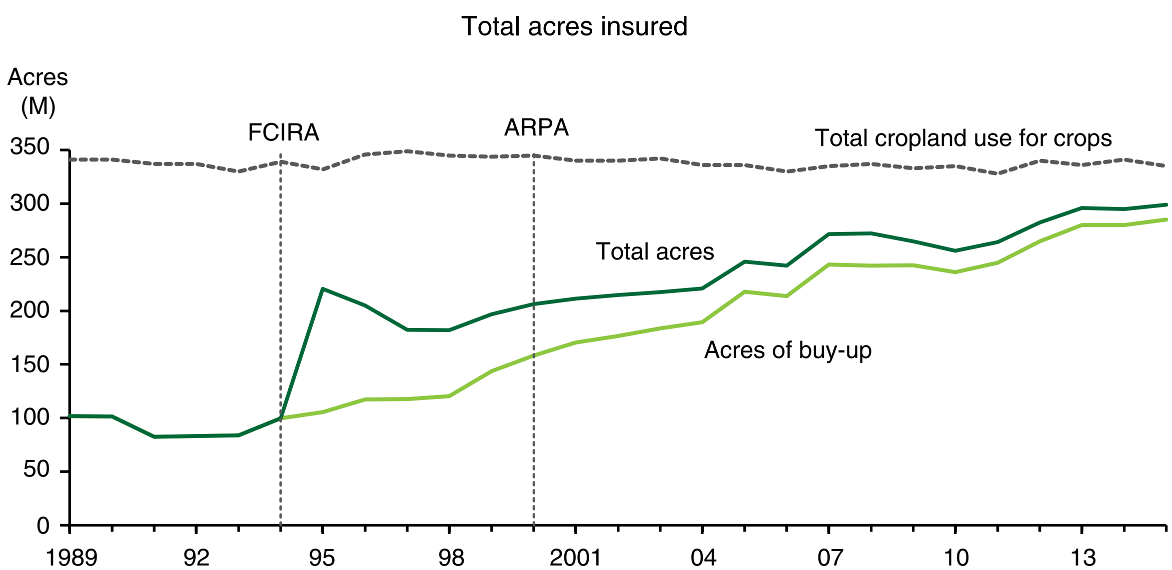
Federal Government expenditures on the Federal crop insurance program have increased since 2004, including the portion of program expenditures devoted to subsidies (figure 3). In addition, the 2014 Farm Bill places new emphasis on crop insurance, increasing coverage options available to farmers as well as introducing additional benefits for newer farmers (Shields 2015).

[1] Between 1970 and 2011, the *American Journal of Agricultural Economics* alone published 274 articles containing "risk" in the title, 80 articles containing "insurance" in the title, and 6 articles containing "risk" and "insurance" in the title.

Figure 1
Growth in the Federal crop insurance program, 1990-2015



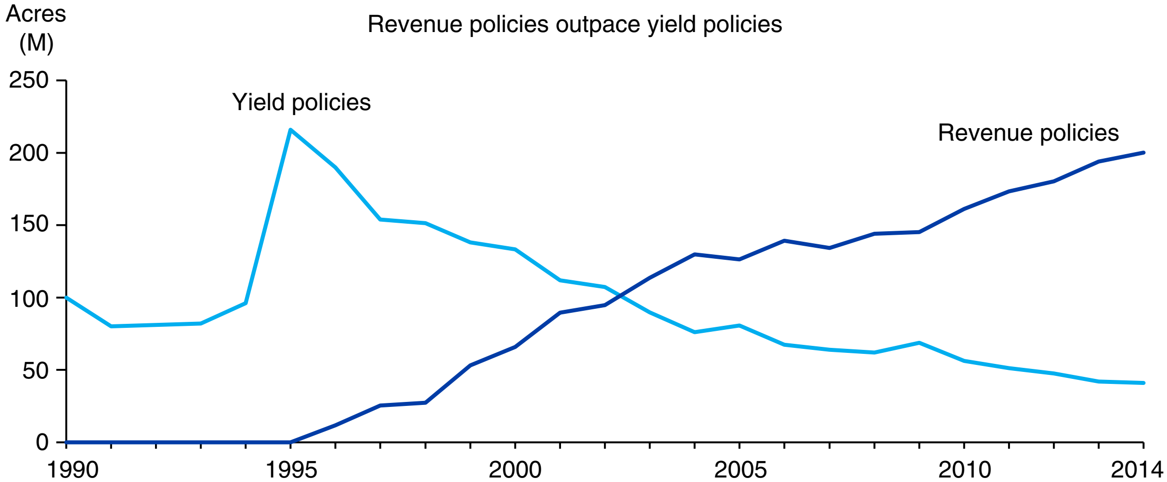
Source: U.S. Department of Agriculture, Economic Research Service calculations based on data from USDA, Risk Management Agency, Summary of Business, 1989-2015.



Source: U.S. Department of Agriculture, Risk Management Agency, Summary of Business, 1989-2015; estimates for 1989-95 are from Daugherty, 1995; 1996-2000 are from Vesterby and Krupa, 2001; 2001-06 are from Lubowski et al. (2006) and unpublished updates and revisions based on USDA/NASS, 2004a; 2004b; 2005; 2006; 2007-11 are based on U.S. Department of Agriculture, National Agricultural Statistics Service (NASS), Census of Agriculture 2007 and Crop Production annual summaries; and 2012-15 are based on National Agricultural Statistics Service (NASS), Census of Agriculture 2012, Crop Production 2014 Summary, and Crop Production 2015 Summary (released January 12, 2016).

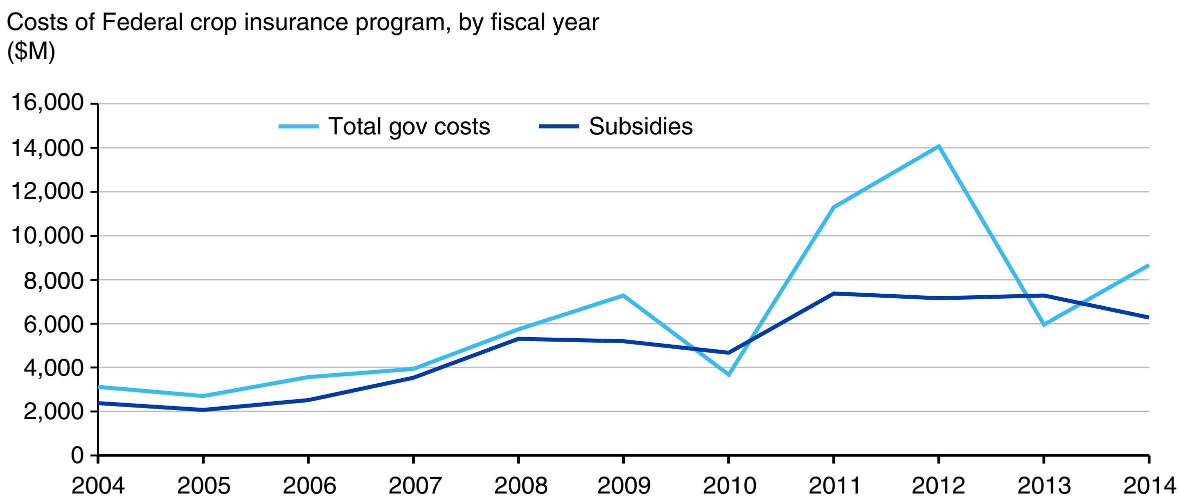
In developing countries—where formal risk markets are largely absent—researchers and practitioners have been testing index insurance products as tools to reduce poverty and increase productive investments among smallholder farmers (Miranda and Farrin 2012). Since the late 1990s, researchers have carried out index insurance feasibility studies and pilot projects throughout the developing world, in countries including Bangladesh, Burkina Faso, China, Dominican Republic, Ethiopia, Ghana, Guatemala, Honduras, India, Indonesia, Jamaica, Kenya, Malawi,

Figure 2
Federal crop insurance program acres insured, yield vs. revenue policies, 1990-2014



Source: U.S. Department of Agriculture, Risk Management Agency, Summary of Business, 1989-2015.

Figure 3
Fiscal year costs (total and subsidy) of Federal crop insurance program, 2004-2014



Source: U.S. Department of Agriculture, Risk Management Agency, Summary of Business, 1989-2015.

Mexico, Mongolia, Morocco, Nicaragua, Peru, Rwanda, Senegal, Tanzania, Thailand, Uruguay, and Vietnam. These activities have been supported by organizations such as the World Bank, the United States Agency for International Development (USAID), Asian Development Bank (ADB), Inter-American Development Bank (IDB), International Livestock Research Institute (ILRI), the United Kingdom Department for International Development (DfID), and United Nations World Food Program (WFP), among many others.

Given the uptick in the use of crop insurance as a means of farm risk management—both in the United States and abroad—this report develops a new approach to improve understanding of factors driving farm-level demand for insurance. What we see farmers doing—when and where they purchase insurance, and how much—does not match up with what we predict they will do using traditional approaches of risk management analysis. In this "traditional" analysis, farmers' attitudes toward risk and their corresponding risk management choices are examined in a bubble: in one, single crop season.[2] This approach typically predicts that a farmer can benefit substantially from buying crop insurance. Risk-averse farmers will always insure under fair premiums (where a farmer expects to come out even given coverage and premium payments), and may even buy insurance when it is *actuarially unfavorable* (i.e., the insurance premium exceeds the farmer's expected payout from the policy).

Even when insurance is subsidized, however, we observe that farmers in the United States do not universally adopt it, nor do they all choose the maximum allowable coverage level.[3] The use of saving, borrowing, and investment over time may significantly change the options available to a farmer, making his or her decisions difficult to explain using traditional risk management analysis; without considering time and financial tools to which farmers have access, the benefits of—and the demand for—crop insurance will be overstated. We thus take on a new approach to see if it can more adequately predict how producers actually behave if there are farm-to-farm differences in net worth, liquidity, and access to and cost of credit.

Although potential tradeoffs between savings and insurance have received relatively less attention from agricultural economists, there has been some research focus on the breadth of risk management options available to farmers, with the recognition that insurance is but one element of a portfolio of strategies farmers use to handle risk. Dismukes and Durst (2006) show how farm savings account programs in Canada and Australia can provide a whole-farm approach to a safety net. Ehrlich and Becker (1972) find self-insurance (e.g., savings) and market insurance to be substitutes and conclude that real risk attitudes of farmers may be hard to tease out without more information on all available financial opportunities. The ability to borrow and save has significant effects on one's stream of consumption, even when alternative risk markets are absent (Deaton 1991; Paxson 1992; Morduch 1995). When approaches to analyze insurance demand include a time component and farmers can save, the presence of a formal insurance market will add very little value to farmers; insurance will only be demanded for catastrophic risks or by individuals short on liquid cash (Gollier 2003; Deaton 1991; Heaton and Lucas 1996; Carroll 1997).

[2] Von Neumann and Morgenstern (1944) developed Expected Utility Theory (EUT) as part of a larger work that looks at how individuals play risky games. Their work, which formalizes the earlier hypotheses of Daniel Bernoulli, characterizes decisionmaking under uncertainty by assuming individuals display certain characteristics that allow their preferences to be represented by a utility function; using this utility function, expected utility can be derived through a linear combination of utilities over an uncertain outcome, multiplied by the probability of that outcome.

[3] Work in both the United States and in developing countries has shown premium subsidies—often used to incentivize farmers to participate in insurance programs—have been a large determinant of insurance demand. O'Donoghue (2014) discusses the American case, where the growth in the Federal crop insurance program is attributed to increased premium subsidies (which increased from $322 million in 1992 to almost $7 billion in 2012). McIntosh et al. (2013) look at the case of Ethiopian farmers, where demand for insurance is only highly responsive to price discount vouchers. Bassoco, Cartas and Norton (1986) use a model of Mexico's public agricultural insurance system to show that mandatory, unsubsidized insurance would make farmers worse off, as premiums include high administrative costs and exceed the value of the risk-reduction benefits provided by the program.

In this analysis, we build upon previous knowledge on risk management to systematically explore how access to finance—specifically, savings—impacts the benefits and optimal uses of crop insurance.[4] Our innovation to the current methods is the use of a time component that assumes farmers have access not only to insurance, but also to other financial instruments that allow for the buildup of wealth reserves over multiple seasons through saving and dissaving.

Our first exercise evaluates the interrelation between savings and insurance when farmers engage in production for two seasons. The results of this approach indicate that demand for crop insurance will depend heavily on a farmer's wealth.[5] Specifically, insurance and savings are found to be substitutes, and demand for insurance will decrease as the interest rate on savings increases; similarly, farmers will save more and insure less as insurance premium rates increase. While there are rates of insuring and saving at which famers will choose to both insure and save simultaneously, there is a clear inverse relationship between the level of spending on insurance and the amount a household chooses to save.

A main finding is that insurance demand, when farmers face two or more growing years, is less dependent on how risk averse a farmer is, as uptake and choice of coverage level is more dependent on the producer's financial wealth. We find that crop insurance is something that low-wealth farmers cannot afford and high-wealth farmers do not want.[6] This result, which does not emerge from the traditional approach to analysis of decisionmaking under risk, has implications for the design and provision of agricultural insurance in the United States as well as in developing country settings.

In a second step, we expand the analysis to consider the farmer's decisionmaking process over many seasons in a "multigenerational" approach. Because this multigenerational analysis of crop insurance demand is complex, we use computational techniques to solve the farmer's *value function*. The value function represents the optimal stream of expected lifetime benefits of a farmer's choices, including those regarding production risk management. In this approach, crop insurance demand depends not solely on a farmer's risk aversion (which determines the curvature of the utility function, a measure of how the farmer values one season's income), but instead on the curvature of the value function. This curvature depends on how much a farmer values consumption, as well as how much access to savings and insurance he or she has (where access to savings and insurance is measured by the interest rate on deposits and the premium rate on insurance, respectively). Results from a multigenerational approach show insurance demand is even less than what is predicted when only two seasons are considered; although premium subsidy levels generally prevent the case of zero

[4] While we choose to focus on savings in this analysis, the model we have developed also allows for borrowing; thus, further analysis may be done to examine the effect of credit on farm risk behavior. Additionally, Farrin and Miranda (2015) analyze the effect of agricultural insurance programs on credit markets; the authors find that certain types of insurance arrangements (specifically, those bundled with loans) can reduce interest rates on credit by lowering portfolio risk for lenders whose borrowers are largely agricultural households facing the same types of weather and price risk.

[5] As a clarification to the approach, we use the term "savings" to represent the amount of money out of current income in each period that a farmer chooses to hold back from consumption or investment, so that the term "wealth" is defined as the accumulation of savings over time; this wealth is driven by savings decisions of a household, which are influenced not only by its starting level of wealth, but on the history of income shocks it has experienced. Note that if a farmer draws down on his or her wealth because of insufficient income, savings can also be negative.

[6] Note that these are results of our baseline approach, which assumes that insurance premiums are priced at market levels rather than at the subsidized premium levels offered through Federal crop insurance programs.

insurance demand among U.S. farmers, under certain settings, there may be no demand whatsoever for crop insurance.

Our research will answer questions of fundamental interest to researchers, practitioners, agricultural economists and policymakers interested in risk management not only in the United States, but also in the developing world. The insights shed light on the role of crop insurance in agricultural risk management. Our findings also inform the emerging debate among development economists on whether poor farmers in developing countries are better served by government programs that promote institutional mechanisms to enable savings or by programs that promote access to crop or weather insurance.

Demand for Crop Insurance: What Do We Know?

We begin by briefly reviewing the demand for insurance according to the Von Neumann-Morgenstern expected utility model, which has been the bulwark of risk analysis in agriculture and in other fields of economics.

Consider a farmer who has a predetermined endowment of wealth, $w > 0$, and who faces an uncertain income, $\tilde{y} \geq 0$, and, additionally, an uncertain but insurable loss, $\tilde{l} \geq 0$, that is independent of income. We also assume that the *expected loss*[7] is positive, i.e., $E\tilde{l} > 0$. The farmer has the option to insure any portion x (between 0 and 1 – i.e., a coverage level) of the loss at a premium rate $\pi > 0$. That is, the farmer pays a premium of $x\pi$ and receives an indemnity $x\tilde{l}$ if a loss of magnitude $\tilde{l}$ occurs. The farmer will choose a level of insurance coverage that maximizes the utility of his or her wealth, which includes net income (indemnity less premium) from insurance.

Examining the farmer's demand for insurance, we look at two factors: how much the farmer expects to lose, and how much the farmer values additional income after a loss occurs. The farmer will only purchase insurance if the premium rate is less than the expected loss multiplied by the farmer's *relative marginal utility of wealth*—i.e., how much satisfaction the farmer receives from one more dollar of income. We call this value—the expected loss multiplied by the relative marginal utility of wealth—the *risk-adjusted expected loss*. The risk-adjusted expected loss is greater than the expected loss when a farmer does not like risk. This is because the farmer's marginal utility of wealth is higher for large losses than for small ones. Thus, a farmer places more value on additional income (from, for example, an insurance payout) after a loss when income is low than the farmer would for that same amount of additional income in a normal or good season.

The farmer will only fully insure (i.e., $x = 1$) if the expected loss equals or exceeds the premium rate. This means the farmer will not purchase coverage for the full loss unless insurance is, at minimum, *actuarially fair*.[8] Even in a one-season setting with no options to manage consumption risk over time, farmers will not buy complete coverage in a viable market setting; because most available commercial insurance policies use premium loads to cover administrative and overhead costs, a farmer will not insure all losses on all land under such policies.

[7] In economics, the expected loss is equal to the size of the loss multiplied by the probability that the loss will occur.

[8] An actuarially fair insurance contract is one for which the premium payment equals the expected loss.

Changes in Farm Behavior When Time Is Considered

We now expand the analysis to a two-season approach, where the farmer can buy insurance in the first period (i.e., the end of a season) to cover any potential losses in the second (where payment would come after harvest time of the second season). Only insurance is available; the farmer cannot save or borrow. Thus, the farmer starts the period—in this case, the agricultural season—with a predetermined level of wealth, w, and knows farming income in the next period is uncertain because it is possible that a loss will occur. The premium and indemnity payment for a chosen level of coverage, x, is the same as in the one-season case above.

Results of this approach show that, unlike in the one-season case, the risk-adjusted expected loss does not have to be greater than the expected loss (it may be greater than, less than, or equal to the expected loss depending on the farmer's risk preferences and wealth). A sufficiently wealthy farmer will buy insurance even if it is actuarially unfavorable, while a sufficiently poor farmer will not buy insurance even if it is *actuarially favorable*.[9] It is still the case that the farmer will only buy insurance if the premium rate is lower than the farmer's risk-adjusted expected loss.

Recalling that π is the premium rate available to the farmer, we let π^* represent the risk-adjusted expected loss, and π^{full} represent the premium rate that would induce a farmer to buy full insurance coverage. Note that π^{full} is positive, but is also less than π^*. Thus, three possible scenarios exist:

1) The farmer buys full insurance coverage: $\pi \leq \pi^{full}$;
2) The farmer partially insures: $\pi^{full} < \pi < \pi$; and
3) The farmer buys no insurance: $\pi^* \leq \pi$.

In the second, partial-insurance scenario, the optimal coverage, x^*, decreases with a higher premium rate and increases with a farmer's wealth. Specifically, the chosen coverage level, given the farmer's wealth and risk preferences, will equate the value of forgone present consumption (what the farmer gives up to pay an insurance premium) to the expected, discounted value of consumption in the next period (what the farmer expects to receive from future indemnities).

We now suppose the loss is of a simple form, i.e., $\tilde{l} = L > 0$ with probability p, and equals zero otherwise. This design of the loss structure represents a simplified version of the farm's situation: we only allow for "normal" years (no loss) and loss years (where the loss is the same, known quantity when it does occur).[10] The expected loss is simply the loss multiplied by the probability of experiencing the loss. Holding the premium and the expected loss constant, we find that a farmer will purchase more insurance coverage for infrequent, catastrophic losses (low p, high L) than for a more frequent but smaller loss event (high p, low L). Again, this is true even though the farmer is paying the same premium rate and for losses that are equal in expected terms.

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[9] An insurance contract that is actuarially favorable is one for which a farmer expects to receive more in payouts than what the farmer has contributed in premiums.

[10] We use this loss structure for clarity, but the model can be adjusted to incorporate a more complicated distribution of farm yields or revenues to better represent farms for specific crops in specific growing areas of interest.

That farmers are more willing to insure against catastrophic, rare events than more frequent, less damaging losses has important implications for the performance of shallow-loss insurance policies, including, for example, the crop insurance provisions in the 2014 Farm Bill.

Adding On: Time and Money, and How Farm Decisions Change in a Two-Season Approach

When a farmer not only has the option to buy insurance coverage but can also save, the farmer's insurance purchase decisions will certainly change. Here, we assume the same structure of starting farm wealth and uncertain agricultural income with an insurable loss, but now the farmer can save as much as he or she would like. While we may assume that the farmer does not make any interest income on savings (which is a reasonable assumption in developing countries as well as under the current market conditions in the United States), the addition of savings brings two additional concepts of returns to the analysis: *the risk-adjusted real rates of return to savings and insurance*, r_s and r_x, respectively. A farmer, when he or she chooses to give up one unit of consumption today in order to save—or, in the alternative, to purchase additional insurance coverage—is expected to receive $(1+r_s)$ or $(1+r_x)$ units of consumption in the following season, depending on the method of risk management he or she chooses.

A farmer will choose savings and/or insurance coverage levels based on these rates of return. Specifically, the optimal choice for a farmer is to save and insure at levels that will equate r_s and r_x, and to have both of the rates of return also equal to the farmer's *discount rate*. A farmer's discount rate is subjective, and is a measure of how he or she values payments that occur in the future versus those that occur in the present.[11] If both the risk-adjusted real rates of return for savings and insurance are less than the discount rate, the farmer will neither save nor insure (if one of these rates is higher than the discount rate, the farmer will choose only one method of risk management, and choose a level of savings or insurance to make the associated rate of return equal to the farmer's discount rate).

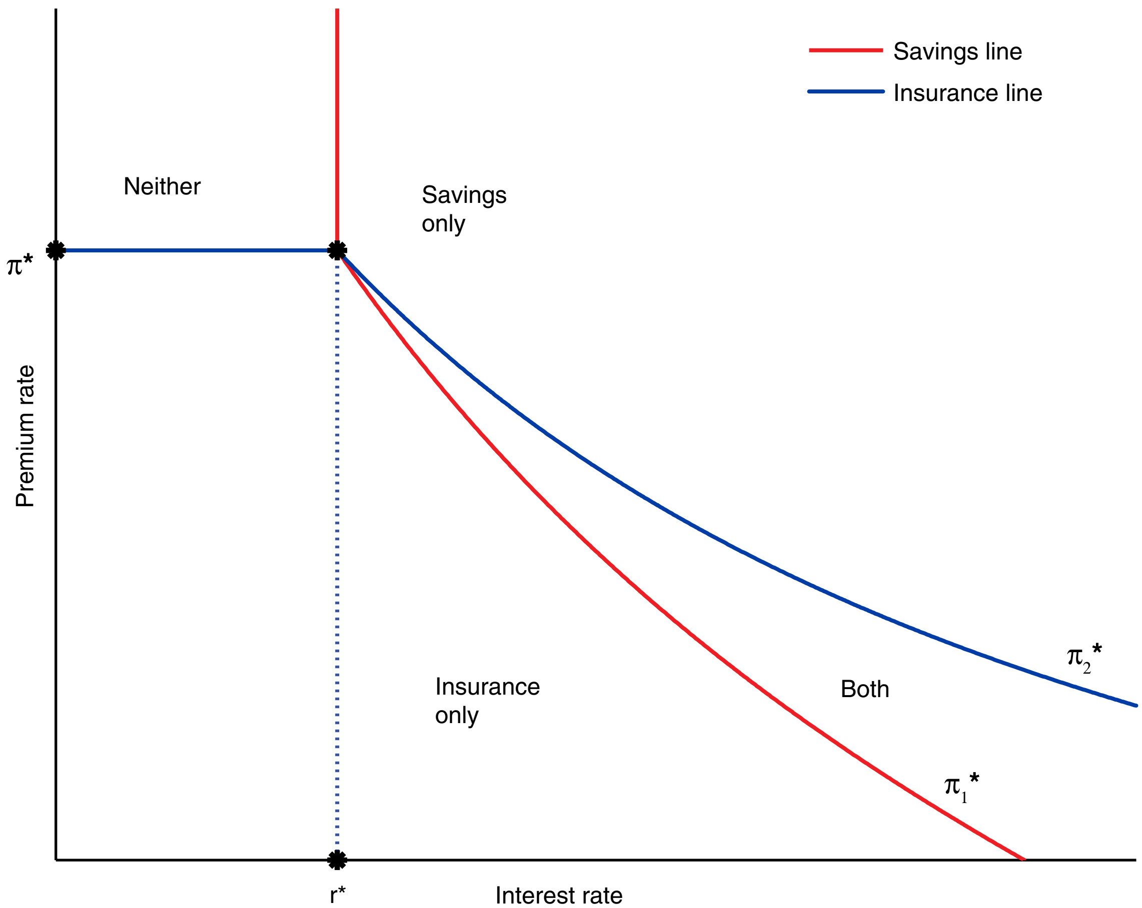
Thus, there are two "critical" rates that will determine risk management choices when a farmer has access to both savings and insurance: the critical interest rate on savings, r^*, below which no savings will be held; and the critical premium rate, π^*, above which a farmer will not purchase insurance coverage. The critical interest rate is decreasing as wealth increases, which, intuitively, suggests that the wealthier a farmer is, the easier it is to save (i.e., the lower the incentives necessary for inducing savings), as additional current consumption isn't as valuable at a level of consumption that is already high. On the other hand, the critical premium rate is increasing in wealth. The intuition behind this is the same: the farmer is willing to give up more money in the present for a future payoff when current consumption is high and future income is uncertain. The main takeaway from this finding is that, given interest and premium rates, relatively wealthier farmers are more likely to both save and insure.

We now can graphically represent four different "risk management regimes" for farmers given the interest and premium rates available to them. Figure 4 shows these regimes.[12] For low interest rates (below r^*) and high premium rates (above π^*), there will be no savings and no insurance coverage. Where interest and premium rates are relatively high (the northeast region of the figure), a farmer

[11] Empirical studies often assume an individual's discount rate is equal to the prevailing interest rate on savings. However, discount rates can vary by individual preference; such rates can be elicited using a series of questions about preferences over current and future payoffs (see, for example, Harrison et al, 2002).

[12] Figure 4 is generated by solving the farmer's two-season decisionmaking process using a computer simulation. More details on this method are provided in the Appendix.

Figure 4
Savings and insurance choices, interest-premium rate plane

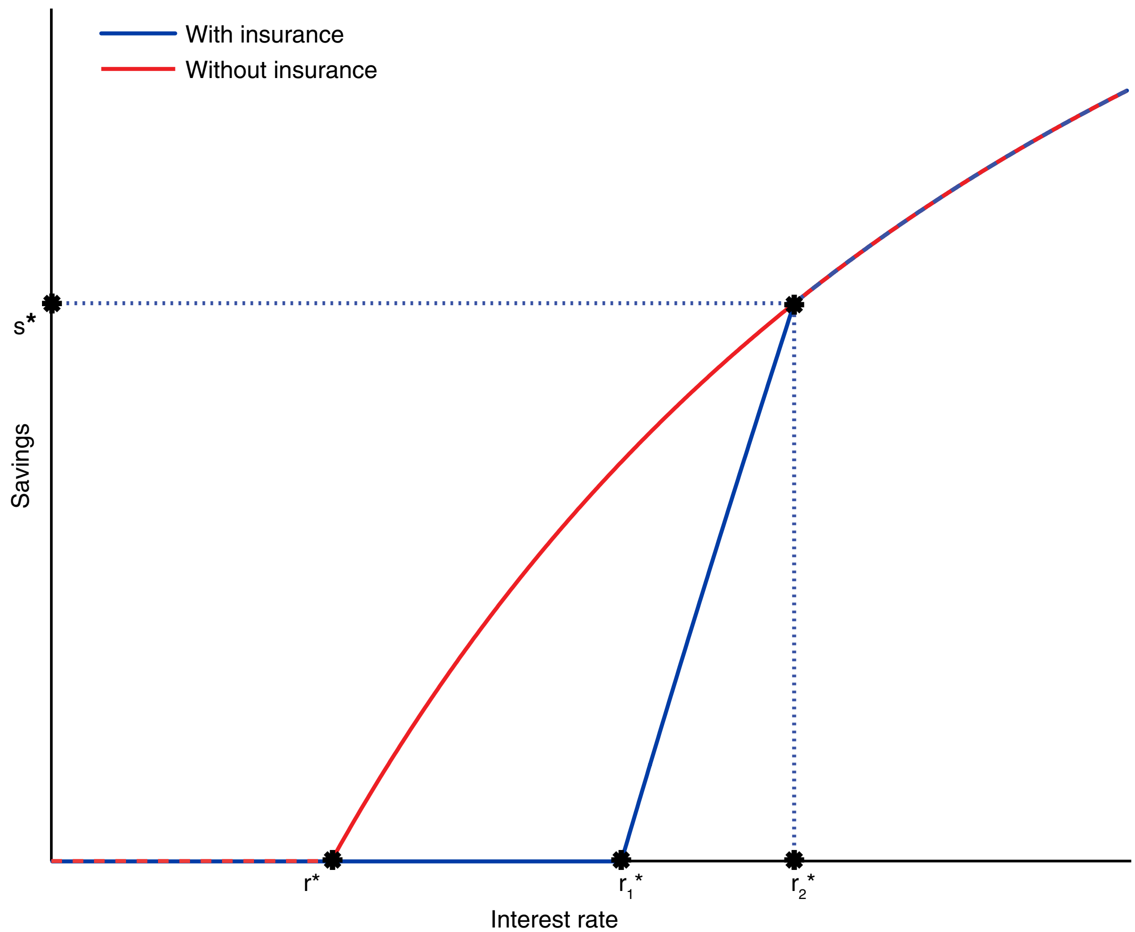


Source: U.S. Department of Agriculture, Economic Research Service, simulation results.

will save, but not insure. The converse is true in the southwest section, where a farmer will only purchase insurance coverage when both interest and premium rates are relatively low. Finally, it is optimal to both save and insure only for interest-premium rate combinations that lie between the lines π_1^* and π_2^*. In this region of the figure, expenditures on each form of risk management will vary, but a farmer will include both savings and insurance coverage in a mixed risk management strategy.

In figure 5, we now compare how a farmer will save both with and without access to insurance. The blue line represents a farmer's savings choices with insurance (holding the premium rate fixed), whereas the red line shows how savings will evolve without a functioning insurance market. At very low interest rates (below r^*), the demand for savings is not affected by access to insurance, as these interest rates are too low to merit savings. Similarly, at very high interest rates (above r_2^*), the demand for savings is the same regardless of whether insurance is available; at these levels of interest, it is more beneficial to save than insure, and therefore no insurance coverage will be purchased. For intermediate interest rates (those between r^* and r_2^*), insurance will "crowd out" savings, i.e., savings without insurance availability will be higher than it will be if insurance is available, as the farmer will choose a mix of savings and insurance at these rates if insurance is available.

Figure 5
Demand for savings, fixed premium rate



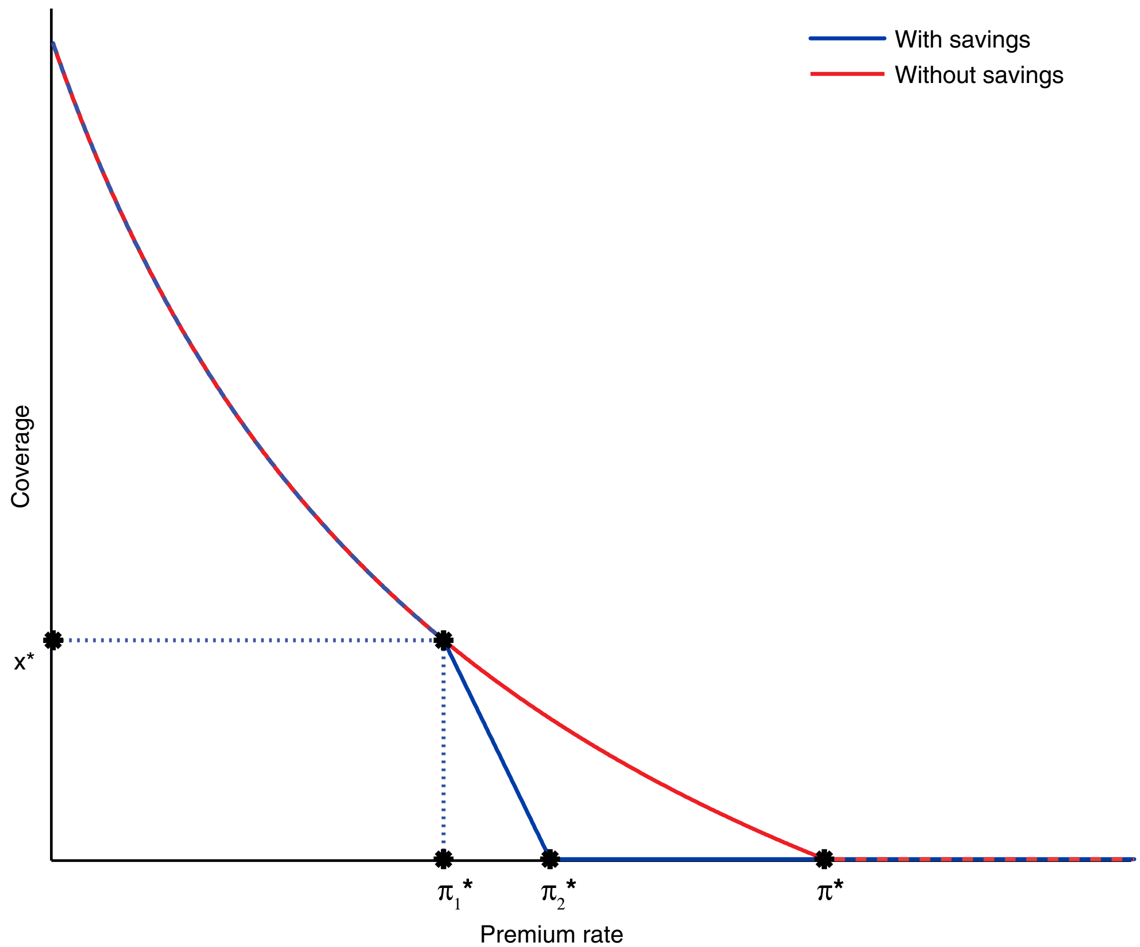
Source: U.S. Department of Agriculture, Economic Research Service, simulation results.

We also examine the converse to look at the demand for insurance both with and without savings. Figure 6 shows how insurance decisions will change if farmers can save at a fixed interest rate. When farmers have access to savings (depicted as the blue line in the figure), the demand for insurance tapers off faster than it would in a scenario in which saving is not an option for risk management. At a premium rate of π_1, a farmer who can save will begin to incorporate savings into his or her risk management portfolio, and will thus substitute some savings for insurance when the latter becomes relatively more expensive. At π_2, a farmer with access to savings will completely stop purchasing insurance, whereas a farmer who cannot save is willing to buy coverage at higher rates, up to π^*.

At premium rates below π_1, the farmer's insurance choice is the same with or without savings, because at rates this low, it is more beneficial to only buy insurance. Similarly, at high premium rates (above π^*), the insurance decision is the same; at these rates, a farmer will not purchase any insurance, regardless of whether or not he or she can save.

In a two-season setting, a farmer's wealth plays a large role in insurance and savings decisions. We now hold both the interest and premium rates set at a given level to study the wealth effects for two

Figure 6
Demand for insurance, fixed interest rate



Source: U.S. Department of Agriculture, Economic Research Service, simulation results.

seasons, where farmers can both buy insurance and save over time. Two critical wealth levels arise in this analysis: w_r^* and w_π^*, for savings and insurance, respectively. At each of these critical wealth levels—which can vary across farmers given their risk preferences—the prevailing interest rate on savings and the insurance premium will be equal to the added value a farmer expects to receive should he or she give up some current wealth to either make a deposit or pay an insurance premium. A farmer, therefore, will only save if his or her current wealth is greater than or equal to w_r^*; the farmer will only insure if his or her current wealth is greater than or equal to w_π^*.

In addition, these critical wealth values will depend on the interest rate and premium available to the farmer. The critical wealth for savings, w_r^*, is lower for relatively higher interest rates on savings, as a higher future return will induce a relatively less wealthy farmer to give up some current consumption to save. The critical wealth for insurance, w_π^*, on the other hand, increases as the premium rate increases, as higher premiums mean more upfront, out-of-pocket expenses that lower current consumption in exchange for a possible—but not certain—future payment. Further, if the farmer insures but does not save, the optimal level of insurance coverage (from zero to full) will be higher as wealth increases.

Even More Time: A Multi-Generational Analysis of Insurance and Savings Among Farmers

When we expand the approach to more than two seasons to make it fully dynamic (while keeping the farmer's decision process identical to that of the two-season approach with savings) we can solve for the optimal levels of savings and insurance given the farmer's current wealth. We denote these optimal choices of savings and insurance as $s(w)$ and $x(w)$, respectively. These choices can be thought of as rules that farmers follow; the w is included in the rules because the rules are wealth dependent. In other words, $s(w)$ and $x(w)$ can be looked at as the answer to the farmer's question, "How much should I save and insure if I have w as my level of wealth?" The farmer chooses these levels of savings and insurance based on the expected returns from both risk management options, as well as the farmer's *marginal rate of intertemporal substitution of consumption*. This is a measure of how much current consumption a farmer is willing to forego in order to consume in the future.

Similar to the case of the two-season approach, the farmer will select savings and insurance to equate his or her risk-adjusted real rates of return to savings and insurance to his or her discount rate. In addition, we arrive at the same result for the two-season and multigenerational approaches: the critical interest rate below which a farmer will not save is decreasing in wealth, while the critical premium above which a farmer will not insure is increasing in wealth. Figures 7 and 8 show the relationship between wealth and the critical interest and premium rates, respectively.

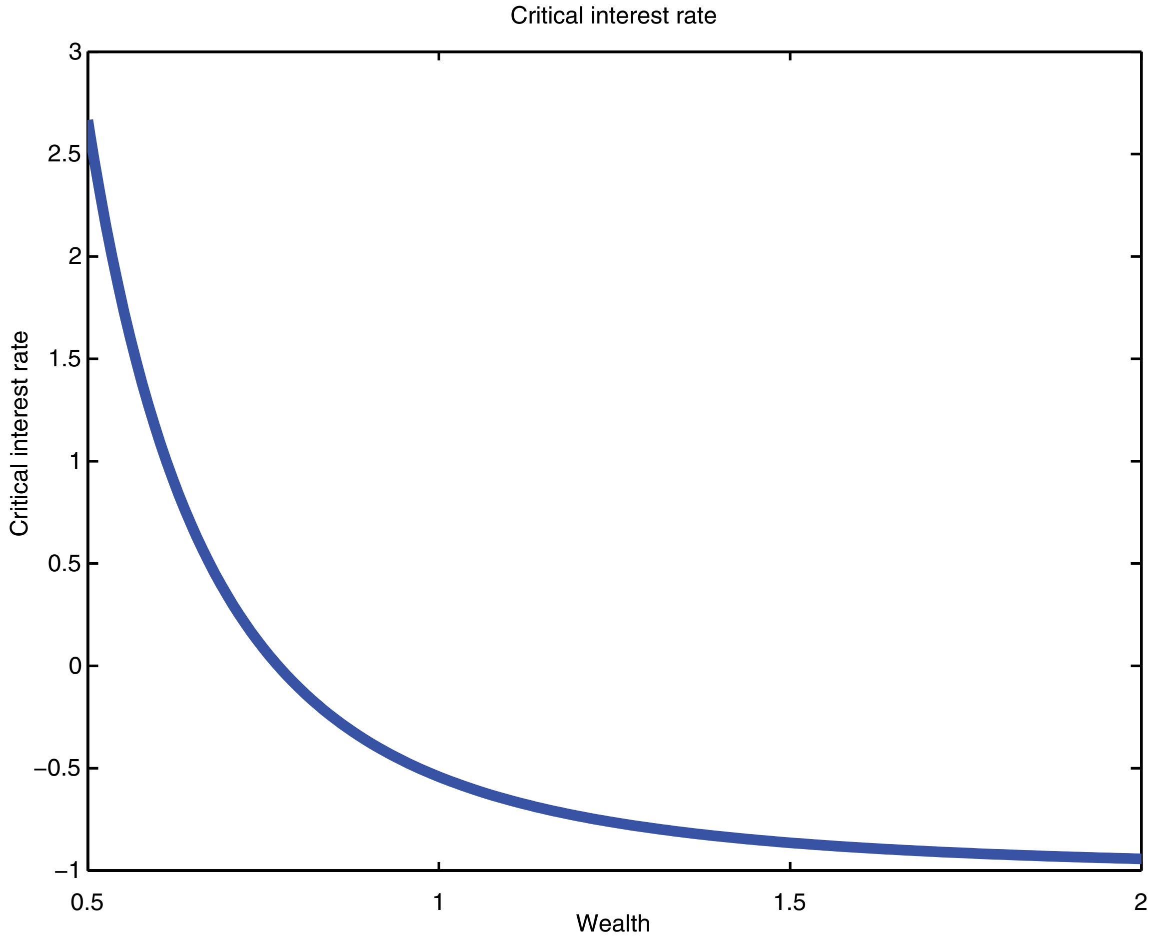
We use an example to highlight the differences between the two-season and the multigenerational approach. Under the same assumptions about farmers' risk attitudes and financial environments, the demand for insurance will be lower when more than two seasons are considered. This is because the farmer can accumulate savings over a longer stretch of time in order to smooth consumption in a year where an income shock occurs.

Comparing the two-season and multigenerational approaches, figure 9 shows how, in a multigenerational setting, the demand for insurance will taper off with wealth. The dotted line in the figure represents a farmer's optimal insurance coverage when making risk management choices with only two seasons in mind, as determined by the farmer's initial wealth level; the solid line does the same, but for a time period of many seasons. At low levels of wealth, zero insurance coverage is purchased in either setting, as farmers at this level of wealth value additional current consumption too highly to be willing to invest in risk management for future seasons.

However, as wealth increases, optimal behavior under the two approaches diverges. While the two-season approach predicts the most coverage at wealth slightly over 1,[13] with a slight decline in coverage at higher wealth levels, behavior under the multigenerational approach is markedly different. There is a clear peak for insurance coverage at a moderate wealth level just under 1, followed by a sharp decline in optimal coverage. No coverage is purchased at a wealth of about 1.6; this

[13] In the computer model, we set agricultural income in a good year to be equal to 1. Thus, wealth in this case can be interpreted as a fraction of annual farm earnings. The model can be adjusted to represent actual farm or regional settings; we use the annual income of 1 as a simplification.

Figure 7
How wealth affects the critical interest rate for savings

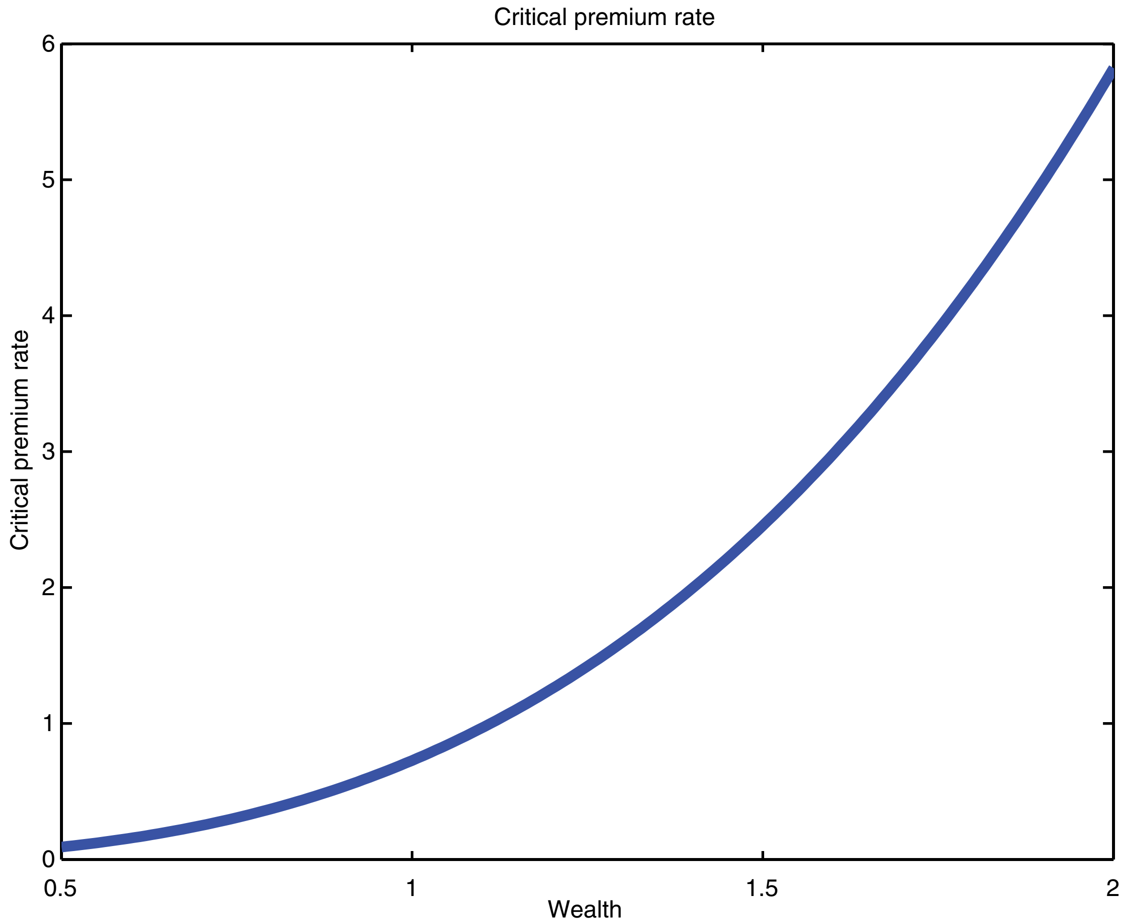


Source: U.S. Department of Agriculture, Economic Research Service, simulation results.

starkly contrasts the prediction of the two-season approach, which shows optimal coverage at the same wealth level to be around 80 percent.

The differences between predictions about farm-level insurance demand when we use different time considerations become even more apparent in figure 10, which shows how savings and insurance investments change with wealth. In a two-season approach, farmers save less and insure more relative to what they would if they were planning with multigenerational considerations. The exception is at low wealth levels for insurance coverage, where expenditures are slightly higher in the multigenerational approach until a wealth level of just under 1 is achieved. However, in the multigenerational approach, once households reach a level of wealth at which it becomes optimal to save, the drop in insurance demand and substitution toward savings is more dramatic than the same transition for the two-season approach. It is in the findings from this multigenerational approach where we see implications of crop insurance as a mezzanine risk management tool. Those with very little accumulated wealth cannot afford to buy insurance, while those who have sufficient wealth do not wish to spend money on insurance; on one end of the wealth spectrum, farmers value current consumption over risk transfer, and on the other, self-insurance through saving is more cost-effective (recall that

Figure 8
How wealth affects the critical premium rate for insurance



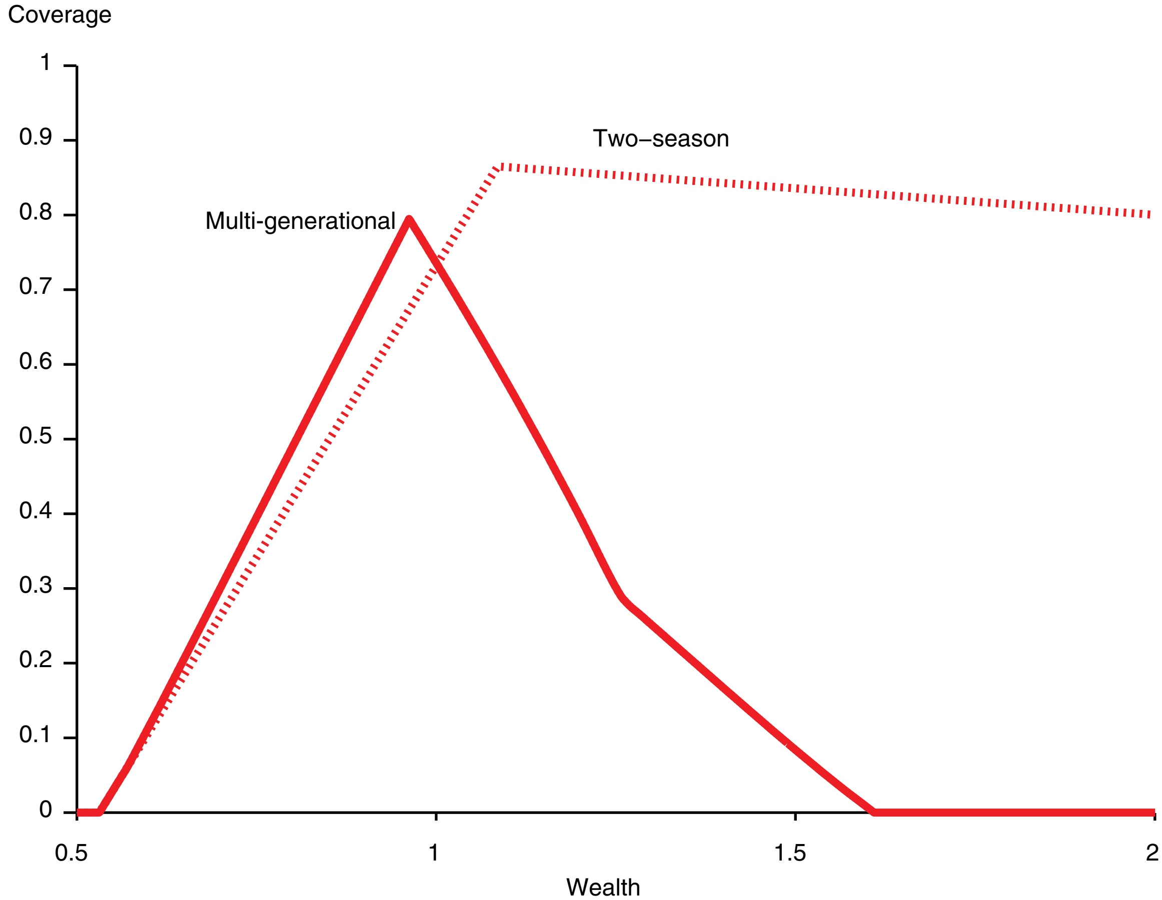
Source: U.S. Department of Agriculture, Economic Research Service, simulation results.

savings has a positive or zero rate of return, while market-priced insurance contracts are actuarially unfavorable when premiums are loaded to cover administrative and other costs).

These results are particularly important in developing country settings, where low-income households are already less likely to invest in insurance because of how important it is for them to use their income for current consumption. Where policymakers plan to introduce new insurance products to attempt to increase the well-being of the poorest rural households, these households may not have any demand for such products if they are not highly subsidized.

As a tool to explain differences in well-being created by different financial environments in a multigenerational approach, figure 11 shows the value functions of farmers under several settings: one with neither savings nor insurance; one with only savings; one with only insurance; and one with both savings and insurance. Recall that the value function is a representation of the optimal stream of expected lifetime benefits of a farmer's choices. At low wealth levels, the value function for the "savings only" environment lies below that for the "insurance only" environment, indicating that poorer farmers would be better off with insurance and not savings if both were not available; in fact,

Figure 9
Optimal insurance coverage and wealth

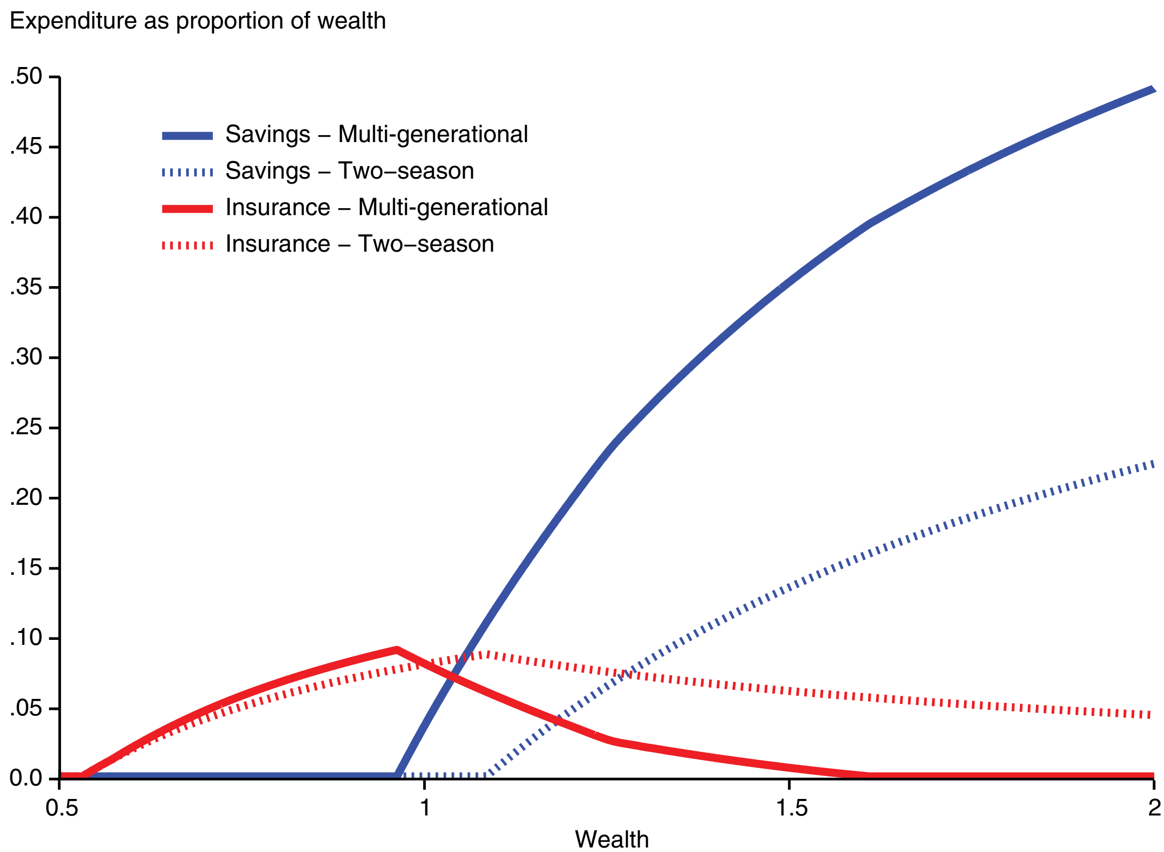


Source: U.S. Department of Agriculture, Economic Research Service, simulation results.

the addition of savings does very little to farmer well-being at low levels of wealth. This is because the premium payment is a smaller amount out of current consumption than would be a larger sum of savings held for the next period's consumption. At these low to medium levels of wealth (assuming savings and insurance are the only options available to them), farmers use insurance for risk management because they cannot afford to save sufficiently to self-insure. At higher levels of wealth, it is savings that increases farmer well-being relatively more than insurance where only one financial tool is available. At very low levels of wealth, however, the gains from either savings or insurance begin to converge, as the only value in having one or the other is the potential to save or insure in the future; low-wealth households neither save nor insure because they need all of the money they make to purchase items for consumption in the now, but at least they have the possibility to do so in a good year.

Finally, we use the new approach to look at the implications of subsidized insurance. As previously discussed, in the United States, agricultural insurance is subsidized and actuarially favorable for farmers; in developing countries, there is often very little demand for crop insurance unless it is offered at a subsidized rate, with the remainder of the premium financed by the national government

Figure 10
Optimal savings and insurance as a proportion of wealth



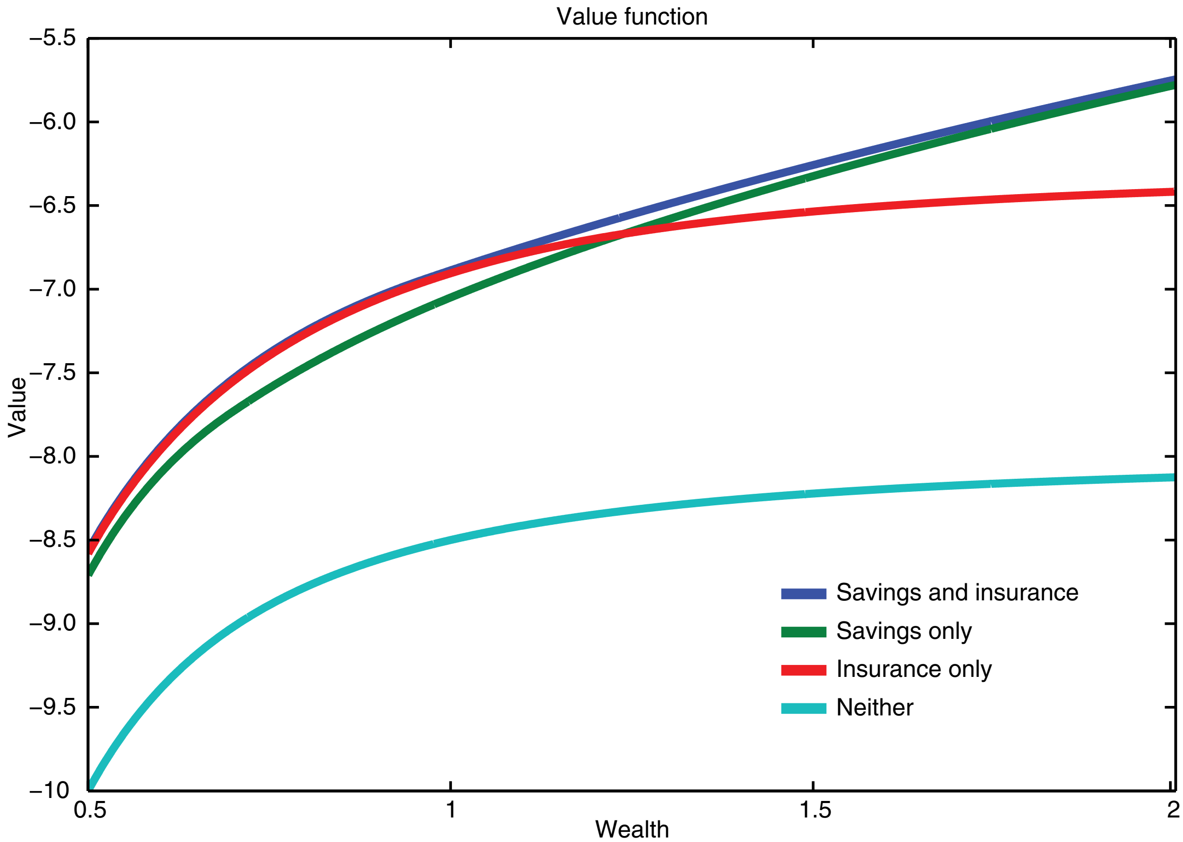
Source: U.S. Department of Agriculture, Economic Research Service, simulation results.

or by donor agencies. Figure 12 shows how demand for insurance is crowded out by that for savings as the *premium load*[14] on insurance increases.

Holding the interest rate on savings constant, the average famer shows high demand for subsidized insurance up until it becomes actuarially fair. This demand declines as the premium load increases from zero. For negative premium loads (i.e., subsidized insurance) up until a load of zero (actuarially fair insurance), expenditures increase due to the increased cost of insurance as subsidies fade out; over this range, the average farmer purchases full insurance coverage (x=1), which is the maximum allowed in our approach (in practice, farmers may not be able to purchase 100 percent coverage, and we assume in these cases that they will purchase the maximum allowable coverage under their policy). Expenditures on insurance continue to increase from loads up to 0.1, as coverage levels decline from full coverage over this range, but at a slower rate than the increase in premium cost. After this point, the demand for insurance declines more sharply, with coverage levels dropping to about 25 percent by the time the load increases to 0.2. This is where we see expenditures for insurance dropping in favor of expenditures on savings. Note that when

[14] The premium load is the fraction of the insurance premium that covers insurer expenses.

Figure 11
Value functions in different financial environments

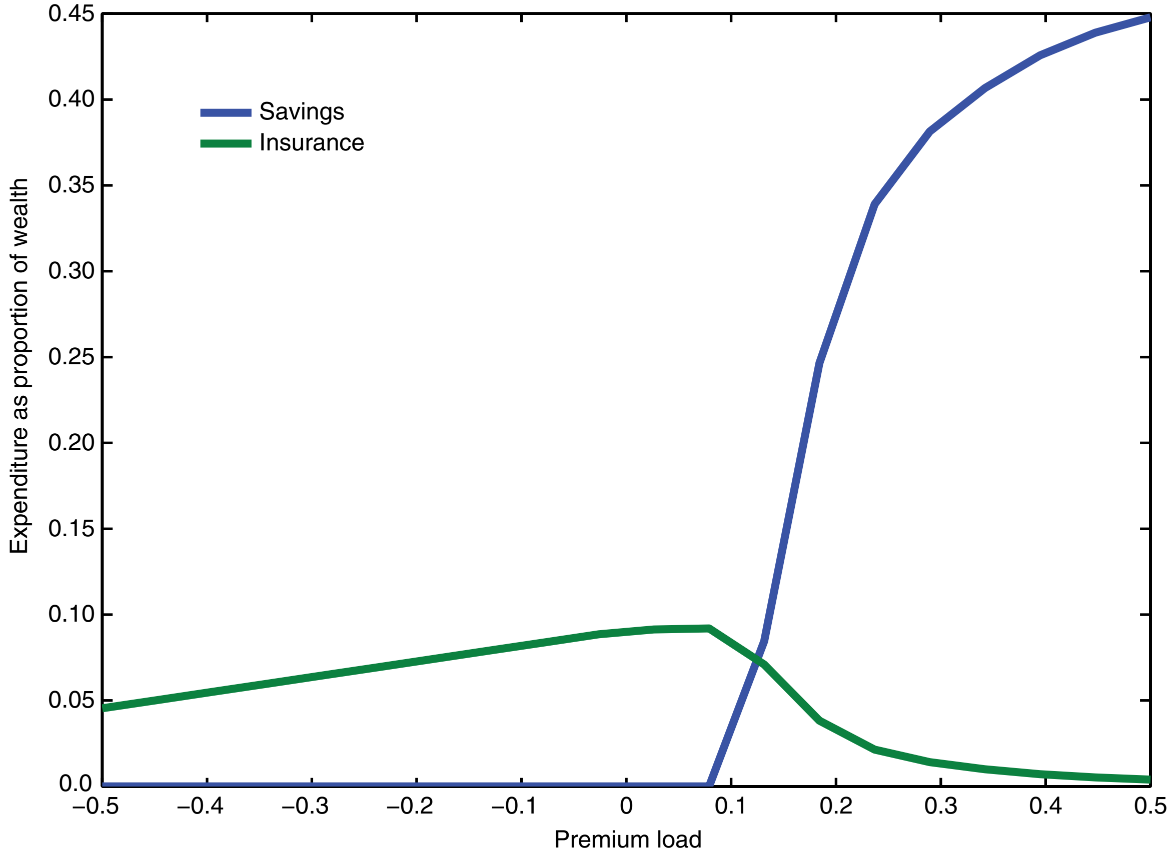


Source: U.S. Department of Agriculture, Economic Research Service, simulation results.

savings becomes a substitute for insurance, households must put more of their current income into savings to get the same risk protection from savings as they previously had from insurance. When households purchase insurance—even when a payout is not guaranteed the next period—they put forward a small premium and receive a much larger payout in the next period if a negative shock occurs; if the households want that same level of payout using savings, they must put forward a large lump sum in the current period to self-insure.

The analysis of insurance purchase decisions under various premium rates shows that low-income farming households would be unlikely to adopt unsubsidized insurance. At very low levels of wealth, insurance subsidies would induce full insurance coverage, which could offer the lowest income households the means to accumulate wealth and eventually attain a level of savings that would move them out of a targeted subsidy population. At higher levels of wealth, households that cannot access premium subsidies have the means to self-insure through savings.

Figure 12
Premium loads and expenditures on savings and insurance



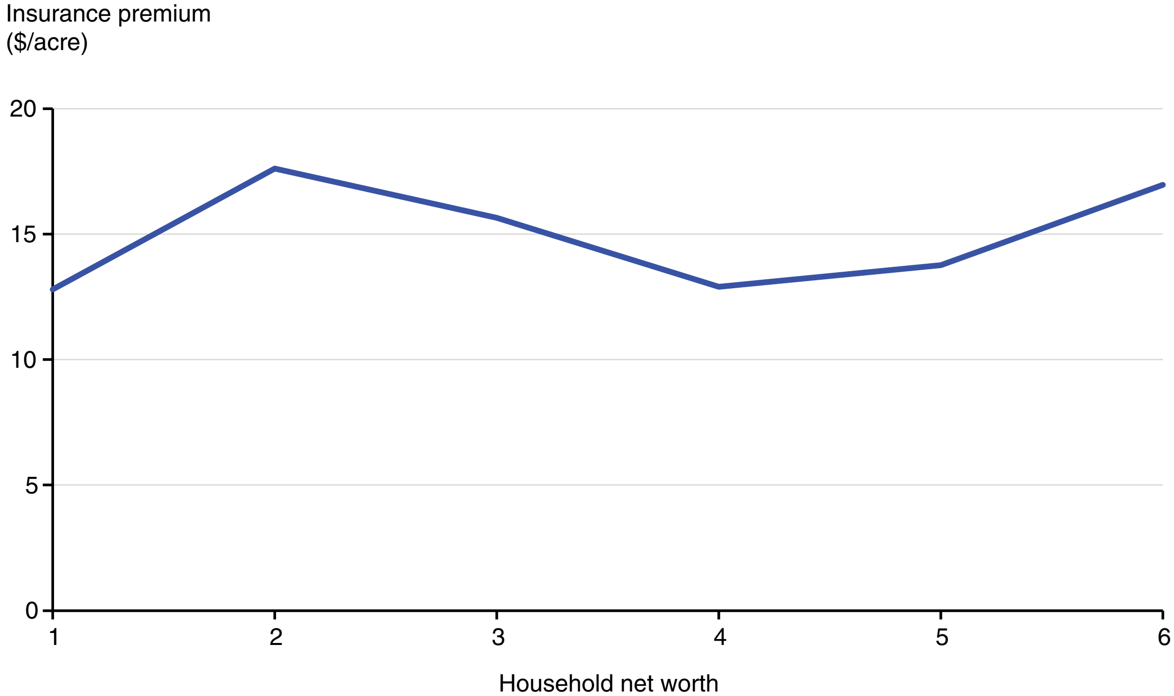
Source: U.S. Department of Agriculture, Economic Research Service, simulation results.

How Does U.S. Farmer Risk Management Compare to Predictions of This Approach?

To examine whether U.S. farmer behavior is consistent with our approach, which examines insurance demand and its relationship with time and financial options, we use the ERS/NASS Agricultural Resource Management Survey (ARMS) data set to look at the relationship between savings and insurance among grain farmers in the United States. ARMS provides nationally representative, farm-level survey data for approximately 10,000 households. The data include information about farm households' financial status and economic well-being, as well as about production practices and resource use. Specifically, we use the 2013 Phase III Whole Cost of Production Survey data, which include detailed information about the farm business and the farm household.

Simply examining the data from our sample shows a bell-shaped relationship between insurance expenditures and wealth (figure 13).[15] Farmers in lower categories of net farm income spend less per acre on insurance premiums, while expenditures peak at $17.61 per acre for Category 3 (farm net worth for these farmers falls between $82,000 and $195,000). While we do see an increase in

Figure 13
Premium loads and expenditures on savings and insurance



Source: U.S. Department of Agriculture, Economic Research Service calculations based on 2013 Agricultural Resource Management Survey (ARMS) data.

[15] We exclude Category 1 farmers from this figure, as they are listed as having negative farm net worth. Farmers in this lowest farm net worth category spend the most on insurance per acre, but this result is not necessarily inconsistent with our new approach (which does not allow for borrowing). In addition, regression results presented subsequently show a positive relationship between farm debt and insurance demand.

premium expenditures per acre for the Category 7 farmers, their per-acre expenditures fall below that of the Category 3 farmers. One explanation for the decline and then small increase in crop insurance expenditures in the highest net worth categories is that, with extreme wealth, farmers have more money to purchase insurance not for risk management, but instead for risky investment in crop insurance; given the high returns to Federal crop insurance, these high-wealth farmers (farm net worth is over $900,000 and $2 million for Category 6 and 7 farmers, respectively) may be willing to invest in insurance for the high expected returns—despite the "risk" of a good season, where premium payments would exceed indemnities.

Because we are interested in better understanding the relationship between insurance use and wealth, we more formally examine farmers' insurance choices using the following empirical model[16]:

$$y_i=\beta_0+\beta_1 W_{i+}\beta_2 LR_i+\beta_2 W_i * LR_i+X_i\theta_\alpha+v_{R(i)}+\eta_i$$

where y_i represents the demand for crop insurance; W_i represents the wealth of the farm household, including both farm and non-farm assets; LR_i is an indicator of a limited-resource farmer; the vector X_i includes a host of characteristics of both the farm household and the farm business; $v_{R(i)}$ represents regional fixed effects, which help to control for issues such as land quality and crop mix that do not tend to change much over time; and η_i is an error term.

Ideally, we would be able to use a panel dataset to test the predictions of our new approach, as the multigenerational approach aims to capture the dynamic interplay between savings, consumption, and crop insurance purchase decisions. However, ARMS is a repeated cross-section, so we are limited to examining a single year. Nonetheless, we still should be able to exploit cross-sectional variation in wealth in order to explore how crop insurance decisions may be affected. We also take advantage of available information on a special class of low-income farmers, which allows us to analyze how wealth can have distinct effects on risk management choices across households with different farm incomes.

We restrict the sample to include only those survey respondents who report crop production in the survey period (this eliminates surveyed households who report only livestock farming), and additionally exclude hobby farmers from the sample. Because we are interested in looking at the factors that determine a farmer's crop insurance purchase, we identify households who reported positive expenditures on insurance in the survey year. We define an insurance-purchasing farm household as one that reported positive expenses on Federal crop insurance, including buyers who are operators, landlords, or contractors. Regardless of the quantity spent, we group the sample into buyers and non-buyers of crop insurance. We use this information—whether or not a household bought insurance—to analyze how differences in farm household demographics and in farm environment will affect the likelihood of an insurance purchase. Out of 6,429 farm households in our sample, 4,315 households reported an insurance purchase, while 2,114 made no insurance purchase.[17]

[16] We include measures of assets and debt in our analysis, recognizing possible endogeneity issues if insurance adoption affects these measures. Thus, the analysis is meant to show correlation, rather than causation, between our variables and insurance uptake.

[17] While 67 percent of our sample report an insurance purchase, we use weights to make the sample nationally representative. This translates to 179,473 out of 385,656 farms being insured, or about 47 percent.

To examine the correlation between savings and insurance purchase, we use total farm and off-farm assets as a measure of savings (*Total Assets per Acre*). Farm assets include the value of land and buildings; trucks, tractors, automobiles, and other farm equipment; livestock; purchased seed, fertilizer and feed on hand; and all crops stored on or off the farm. Off-farm assets include financial assets held in non-retirement accounts (cash, checking, savings, money market, cancellation of debt income, and savings bonds); retirement accounts; and real estate (including the operator's dwelling if not owned by the operation, personal and secondary homes, other farms, residential rental and commercial property, non-arm businesses, and household vehicles). We take this measure of savings and normalize it to a per-acre measure by dividing the value by the number of acres in operation (this includes acres rented by the operator and excludes acres rented to other operators). In the primary specification of the empirical model, we use the *Total Assets per Acre* variable in log form.

Liquidity is how quickly or easily one's assets can be converted to cash to meet financial demands. It is an important part of farm risk management. Harwood et al. (1999) provide a useful overview of liquidity and farm risk management, including a summary of various risk management strategies that farmers can choose to use either in conjunction with or in place of any available crop insurance programs; these strategies include selling assets, managing the pacing of investments and withdrawals, and holding liquid credit. In our analysis, we choose to group all farm households' assets together as a measure of wealth, although some of these assets are more liquid than others. For example, if a farmer experiences an income shock in a season—whether it be low yields or low output prices—certain types of income are more readily available for use in coping with such a shock, while other assets are more difficult to use as a substitute for (or complement to) insurance. These less liquid assets include real estate and farm assets such as machinery and buildings, which are "lumpy" assets and likely would not be sold so the household would have extra cash on hand; and other investment assets such as retirement accounts, which, while technically available for use by the farm household, would carry a penalty for early withdrawal.

However, our analysis of the ARMS data shows that different types of wealth have a very similar effect on insurance uptake. Because liquid and illiquid assets among farmers in our sample are so highly correlated, separating the two types of income makes each type of income appear less significant a factor in a farm's insurance uptake decision. In addition, if we remove less liquid assets and use only a farmer's more liquid assets in the estimation, we lose valuable information about the farmer's durable assets – and these assets can comprise a large part of a farmer's wealth. While durables and commitment savings accounts are not likely to be used as cash should a farmer need additional liquidity, they are available and could be used in the case of a catastrophic shock. Thus, these relatively non-liquid assets play an important role in a farmer's risk management portfolio, and for that reason we include them in the measure of wealth we use in this analysis.[18]

The vector of farm household and business characteristics includes variables such as whether the farm is incorporated; household size; age, maximum education level attained, race, and sex of the primary operator; the ratio of acres planted to corn, soybeans, and wheat; and the amount of debt the farm is carrying—many of which have commonly been used in empirical approaches to crop

[18] Mishra et al. (2013) use a similar measure of combined total household net worth (including farm and non-farm assets) when using ARMS data to examine the effect of wealth on precautionary savings. Mishra and Chang (2009) separate farm and non-farm net worth when determining what factors affect a household's choice to save, but do not separate liquid from illiquid assets in this analysis; both farm and non-farm assets are found to increase the likelihood of precautionary savings among farm households.

insurance demand (e.g., Goodwin, 1993; Coble et al., 1996; Smith and Baquet, 1996; Goodwin et al., 2004). In addition, we use a limited-resource farmer dummy variable to focus on whether those producers with low incomes over multiple years act differently than farmers who are wealthier due to a stream of higher annual crop incomes. A detailed description of the explanatory variables in X_i can be found in tables 1 and 2.

Table 1

Definition and description of farm characteristic variables used in analysis

Variables and definitions
Limited-resource farmer   An indicator of whether or not the farmer surveyed comes from a "limited resource farm." Such a farm is defined as (i) one with direct or indirect gross farm sales not more than $172,800 (for fiscal year 2013) in each of the previous 2 years; and (ii) one whose operator's household earns a total income at or below the national poverty level for a family of four, or less than 50 percent of the county median household income in each of the previous 2 years. We include this variable because we hypothesize that limited-resource farmers will have limited liquidity, and thus will be less likely to purchase crop insurance. In addition to simply including the *Limited-Resource Farmer* variable, we also interact this variable with the log of *Total Assets per Acre* variable to test how access to savings will affect insurance decisions among relatively lower income farmers.
Farm debt per acre   The operator's share of total farm debt divided by total acres; this debt can be shared among multiple operators. Farm debt includes short- and long-term debt, accounts payable, accrued interest, and non-current liabilities. Prior to estimation, it is unclear what the effect of farm debt will be on crop insurance uptake. On one hand, an upfront premium payment that results from an insurance purchase will take away from the cash-on-hand available for a farmer to pay down his debt. On the other hand, insurance requires a smaller upfront payment and could protect against a catastrophic event that may further increase a farmer's debt; thus, a more indebted farmer may be more likely to purchase crop insurance. In the primary specification of the model, this variable is in log form.
Household debt per acre   Non-farm debt plus farm debt to the household. Non-farm debt includes mortgages (on operator's dwelling plus any other real estate that is not the farm), business loans (not to the operation but for another business), personal loans (credit cards, auto loans, etc.), and all other off-farm debt. Again, prior to estimation, the correlation between household debt and crop insurance purchase is unclear; we suspect household debt may have a different effect on insurance choice than farm debt and thus have included both variables in the econometric specification.
Farm corporation   An indicator variable that takes on a value of one if the farm is organized as an S or C corporation, and zero otherwise. We expect that corporate farms will be less likely to adopt crop insurance, as these farms tend to be larger (this goes hand-in-hand with the savings argument); in addition, farmers operating on a corporate farm enjoy limited liability. However, farm incorporation may require business and taxation knowledge, and thus may be a proxy for education; if this is the case, operators of incorporated farms may be more likely to adopt insurance.

—continued

Table 1

Definition and description of farm characteristic variables used in analysis—continued

Variables and definitions
Education
A vector of two variables: an indicator of whether or not the operator graduated high school but did not attend college; and an indicator of whether or not the operator has had some high school but did not graduate. The omitted group is farmers who have completed all or some college. Comparing farmers with differences in relative education levels, theory and evidence suggest that less educated farmers are less likely to purchase crop insurance.
Crop ratio
A vector of three variables that indicate the percent of an operator's total harvested acres for corn, wheat and soy crops. We include this variable to take into account that different crops in diverse areas are subject to distinct growing conditions, and may react differently to weather shocks.
Government payment
Direct payments divided by total acres. The effect of Government payments on insurance purchase is ambiguous. These payments may be a substitute for insurance; in the alternative, a farm household that receives more Government payments may be more likely to enroll in a Federal crop insurance program.[1]
Region
An eight-variable vector of indicators for the nine Farm Resource Regions constructed by ERS to depict geographic specialization in production of U.S. farm commodities. Table 2 describes these regions. In the estimation, the omitted region is the Mississippi Portal.[2]

[1] While direct payments were eliminated in the 2014 Farm Bill, they were still in effect for the survey period used in this analysis.

[2] For more information on Farm Resource Regions, see Heimlich, 2000.

Table 3 presents summary statistics for our sample. The average farmer spent just under $8 per acre on Federal crop insurance in 2013. Average total household assets per acre are approximately $25,000 (median household assets are much lower, at $5,859 per acre), with average farm debt per acre just over $1,375 and household debt per acre approaching $3,100. The majority of operators are White, male, and have completed at least a high school education. Their crops are more heavily made up of soy and corn compared to wheat. A small number of these farmers—about 13 percent—are categorized as limited-resource farmers.

Results presented in table 4 show that farmers with more savings appear less likely to purchase crop insurance.[19] This is consistent with the findings of the multigenerational approach, where savings and insurance uptake are inversely related at high levels of wealth. In the econometric model, the relationship between crop insurance purchase and a farm household's assets is highly nonlinear, making point estimates difficult to interpret. To give a practical example of what the results indicate in terms of farmers' asset levels and corresponding crop insurance uptake, we use

[19] Results are similar for a sample of grains, oilseeds, dry peas, and dry beans farmers (compared to the base sample of all crop farmers). This suggests that results of the model are robust. Results of the model using only these farmers are available upon request.

Table 2

Description of farm resource regions

	Farm resource region	States included	Primary crops
1	Heartland	IA, IL, IN, KY, MN, MO, NE, OH, SD	Cash grains, cattle
2	Northern Crescent	CT, MA, MD, ME, MI, MN, NH, NJ, NY, OH, PA, RI, VT, WI	Dairy, general crops, cash grains
3	Northern Great Plains	CO, MN, MT, ND, NE SD, WY	Wheat, cattle, sheep
4	Prairie Gateway	CO, KS, NE, NM, OK, TX	Cattle, wheat, sorghum, cotton, rice
5	Eastern Uplands	AL, AR, GA, KY, MD, MO, NC, OH, OK, PA, TN, VA, WV	Cattle, tobacco, poultry
6	Southern Seaboard	AL, AR, DE, GA, LA, MD, MI, NC, SC, TX, VA	Cattle, general crops, poultry
7	Fruitful Rim	AZ, CA, FL, GA, ID, OR, SC, TX, WA	Fruit, vegetables, nursery crops, cotton
8	Basin and Range	AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY	Cattle, wheat, sorghum
9	Mississippi Portal	AR, LA, MI, TN	Cotton, rice, poultry, hogs

Table 3

Summary statistics

Variable	Mean	Standard error
Federal crop insurance expenditures per acre	7.77	2.33
Total household assets per acre	25,017	10,806
Limited-resource farmer	0.13	0.03
Farm debt per acre	1378	1192
Household debt per acre	3061	1643
Farm corporation	0.08	0.03
Household size	2.54	0.14
Operator age	59.7	1.26
Operator male	0.94	0.02
Operator White	0.94	0.02
Education – less than high school	0.06	0.02
Education – completed high school	0.36	0.05
Corn ratio	0.17	0.02
Soy ratio	0.16	0.02
Wheat ratio	0.05	0.01
Direct payments per acre	0.80	0.30

Source: U.S. Department of Agriculture, Economic Research Service.

Total household assets, farm debt, household debt, and direct payments are listed in dollars per acre. Limited-resource farmer, farm corporation, operator male, operator White, and the two education variables are indicators taking a value of either 0 or 1.

the model estimates to calculate the difference between the likelihood of buying crop insurance across farmers at different asset levels and different initial probabilities of crop insurance adoption. Consider a farmer whose characteristics predict that he or she has a 50-percent probability of buying crop insurance. Holding all other characteristics constant, the results suggest that a 2.732-fold increase in the farmer's initial wealth will decrease the probability that he or she buys insurance to 35 percent. If, instead, the farmer's initial probability of adopting crop insurance is 90 percent, the

Table 4

Factors affecting crop insurance purchase

Parameter	Estimate	Standard error
Intercept	3.59***	0.46
ln (Total household assets per acre)	-0.61***	0.04
Limited-resource farmer	-1.72*	0.90
Limited-resource farmer*ln (total household assets per acre)	0.10	0.10
ln (Farm debt per acre)	0.26***	0.02
ln (Household debt per acre)	-0.16***	0.02
Farm corporation	-0.04	0.13
Household size	-0.07**	0.03
Operator age	-0.01***	<0.01
Operator male	0.26	0.17
Operator White	0.43***	0.15
Education – less than high school	-0.87***	0.17
Education – completed high school	-0.39***	0.08
Corn ratio	3.87***	0.20
Soy ratio	2.77***	0.19
Wheat ratio	1.75***	0.27
ln (Direct payments per acre)	-0.01	<0.01
Regional fixed effects?	Yes	
N	6,429	

Source: U.S. Department of Agriculture, Economic Research Service, regression results.

In the estimates column, * denotes statistical significance at the 10-percent level, ** denotes statistical significance at the 5-percent level, and *** denotes statistical significance at the 1-percent level.

same increase in wealth suggests a decrease in the probability of adoption to 83 percent. Finally, if the farmer's prior probability of adoption is 25 percent, the almost tripling of the farmer's wealth suggests a decrease of that probability to 15 percent.[20]

Interestingly—and also in line with the predictions of the new approach—the relationship between savings and insurance is the opposite for limited-resource farmers. While limited-resource farmers are less likely to purchase insurance than those who do not fall under the limited-resource definition, our findings suggest that limited-resource farmers with more access to savings are relatively more likely to purchase insurance. This is reflected in the positive parameter estimate for the interaction of *Limited Resource Farmer* and *Total Assets per Acre*. Thus, we see a mitigating effect of wealth on a low likelihood to purchase crop insurance among limited-resource farmers. The combined findings for the relationship between wealth and insurance—for both non-limited-resource and limited-resource farmers—support the theory of crop insurance as an effective risk management tool for low- to middle-income farmers; the low-wealth households (i.e., those with low incomes and with little to no savings) and the relatively high-wealth households appear less likely to purchase crop insurance, whereas middle-income and limited-resource farmers with some wealth due to accumulated savings appear more likely to purchase.

[20] This assumes the farmer is not a limited-resource farmer. The mathematical derivation of these findings can be provided by the authors upon request.

As for farmer indebtedness, results suggest that operators with more farm debt are also more likely to purchase insurance—perhaps to avoid falling further into debt should a weather shock affect production in a given season. The opposite is true for household debt, where operators with more household debt appear less likely to purchase insurance; this may be due to liquidity issues unrelated to farm-level risk. Farmers who are male, White, and have at least some college education appear more likely to purchase insurance; the same holds for operators whose land is more heavily devoted to grains crops. Older farm operators with larger households and operators receiving more direct payments appear less likely to purchase crop insurance.

To test the robustness of our empirical model, we run a second specification where the dependent variable is producer-paid premiums (rather than the zero-one variable of insurance uptake used in our primary specification). The results of this ordinary least squares (OLS) model are presented in table 5. The estimates can be interpreted as a percent increase (or decrease) in premium payments per one-unit (1 percent, for logged variables) increase in the independent variable. The estimates of this specification are consistent with those of the primary empirical specification: farmers with more wealth and limited-resource farmers appear to spend less on insurance; limited-resource farmers, however, appear to spend more if they have some accumulated wealth; and farm households with higher levels of farm debt appear to spend relatively more on crop insurance.

Table 5

Factors affecting quantity spent on crop insurance

Parameter	Estimate	Standard error
Intercept	1.34	1.08
ln (Total farm assets per acre)	-1.57***	0.09
Limited-resource farmer	-7.88***	1.83
Limited-resource farmer*ln (total farm assets per acre)	0.61***	0.20
ln(Farm debt per acre)	0.71***	0.05
ln (Household debt per acre)	-0.39***	0.05
Farm corporation	-0.08	0.32
Household size	-0.18***	0.07
Operator age	-0.03***	0.01
Operator male	0.31	0.36
Operator White	0.97***	0.36
Education – less than high school	-2.21***	0.38
Education – completed high school	-1.05***	0.18
Corn ratio	12.37***	0.47
Soybean ratio	9.15**	0.48
Wheat ratio	6.74***	0.71
ln (Direct payments per acre)	-0.02	0.01
Regional fixed effects?	Yes	
R^2	0.48	
N	6,429	

Source: U.S. Department of Agriculture, Economic Research Service, regression results.

In the estimates column, * denotes statistical significance at the 10-percent level, ** denotes statistical significance at the 5-percent level, and *** denotes statistical significance at the 1-percent level.

Conclusion

When farm-level insurance demand is lower than we expect it to be, new approaches are necessary to understand why observed coverage rates do not match up with predictions. By incorporating time and money into our analysis of the farm's insurance decisionmaking process, we get a picture that better captures the real environment under which farmers manage risk. Time—and with it, the ability to accumulate wealth through savings—becomes a crucial determinant of a farmer's demand for insurance. The results highlight a central implication for farm risk management policy in both the United States and in developing country settings: when other risk-management mechanisms are not taken into account, we tend to overestimate the value of insurance to farmers. In addition, when we fail to recognize that farmers may be planning not just for one, two, or five seasons, but instead for future generations, the value of savings is underestimated relative to the value of insurance.

The findings of this report show that U.S. farmers with more wealth are less likely to purchase crop insurance—unless those farmers are low-income operators. While low-income farmers are less likely to purchase crop insurance, savings mitigates this low demand and increases the likelihood of insurance adoption. Implications from the findings of this report apply to policymaking in the areas of farm risk management programs, including provisions for insurance and subsidies for such insurance. Given the findings of this new approach, the role of insurance as a risk management tool for low- to mid-income households is one that requires further research—particularly in developing countries, where failures in risk and credit markets could be corrected through subsidized insurance premiums. While middle-wealth households can afford (and choose to purchase) insurance, and high-wealth households prefer savings over insurance, it is the poorest households who have the potential to benefit the most from risk protection through insurance—even if liquidity constraints prevent them from being able to afford insurance at market rates. In developed country insurance markets, for example, the Federal crop insurance program in the United States, this study and the new approach it presents serves as a tool to increase understanding of the determinants of farm-level insurance demand, including time, wealth, and subsidy levels.

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Appendix

A formal exposition of the infinite-horizon dynamic model with savings (what we call the "multi-generational approach") is as follows:

An infinitely lived farmer begins each period endowed with predetermined wealth w, which he or she must then allocate among consumption, savings, and purchases of insurance. The farmer faces an uncertain income $\tilde{y} \geq 0$ the following period and, additionally, an uncertain but insurable loss $\tilde{l} \geq 0$ that is independent of income, with $E\tilde{l} \geq 0$. In order to preclude the possibility of nonpositive wealth in any period, we further assume that $\underline{y} > \overline{l}$, where $\underline{y} \equiv sup\{y | Pr(\tilde{y} \leq y) = 0\}$ is the greatest lower bound on attainable income and $\overline{l} \equiv inf\{l | Pr(\tilde{l} \geq 0) = 1\}$ is the least upper bound on attainable losses.

The farmer may save as much wealth $s \geq 0$ as he or she pleases, earning a per-period interest rate $r > 0$. The farmer may also insure any portion $x \geq 0$ of the uncertain loss the following period at a premium rate $\pi \geq 0$. That is, if the farmer pays a premium $x\pi$ this period, he or she receives an indemnity $x\tilde{l}$ next period if a loss of magnitude $\tilde{l}$ occurs.

The farmer chooses the savings s and coverage x that maximize the sum of current and discounted expected future utility of consumption over an infinite horizon. By Bellman's Principle of Optimality, the farmer's value function, $V(w)$, which denotes the maximum attainable sum of current and discounted expected future utility of consumption given the agent's current wealth w, is characterized by the functional equation

$$V(w) = max_{s \geq 0,\, x \geq 0} \{u(w - s - \pi x) + \delta E V(\tilde{y} + (1 + r)s - (1 - x)\tilde{l}\}.$$

Here, $\delta \equiv (1 + p)^{-1}$ where $p > 0$ is the farmer's subjective discount rate and u is the agent's utility of consumption, which is presumed to be twice continuously differentiable, strictly increasing, and strictly concave. The farmer's consumption equals his or her predetermined wealth, plus borrowing, less production costs, less index insurance premium payments. Further, utility is assumed to be isoelastic—taking on the form $u(c) = c^{(1-\alpha)}/(1-\alpha)$—so that farmers display constant relative risk aversion (CRRA).[21]

We denote by $s(w)$ and $x(w)$ the optimal levels of savings and insurance coverage, respectively, given wealth w. These are the farmer's optimal policy functions.

For any admissible level of wealth w, let

$$r_s(w) \equiv E\tilde{\lambda}(w, \tilde{y}, \tilde{l})(1 + r) - 1$$

and

$$r_x(w) \equiv E\tilde{\lambda}(w; \tilde{y}, \tilde{l})\frac{\tilde{l}}{\pi} - 1$$

[21] CRRA is a subset of decreasing absolute risk aversion (DARA) preferences. Several studies have found that agricultural decisionmaker preferences are consistent with DARA (see, for example, Makki, Somwaru and Vandeveer 2004).

denote, respectively, the expected rates of return on savings and insurance coverage, weighted by the realized marginal rate of intertemporal substitution of consumption

$$\tilde{\lambda}(w;\tilde{y},\tilde{l}) \equiv \frac{V'(\tilde{y}+(1+r)s(w)-(1-x(w))\tilde{l})}{u'(w-s(w)-\pi x(w))}.$$

We refer to $r_s(w)$ and $r_x(w)$, respectively, as the "risk-adjusted real rates of return" on savings and insurance. Forgoing a marginal unit of consumption today in order to save is expected to yield tomorrow the current equivalent of 1+ r_s units of consumption; forgoing a marginal unit of consumption today in order to purchase additional insurance coverage is expected to yield tomorrow the current equivalent of 1+ r_x units of consumption tomorrow.

We assume that, aside from the cost of the insurance premium, saving and purchasing insurance are frictionless transactions (i.e., no fixed cost is incurred by the farmer when he or she decides to begin saving or insuring, nor when he or she increases, decreases, or stops saving and/or insuring). This may not be the case, if, for example, farmers must spend time and money to arrive to a bank or insurance office to conduct their risk management activities, or if application fees are required for either saving or insuring. Recall that we further assume a two-point distribution for losses (perhaps considered as "normal" and "drought" years), where a farmer knows with certainty the probability of loss and the quantity he or she will lose if a loss is incurred.

To solve the farm household's Bellman equation using computational methods, we use collocation to numerically approximate the value function by using a series of known basis functions whose unknown coefficients are estimated using a series of multivariate rootfinding routines (Broyden's method), one for each chosen node at which the Bellman is required to be satisfied (Miranda and Fackler 2002). This method reduces a problem of infinite dimension to a finite one—as the value function must be solved exactly only at pre-specified points, or nodes. Everywhere else over the range of the function, residuals can be calculated to analyze the goodness of fit of the approximation. We take advantage of the CompEcon Toolbox for MATLAB, which is freely available, to employ the collocation method.

Appendix table 1 lists the parameter values used to solve the farmer's Bellman equation; these are the parameters upon which the figures are based.

Appendix table 1

Definition of model parameters

Parameter	Value	Definition
s_{min}	0.00	Minimum savings
s_{max}	3.50	Maximum savings
x_{max}	1.00	Maximum insurance coverage
α	3.00	Coefficient of relative risk aversion
r	0.08	Interest rate on savings
p	0.10	Discount rate
$\bar{y}$	1.00	Mean income
σ	0.00	Idiosyncratic income volatility
L	0.50	Magnitude of insurable loss
p	0.20	Probability of insurable loss
θ	0.20	Insurance loading factor