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Impact of interest rates on the decision to insure in agricultural production

This paper seeks to define the relationship between interest rates and decisions to insure among agricultural producers using the financial methodology. The choices are ultimately reduced to two options: to insure or to limit and absorb risk. Each choice produces a complex cash flow that is compared to the alternative and discounted by several factors. The difference between the options produces a quantitative measure of the financial incentive to insure. Some discounting factors of the cash flows follow the key interest rate to an extent for the latter to influence the decision to insure along with demand for insurance. The proposed method is tested on data from the emerging economy of Ukraine and the United States for the period 2002-2011. All participants of agricultural insurance markets can use the proposed methods to maximise efficiency. The research shows that *ceteris paribus* agricultural insurance requires bigger government subsidies to be viable under higher interest rates. Further empirical research is suggested.

Keywords: risk management, agricultural insurance, interest rates, demand for insurance

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Introduction

A strong effect of interest rates on insurance markets is acknowledged by many economists. There is no consensus on the nature of the relationship between interest rates and the insurance industry performance. Equity, underwriting profitability and supply of insurance all appear to be affected by interest rates. Although interest rate changes are systematic and affect the entire insurance sector across all lines simultaneously, empirical results differ, as well as theoretical explanations for such results.

Haley (1993) shows a negative relationship between interest rates and underwriting margins for stock property-liability insurers across an extended period. Grace and Hotchkiss (1995) find a positive relationship between a combined ratio and interest rates, hence a negative relationship between underwriting profits and interest rates. Other research shows mixed results regarding the relationship between the insurer's profits and interest rates (Leng and Meier, 2002; Park and Choi, 2011). Mixed results are mostly explained by the fact that both assets and liabilities of insurers are sensitive to interest rates (Doherty and Garven, 1995). Therefore, the relationship of equity and profits with interest rates is determined by the balance between durations of assets and liabilities. The problem is further complicated by the influence of capacity constraints, caused by exogenous factors, such as business cycles or systemic shocks to the insurance industry.

Interest rates affect assets through the insurer's investment portfolio. Low interest rates tend to decrease the supply of premiums owing to the fact that portfolios of most property and casualty insurers consist largely of various government, municipal and high-grade corporate bonds according to NAIC (2011), which intrinsically are highly correlated with the key interest rate (Merton, 1973). In fact, researchers that investigate the interest rate impact on the insurance industry often refer to bond yields as interest rates. Decline in the investment portfolio yield of insurance companies forces them to raise premiums in order to cover expenses. Owing to the elasticity of supply for insurance (Gron, 1994), the amount of insurance policies sold eventually decreases as well.

Insurer's liabilities are also subject to duration if the firm is leveraged. Higher rates, for example, increase the cost of capital and reduce net income. Although in most cases duration of assets exceeds duration of liabilities (Doherty and Garven, 1995), therefore there is weakness in such explanation for the negative relationship between interest rates and insurers' financial results.

Alternatively, there is another explanation from a perspective of financial theory for the negative impact of high interest rates on insurers' profitability: the capital asset pricing model (CAPM), modified for the insurance industry (Fairley, 1979; Hill, 1979). Haley (1993), Doherty and Garven (1995), and Leng and Meier (2002) use CAPM along with other similar insurance pricing models to justify the negative relationship between interest rates and the performance of the insurance industry. An interest rate in a form of a risk free rate is used to discount earnings and obtain an internal rate of return. The rise of interest rates reduces the internal rate of return; however, it has no effect on accounting profit figures, which are used for empirical testing. There is also no evident connection between a quantity of premiums supplied and interest rates that can be explained by CAPM and the other insurance pricing models.

All of the above-mentioned literature studies the impact of interest rates on the supply-side, represented by insurers, while there is a gap in the demand-side research. Aside from the financial sector, production risks in most industries are not directly affected by interest rates. However, high interest rates may create certain conditions, under which some alternatives to insurance become more appealing, thereby decreasing a financial incentive to insure. It may provide another theoretical explanation of the negative relationship between interest rates and insurance industry performance based on the impact of interest rates on the demand-side of the insurance market. This hypothesis is thoroughly discussed in this paper with a focus on the case of agricultural producers.

Methodology

In order to provide sufficient in-depth analysis of the problem, observations, data samples and the conceptual framework are narrowed down to the specifics of the agricultural sector. The initial hypothesis is that at some point interest rates should be high enough for an agricultural producer to be able to limit some of the risk by refraining from usual production activities without bearing significant opportunity costs. To the author's knowledge, much of the research about interest rate impacts on insurance markets ever since Cummins and Outreville (1987) has been done mostly in highly developed countries, possibly because of the availability of information. However, most of the developed countries historically had relatively low interest rates for the past 25 years. All of the research has been carried out in a relatively lower margin of the interest rate fluctuations in comparison to global interest rates. In order to observe possible negative influence of high interest rates on decisions to insure, it is proposed to take a look at agricultural insurance markets in developing economies.

There are several emerging economies, also large agricultural producers, with constantly high interest rates, which have problematic agricultural insurance markets. The initial observation is made in Ukraine, one of the world's top producers of sunflower seeds and barley. Despite government attempts to facilitate agricultural insurance market development, it is poor and inefficient mostly due to low demand for insurance. Meanwhile, the key interest rate in Ukraine averages 9 per cent for the past ten years. Further observations show that Brazil, currently with a key interest rate of 9.75 per cent (as of March 2012[1]), is known to struggle with the implementation of insurance in its massive agricultural sector. Most farmers choose not to purchase insurance and, as observed by Tueller *et al.* (2009), bear substantial losses owing to such choice, while government support appears futile. Another notable example is Argentina, where supply of insurance is abundant with 26 companies providing cheap hail insurance for nearly half of the cereals and oilseeds produced, and yet only 5 per cent is covered by a multiple peril crop insurance (Miguez, 2010). Implementation of non-hail insurance products is still problematic in the country. Hail insurance is naturally viable with very low premium rates as it avoids two of the major drawbacks of agricultural insurance: asymmetry of information and systematic losses (Hertzler, 2005). Unfortunately, hail insurance only covers a small part of the production risks that farmers face. There are numerous factors that put pressure on demand for agricultural insurance in developing economies, making it difficult to isolate the interest rate factor. Among the most important of these factors in Ukraine, for instance, are lacking statistical data and an inefficient law system that makes it difficult to settle any possible disputes between the insurer and the insured. The influence of these and other issues on the demand for insurance is hard to quantify or control for. While all of the factors are interconnected and undoubtedly considered in the decision making process, the quantitative measure of the interest rate factor can be independently determined under the assumption that the farmer is risk neutral and rational.

[1] Central Bank of Brazil SELIC interest rates: http://www.bcb.gov.br/?INTEREST.

To adequately compare conditions under which insurers operate, we can look at a simple demand function for insurance (*ID(p,q)*), proposed by Weiss (2007):

$$ID(p,q) = f(\mu_\Lambda(\iota), E, S, \sigma^2_\Lambda, \sigma_{\Lambda\varepsilon}, O) \tag{1}$$

where p is price, q is quantity, μ_Λ is the average of expected losses, ι is expected inflation, E is equity, S is assets, σ^2_Λ is the variance of expected losses, $\sigma_{\Lambda\varepsilon}$ is the covariance between expected losses (Λ) and expected income (ε), and O is business opportunities (general growth of the economy). Notable variables are inflation and business opportunities. However, both are proportional to demand and are high in emerging economies by definition. That is, emerging economies expand at a faster pace and provide opportunities for business growth, and inflation accompanies rapid growth. Therefore, there may be something missing, and to logically come up with a missing variable it is worth taking a closer look at the overall process of managing production risk in agriculture, specifically at alternatives to insurance.

Production risk in agriculture is mainly caused by weather patterns, which are unpredictable and stochastic in nature. Owing to the natural lag between the allocation of capital and the time of harvest, weather conditions are impossible to predict with certainty. Unlike price risk, which can be minimised by hedging, production risk (beyond horizontal diversification) can only be insured against, pooled, or limited to the point where it can be absorbed by a farm. Risk pooling is not suitable for all farm businesses, as it requires a certain degree of cooperation based on trust and ethics among members. Risk pooling is obviously a preferred method, since it does not have any associated costs except loss costs, and it is fair to assume that, if it is among options, farm businesses already use it. Farmers that do not pool risks have two options: to purchase an insurance policy and eliminate some or all of the risk, or limit the risk by diversification (other than horizontal) and absorb it. 'Wright and Hewitt (1994) suggest that the perceived demand for agricultural insurance may be overstated, because farmers can use diversification and savings to cushion the impact of production shortfalls on consumption' (Mahul and Stutley, 2010, p.23).

A common opinion is that a decision to insure is mostly determined by an individual preference towards risk (Hojjati and Bockstael, 1988; Coble *et al.*, 1996; Guiso and Jappelli, 1998). This may be relevant for some small family farms to a certain extent, but risk aversion is hardly a determinant in decisions to insure by medium to large agribusinesses and corporate entities, as noted by Mayers and Smith (1982). Von Neumann and Morgenstern (1944) originally stated that it is pointless to measure risk preference for entities that operate in terms of costs and profits. Therefore the following research is set in a framework of financially motivated decisions that are defined by the rules of financial theory.

Definition of choices

There are many choices that agricultural producers face when it comes to insurance. Hojjati and Bockstael (1988) show that a farmer can choose between insurance plans as well as crops to plant, which crop to insure, and to what extent, thereby facing a countless variety of choices. Selecting an appropriate insurance plan by itself is a complicated process that makes choice analysis quite difficult (Ginder *et al.*, 2009). Crop rotation and other technical factors further sophisticate decision making. Clearly, on a macroeconomic level, given territorial differences, the approach that would consider even simplified versions of all important choices is hard to apply. In this paper choices are limited to two ultimate options: to insure or not to insure. It implies that when an agricultural producer considers insurance, it is the optimal insurance solution that is available along with an optimal production portfolio. In this way the theory has few constraints and can be applied to any area and any country.

Let the decision to insure be choice A, and the decision to limit and absorb risk be choice B. Choice A leads to cash flows C_{An}, where n is a number of a cash flow. A net future value of cash flows ΣC_{An} is C_A. Choice B leads to cash flows C_{Bn} with the net future value C_B. If an agricultural producer has no personal risk preference or is risk-neutral, then the decision to insure (A) is determined by equation (2):

$$A\begin{cases} = 1\, if\ C_A \geq C_B \\ = 0\, if\ C_A < C_B \end{cases} \tag{2}$$

Let us closer examine cash flows from choice A:

$$C_A = -\pi + \varphi$$

$$\varphi = l \times x \tag{3}$$

where π is the future value of the insurance premium and φ is an indemnity payment *(l)* multiplied by its probability to occur *(x)*, assuming, for simplicity's sake, that 100% of the loss from a risk event is indemnified.

The premium for a property and casualty insurance generally consists of loss expenses (L_e), profit of the insurer (R_I), and administrative and operating expenses (O_e). Also return on the insurer's investment portfolio in currency form (I_I) and government subsidies (G) are subtracted from the premium, because they are positive cash flows from a point of view of an insured. The future value of cash flows from choice A with a disaggregate premium looks as follows:

$$C_A = -L_e - R_I + I_I - O_e + G + \varphi \tag{4}$$

It is easy to approximate the amount of the insurer's profit in a premium using equation (5). The ratio of equity (or surplus) (TE) to premiums (TP) can be calculated from data available in financial statements of the insurer along with the insurer's return on equity ($RoIE$):

$$R_I = P \times \frac{TE}{TP} \times RoIE \tag{5}$$

where P is the amount of insurance premium, TE is the insurer's total equity, TP is the total amount of premiums, which the insurer collects in a year, $RoIE$ is a rate of return on the insurer's equity. Note that all returns on equity in this research are calculated using current local currency units; therefore, there is no need for inflation adjustments.

$$I_I = P \times r_i \tag{6}$$

where r_i is a rate of return on the insurer's investment portfolio.

Equation (4) represents the future value of cash flows of choice A with two variables discounted by two different factors. It is important to discount cash flows separately, because one of the discounting factors has an evident high correlation with interest rates, while the other does not. The importance of this correlation will be demonstrated later on. Both discounted variables (equations 5 and 6) are approximated for simplification. Return on the insurer's investment portfolio and profit per a specific amount of premium can only be determined by the insurer using detailed information that is usually not disclosed in accounting statements. Discounting factors throughout this paper are assumed to be in a form that incorporates all of the time specifications and the frequency of compounding for simplicity's sake. For instance, r_i and other discounting factors in this paper can be calculated using a nominal interest rate (z) and a number of compounding periods (t) as follows:

$$r_i = (1 + z)^t - 1$$

For more complicated cases of discounting refer to Jorion (2009).

The alternative to insurance is the second choice B: not to insure or to limit and absorb risk. Whenever any production is intentionally limited, a certain amount of capital is turned into cash or financial assets and acts as a reserve (R) or is used to reduce debt. In agricultural production any type of a liquid asset can act as a reserve with a purpose of self-insurance (Binswanger and Rosenzweig, 1986), yet cash and short-term financial assets are clearly preferred in a majority of scenarios and are analysed in this research. Although we do not have comprehensive information on savings rates among agricultural producers in developing countries, there are supporting data that farmers in developed countries rely on savings to smoothen financial consequences of the yield variability. A study of farmers in the Australian Mallee indicates that almost all farmers build reserves or reduce debt in good years in an effort to reduce the magnitude and impact of income variability (Wright and Hewitt, 1994). At the same time as the reserve is formed, opportunity costs (C_o) occur owing to reduced operating income. If a farm chooses to limit and absorb risk, financial consequences of such decision are demonstrated by the following formula:

$$C_B = -C_o + Y_R - \gamma \tag{7}$$

where C_o is the opportunity cost, Y_R is the yield of the reserved capital, and γ represents additional losses, caused by a sharp decline in revenue owing to a risk event.

The opportunity (C_o) cost can be defined as a product of a rate of return on the farm's equity ($RoFE$) and the amount of the reserved capital (R):

$$C_o = RoFE \times R \tag{8}$$

The yield of the reserved capital (Y_R) is represented as a product of a rate of return on the reserved capital (y_r) and the size of the reserve (R):

$$Y_R = y_r \times R \tag{9}$$

Note that the loss from a risk event itself is not included as a negative cash flow for choice *B*, simply because it does not exist in such form for a farm that is profitable in the long term. Such a variable would be a part of an average income from agricultural production, hence it is superfluous.

Intuition behind γ is a sum of negative financial consequences which an agricultural producer faces by experiencing a large loss at once, rather than it being averaged across an extended period:

$$\gamma = f(\sigma, R, \omega, L_F, L_O) \tag{10}$$

where σ is a quantitative measure of production and/or price risk, ω is a level of diversification, L_F is a measure of financial leverage, L_O is a measure of operating leverage. σ is not necessarily volatility, it can be a more comprehensive measure of risk (e.g. probability distribution function, value-at-risk).

In other words, γ is a residual between all losses that a risk event causes and the expected loss over time, which can be described as φ (equation 3). Thereby, when a farm experiences a risk event with a loss (l), it also suffers additional to φ losses, determined by γ. The primary reason behind insurance is to eliminate γ by swapping l for φ for a price of π.

Equation (7) is set up in a way for the following to be true:

$Y_R \propto C_o \propto R$

$$R = -b \times \gamma + a \tag{11}$$

where b represents the relationship between R and γ as well as Y_R and γ, and a is a level of R, at which γ is deemed insignificant. The linear inverse relationship here suggests that for the value of the function γ to decrease, more cash must be reserved by limiting production. More opportunity costs (C_o) will occur and the yield on the reserved capital will increase (Y_R). The opposite should also be true. If a farm does not use any debt, has few fixed costs, and the revenue cash flows are highly diversified, then γ should be insignificant. The reserved capital (R) directly reduces γ and also produces a diversified cash flow (Y_R) with no correlation to income from agricultural production.

If a farm business is leveraged, choice *B* becomes even more appealing with higher interest rates (lending rates in this case). Instead of reserving capital, a farm uses cash to pay out debt and limits production in exactly the same way (equation 7). Decline in the cost of debt in currency form (C_D) replaces increment in the yield on the reserved capital (Y_R). For instance, consider $L_F = \frac{D}{E}$, where D is debt, E is equity, and $E \neq 0$. If $L_F > 0$, then $C_B = -C_o - C_D - \gamma$, where $C_D = -D \times r_D$. The cost of debt (r_D) should always be greater than the rate of return on the reserved capital (y_r) for the same time setting: $r_D > y_r$. This is simply because capital, lent to any farm business, holds more risk than a nearly risk-free financial asset (e.g. a deposit certificate) and therefore requires an additional risk premium. The case of a leveraged farm business is described in detail in Appendix A.

Comparing the choices

The choice to insure (*A*) and the choice not to insure or to limit and absorb risk (*B*), as mentioned earlier, are determined by equation (2). It can also be written alternatively as a function ΔC to allow continuity:

$$\Delta C = C_A - C_B \tag{12}$$

Positive values of ΔC indicate that insurance is financially viable, while negative ΔC shows the opposite. ΔC can be viewed as a quantitative measure of the *financial incentive to insure*. If we substitute formulas for C_A and C_B from equations (4, 5, 6, 7, 8, and 9) into equation (12), the result will be as follows:

$$\Delta C = -L_e + P \times \left(r_i - \frac{TE}{TP} \times RoIE\right) - O_e + G + \varphi + R(RoFE - y_r) + \gamma \tag{13}$$

For further analysis it is necessary to eliminate similar variables by several assumptions and isolate interest rate correlated variables. Once interest rate related factors are defined, the assumptions can be then relaxed if needed. It can be set that the loss expenses (L_e) are equal to the indemnity φ (equation 3). If $L_e = \varphi$, then:

$$\Delta C = P \times \left(r_i - \frac{TE}{TP} \times RoIE\right) - O_e + G + R(RoFE - y_r) + \gamma$$

Consider a scenario, where an agricultural producer chooses to limit agricultural production and instead store freed up capital in nearly riskless financial assets to achieve a level of income diversification, at which γ becomes insignificant and equals to zero. This is ultimately choice *B*, which opposes insurance. It is an equivalent of a combination of what was originally defined as a self-protection and self-insurance by Ehrlich and Becker (1972). If $R = \frac{\varphi}{x} = l$, then $\gamma = 0$; if $\gamma = 0$, then:

$C_B = -C_o + Y_R$

$$\Delta C = P \times \left(r_i - \frac{TE}{TP} \times RoIE\right) - O_e + G + R(RoFE - y_r) \tag{14}$$

Interest rate sensitivity

Equation (14) consists of four terms, two of which can be highly correlated with the key interest rate, and the other two have no clear correlation. The return on the insurer's equity (equation 5) and the farm's opportunity costs (C_o) or the return on the farm's equity are determined by market conditions that incorporate multiple factors and have no evident consistent connection to interest rates[2]. The return on the insurer's investment portfolio, which is roughly estimated by equation (6), and the yield of the reserved capital (Y_R) are basically determined by interest rates.

It is appropriate to use a specific interest rate if the correlation with the key interest rate is too low to achieve a

[2] Return on the insurer's equity cannot be adequately represented in any correlation with interest rates, although logically some positive correlation may exist. Venezian (2002) states that in order to relate insurer's returns to interest rates a complex model must be built that is beyond verification owing to the amount of data needed.

desired level of accuracy. Otherwise the key interest rate can be used to calculate r_i and y_r with an adjustment for their historical ratio as follows:

$$r_i = r \times \mu\left(\frac{r_{in}}{r_n}\right)$$

$$y_r = r \times \mu\left(\frac{y_{rn}}{r_n}\right)$$

where r is the key interest rate set by the central bank of a country, μ is the average value represented by the arithmetic mean, r_{in} is the rate of return on the insurer's investment portfolio or the bond yield in this particular case at time n, r_n is the key interest rate at time n, and y_{rn} is the rate of return on the reserved capital or the yield of deposit certificates at time n.

The financial incentive to insure can be written as a function of the key interest rate r:

$$\Delta C = f(r) = P \times \left[r \times \mu\left(\frac{r_{in}}{r_n}\right) - \frac{TE}{TP} \times RoIE\right] - O_e + G + R \times \left[RoFE - r \times \mu\left(\frac{y_{rn}}{r_n}\right)\right] \quad (15)$$

If ΔC is calculated for a particular crop and a risk event with a known size of casualty and the probability to occur, then the financial incentive to insure can be computed with equation (15). A graph of the function *f(r)* on Figure 1 demonstrates the linear relationship between interest rate changes and the financial incentive to insure (ΔC).

The slope of *f(r)*, however, also depends on the values of the premium (P) and the reserved capital (R), which can change across different crops and levels of risk. The slope of *f(r)* may change at a rate that is determined by a ratio of yields that the insurer and the farm business get on their capital (P and R respectively) to the key interest rate (see Appendix B for a mathematical explanation). The change of the financial incentive to insure (ΔC) caused by varying P depends on $\mu\left(\frac{r_{in}}{r_n}\right)$, and the change owing to varying R is determined by $\mu\left(\frac{y_{rn}}{r_n}\right)$. An important implication of this is that a moderate increase in R tends to amplify either a positive or a negative value of ΔC without changing its sign. A large increase in R, as in presence of catastrophic risk, may, however, shift ΔC into a positive value (owing to the relationship in equation 11) and favour the decision to insure. The main purpose of this research, however, is to establish the impact of the key interest rate on decisions to insure using the financial incentive to insure (ΔC or *f(r)*).

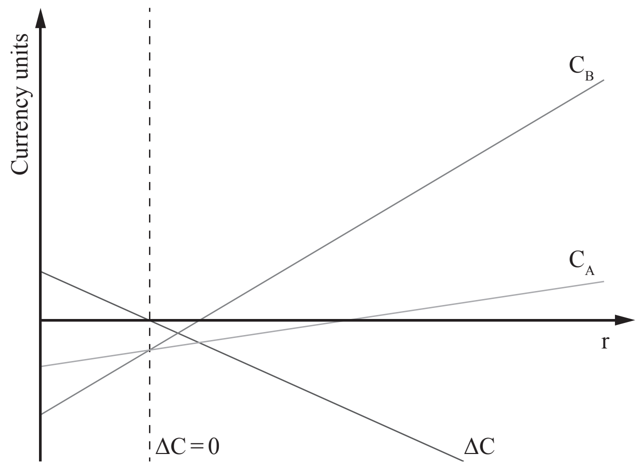

Figure 1: The relationship between interest rates and the financial incentive to insure.

Results

We apply the proposed technique to agricultural insurance markets of Ukraine and the United States. Input parameters and the financial incentive to insure, shown in Table 1, demonstrate differences between agricultural insurance markets of the developing and developed economies.

Logically, insurance should not be viable if ΔC is significantly negative in a medium to long term, unless there are factors, aside from ΔC components, that outweigh the negative impact. Empirical study shows that in the developing economy of Ukraine the financial incentive to insure is at the average of -0.18 per 1 LCU of producer premium, while in the United States it is at USD 1.15 per USD 1 of premium (Table 1). The measure is so high in the United States mainly owing to abundant government subsidies and low interest rates. Notably, the returns on insurers' equity among seven insurance companies that share 91 per cent of the agricultural insurance market in Ukraine is below the rate of inflation, key interest rate, and lower than the rate of return of the United States insurance companies for the years 2002-2011. Insurance companies in Ukraine also take more risk by lowering the *TE/TP* ratio. This demonstrates possible relationships between ΔC components and demand for insurance, which can be useful to insurers seeking to implement new products in emerging economies with high interest rates.

Table 1: Input parameters and the financial incentive to insure for agricultural producers of Ukraine and Kansas farms of the United States, 2002-2011.

Parameter	Ukraine	Kansas state of the United States
Interest rates (%)*		
Average	14.4	2.1
Standard deviation	3.2	1.7
Return on farmers' equity (%)		
Average	13.0	1.1
Standard deviation	7.0	1.6
Return on insurers' equity (%)		
Average	5.8	7.1
Standard deviation	5.0	4.1
Ratio of total equity to total premiums of insurers		
Average	0.63	1.09
Standard deviation	0.26	0.30
ΔC (LCU)**		
Average	-0.18	1.15
Standard deviation	0.43	0.34

* Yields on three month deposit certificates for Ukraine and one year treasuries for the United States.
** The financial incentive to insure in local currency units (LCU) per one LCU of premium paid by the farmer.
Source: Author's calculations based on the USDA RMA data, the Federal Reserve data, Insurance Services Office data, and financial statements of insurers. The raw data are available from the author upon request.

Discussion

This research provides a method for evaluating agricultural insurance decisions from a financial perspective. The choice to insure opposes the choice to limit and absorb risk, and each choice has financial consequences for a farm business, represented in a form of cash flows. The sensitivity of some of the cash flows to interest rates is significant enough to influence the decision to insure on a microeconomic level and demand for insurance on a macroeconomic level. The *financial incentive to insure* quantitatively measures a gain or a loss from the choice to insure in the context of the financial outcome of the choice not to insure in currency form per a specific amount of premium. The use of such a method has a variety of implications for agricultural producers, insurers and government support for insurance. Agricultural producers benefit greatly from quantifying information about risk and risk minimisation techniques. It allows large producers to seamlessly integrate risk management into an enterprise financial management system and decrease risk management costs. Small farms can rely less on intuition and more on objective data and avoid costly mistakes. The financial incentive to insure (ΔC) is a useful criterion for such decision making. Owing to the quantitative nature of the measure, it can be used with other factors that may influence the decision to insure, including risk preference, tax policy etc. The empirical research shows that it would require considerable government subsidies, in addition to informational support, to facilitate the development of agricultural insurance markets in emerging economies. Demand for agricultural insurance in emerging economies, in particular those of Eastern Europe, should be negatively affected by the financial incentive to insure owing to higher interest rates.

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Appendix A

The case of a leveraged enterprise

A leveraged agricultural producer has an option to reduce risk by lowering or eliminating financial leverage. If available, this option is preferred over reserving funds because it is cheaper by definition, as the cost of debt incorporates the risk premium: $r_D = r_f + r_p$ (Brigham and Ehrhardt, 2011), while $y_r \approx r_f$, where r_f is a risk free rate and r_p is a risk premium. In this case:

$$C_B = -C_o - C_D - \gamma \tag{A.1}$$

$$C_D = -D \times r_D \tag{A.2}$$

where C_D is the cost of debt in currency form, and D is the amount of debt that is liquidated in order to reduce risk. The direct relationship $|C_D| \propto C_o$ in equation (A.1) remains accurate and determines the amount of D. Note that in function γ (equation 10) decline in D reduces L_F, while in the case of an unleveraged farm business rising R reduces the impact of income variability and Y_R increases ω. In both cases γ is reduced. When $\gamma = 0$,

$$C_B = r_D \times D - RoFE \times D \tag{A.3}$$

Return on equity should be similar to return on debt according to Modigliani and Miller (1958). Return on equity in equation (A.3) can be replaced with return on debt for a higher precision if enough information is available for its calculation. The financial incentive to insure for a leveraged farm is calculated as follows:

$$\Delta C = P \times \left[r \times \mu\left(\frac{r_{in}}{r_n}\right) - \frac{TE}{TP} \times RoIE \right] - O_e + G + D \times \left[RoFE - r \times \mu\left(\frac{r_{Dn}}{r_n}\right) \right] \tag{A.4}$$

If a tax shield is applicable, then

$$C_B = r_D \times D \times (1 - \tau) - RoFE \times D \tag{A.5}$$

where τ is the tax rate.

If debt is fully eliminated ($L_F = 0$ in equation 10), yet γ (equation 10) is not decreased to an acceptable level, then R needs to increase to reduce γ further:

$$C_B = -C_o - C_D + Y_R - \gamma \tag{A.6}$$

$$\Delta C = P \times \left[r \times \mu\left(\frac{r_{in}}{r_n}\right) - \frac{TE}{TP} \times RoIE \right] - O_e + G + RoFE \times (D + R) - r_D \times D - y_r \times R \tag{A.7}$$

The cost of debt (r_D) that is closely correlated to the key interest rate r can be alternatively calculated as $r_D = r \times \mu\left(\frac{r_{Dn}}{r_n}\right)$.

Appendix B

If the amount of premium (P) and the reserved capital (R) vary along with interest rates, the financial incentive to insure is:

$$f(r,R,P) = P \times \left[r \times \mu\left(\frac{r_{in}}{r_n}\right) - \frac{TE}{TP} \times RoIE \right] - O_e + G + R \times \left[RoFE - r \times \mu\left(\frac{y_{rn}}{r_n}\right) \right]$$

where TE, TP, $RoIE$, $RoFE$, O_e, *and* G are held constant.

$$f_r = P \times \mu\left(\frac{r_{in}}{r_n}\right) - R \times \mu\left(\frac{y_{rn}}{r_n}\right)$$

$$f_R = RoFE - r \times \mu\left(\frac{y_{rn}}{r_n}\right)$$

$$f_P = r \times \mu\left(\frac{r_{in}}{r_n}\right) - RoIE \times \frac{TE}{TP}$$

$$f_{rR} = -\mu\left(\frac{y_{rn}}{r_n}\right)$$

$$f_{Rr} = -\mu\left(\frac{y_{rn}}{r_n}\right)$$

$$f_{Pr} = \mu\left(\frac{r_{in}}{r_n}\right)$$

Therefore the rate of change of the financial incentive to insure ultimately depends on yields, at which both the insurer and the farm business are able to store their financial assets.