**Agricultural credit, crop insurance and the risk balancing hypothesis:**

**Evidence from Brazil[[1]](#footnote-1)[[2]](#footnote-2)**

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**Resumo**: A hipótese de balanceamento dos riscos afirma que produtores avessos ao risco, que buscam um estado estacionário em termos do risco total, compensarão os aumentos no risco financeiro com reduções no risco do negócio. Tomando o seguro rural como indutor de quedas no risco de negócio, o presente artigo buscou testar empiricamente a hipótese de balanceamento dos riscos para a agricultura brasileira. Para tanto, aplicou-se um modelo GMM-3SLS à uma amostra de aproximadamente 50.000 produtores rurais. As estimativas apontaram a existência de causalidade bidirecional entre a adoção do seguro rural e a intensidade do crédito agrícola. Deste modo, confirmou-se a existência de um comportamento de balanceamento de risco entre os produtores rurais brasileiros, fato que pode trazer implicações importante para a política agrícola do Brasil.

**Palavras-chave**: crédito agrícola; seguro rural; balanceamento de riscos; Brasil

**Abstract**: The risk balancing hypothesis states that risk averse farmers seeking a steady state in terms of total risk will compensate increases in financial risk with reductions in business risk. Taking crop insurance as a driver of business risk declines, this article sought to empirically test the risk balancing hypothesis for the Brazilian agriculture. To this end, a GMM-3SLS model was applied to a sample of approximately 50,000 farmers. Estimates pointed to the existence of bidirectional causality between crop insurance adoption and agricultural credit. Thus, it was possible to confirm the existence of risk balancing behavior among Brazilian farmers, which may have important implications for Brazil's agricultural policy.

**Keywords**: agricultural credit; crop insurance; risk balancing; Brazil

**JEL Codes**: G22, G32, Q12, Q14

1. **Introduction**

Certain conjectures about the balancing of business and financial risks by farmers in the context of agricultural policies have been in common use in the agricultural economics and finance literature since the early 1980s. The risk balancing hypothesis was first introduced by Gabriel and Baker in 1980. Collins (1985) later provided a conceptual framework that was further expanded by Featherstone et al. (1988). The details of this work will be developed presently; however, the main conjecture drives from the ‘risk-balancing hypothesis’ which states that risk averse farmers seeking a steady state in terms of total risk will substitute increases in business risk with a decrease in financial risk, or an increase in financial risk with a compensating reduction in business risk.

A consequence of the risk balancing hypothesis is the endogenously self-regulating tradeoff between two independent sources of risk. The balancing of business and financial risks implies that farmers seeking to increase financial leverage (and thereby increasing financial risk) will causally take actions to reduce business risk through diversification, hedging, insurance or some other means. Likewise, a farmer facing an increase in business risk will causally make decisions to reduce financial risks.

Empirical tests of risk balancing are few but have significant policy implications. The policy perspective developed in Featherstone et al. (1988) concerned what they referred to as an induced leverage effect, under which an unintended consequence of farm programs (e.g. support prices or crop insurance) was that in providing policies that reduce business risks, governments could unwittingly be encouraging an increase in financial risk. This was explored further in Turvey and Baker (1989, 1990) who used optimization to show how high debt farms with low credit reserves and liquidity constraints would hedge more than low debt, high liquidity farms, and that the presence for loan rates and target prices with options-like qualities reduced incentives to hedge and increased optimum debt.

Bampasidou et al. (2017) examined the variance of the return on assets (ROA) across 15 US states between 1960 and 2011, showing that the variance of ROA had a significant and negative effect on farmers’ debt choices[[6]](#footnote-6). From Canada, Uzea et al. (2014) provide mixed evidence of risk balancing under the Canadian Agricultural Income Stabilization (CAIS) program. Turvey and Kong (2009) developed revenue variance measures from prices and crop yields from 400 Chinese farmers and found that agricultural risks do impact farmers’ credit choices, with higher business risk (the variance of income) indicating lower credit use and financial risk. They showed an inverse relationship between the coefficient of variation (risk to return) on a binary debt/no debt choice model and the total amount borrowed but did not find a relationship between risk and the debt to asset ratio.

In an examination of farms within the European Union, de Mey et al. (2014) show evidence of what they refer to as ‘weak-form’ risk balancing as they found an inverse relationship between business and financial risks, but they do not find evidence of ‘strong-form’ risk balancing that holds total risk constant under the originating Collins’ hypothesis. Featherstone et al. (1990) outline the effects of liquidity risk, collateral risk, and credit-reserve risk on optimizing debt using discrete sequential programing (DSP).[[7]](#footnote-7) Escalante and Barry (2001) combined simulation and optimization techniques, showing that an inverse relationship between reduced business risk and financial risks still holds even under general diversification strategies.

Wauters et al. (2015) extend the basic model of risk balancing to show that a farm household that wants to minimize household cash flow relative to consumption, may exhibit a wide variety of behavioral responses to changes in both policy and economic environments. In a quite different way, Collins and Karp (1993), using a dynamic consumption based model, show that optimum debt can also be influenced by farmers age (position in life cycle) with lower leverage taking precedence as the farmer nears retirement, which in turn depends on levels of wealth.

Cheng and Gloy (2008) developed an optimal control problem for risk balancing with both operating revenue and interest rates being stochastic. Their solution shows a dampening effect of risk balancing if interest rates are correlated with the return on farm assets, but for uncorrelated risk the standard solution holds, except that the presence of interest rate risk will result in lower optimal debt. Cheng and Gloy do show one possibility in a dynamic optimal control framework in which an increase in business risk can actually increase leverage (case 4, page 14) but this would require an improbably high correlation between ROA and interest rates, and a business risk low relative to interest rate risks. Since business risks, by definition, are measured independent of financial structure, then the likelihood that the two are correlated would be low or spurious.

In this paper we examine risk balancing in the context of agricultural credit and crop insurance in Brazil using a cross-section of approximately 50,000 farmers. Our objective is to provide an empirical test of risk balancing using crop insurance participation to capture reductions in business risk. Our central hypotheses are that a) farmers who adopt crop insurance are probabilistically more likely to use higher level of debt on a per hectare basis, and b) farmers who use more debt are probabilistically more likely to participate in crop insurance. In addition to the relevance of the empirical findings, we also contribute to the literature by presenting a conceptual framework that explicit considers crop insurance decision within the risk balancing hypothesis.

We find, using a GMM-3SLS model, that bidirectional causality holds. Both endogeneity and heteroskedasticity problems are explicit considered in our system of equations. Thus, we provide empirical evidence that credit choices and risk management decisions are endogenous to each other, at least when it comes to insurance participation. Additionally, our results are consistent with Ifft et al. (2015) who, using data from the Agricultural Resource Management Survey (ARMS), found that in the US there is an association between Federal Crop Insurance participation and short-term credit that is consistent with risk balancing behavior. However, they were not able to show causality as we do in this paper.

1. **Background**
   1. *Agricultural credit*

Brazilian government started its involvement in the agricultural credit market in the mid-1930s when the Agricultural and Industrial Portfolio was instituted. Being operated by Banco do Brasil (Bank of Brazil), this was the first concrete initiative for the institutionalization of an agricultural credit policy in the country (Ramos and Martha, 2010). Despite a relatively good performance, the available credit was unable to reach all parts of the country, also failing in its role as a vector of agricultural modernization (Rodrigues et al., 1978).

A broader governmental approach to the agricultural credit issue took place in the mid-1960s, when the National Agricultural Credit System (SNCR) was implemented, which is still in force in the present days. Among other objectives, the SNCR aims to stimulate investments for production, storage, processing and industrialization of agricultural products; to favor the timely and adequate purchase of inputs and commercialization of products; and to encourage the introduction of rational methods into the production system (Central Bank of Brazil [BCB], 2018).

Two main institutions stand out in the SNCR context. First, there is the National Monetary Council (CMN). Being the main institution of the Brazilian Financial System, it is responsible for formulating monetary and credit policies, including those related to agricultural credit (Brazilian Agriculture and Livestock Confederation [CNA], 2017). Second, there is the Central Bank of Brazil (BCB). This is the institution that effectively controls SNCR and it is responsible for directing, coordinating and supervising the compliance of farmers and financial organizations with CMN resolutions that apply to agricultural credit (BCB, 2018).

The financial resources made available under the SNCR are contracted by farmers in order to fulfill one of the following purposes: production financing, intended to cover operating expenses, such as the purchase of seeds and fertilizer; investment, for the acquisition of production goods lasting for several harvests, such as tractors and combine harvesters; and commercialization, intended to cover post-production expenses, such as storage and transportation (CNA, 2017).

Historically, the largest volume of resources contracted within the SNCR is devoted to production financing. Since the late 1960s, production financing has accounted for roughly 55 percent of the total value of the loans granted, although the relative share has varied over the years (Araújo, 2011). In recent years, according to data from BCB’s Agricultural credit Data Matrix, this has been the case either. In fact, from 2013 to 2017 this percentage ranged between 53 and 59 percent.

In 2017, agricultural loans contracted under SNCR amounted to more than R$ 163 billion (roughly US$ 41.8 billion as of April 2019), of which approximately R$ 94.8 billion were used to finance production. These resources, however, are not evenly distributed across the country. Mainly due to the concentration of commercial agriculture in the Center-South part of Brazil, this area – which comprehends the South, Southeast and Center-West regions – concentrated more than R$ 84 billion of the production financing totals.

* 1. *Crop insurance*

The involvement of the Brazilian government with crop insurance also dates to the mid-twentieth century. The crop insurance system currently in place, however, is significantly younger than SNCR. Starting in 2005, governmental approach to the crop insurance issue dramatically changed as premiums paid by farmers have become eligible for partial economic subvention. Prior to that date most government-led initiatives proved to be inefficient.

The Brazilian government tried to act as a direct insurer for country’s agricultural production as insurance operations started to be conducted through the National Agricultural Insurance Company (CNSA). Acting only in the Center-South part of the country, the company offered insurance policies for five crops: herbaceous cotton, wheat, rice, coffee and grape. Successive deficits, however, led to the extinction of CNSA in the mid-1960s (Ozaki, 2005).

Posteriorly, in order to protect the financial system in case farmers defaulted the loans took under SNCR, the government launched the Agricultural and Livestock Guarantee Program (Proagro) in the mid-1970s. Having undergone a major reformulation in the early 1990s, the program is still in place today. Up until the early 2000s, Proagro was the only government initiative for financial protection of Brazilian farmers. Specifically, it works as a credit insurance directly linked agricultural credit use, being managed by the Central Bank of Brazil.

In one way or another, these two approaches ended up not fulfilling the objective of protecting both income and wealth of Brazilian farmers in an economically feasible way. Therefore, inspired by successful initiatives carried out in some developed countries, the Brazilian government started to grant economic subvention to farmers for the payment of crop insurance premium through the Rural Insurance Premium Subvention Program (PSR).

Implemented in the end of 2005, PSR is operationalized by the Ministry of Agriculture, Livestock and Supply (MAPA). Farmers negotiate the terms of the crop insurance policy with the insurer who, in turn, requests the subvention to MAPA. If the financial aid is granted, the subsidized value is directly transferred from MAPA to the insurer, which then deducts the amount paid by the government from the total charged to the farmer.

Although some crop insurance operations continued to be carried out in the country between the dissolution of CNSA and the beginning of the 2000s, the implementation of PSR was able to foment the Brazilian crop insurance market. When analyzing data from Superintendence of Private Insurance (SUSEP) and MAPA together, it is observed how PSR seems to have driven crop insurance in Brazil. Between 2006 and 2017, the amount collected in crop insurance premiums increased from R$ 81.9 million to R$ 1.87 billion.

1. **Conceptual framework**

The risk balancing hypothesis was first introduced by Gabriel and Baker (1980). Collins (1985) later provided a conceptual framework that was further expanded by Featherstone et al. (1988). Such framework forms the conceptual ground for our theoretical model, which explicitly considers the effect of crop insurance on agricultural credit. The starting point of Collins’ model is the duPont identity (Equation 1), which presents the return on equity (*ROE*) as a function of return on assets (*ROA*), debt to equity ratio () and interest rate on debt ():

|  |  |
| --- | --- |
|  | (1) |

If farmers behave as expected utility maximizers, their objective function could be written as a mean-variance optimization model[[8]](#footnote-8) in which negative exponential utility, relative risk aversion and normality of distribution are inherently assumed:

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  | (2) |

where and denote, respectively, the variance of return on equity and return on assets; and denotes the risk aversion parameter.

Taking the derivative of (2) with respect to gives:

|  |  |
| --- | --- |
|  | (3) |

Setting (3) equal to zero provides the optimal debt to equity ratio, which directly connects financial and business risks :

|  |  |
| --- | --- |
|  | (4) |

In order to add the crop insurance decision into such framework, we consider a single-crop farm operation. For simplicity, the indemnity schedule is based on the market price at the harvest ; additionally, production costs are assumed to be fixed. In this context, the return on assets is given by:

|  |  |
| --- | --- |
|  | (5) |

where is a random variable denoting crop yield; is an indicator that equals one when insurance is adopted and zero otherwise; is the insurance coverage; is the insurance premium; is the loading factor; and denotes farmer’s assets.

Our interest here is to show how insurance adoption affects financial risk—i.e., how changing from to impacts . Specifically, insurance adoption alters the debt to equity ratio through changes on both the expected value and variance of return on assets, as follows

|  |  |
| --- | --- |
|  | (6) |

The variation on the expected value of return on assets with respect to the change on the indicator of insurance adoption is

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  | (7) |

which is positive for risk-averse farmers, since they would adopt crop insurance if and only if a positive difference is found between the indemnity schedule and the insurance premium. Such assumption is in fact realistic since most of crop insurance schemes worldwide—including Brazil’s PSR—are heavily subsidized, which is translated in a negative and the consequent decrease of the premium paid by farmers.

Conversely, the variation on the variance of return on assets with respect to the change on the indicator of insurance adoption is

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  | (8) |

which is clearly negative.

Plugging (7) and (8) into (6) provides

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  | (9) |

which is positive if the expected return on assets is larger than the interest rate.

Thus, as initially expected, crop insurance adoption decreases business risk since it truncates crop yield distribution, decreasing the variance of returns. This creates a slack in the relationship between business and financial risks. Therefore, farmers can increase their debt level in order to keep total risk in balance.

1. **Empirical strategy**

Admitting that credit and insurance decisions are jointly determined, endogeneity becomes a truly concern for the empirical investigation of such relationship. In order to overcome this issue, we implement a system instrumental variables (SIV) estimation. Since heteroskedasticity is also a feature of our data[[9]](#footnote-9), we apply the empirical model referred by Wooldridge (2010) as the generalized method of moments three-stage least squares (GMM-3SLS) model. Specifically, the following system is estimated, in which each endogenous variable has its own structural equation:

|  |  |  |
| --- | --- | --- |
| Agricultural credit: |  | (10) |
|  |  |  |
| Crop insurance: |  | (11) |

where and are vectors of agricultural credit and crop insurance variables, respectively; is an matrix of exogenous regressors affecting both credit and insurance; is an matrix of exogenous regressors affecting only agricultural credit; is an matrix of exogenous regressors affecting only crop insurance; and and are vectors of errors.

System identification is guaranteed by both rank and order conditions due to the consideration of in (10) and in (11) and the fact that any variable in is not present in and vice versa. In this context, both structural equations are overidentified because there are more exogenous regressors than endogenous ones. If instead some of them were just-identified, i.e., the number of endogenous and exogenous regressors is the same, system estimation would reduce to equation-by-equation two-stage least squares (2SLS). In such scenario, however, the possible (and expected) correlation among and would be naively neglected.

In addition to circumventing the problem of heteroscedasticity, the GMM-3SLS model presents another operational advantage to the traditional 3SLS model. The equations estimated in our system have their own instruments—i.e., as previously discussed—and, according to Wooldridge (2010), the GMM version of the 3SLS model is preferable in such cases because it is more generally valid than traditional 3SLS.

Simply put, the 3SLS model can be tough as a mix of 2SLS and generalized least squares (GLS) approaches, as follows. First, it develops instrumented values all endogenous variables—similarly to the first stage of a 2SLS model. Second, based on the residuals of equation-by-equation 2SLS estimates, a consistent estimate for the covariance matrix of disturbances is obtained. Third, using the estimate for the covariance matrix of disturbances as a weighting matrix and replacing the right-hand-side endogenous variables by their respective instrumented values, consistent estimates are produced by GLS.

1. **Data and descriptive statistics**

The relationship between farm debt level and crop insurance adoption is examined using micro-level data from the BCB. Due to operational restriction, we rely on data comprising the agricultural credit operations conducted in Brazil throughout 2017 only. Specifically, our sample comprehends the loans took to finance short-term operating funds of the agricultural production. Thus, livestock operations are disregarded, as well as those loans whose purpose is other than short-term production financing—such as investment in physical assets and production commercialization. The reasons for this filtering are twofold and are explained ahead.

First, although livestock—especially cattle ranching—accounts for an important share of the loans subscribed under the SNCR, its participation in the crop insurance market is practically residual. Such imbalance is clearly perceived when livestock insurance operations are compared to the agricultural ones. SUSEP data shows that, in 2017, more than R$1.8 billion was collected in agricultural premiums, whilst only R$12.4 million were collected in livestock premiums. Therefore, studying the insurance-credit relationship for livestock production would provide no practical outcomes, at least in the Brazilian context.

Second, in addition to the fact that short-term operating funds have been responding to the largest share of resources since the implementation of the SNCR, loans taken for this purpose are subscribed in such a way that they usually match crop insurance cycle. On the one hand, according to BCB data, short-term operating funds credit accounted for approximately 58 percent of the loans contracted under the SNCR in 2017. On the other hand, the correspondence between crop insurance cycle and the maturity of such loans is of a great relevance in a risk-balancing context. Insurance policies are annually contracted, while short-term credit must usually be paid within a one-year span.

Furthermore, it is also important to highlight that our sample comprises only the loans for which the respective borrowers (farmers) have contracted a crop insurance policy or have not contracted any insurance at all. In this sense, those farmers who participate in governmental credit insurance programs—e.g., Proagro and Proagro Mais—are disregarded. Such programs, as previously described, cannot be labeled as true crop insurance initiatives since what is guaranteed is not crop yield or farm revenue but the repayment of the loan. Also, the participation in such programs are usually mandatory for certain credit lines and, consequently, these farmers are not in charge of the balancing decision anymore.

Agricultural credit, taken as a proxy for the debt to equity ratio, is adjusted in terms of the financed area (i.e., ) to smooth the large variation in both the size of the analyzed loans and the area of the financed farms . Such adjustment ensures that our analysis indeed captures the relative variations in agricultural credit within the examined farmers. In turn, crop insurance adoption is represented by a dummy that equals one if the farmer adopts crop insurance and zero otherwise. Following the risk-balancing hypothesis, we expect these variables to positively affect each other, as described in our theoretical model.

Some variables are expected to influence both the loan size and insurance adoption, appearing as regressors in both structural equations. They are farmer’s gender, the operation scale of the farm, it’s geographical location and the crop cultivated. The gender dummy equals one if farmer is female and zero otherwise. On the one hand, women are less likely to default (Demirgüç-Kunt et al., 2008), which could make lenders prefer them to men. On the other hand, women tend to be more risk averse (Hallahan et al., 2004), which may both prevent them to take large loans and encourage insurance adoption. While the signal of the relation between gender and loan size, being female is expected to positively affect crop insurance decision.

The operation scale of the farm is measured by a set of three dummies, which indicate if each unit investigated is of small, medium or large scale. Following BCB’s classification, when loans do not exceed R$ 415,000 and the area financed is less than 800 hectares, farms are referred to as small. Medium farms, in turn, are those with loan and financed area up to R$ 2 million and 3,000 hectares, respectively. Finally, those farms which surpass these limits are categorize as large. As credit is measured in relative terms, its relationship with operation scale is not straightforward since both loan size and insured area vary for observations within each scale group. Such unpredictability is also true for insurance adoption. In absolute terms, such as production value, large farms are more exposed to risk, having more incentive to insure. In relative terms, such as the ratio of crop revenue to total revenue, small farms tend to be more exposed and, consequently, more prone to adopt crop insurance.

Geographic location of farms and the crop each loan is intended to finance are included in the model in order to control for the great heterogeneity observed in Brazil in terms of crop distribution across country’s states. As some crops are more input-intensive than others, short-term operating loans may be unevenly distributed—both in terms of quantity and size—between crops and, consequently, states. The same holds true for crop insurance as more risky crops, such as temperate fruits, are also geographically concentrated. For example, input-intensive grains—such as corn and soybeans—are mainly grown in the Center-West, while temperate fruits—such as apple and grape—are concentrated in the South.

As previously detailed, the identification of a 3SLS model requires some of the regressors to be excluded from each equation of the analyzed system. It means that each equation of the system needs to have at least one exclusive covariate. Natural candidates for such roles are loan interest rate and insurance premium rate. Unfortunately, none of these variables are available in the database used. For the credit part, we capture the effect of interest rate on loan size through a dummy that equals one if the loan has a subsidized interest rate and, since subsidized loans are expected to have smaller interest rates than their counterparts, a positive relationship with loan size is expected.

For the insurance part, on the other hand, data restrictions arise. The only variable regarding crop insurance that is present on the BCB database is precisely the insurance adoption indicator, one of our endogenous variables. In this sense, we resort to the Crop Insurance Atlas, a database comprising the main indicators of the PSR[[10]](#footnote-10). Specifically, two variables are used: the previous year loss-ratio[[11]](#footnote-11) and the premium subsidy rate. Given the level of aggregation in which variables are presented in this database, the average value for each municipality-crop combination is imputed to each observation.

Previous year loss ratio is expected to positively affect farmers’ decision to purchase insurance in current year, as indicated by Cole et al. (2014) and Stein (2018), since it works as an indicator of the magnitude of indemnity payments in each municipality. When it is not the farmer himself who receives the indemnity, but rather a neighbor, a positive relation is still expected due to the so-called demonstration effect. The mean premium subsidy rate, in turn, is presumed to positively affect crop insurance adoption due to the law of demand, since farmers’ willingness to contract crop insurance should increase as policy price (premium) decreases. In fact, Lavorato and Braga (2018) provide evidence that Brazilian farmers positively respond to crop insurance subsidies.

After all, the analyzed sample consists of 49,734 observations. In terms of operation scale, farms are classified as small (37%), medium (44%) and large (19%). Roughly 83% of the sample are comprised of loans with subsidized interest rates, while men were responsible for approximately 86% of the analyzed loans. Considering the whole sample, it is observed that more than two thirds of farmers participated in crop insurance. When farms are segregated by operation scale, the pattern of insurance adoption expressively varies among the groups. Indeed, adopters account for 74%, 80% and 27% of small-, medium- and large-scale farms. Additionally, it is observed that more than 78% of subsidized loans were taken by insurance adopters, while only 16% of farmers who took non-subsidized loans participated in crop insurance. Finally, only a slight difference in insurance adoption is observed between men (68%) and women (65%).

Table 1 describes the main categorical variables used in our model in terms agricultural credit level. Descriptive statistics—mean and standard deviation—are presented for the whole sample as well as for adopters and non-adopters. The average farmer has an area-adjusted credit of roughly R$5,125. Such value, however, varies considerably when farms are segregated by operation scale. On the one hand, the mean for the small-scale group is roughly R$ 1,450 above the average farmer. On the other hand, both medium- and large-scale groups present average values that lie below the sample mean, with the latter presenting the lowest mean between the three groups. This scenario indicates that, at least for our sample, small-scale farms are considerably more credit intensive than its counterparts, which may be explained by the existence of several subsidized credit lines specifically targeting these farmers.

Considering the nature of loan’s interest rate, it is observed that, on average, loans with subsidized interest rates are 6% larger than non-subsidized loans in terms of credit per hectare. The bulk of the sample consists of subsidized loans, while most of subsidized credit lines are intended for small-scale farmers—those who, as noted earlier, are more credit-intensive than the other groups. Therefore, such scenario helps to explain the small difference in favor of subsidized loans. In terms of farmer’s gender, it is noticed that, on average, men present an area-adjusted credit 5% larger than women. This slight difference may be associated with the fact that, according to the literature, women are more risk averse than men.

**Table 1**. Mean and standard deviation of credit per hectare by crop insurance adoption, selected categorical variables

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | All farms | Crop insurance adoption | | Difference in means |
| Yes | No |
| All farms | 5,125.11 | 5,214.14 | 4,939.66 | 274.48\*\*\* |
|  | (7,175.03) | (6,935.09) | (7,647.62) |  |
| Operation scale |  |  |  |  |
| Small | 6,577.32 | 6,680.27 | 6,286.36 | 393.91\*\*\* |
|  | (7,022.14) | (6,692.70) | (7,872.60) |  |
| Medium | 4,493.16 | 4,231.18 | 5,511.34 | -1,280.16\*\*\* |
|  | (7,524.80) | (7,115.36) | (8,867.46) |  |
| Large | 3,746.98 | 4,109.88 | 3,612.45 | 497.43\*\*\* |
|  | (6,058.36) | (5,381.04) | (6,286.00) |  |
| Interest rate |  |  |  |  |
| Subsidized | 5,175.57 | 5,232.92 | 4,969.04 | 263.87\*\*\* |
|  | (7,206.52) | (6,704.04) | (8,778.35) |  |
| Non-subsidized | 4,880.72 | 4,761.61 | 4,902.96 | -141.35 |
|  | (7,015.80) | (11,131.33) | (5,940.55) |  |
| Gender |  |  |  |  |
| Men | 5,159.10 | 5,303.78 | 4,852.21 | 451.57\*\*\* |
|  | (7,199.29) | (7,173.46) | (7,244.49) |  |
| Women | 4,912.09 | 4,627.47 | 5,442.73 | -815.26\*\*\* |
|  | (7,017.82) | (5,069.15) | (9,631.14) |  |

Note: Standard deviations in parenthesis.

When the means for the area-adjusted credit are compared in terms of crop insurance adoption, it is observed that almost all differences are statistically significant. On average, insurance adopters have a 5.5% larger area-adjusted credit than non-adopters. This pattern, however, does not hold across all operation scale groups. Indeed, considering the medium-scale farmers, it is observed that adopters are 23% less credit-intensive than non-adopters. Such unexpected scenario may indicate that, within the medium-scale group, the farmers with the highest area-adjusted credit tend to opt for risk management tools other than crop insurance—such as crop or geographical diversification and hedge operations—or even to not protect their crops at all. Both small- and large-scale groups, in turn, present a positive difference in means as insurance adopters of these groups are more credit-intensive than non-adopters.

For the nature of loan’s interest rate, in turn, it is detected that farmers whose loans are subsidized are, on average, more credit-intensive when crop insurance is adopted. Such difference is around 5%. Differently, no statistically significant difference is observed between adopters and non-adopters when considered farmers with non-subsidized loans. Regarding farmer’s gender, opposite patterns are observed. On the one hand, male adopters have a 9% larger area-adjusted credit than male non-adopters. On the other hand, female adopters are 15% less credit-intensive than female non-adopters, which constitutes an intriguing situation as a clear risk-prone pattern arises for women.

1. **Results**

As crop insurance adoption, one of system’s endogenous variables, has a dichotomous nature, a linear probability model (LPM) is estimated for such structural equation. Despite all the known shortcomings of such model[[12]](#footnote-12), this is still used here in order to avoid the trap of Hausman’s forbidden regressions[[13]](#footnote-13) (Angrist and Pischke, 2009). Therefore, we interpret the estimated coefficients as the marginal effects—which holds true for LPM models—of covariates on the probability of adopting crop insurance.

After controlling for endogeneity and heteroskedasticity through the GMM-3SLS model, agricultural credit and crop insurance appear to positively affect each other as initially presumed. The estimates presented in Table 2 provide empirical evidence that the risk balancing hypothesis in fact holds in the Brazilian context. Further, these results corroborate the idea of a bidirectional causality between risk management and financing decisions. Specifically, it was found that, on the one hand, the probability of adopting crop insurance increases by roughly 0.5 in response to an increase of R$ 1,000 per hectare in agricultural credit[[14]](#footnote-14) and, on the other hand, the adoption of crop insurance makes agricultural credit to increase in approximately R$ 8,550 per hectare.

**Table 2**. Estimates of the GMM-3SLS model, Brazil, 2017

|  |  |  |
| --- | --- | --- |
| Independent variable | Dependent variable | |
| Crop insurance | Loan size |
| (adopted = 1) | (credit per hectare) |
| Loan size | 0.000514\*\*\* |  |
|  | (0.000025) |  |
| Crop insurance |  | 8,856.72\*\* |
|  |  | (4,123.03) |
| Previous year loss ratio | -0.010205\*\* |  |
|  | (0.004017) |  |
| Premium subsidy rate | 0.012240\*\* |  |
|  | (0.005955) |  |
| Subsidized interest rate |  | -4,287.93\* |
|  |  | (2,562.18) |
| Gender | -0.036891 | 225.53\* |
|  | (0.030942) | (116.69) |
| Operation scale |  |  |
| Small | -5.497992\*\*\* | 8,855.23\*\*\* |
|  | (0.443895) | (590.22) |
| Medium | -6.456691\*\*\* | 10,835.94\*\*\* |
|  | (0.482134) | (543.92) |
| Large | -6.892501\*\*\* | 14,775.69\*\*\* |
|  | (0.480395) | (1,505.91) |
| States | YES | YES |
| Crops | YES | YES |
| Observations | 49,734 | 49,734 |

Notes: Standard errors in parenthesis; \*\*\* significant at 1%; \*\* significant at 5%; \* significant at 10%.

The interpretation of the coefficients on crop insurance and agricultural credit becomes more interesting when such values are relativized in terms of the coefficients estimated for operation scale indicators, which serve as base values since neither of system’s equations were specified with a constant. Adopting crop insurance causes small-scale farmers to double the amount of credit per hectare, while the impact observed for medium- and large-scale farmers is of increases of roughly 82 and 60 percent, respectively. That is, the impact of crop insurance on agricultural credit increases as production scale decreases, which shows how important such risk management tool can be to the promotion of agricultural credit usage among Brazilian small-scale farmers.

The coefficients on production scale for the crop insurance structural equation, in turn, present less meaningful interpretation. As the dependent variable of such equation is binary and a linear regression was estimated, such coefficients must be interpreted as the probabilities of insurance adoption for each group of farmers when the other covariates have a null value. One should not be astonished by the negative estimates since they are measuring the average marginal effect of group allocation on insurance adoption probability when agricultural credit is equal to zero (in monetary terms). Therefore, these results indicate that, independent of the scale of operation, it is extremely unlikely that a farmer will adopt crop insurance when no credit is taken.

Interestingly, the coefficients estimated for the gender dummy presented opposite signals than initially expected. Literature has presented evidence that women tend to be more risk-averse than men and thus a positive (negative) relationship was expected between the gender variable and crop insurance adoption (agricultural credit size). The estimate on gender is not statistically significant for the crop insurance equation, indicating that gender differences do not impact the probability of adopting crop insurance. Conversely, a positive relationship was found between the gender dummy and agricultural credit. However, when contrasted with the base values of operation scale dummies, it is noticed that the positive difference in credit per hectare between women and men is relatively small.

The two variables entered exclusively in the crop insurance equation presented statistically significant coefficients, although the estimated effects were relatively small. Differently than expected, a higher loss ratio is related to a decrease in the probability of adopting crop insurance. A possible explanation lies on supply shortage because insurers can limit insurance coverage for riskier municipality-crop combinations—i.e., those presenting high loss ratios. The estimate on the premium subsidy rate, in turn, shows that an insurance price decrease leads to an (small) increase in the probability of adopting crop insurance. Thus, at least for this variable, theoretical expectation was indeed met.

Surprisingly, taking credit with government-subsidized interest rates leads to a decrease in area-adjusted credit. As the empirical (linear) model is estimated without intercept, its coefficients can be interpreted in an additive manner. Therefore, government subsidies on loans seem to decrease the impact of crop insurance adoption on area-adjusted credit. Some features of the loans operated under the SNCR may explain such result. First, it is important to note that government credit lines usually have a certain cap that limits the loan’s size.[[15]](#footnote-15) Second, depending on the operation scale and the credit line used, farmers may be obligated to participate on government’s credit insurance programs such as Proagro and Proagro Mais.

1. **Conclusion and policy implication**

The overall objective of this paper was to provide an empirical test of the risk balancing hypothesis, jointly analyzing crop insurance adoption and farm’s debt level. Using a sample of roughly 50,000 farmers from Brazil, we found strong evidence of low-level risk balancing behavior. By low-level we mean we have evidence of joint causality between adoption of crop insurance and increased use of debt—considering a debt per hectare basis. In other words, we concomitantly found that farmers who take on higher debt are more likely to insure and farmers who insure are more likely to take on higher debt. However, having stated this, it must be kept in mind that we still cannot say whether the incremental increase in financial risk is higher or lower than the incremental decrease in business risk as this relates to the original pre-policy total risk position.

Returning to the concerns of Collins (1985) and Featherstone et al. (1990), this evidence suggests several policy directions. On the one hand, provision of insurance may lead to risk balancing—i.e., a reduction in business risk is translated into an increase in financial risk. This may or may not be consistent with policy objectives. For example, if the goal of policy is to encourage greater use of debt, then the provision of crop insurance may be an attractive way to achieve such objective. In fact, this argument has been used in several agricultural development initiatives in which (unmitigated) business risks are simply too high to attract lenders into the agricultural marketplace. Linked or risk-contingent credit, a financial product usually suggested in such cases, combines risk protection with a credit product in order to reduce the business risks, absorbing the financial risks of credit.

In terms of the Brazilian agricultural policy, which historically uses subsidized credit lines to promote technology adoption and productivity gains, our evidence suggests that investing in crop insurance is an effective mechanism for achieving these objectives. Despite the recent evolution guided by PSR implementation, crop insurance take-up remains considerably low in Brazil. Therefore, an increase in government efforts regarding insurance spread within the Brazilian territory is highly recommended. Special emphasis, in this case, should be given northern and northeastern farmers as they has been accounting for only a slight part of PSR resources.

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2. Authors are thankful to the Institute for Applied Economic Research (Ipea) for data availability. [↑](#footnote-ref-2)
3. Ph.D. student in Applied Economics at the Federal University of Viçosa, Brazil, and Visiting Scholar at the Cornell University, USA. [↑](#footnote-ref-3)
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5. Professor at the Department of Rural Economics, Federal University of Viçosa, Brazil. [↑](#footnote-ref-5)
6. It is interesting to note, however, that Bekkerman et al. (2015) show that when government payments are decoupled from farm production and thus ostensibly independent of farm business risks, the payments appear to be used to pay down debt, consequently reducing financial risk. [↑](#footnote-ref-6)
7. See also Moss et al. (1989). [↑](#footnote-ref-7)
8. Such model could be expanded through the addition of two constraints since both credit rationing and risk-contingent credit would bound debt. Thus, we would end up with the following Lagrangean:

   where is farmer’s maximum debt to equity ratio an insurer would accept; is the total collateral owned by the farmer; and . In our application we cannot determine the constrained debt to equity nor any collateral restrictions. We assume that so that is an interior solution. However, if either constraint is binding, there may be corner points or other unobserved non-convexities in the empirical model. [↑](#footnote-ref-8)
9. We tested the null hypothesis of overall system homoskedasticity through Breusch-Pagan LM Test, Likelihood Ratio LR Test and Wald Test. In all cases, heteroskedasticity were confirmed as the null hypothesis was rejected. [↑](#footnote-ref-9)
10. The use of PSR data is seen as a second-best scenario, given that SUSEP data—which comprises all policies negotiated in the country—are made available only at the state level. Therefore, the use of PSR data rather than SUSEP ones leads to variability gain. [↑](#footnote-ref-10)
11. Loss-ratio denotes the ratio of indemnities paid to premiums collected. When equal to zero, no indemnity payment was made for the crop-municipality pair. If bigger than zero and smaller than one, only a fraction of total premium returns to farmers as indemnity payments. Finally, when bigger than one, indemnity payments are comparatively larger than total premiums. [↑](#footnote-ref-11)
12. In linear probability models, the predicted probabilities are not bounded between zero and one. Also, the change in probability—and thus the marginal effect—is constant for any unit change in regressors. [↑](#footnote-ref-12)
13. According to Angrist and Pischke (2009), the term forbidden regressions was coined by the Professor Jerry Hausman and it refers to the cases where the 2SLS reasoning is directly applied to nonlinear models. [↑](#footnote-ref-13)
14. Suspecting on a possible nonlinear relationship between agricultural credit and crop insurance, we also estimated a quadratic 2SLS model and a 3SLS model with credit per hectare in logs. For the former, the marginal effect of agricultural credit on insurance adoption is of 0.0004464, while it is of 0.0004829 for the latter. Since both are smaller than the estimate for the 3SLS model (0.0005136), one should be aware that, if the relationship is in fact nonlinear, the marginal effect of agricultural credit on the probability of adopting crop insurance would be smaller than we estimated in our empirical model. Additionally, using the estimates for the quadratic 2SLS, we found that the likelihood of adopting crop insurance increases up to R$ 18,734 ha-1 and after that it starts to decrease. [↑](#footnote-ref-14)
15. Pronaf and Pronamp illustrate this issue. Together, these programs accounted for roughly 25 percent of the agricultural credit negotiated in 2016/2017 (Assunção and Souza, 2018). Pronaf, which targets small-scale farmers, has a cap of R$ 250,000; Pronamp, in turn, is intended for medium-scale farmers and has a cap of R$ 1.5 million (BCB, 2018). For instance, a small farmer that is slightly below the operation scale threshold and takes the maximum loan permitted under Pronaf would have an area-adjusted credit of roughly R$ 830 per hectare. Therefore, such caps may indeed have a limiting effect on the variable of interest. [↑](#footnote-ref-15)