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Insurance, Weather, and Financial Stability

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Insurance, Weather, and Financial Stability

Abstract

In this paper, we introduce a model to study the interaction between insurance and banking. We build on the Federal Crop Insurance Act of 1980, which significantly expanded and restructured the decades-old federal crop insurance program and adverse weather shocks – over-exposure of crops to heat and acute weather events – to investigate some insights from our model. Banks increased lending to the agricultural sector in counties with higher insurance coverage after 1980, even when affected by adverse weather shocks. Further, while they increased risky lending, they were sufficiently compensated by insurance such that their overall risk did not increase meaningfully. We discuss the implications of our results in the light of potential changes to insurance availability as a consequence of global warming.

1 Introduction

Global warming will affect risks of bank lending and potentially the stability of the banking sector. This paper is an initial attempt to examine how the effects of weather are modified by actions in the insurance sector and related public insurance policies.

Observers have noted several potential risks to financial institutions from climate change. These can be subdivided into "physical risks" – those associated with damage either acute or long term from changes in weather patterns and events – and "transition risks"– those associated with changes in policies, technologies or tastes, induced by climate changes (Brunetti et al. (2022)).

In general, the purpose of insurance is to mitigate risk. It does so by pooling independent and idiosyncratic risks across sectors or regions, and reallocating those risks to the institutions best able to cover them. Individuals or institutions that are less able to take advantage of diversification of risks link up to institutions best able to carry out these roles.

While banks are in the business of managing risk and do pool individual loans in order to diversify idiosyncratic risks, it may still be the case that geographical and sectoral limitations to their lending activities mean that further offloading of risks to other institutions is desirable. Insurance companies and reinsurance more broadly are arguably a better capitalized sector and thus a candidate for interaction with banks. The US government itself has even deeper pockets, and thus is also a natural source of insurance.

To the extent that climate change increases correlations, the effectiveness of insurance is reduced. To the extent that financial institutions carry on their activities without awareness of such changes, they become fragile. Nonetheless these changes are long term and banks are likely able to adjust to risks, even with a lag.

If insurance programs in general should be a source of stability for banks, are there situations where availability of insurance could actually become destabilizing?

In this paper, we consider one important potential channel for such destabilization, through bank incentives. Insurance arrangements reduce the risk of banks for their existing assets, but increase their appetites for riskier assets. The net effect of these two tendencies is ambiguous.

We examine an instance in which a government program dramatically increased the availability of insurance in order to determine the extent to which banks appetite for risk changed. Specifically, we use the passage of the Federal Crop Insurance Act of 1980, which significantly expanded and restructured the decades-old federal crop insurance program, to test how banks' appetite for lending and risk-taking changed with insurance. We use two types of adverse weather shocks – over-exposure of crops to heat and acute weather events – to isolate the effect of the expansion of crop insurance on banks' lending from potential concurrent sectoral effect.[1]

We find that banks increased their exposure to the agricultural sector by increasing the volume of farm loans and loans collateralized by farm real estate as a share of their loan book in counties with higher insurance coverage after 1980, even when affected by adverse weather shocks. We find that banks' additional farm loans are riskier: banks' return on loans increased but so did their provisional loan losses and charge-offs in counties with more insurance coverage after 1980. Using weather shocks to isolate the effect of insurance expansion on banks' risk appetite from other developments in the ag banking sector, we find that banks in counties affected by adverse weather shocks were sufficiently compensated by insurance such that their overall risk did not increase meaningfully.

Our theoretical model is a simple, partial equilibrium approach. (For an early model relating bank choices and insurance see Dermine (1986). For an example of a general equilibrium model which incidentally examines the responses of banks to subsidized insurance, see Begenau and Landvoigt (2022).) Our empirical investigation, in

[1]For example, Calomiris et al. (1986) point to a financial crisis among agricultural banks over this period.

turn, is related to the literature on banks' responses to arrangements which allow them to transfer risk and/or securities emanating from their business, including insurance, securitization, and the CDS and secondary loan markets. Data limitations on insurance have led researchers to focus on the Federal Flood Insurance Program. Building on flood maps' changes nationwide, Blickle and Santos (2022) document that banks reduce mortgage lending in response to mandatory flood insurance along the extensive and intensive (through lower LTVs) margins, particularly for low-income borrowers. Given that their findings are driven by the insurance mandate – rather than the underlying flood risk – it suggests banks respond to the impact costs of insurance have on borrowers' financial capacity. Sastri (2021) finds similar bank responses but while building on flood map changes in Florida.

This evidence, however, does not extend to banks' responses to the other risk management arrangements. For example, Loutskina and Strahan (2009) document an increase in mortgage origination in connection to securitization; Goderis et al. (2006) find that banks that securitize corporate loans experience a permanent increase in loan originations; and Cebenoyan and Strahan (2004) find that banks which are active in the secondary loan market grant more loans. Hirtle (2009), on the other hand, find only limited evidence that greater use of CDS is associated with greater supply of bank credit.

Similarly, in contrast to banks' response to reducing lending to low-income borrowers forced to acquire flood insurance, several researchers, including Mian and Sufi (2009), Keys et al. (2010), Purnanandam (2011), DellAriccia et al. (2012), argue that securitization contributed to the the origination of poor-quality mortgages; Dahiya et al. (2003) document that over half of the firms whose loans are sold file for bankruptcy within 3 years of the initial sale of one of their loan; and Bord and Santos (2015) find that securitized corporate loans perform worse than similar loans originated by the same bank. Benmelech et al. (2012), Shivdasani and Wang (2011), and Wang and Xia (2014), however, generally fail to find evidence that securitized loans perform worse.

Our findings are in line with those of papers that have shown an increase of lending accompanied with a rise in riskier lending following the rise in securitization or the development of the CDS and secondary loan markets. Our paper, however, is closer to studies of the Federal Flood Insurance Program, but it differs from them in several important ways. That program covers only flood risk while the Federal Crop Insurance aimed at covering a wide range of perils affecting farmers, and consequently offered farm lenders, and by extension banks, more protection.[2] On the other hand, the flood insurance program mandates mortgage borrowers to buy flood insurance while participation in the crop insurance program is voluntary. We attempt to address the challenges voluntary participation pose by controlling for local farmers' adoption of crop insurance and capitalize on local weather shocks that have the potential to adversely impact agriculture.

Our paper is also related to the literature which has investigated the 1980s crisis in the US agricultural sector and its impact on banks, including Belongia and Gilbert (1987), Belongia (1986), Belongia and Carraro (1985) and Calomiris et al. (1986), and Calomiris (2006) (chapter 1). Surprisingly, none of these studies discusses the potential importance of the Federal Crop Insurance program, including its 1980 expansion, for banks and how it may have helped shield them from problems affecting the agricultural sector. Yet, as we will document in Section 3 in the years after 1980, FICP' maximum liability, a proxy for the amount of insured credit outstanding, represented about 14.3% of banks' outstanding farm debt or 4.5% of total farm debt outstanding.[3] Our paper adds to this literature by documenting that the 1980 expansion of crop insurance helped banks by reducing the adverse effects of weather shocks on farming. Given that the

[2]The Federal Crop Insurance Program is often referred as an "all-risk" program even though it provides insurance against pre-specified perils, which nonetheless kept increasing over time. See Section 3 for further details.

[3]Over the period 1981-85, banks accounted for 31% of the total farm debt outstanding with the Farm Credit System, Farmers Home Administration, Life Insurance Companies accounting for 45%, 15% and 9% of total outstanding farm debt, respectively.

1980 expansion broaden the scope of insurance (e.g. to include income protection) it also likely reduced the impact of the agricultural crisis on banks.

The rest of the paper is organized as follows. In the next section, we present a model to investigate banks' responses to the presence of insurance. Section 3 discusses the empirical implications of our model and presents a summary of the Federal Crop Insurance program together with a discussion on how we use it to test our model. Section 4 introduces our methodology and data sources and characterizes our sample. Section 5 presents our empirical findings while Section 6 concludes with some final remarks.

2 Model

A bank has an investment portfolio of size S providing a payoff of

$$V(z;S) = M(S) + Sz$$

where z is stochastic with mean 0 and distribution $F(z)$.

Let

$$\mu(S) = M'(S)$$

be the marginal expected return, a decreasing function. (It will also be handy to let

$$\overline{\mu}(S) = \frac{M(S)}{S}$$

be the average expected return, so that $\mu(S) < \overline{\mu}(S)$.) Let σ be the standard deviation of z. Thus a portfolio's standard deviation is proportional to its size, a reasonable assumption if the portfolio is well-diversified.

The bank is financed by debt and equity. There is a leverage constraint; equity must be held in proportion to the size of the portfolio, with proportion χ. Debt costs a solvent bank a fixed amount r_d per unit (which can be taken to be financed by riskless deposits for too-big-to-fail banks). Equity costs is $r_e > r_d$ per unit. Thus the cost of funding a unit of the project is

$$r \equiv (1-\chi)r_d + \chi r_e$$

The probability of a bank's failure is

$$F((1-\chi) - \overline{\mu}(S))$$

A bank's preferences are based on the mean and variance of its portfolio with α indexing its risk aversion. That is, the uninsured bank chooses S to satisfy

$$\mu(S) - r = \alpha\sigma$$

In other words if the risk of the portfolio increases, the bank cuts back on its lending, mitigating the increase in risk. Similarly, consider a small increase in expected value dc of all investments in the portfolio. The direct effect is to reduce the probability of bankruptcy:

$$\frac{dF}{dc} = -F' < 0$$

The indirect effect has the opposite sign. For instance, suppose

$$M(S) = S^b$$

for $0 < b < 1$ ("constant elasticity"). Then the indirect effect is

$$\frac{F'}{b} > 0$$

swamping the direct effect.

2.1 Incorporating insurance

We next incorporate an insurance sector, modeled as a second institution better capitalized or more risk tolerant than the bank. The actual institutional arrangements which implement insurance opportunities can vary: Banks can contract directly with insurance companies for a variety of insurance products, and the companies may turn may lay off some of the resultant risks on reinsurers. Banks may require their borrowers to purchase insurance for their collateral, making loans safer. Banks can also offload risk through securitization or purchase of derivatives on financial markets.

Our simplification is as follows: A unit of insurance replaces a unit of the portfolio with a fixed payment $\hat{\imath}$. The bank obtains $\tilde{S}$ units of insurance. The maximum insurance obtainable is limited to $(1-k)S$. where k is the exogenously specified minimum skin in the game. (Thus $k = 1$ is the case where no insurance is available). If the insurance is provided privately, then the degree of coinsurance required of the bank depends on moral hazard. Effective insurance may also be limited by regulation capping securitization. For simplicity we assume that k is fixed exogenously.

As long as the insurance payment is at least actuarially fair—that is as long as

$$\hat{\imath} \geq \overline{\mu}(S)$$

—then increasing insurance increases expected value and decreases risk. Thus the bank takes on the maximum permitted insurance, and the bank fails if

$$kV(z; S) + S((1-k)\hat{\imath} - (1-\chi)r_d) < 0.$$

The probability of failure of an insured bank is

$$\pi_b \equiv F\left(\frac{(1-\chi)r_d - (1-k)\hat{\imath}}{k} - \overline{\mu}(S)\right)$$

The maximally insured bank chooses S such that

$$\mu(S) - \frac{r - (1-k)\hat{\imath}}{k} = \alpha\sigma. \tag{1}$$

For a given portfolio, insurance reduces the chance of default. However increasing insurance payoff causes the bank to increase the size of its portfolio. As above, depending on the quality of available loans, this can increase the overall riskiness of the bank's portfolio.

An increase in the insurance limit has a more complicated, but largely similar effect: For instance, in the case of constant elasticity, an increase in the insurance limit has a total effect

$$\frac{dF}{dk} = \frac{1}{k^2 b}\big((1-b)\hat{\imath} - \chi r_e - (1-\chi)(1-b)r_d\big)F'$$

Again, for sufficiently generous insurance, the indirect effect overwhelms the direct effect. The effects are magnified as the insurance limit increases.

2.2 Risk adjustment for insurance

If the bank chooses its portfolio size and the insurance is set to be actuarially fair, then S and $\hat{\imath}$ are determined simultaneously by (1) and

$$\hat{\imath} = \overline{\mu}(S)$$

For example if

$$M(S) = aS^b + c$$

where $1 > b > 0$, $a > 0$, and $R > c \geq 0$ then

$$S^{1-b} = a\frac{1 - k(1-b)}{r + k\alpha\sigma - c}.$$

The comparative statics are intuitive: As long as insurance terms remain actuarially fair, then increases in the cost of funds or the riskiness of investment reduces the bank's portfolio size. Increases in k (reductions in the permitted insurance) also decrease portfolio size. In any of these cases the effects are partially offset by improved insurance terms as the portfolio's quality increases. On the other hand, if the insurance terms remain fixed, then (1) alone determines comparative statics.

2.3 Extensions

While the model described thus far is extremely simple, extensions leave the fundamental relationships unchanged. For example, we can extend the portfolio of projects available to the bank to include projects which require varying levels of skin in the game. Across classes, the bank equates margins of risk and return, and the overall responses act on the composite portfolio. The portfolio can also include idiosyncratic risk. In this case the critical level for bankruptcy to arise becomes stochastic, and unexpected increases in idiosyncratic risk become a second source of variation, while anticipated increases in idiosyncratic risk become a second source of conservatism. In general these additional considerations dampen but do not reverse the effects described in the preceding section.

Although we have emphasized the limitations to the risk tolerance of the bank in our account, the same analysis would apply to any insurance company standing behind the bank: Increased risks reduce the willingness of the insurance company to back the loans. For fixed portfolios this increases bank riskiness, but also induces the bank to cut back on the lending. Similarly for fixed insurance offerings, reduction in the generosity of government subsidy programs increases the exposure of the insurance company, but also induces the insurance company to cut back on the insurance offerings it provides.

3 Building on Federal Crop Insurance to test our Model

3.1 Empirical Implications

Our framework yields to the following observations: If exogenous factors such as climate change decrease the quality of the bank's portfolio of loans, either through decreasing the likelihood of repayment of individual loans, or increasing the correlation between the loans, then the risk of bank failure increases. But the ability of the bank to adjust its portfolio in response mitigates the risk in general, and can even reverse the effect entirely (provided the bank is not in such bad shape as to engage in gambling for resurrection). When insurance options are available to the bank, they reduce the bank's incentives to correct for the change in risks. In particular, increased insurance can increase the risk of failure, unless accompanied by increased regulatory restrictions on bank lending.

In order to determine whether the interaction of insurance and banking is a cause for concern, we need to understand the extent to which insurance can increase banks' risk appetite and decrease their overall lending quality. To do so, we looked for instances where a major change in availability of insurance could be traced through to bank behavior and performance. Government programs, like the National Flood Insurance Program and the Federal Crop Insurance Program (FCIP), are good candidates for natural experiments of this sort because of their wide scope and the large role that banks play in mortgage lending and farm lending, respectively.[4] We focus on the crop insurance program because a crucial piece of information pertaining to the flood insurance program – the flood maps which indicate the areas where flood insurance is "mandatory" – is not available around 1968 when the program was introduced or around 1973 when it was

[4]Other candidates include the first US insurer established in 1752 – the Philadelphia Contributionship for the Insurance of Houses from Loss by Fire, the development of the CDS market in late 1990s, and the exodus of private insurance from Florida and California following the 1992 Hurricane Andrew and the 1994 Northridge Earthquake, respectively. However, the reduced number of mortgages with all the necessary information and the absence of granular data on bank-firm CDS holdings for hedging purposes rendered the first two events ineffective. Similarly, the moratoriums together with the state arrangements lawmakers put in place in Florida and California to offer insurance precluded a sharp decline in insurance supply also rendering the last two events ineffective for the purposes of studying banks' responses to insurance (or lack of).

amended to strengthened adherence to flood insurance.[5]

As we document in the next subsection, the FCIP was established in 1938, but it was the 1980 Federal Crop Insurance Act that had a substantial impact on farmers' use of crop insurance. This was because it greatly expanded the number of crops covered, the type of policies offered, made the program available nationwide, and also introduced subsidies to entice farmers to adhere to the program. We, therefore, build on the increase in the use of crop insurance which followed these changes in 1980 to test the predictions from our framework.

Specifically, according to our model, the introduction of the new program should increase agricultural lending, and reduce the variability of the supply of lending to the agricultural sector with exogenous shocks to farmers' situation. On the margin, banks will take on riskier loans, but whether the overall quality of the loan portfolio increases or decreases is ambiguous, depending on the elasticity of supply of lending opportunities and bank risk tolerance.

So the ultimate effects meriting attention are the questions of performance: How are returns affected by the change? How are loan losses affected? Does the insurance reduce banks' sensitivity to shocks to agricultural productivity? In examining these questions we build on a convenient exogenous instrument for productivity shocks, local weather shocks.

3.2 Federal Crop Insurance Program

The FCIP was created in 1938 as part of the agricultural policy response to the Great Depression and after several unsuccessful private efforts to provide crop insurance It aimed at providing agricultural producers protection from losses caused by unavoidable natural hazards, such as insects, plant diseases, fire, hail, drought, excessive moisture, freeze, wind, and other weather conditions. However, up to 1980, the program was

[5]See Blicle and Santos (2023) for detailed information on the Federal Flood Insurance Program and its changes over time.

rather rudimentary and did not attract much participation. The program initially had no private sector involvement and covered only wheat. It was expended to include cotton in 1941, and wheat and flax in 1944. But, because of consistently high loss ratios in certain areas and for the program as a whole, in 1947 Congress enacted legislation to restrict the geographic scope of the program.

In 1980, the FICP was the subject of a profound revamp. In response to high disaster support payments and low crop insurance participation throughout the 1970s, Congress enacted the Federal Crop Insurance Act of 1980. The law mandated the Federal Crop Insurance Corporation (FCIC) to make a wide range of changes to the insurance program including, expand the commodities covered and the geographic scope nationwide; allow producers to delete hail and fire coverage from the FCIC's policies (with a corresponding reduction in the premium) when he/she obtains at least equal coverage from a private insurer; and provide different coverage levels up to 75 percent of protection against loss in yields and to offer various levels of price elections with one not being less than 90 percent of the projected market price for the commodity involved.

The law also mandated the FCIC to develop insurance' premium rates that were sufficient to cover claims for losses and to establish a reasonable reserve against unforeseen losses. At the same time, to encourage the broadest possible participation in the program, the law mandated the FCIC to pay 30 percent of each producer's premium up to a maximum of 65 percent of the recorded or appraised average yield. Further, beginning in the 1981 crop year and ending after the 1985 crop year, it required the FCIC to conduct a pilot program of individual risk underwriting of crop insurance in not less than 25 counties. This program allows purchasers of FCIC insurance to obtain an increase in the coverage offered based on his/her actual yield history. Finally, the 1980 law allowed private insurance companies to sell and service crop insurance, and provided for a test program of reinsurance (whereby part or all of the risk is transferred from one party to another, including the FCIC), to the maximum extent possible, to begin not later than with the 1982 crops.[6]

The Federal Crop Insurance Act 1980 had a profound impact on the insurance program not only by broadening its scope, but also by increasing the generosity of the insurance policies, triggering an equally large response by farmers. The number of insured crops as well as the number of counties with available crop insurance increased sharply after 1980 (Figure 1). These reflect FCIC's response to the mandate it received from the 1980 Act to increase the availability of crop insurance.

The introduction of subsidized premiums in 1980 likely made crop insurance more attractive to farmers. The program's payouts appear to have become more generous thereby also likely making crop insurance more attractive. As we can see from Figure 2, both the payouts per policy and per insured acre increased significantly after 1980. Granted, some of this increase in payouts may be attributed to the financial difficulties many farmers experienced in the early 1980s following the 1981 worldwide recession, which reduced export sales of U.S. farm products, and the reduction in inflation expectations, which lowered the demand farmland.[7]

Farmers responded positively to the 1980 changes introduced to the crop insurance program. This is evident in the sharp rise soon after 1980 in the number of policies as well as the area insured (Figure 3). Further, and importantly for our purposes, the expansion of insurance coverage appears to have been meaningful when compared to bank farm lending. Over the period 1981-85, FICP' maximum liability, a proxy for the amount of insured credit outstanding, represented about 4.5% of total outstanding farm debt or 14.3% of banks' farm debt outstanding (Figure 4). As we can also see from Figure 4, FICP's maximum liability relative to banks' farm lending almost doubled after 1980, going from 7,6% for the 1975-80 period to 14.3% for the 1981-85 period.

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[6]See GAO (1981), D'Agostino and Schlenker (2008) and CRS (1921) for further details of the FCIP and the changes it went over the years.

[7]See Belongia and Gilbert (1987), Belongia (1986) and Calomiris et al. (1986) for more detail discussion on the agricultural crisis of the 1980s.

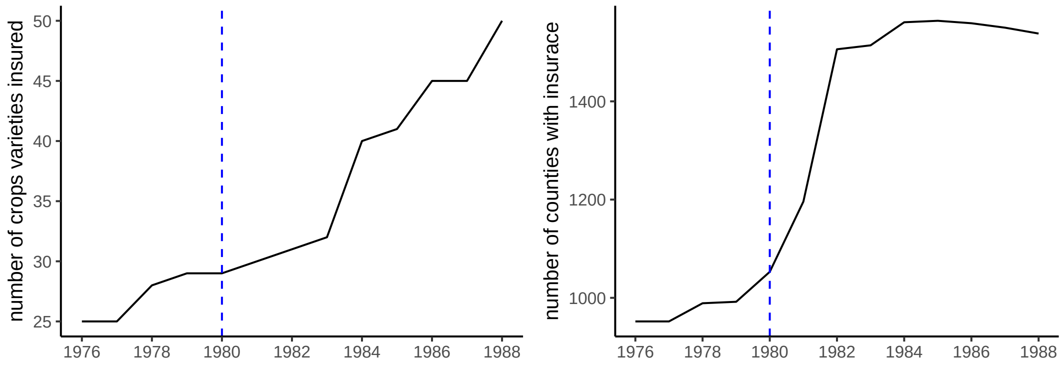

Figure 1: Expansion of federal crop insurance program The left panel in this figure shows the number distinct crop varieties eligible for federal crop insurance coverage over time. The right panel shows the number of counties that were covered by the federal crop insurance program over time. Both, the number of varieties and the number of counties insured, increased after 1980.

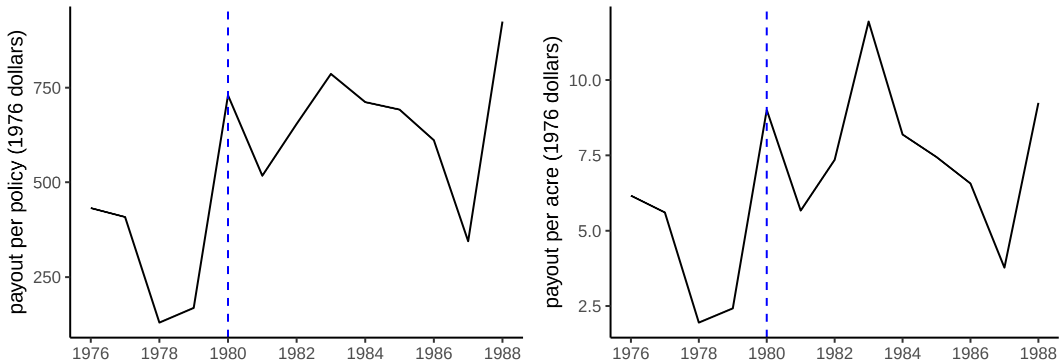

Figure 2: Federal crop insurance payouts The left panel in this figure shows the mean crop insurance payout per policy; the right panel shows the mean crop insurance payout per acre. Payouts are in 1976 dollars in both panels.

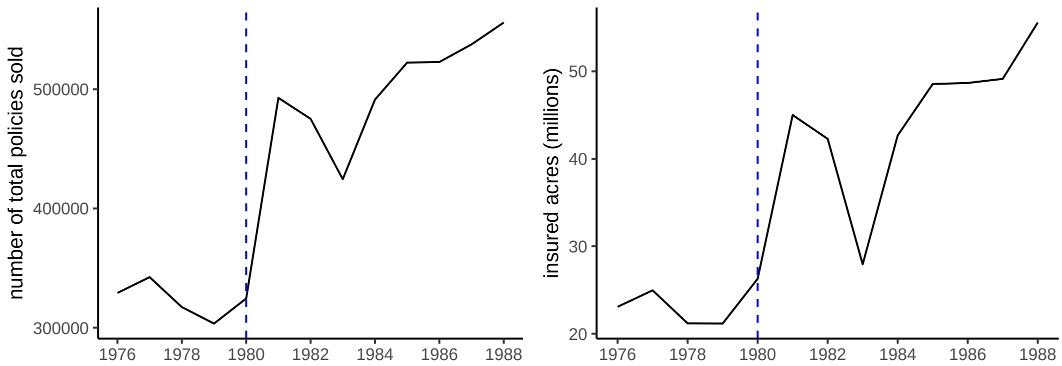

Figure 3: Federal crop insurance coverage The left panel in this figure shows the number of policies sold; the right panel shows the number of acres insured (in millions) as part of the federal crop insurance program.

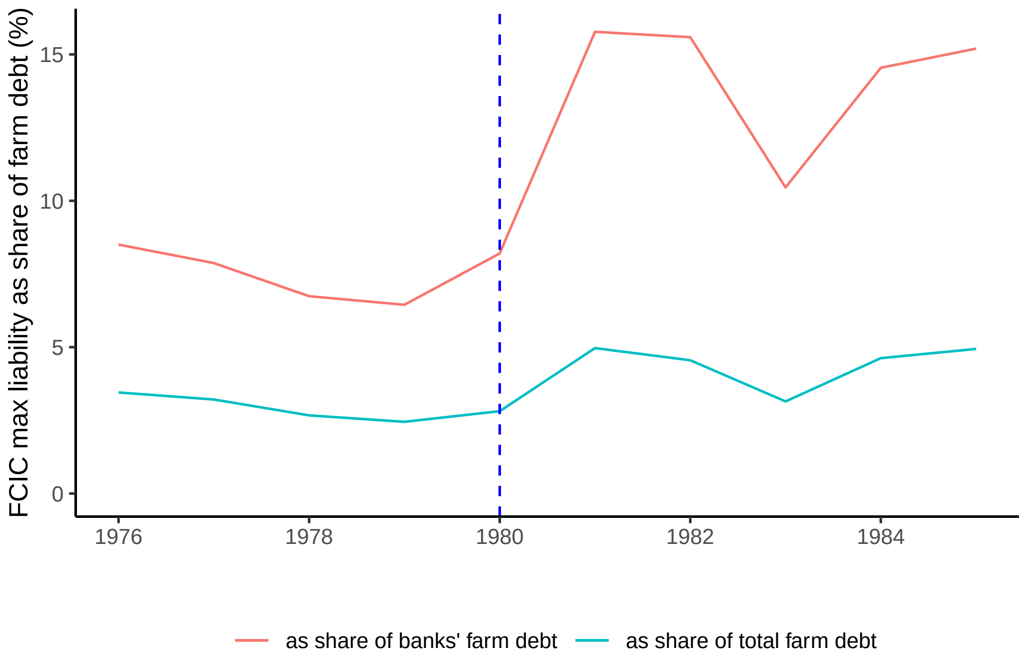

Figure 4: FCIC maximum liability and farm debt This figure shows FCIC's maximum annual liability as a ratio of farm debt held by the banking system (red) and as a ratio of total farm debt (blue). Dashed blue line indicates the passage of the Federal Crop Insurance Act of 1980. Data on farm debt are from FRB (1985); data on FCIC maximum liability is from USDA Summary of Business Crop Insurance Experience 1948-1988. Ratio calculated based on 1984 dollars.

4 Methodology, Data Sources, and Sample Characterization

In this section, we begin by describing the methodology we follow in our empirical investigation. After that, we present our data sources and characterize our sample.

4.1 Methodology

Our methodology has two parts. The first part aims at investigating whether banks increased lending in response to the 1980 expansion of crop insurance. Towards that end, we begin by investigating whether banks increased lending in response to the 1980 expansion of crop insurance using the following econometric model:

$$\begin{aligned} Lending_{bct} = {} & \beta_1 \text{Insurance Coverage}_{ct} + \beta_2 \mathbf{1}(t > 1980) \\ & + \gamma \text{Insurance Coverage}_{ct} \times \mathbf{1}(t > 1980) + X_{bct} \end{aligned} \tag{2a}$$

for bank b in county c in quarter t. We use two measures of *Lending*: farm loans share – the volume of farm loans as a share of total loan volume of the bank, and real estate (RE) loans share – the volume of loans secured by farm land as a share of total loan volume of the bank as of the third quarter of the year (Q3). $(t > 1980)$ is a dummy variable equal to one for the period post 1980, and $InsuranceCoverage$ is our measure of farmers' insurance adoption, which we proxy by the insured acres in the county where the bank is located, in same year as the Q3 of farm loan share.[8]

We interact the post 1980 period with our measure of insurance adoption because we noted in the previous section, the Federal Crop Insurance Act of 1980 not only expanded crop insurance (by including more crops and making it available nationwide), but also changed the terms of insurance policies, including broadening the insurance coverage and subsidizing the policies. X_{bct} are bank and county-related controls including

[8]Crop insurance policies are annual while call reports are quarterly. FRB (1985) shows that most ag loans have a maturity of less than one year. Given the importance of seasonality in the ag context, the measuring these variables at appropriate times is crucial.

(e.g., federal funds rate, bank and county fixed effects, etc.). To help with identification, we estimate model (2a) with bank, year and county fixed effects on a sample of unit banks, that is banks operating in states that did not allow branching. Standard errors clustered at the county-level in line with Abadie et al. (2023).

We investigate whether our results are robust to proxying for farmers' insurance adoption by the number of farm insurance policies in the county where the bank is located instead of the number of insured acres in that county. As another robustness test we restrict the sample to agricultural banks.[9]

Even though we estimate model (2a) with year and county fixed effects one may still worry that its results may be contaminated by time series effects unrelated to the expansion of crop insurance. To alleviate these concerns, we expand model (2a) to investigate whether banks' farm lending becomes less sensitive to shocks that have a negative impact on the financial condition of farmers. Specifically, we use the following econometric model:

$$\begin{aligned} Lending_{bct+1} = {} & \beta_1 \text{Weather}_{ct} + \beta_2 \text{Insurance Coverage}_{ct} + \beta_3 \mathbf{1}(t > 1980) \\ & + \beta_4 \text{Weather}_{ct} \times \text{Insurance Coverage}_{ct} \\ & + \beta_5 \text{Weather}_{ct} \times \mathbf{1}(t > 1980) \\ & + \beta_6 \text{Insurance Coverage}_{ct} \times \mathbf{1}(t > 1980) \\ & + \gamma \text{Weather}_{ct} \times \text{Insurance Coverage}_{ct} \times \mathbf{1}(t > 1980) + X_{bct} \end{aligned} \tag{3a}$$

where weather is one of two possible measures of adverse shock to farmers: (i) a cooling degree day measure based on D'Agostino and Schlenker (2016) in the second quarter of the year (Q2) or (ii) crop damages due to hazard and peril-based weather shocks (e.g.,

[9] We define ag banks as banks having farm loans as a share of total loans in the third (equivalently, top) tercile of the farm loans share distribution before 1980. This definition implies that a bank with farm loan share above 15.7% is classified as an ag bank. Smith (1987) documents that due the decline in farm loans as a share of all loans, the Federal Reserve changed its classification of ag banks from a fixed 25% threshold to a variable definition that implied an effective threshold of 16%.

frost, floods, or fires) in the second and third quarter of the year (Q2 and Q3). As in (2a), lending is measured in Q3 and insurance coverage is measured in the same year.

Conceptually, the two measures of weather shocks reflect the two types of physical climate risks: chronic and acute risks.[10] Chronic physical risks are long-term changes in climate patters, e.g. sustained higher temperatures. One way of capturing this risk in the agriculture context is cooling degree days which is a measure of the over-exposure of crops to heat due to temperatures being above a threshold for some part of the day. Schlenker and Roberts (2009) document that the optimal temperature is 29C for corn, 30C for soybeans, and 32C for cotton. As the temperature surpasses this threshold, crops are adversely affected. We compute the cooling degree days for each day and sum over quarters to get the total over-exposure of crops to heat in a quarter.[11] Acute physical risks, on the other hand, refer to risks from extreme weather events like hail, wildfire, and freeze which may also impact farm productivity, for example either by hampering timely sowing, application of fertilizer and pesticide, or damaging maturing crops. To the extent that crop insurance is valuable for banks then we would expect them to respond less to weather shocks after the 1980 crop insurance expansion in counties with large insurance coverage.

The second part of our methodology aims at investigating whether banks take on additional risks in response to the expansion of crop insurance. To investigate this

[10]For detailed discussion of physical climate risks, see EPA: Climate Risks and Opportunities Defined.

[11]Our unit of analysis is bank-county-quarter; we use 29C as the the common threshold above which crops are over-exposed to heat.

question, we consider the following version of model (2a)

$$
\begin{aligned}
Risk_{bct+1} = {} & \beta_1 \text{Insurance Coverage}_{ct} + \beta_2 \text{Farm Loans}_{bct} \\
& + \beta_3 \mathbf{1}(t > 1980) \\
& + \beta_4 \text{Insurance Coverage}_{ct} \times \text{Farm Loans}_{bct} \\
& + \beta_5 \text{Insurance Coverage}_{ct} \times \mathbf{1}(t > 1980) \\
& + \beta_6 \text{Farm Loans}_{bct} \times \mathbf{1}(t > 1980) \\
& + \gamma \text{Insurance Coverage}_{ct} \times \text{Farm Loans}_{bct} \times \mathbf{1}(t > 1980) + X_{bct}
\end{aligned} \tag{4a}
$$

expanded to account for the share of the bank's loans extended to farmers, $FarmLoans$. We consider several proxies of risk in an attempt to separate the bank's risk taking from any protection its farmers' borrowers might receive from crop insurance. Ideally, we would like to consider risk measures specific to farm loans. Given that these are not available, we rely instead on bank-level variables, including the bank's loan loss provisions, charge-offs, recoveries, return on loans and return on assets. To the extent the bank responds to the expansion of crop insurance by taking on additional risk, this should lead to an increase in loan loss provisions and charge-offs. Of course these effects may be alleviated by the crop insurance in which case we might also see evidence of this in the recoveries and return on assets. We measure these risk-related variables over the one year following the Q3 in which farm loans are measured and the year insurance coverage is taken out.[12]

We complement the investigation of these measures with an investigation of the riskiness of the bank as captured by its Z-score, which is an indicator of a bank's probability of failure in the sense that it estimates the number of standard deviations below the mean that the bank's profits would have to fall before its equity became negative.

[12]I.e., insurance coverage and farm loans in Q3 are measured in the same year, risk-related variables are measure over Q3 and Q4 of the same year and Q1 and Q2 of the following year.

Following Boyd et al. (1993) and Craig and Santos (1997) we compute the banks' Z-score as

$$Z = \frac{\sum_{i=1}^{n} \frac{1}{n} \frac{\pi_i}{A_i} + \sum_{i=1}^{n} \frac{1}{n} \frac{E_i}{A_i}}{\left[\sum_{i=1}^{n} \left(\frac{\pi_i}{A_i} - \sum_{i=1}^{n} \frac{1}{n} \frac{\pi_i}{A_i} \right)^2 \frac{1}{n-1} \right]^{\frac{1}{2}}} \tag{5}$$

where π_i, A_i, and E_i are the bank's net income, assets, and equity in quarter i. The value of the Z-score depends positively on the banks return on assets (π_i/A_i) and capital-asset ratio (E_i/A_i) and negatively on the variability of its return on assets (represented by the standard deviation of its return on assets in the denominator in (5)). Thus, the smaller the value of Z, the larger the bank's risk of failure.[13]

Further, like we did in our investigation of banks' farm lending, we investigate whether banks' risk becomes more sensitive to weather shocks after the 1980 expansion of crop insurance. We use a model similar to model (3a) but with our risk proxies on the left-hand side. To get a sense whether the results depend on banks' exposure to farm lending, we run the models separately on our sample of banks with some exposure to farm lending and our sample of agricultural banks. To the extent that banks increase risk taking after the 1980 insurance expansion and crop insurance does not fully hedge them then we would expect weather shocks to become bigger drivers of their risk after 1980, particularly among agricultural banks. As discussed above, we consider two measures of weather shocks: cooling degree days and crop damages stemming from hazard and perils-based weather shocks, e.g., frost, floods, and fires.[14]

[13]We compute z-scores using a moving window of 12 quarters ($n = 12$). Since net income was reported at quarterly frequency starting in 1976, our first observation for the z-score is in Q4:1978. Given the time structure of the z-score, we estimate the effect of the expansion of crop insurance on the z-score two years following the year in which insurance coverage and farm loan are measured.

[14]For a complete list of hazards and perils covered, see SHELDUS Version 22.0 Metadata.

4.2 Data Sources

The data we use in the methodology presented above comes primarily from three sources. First, we use historic call report data for bank-level data including their total lending volume, farm lending volume, volume of loans secured by farmland, loan income, net income, reserves for loan losses, charge-offs, and equity capital. We also rely on historic call reports to gather bank location data, in particular the five-digit FIPS county code to merge with weather and insurance data.

We use USDA Summary of Business Crop Insurance Experience 1948-1988 to gather county-level information on insurance provided by the Federal Crop Insurance Program, including number of policies sold, number of acres insured, total premium amount (before application of any subsidies), amount of subsidized premium, indemnity amounts, as well as loss ratio (indemnity/total premium). These data are at an annual frequency.

Finally, for our chronic weather shock, we use Schlenker (2024) to get daily weather data by county and construct the cooling degree day measure of D'Agostino and Schlenker (2016), which captures crops' over-exposure to heat throughout the day (more details above). We aggregate this data to quarterly frequency to align with the panel structure of the call report data. For our acute weather shock, we use SHELDUS version 22 (CEMHS, 2024) to get quarterly crop damage data aggregated across hazard- and peril-types at the county-level adjusted to 1976 dollars.

4.3 Sample Characterization

We focus our investigation on the 1976-1988 time period, giving us five years before and eight years after the passage of the 1980 Federal Crop Insurance Act. We begin in 1976 because this is the first year for which the call reports provide quarterly data on the key variables for our study including farm lending, loan income, loan-loss provisions and charge-offs. We end in 1988 because this is the last year for which we have the necessary data on crop insurance.

We restrict our sample to banks operating in states that only allowed unit banking during our sample period. This condition is not very restrictive: by 1975 only 14 states allowed statewide branching, 12 prohibited any kind of branching, and the remaining imposed restrictions of varying degrees Jayaratne and Strahan (1997).[15] Further, while we do not have loan-level data, we have precise information on banks' geographic location. Therefore, restricting the analysis to unit banks increases the chances that most of their activity is in the counties where they are located and thus exposed to the insurance availability and weather shocks in their counties. We determine whether a bank was a unit bank in a given year using the data compiled in Amel (1993) and Jayaratne and Strahan (1997).

Additionally, we restrict our sample to banks that had at least some farm lending. We do so because banks which did not make any agriculture-related loans are likely structurally different and unlikely to respond to any changes in crop insurance. This leaves us with a sample of 12,600 banks. In robustness tests we investigate whether our results change if we further restrict our sample to agricultural banks, which following the literature (e.g. Corporation (1997), chapter 8, Smith (1987)) we classify as banks whose farm loans are approximately 16 percent or more of total loans prior to the 1980 crop insurance reform. This subsample encompasses 5,360 banks.

Table 1 characterizes our sample, distinguishing banks before and after the 1980 reform. Panel A reports statistics for the set of banks that have some farm lending. Panel B reports statistics after we restrict the sample to agricultural banks. Finally, Panel C reports data on our weather and insurance variables.

Looking at Panel A, we see that banks increased the share of farm lending following the expansion of crop insurance promoted by the 1980 Federal Crop Insurance Act. By contrast, they reduced the portion of lending backed by farm real estate assets,

[15] Jayaratne and Strahan (1997) note that Pennsylvania was representative of the partially-restrictive states in that until 1982 Pennsylvania allowed banks to have branches only in the banks' home county and contiguous counties.

	pre-1980	post-1980
all banks with positive farm loan share		
number of banks	12300.00	12600.00
farm loans share (%)	1970.00	2010.00
farm RE-backed loans share (%)	512.00	501.00
return on loans (%)	930.00	1250.00
return on assets (%)	104.00	79.10
provisional losses share (%)	0.39	1.18
loan charge offs share (%)	43.70	126.00
recovery share (%)	0.13	0.24
Z-score	1.97	1.54
ag banks only		
number of banks	5360.00	5120.00
farm loans share (%)	4070.00	4040.00
farm RE-backed loans share (%)	619.00	721.00
return on loans (%)	913.00	1280.00
return on assets (%)	114.00	81.40
provisional losses share (%)	0.32	1.42
loan charge offs share (%)	36.80	151.00
recovery share (%)	0.12	0.26
Z-score	2.19	1.40
crop insurance		
policies sold per county	256.00	280.00
insured acres per county	17300.00	24700.00
payout per policy (1976 dollars)	460.00	915.00
payout per acre (1976 dollars)	9.43	11.10
weather		
cooling degree days	35200.00	36400.00
crop damage due to acute risks (1976 dollars, SHELDUS)	376000.00	417000.00

Table 1: Summary statistics This table summarizes the key set of variables used in our analysis. We present bank-related variables for all banks in the call report that have a positive volume of farm loans as a share of their total loan book and for the subset of agriculture banks which are defined as banks whose farm loans as a share of total loan volumes is above 16%. We also include key measures of crop insurance coverage and payouts from the USDA, weather from Schlenker (2024) based on the methodology in D'Agostino and Schlenker (2016), and crop damage estimates from SHELDUS version 22 (CEMHS, 2024).

possibly because of the adverse effect of the early 1980s' decline in inflation expectations on farmland assets. In either case, the change however is rather small.

Over the same period of time, we see an increase in loan returns as well as in recovery rates, coinciding with the expansion of crop insurance program and the rise in the generosity of its insurance policies. However, we also see a large rise in loan charge-offs. This could be the result of riskier lending, but it also likely reflects the financial difficulties many farmers experienced in the early 1980s. Farm debt rose sharply and persistently throughout the 1970s in tandem with the rise in the price of farmland. These trends changed abruptly in 1981 when a world recession reduced export sales of U.S. farm products and real net farm income, and expectations of future inflation suddenly declined, reducing the demand farmland. With lower export sales and lower income, many farmers could not generate sufficient cash flow to service their debts. Moreover, with land values declining sharply, farmers could not pay off their debts by selling their land. As a result, many of them had to default on their bank loans.[16] Given these losses it is not surprising that both the banks' ROA and Z-scores declined in the 1980s, indicating that banks became less profitable and riskier.

Panel B shows these patterns extend to farm banks with two minor differences: they reduced share of farm lending in the 1980s but increased the portion of lending backed by farm real estate assets. As with all the banks, these changes were rather small among farm banks.

Turning to Panel C, we see consistent with expectations, that there was a large increase in insurance coverage after 1980. This is particularly evident in the average area insured per county which went up by 43%, but is also apparent in the average number of policies per county which rose by 9%. We also see a large increase in insurance payouts. Notwithstanding the large increase in the insured area, the average payout per acre (in real terms) increased by 18% while the average payout per policy doubled. These

[16]See, for example, Belongia and Gilbert (1987) and Belongia (1986) for a discussion on farm prices, income and asset values post 1981, and Belongia and Carraro (1985) and Calomiris et al. (1986) for the impact of these changes on banks.

increases outpace the rise in the average number of cooling days per quarter in each county, our proxy for weather shocks, which went up by 3%, and are a reflection of the increase in the coverage scope/generosity of the crop insurance program.

5 Banks' Response to Insurance

In this section, we present the results of our investigation of the empirical implications of our model on banks and insurance. We begin with the results on banks' lending responses to the expansion of crop insurance in 1980. After that, we report our results on their risk taking behavior. In both parts, we focus on results derived using cooling degree days as the measure of weather shocks. However, as a robustness test in subsection 5.3 we report results when we consider instead the crop damages due to acute weather events from SHELDUS.

5.1 Did Banks Increase Lending?

We begin our investigation of banks' lending responses to the 1980 expansion of the FCIP by estimating Model 2a. The results of this exercise, which are reported in columns (1) and (2) of Table 2, show that banks increased farm lending and loans backed by farm real estate following the expansion of crop insurance in 1980. Conditional on having a positive farm loan share a one standard deviation increase in insurance coverage increased banks' farm loan share and farm RE-backed loan share by 0.62 and 0.55 percentage points, respectively.[17]

The results reported in Columns (1) and (2) were derived with bank, county and year fixed effects. To further ensure that increases in banks' ag lending are not driven by reasons other than the expansion of crop insurance we estimate Model 3a which aims at ascertaining whether banks' ag lending became less sensitive to adverse weather shocks

[17]We standardize all of the dependent variables. Consequently, a one standard deviation increase in the independent variable is associated with a β percentage point change in the outcome variable.

after the expansion of insurance. The results of this exercise are reported in Columns (3) and (4) of Table 2. Focusing on Column (3), we see that banks increased their farm loan share by 0.13 percentage points despite an adverse weather shock—a one standard deviation increase in cooling degree days—when there was a one standard deviation increase in insurance coverage. This outcome is in stark contrast to banks' lending decisions before the expansion: they reduced farm loan share by 0.34 percentage points when affected by an adverse weather shock and by 0.19 percentage points even with higher insurance coverage. Lastly, column (4) indicates that adverse weather shocks did not materially affect banks' farm RE-back loan share.

Table 3 shows the same set of results for ag banks only. We find that while the general findings do not change across the two sub-samples, the estimated magnitudes are larger. In particular, column (1) shows that a one standard deviation increase in insurance coverage led ag banks to increase farm loan share by 0.77 percentage point after the expansion of crop insurance compared to 0.62 percentage point for the larger sample. Likewise, column (3) shows that a one standard deviation increase in cooling degree days and insurance coverage led ag banks to increase farm loan share by 0.33 percentage points compared to 0.13 percentage points for the larger sample. Thus, we find evidence that the benefits of the expansion of crop insurance accrued on the intensive margin as banks with already larger farm loan share increased farm lending even more.

Based on survey data from farmers in Illinois, Indiana, and Iowa, Sherrick et al. (2004) find that highly leveraged farms and farmers with higher perceived yield risk are more likely to use crop insurance. This finding explains the negative relationship between insurance coverage and farm loan share before 1980 in Tables 2 and 3. For example, column (1) in Table 2 shows that a one standard deviation increase in insurance coverage before 1980 led banks to reduce farm loan share by 0.75 percentage point. In fact, a key motivation for reforming and expanding the federal crop insurance program was to reduce the adverse selection into the insurance pool by making crop insurance actuarially fair, among other measures (GAO (1981)).

	Dependent variable:			
	farm loan share Q3	farm RE-backed loans share Q3	farm loan share Q3	farm RE-backed loans share Q3
	(1)	(2)	(3)	(4)
weather Q2			-0.34^{***}	0.02
			−6.73	1.01
insurance coverage	-0.75^{***}	-0.27^{***}	-0.64^{***}	-0.30^{***}
	−6.89	−4.84	−5.51	−5.18
weather Q2 × insurance coverage			-0.19^{***}	0.08^{***}
			−3.11	2.62
weather Q2 × 1(t > 1980)			0.14^{**}	−0.04
			2.15	−1.36
insurance coverage × 1(t > 1980)	0.62^{***}	0.55^{***}	0.52^{***}	0.58^{***}
	5.54	9.11	4.35	9.35
weather Q2 × insurance coverage × 1(t > 1980)			0.13^{*}	0.03
			1.89	0.65
bank FE	Y	Y	Y	Y
county FE	Y	Y	Y	Y
year FE	Y	Y	Y	Y
ag exposure	+ve	+ve	+ve	+ve
Observations	95,689	95,689	95,689	95,689
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 2: Banks' exposure to agriculture This table shows the effect of the 1980 federal crop insurance reform on banks' ag exposure. Columns (1) and (2) show that a one standard deviation increase in county-level insurance coverage after 1980 increased banks' farm loans and loans backed by farm real estate as a share of total loans by 0.62 and 0.55 percentage points, respectively. Column (3) indicates that banks increased their farm loan share even when the county experienced a weather shock and had more insurance coverage by 0.13 percentage points. Column (4) shows that weather shocks and insurance coverage jointly do not significantly effect banks' loans backed by farm real estate. SEs clustered at county-level; t-stats reported under coefficients.

	Dependent variable:			
	farm loan share Q3	farm RE-backed loans share Q3	farm loan share Q3	farm RE-backed loans share Q3
	(1)	(2)	(3)	(4)
weather Q2			-0.47^{***}	0.05
			-6.09	1.40
insurance coverage	-0.83^{***}	-0.10	-0.70^{***}	-0.15^{**}
	-4.81	-1.39	-3.72	-1.96
weather Q2 × insurance coverage			-0.24^{**}	0.12^{***}
			-2.48	2.90
weather Q2 × 1(t > 1980)			0.26^{***}	-0.06
			2.62	-1.32
insurance coverage × 1(t > 1980)	0.77^{***}	0.37^{***}	0.65^{***}	0.43^{***}
	4.18	4.73	3.30	5.16
weather Q2 × insurance coverage × 1(t > 1980)			0.33^{***}	-0.08
			2.89	-1.56
bank FE	Y	Y	Y	Y
county FE	Y	Y	Y	Y
year FE	Y	Y	Y	Y
ag exposure	ag banks only	ag banks only	ag banks only	ag banks only
Observations	48,695	48,695	48,695	48,695
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 3: Ag banks' exposure to agriculture This table shows the effect of the 1980 federal crop insurance reform on banks' ag exposure. Columns (1) and (2) show that a one standard deviation increase in county-level insurance coverage after 1980 increased banks' farm loans and loans backed by farm real estate as a share of total loans by 0.77 and 0.37 percentage points, respectively. Column (3) indicates that banks increased their farm loan share even when the county experienced a weather shock and had more insurance coverage by 0.33 percentage points. Column (4) shows that weather shocks and insurance coverage jointly do not significantly affect banks' loans backed by farm real estate. Conditioning on ag banks yields stronger results for farm loans share (columns (1) and (3)), compared with Table 2. SEs clustered at county-level; *t*-stats reported under coefficients.

In sum, the results from our investigation of bank lending, in particular those derived from banks' responses to adverse weather shocks, show consistent with the insight from our model that banks increase lending in response to the presence of insurance.

5.2 Did Banks take on Additional Risk?

We now turn our attention to the question as to whether banks took on additional risk in response to the expansion of the crop insurance program. Towards that end, we first estimate 4a which aims at investigating whether banks increased risk taking after 1980. The results of this exercise for the sample of banks that had some farm lending are reported in Table 4. Table 5 reports results for the sample of ag banks. Overall, the results suggest that banks with a higher farm loan share in counties with more insurance coverage took on more risk after the expansion of crop insurance but this was enough to increase their overall risk.

Specifically, column (1) in Table 4 shows that a one standard deviation increase in farm loan share in a county with one standard deviation more insurance coverage after 1980 increased banks' return on loans by 0.04 percentage points. In parallel, column (2) shows that this increase in farm loan share and insurance coverage also led banks to provision more for potential loan losses by 0.06 percentage points as a share of their total loan volume after 1980. Column (3) shows the net effect of these two forces: return on assets was lower by 0.3 pecentage points after 1980.[18]

Column (4) in Table 4 shows that banks charged off 0.06 percentage point more loans from their books after 1980 if they had one standard deviation more farm loan share and insurance coverage. Lastly, column (5) shows that on net, a one standard deviation increase in farm loan share and insurance coverage was correlated with a 1.01 percentage point increase in banks' Z-score, i.e., on average a bank was less risky after the expansion of crop insurance. Table 5 confirms the same set of results for ag banks.

Taken together, this set of results indicates that banks may be making riskier loans following the expansion of crop insurance: return on loans increase but they provision more for potential losses and charge off more loans as well. Due to data limitations, we can only compute the Z-score after after 1980 so the Z-score only provides a partial picture about the overall riskiness of the bank.[19]

An important concern with the results presented above is that there was a crisis in agriculture in the early 1980s, which undoubtedly affected banks in particular ag banks. Thus, to isolate the effect of the expansion we investigate the effect of adverse weather shocks on banks' risk-taking behavior. Specifically, we estimate a modified version of Model 3a where we use our measures of risk on the left-hand side. The results of this

[18] In the call report, net income equals total income (including loan income) minus expenses (including amount provisioned for possible loan losses). Hence, column (3) almost mechanically follows from columns (1) and (2) in Table 4. 1976-1978 version of the call report available here.

[19] Variables needed to construct the Z-score are only available at a quarterly frequency starting in 1976, albeit even then only for a minority of banks in the sample. Given that the Z-score is calculated using 12 quarters of data, we only have a meaningfully sufficient number of observations after 1980.

investigation are reported in Tables 6 and 7. As we discuss next, overall the results show that banks in counties affected by adverse weather shocks were sufficiently compensated by insurance coverage such that their overall risk did not increase.

	Dependent variable:				
	return on loans	provisional losses shares	return on assets	charge-offs share	Z-score
	(1)	(2)	(3)	(4)	(5)
insurance coverage	0.01	0.03**	−0.03***	0.03**	
	0.68	2.09	−2.93	2.10	
farm loans share Q3	0.04***	−0.03***	0.02***	−0.02***	
	5.38	−3.75	3.56	−2.85	
insurance coverage × farm loans share Q3	−0.02*	−0.02*	0.01*	−0.02	
	−1.69	−1.81	1.94	−1.58	
insurance coverage × 1(t > 1980)	−0.01	0.06***	−0.01	0.06***	4.71***
	−0.41	2.80	−0.90	2.94	5.79
farm loans share Q3× 1(t > 1980)	−0.002	0.15***	−0.05***	0.12***	0.58
	−0.18	8.94	−4.97	7.77	0.72
insurance coverage × farm loans share Q3× 1(t > 1980)	0.04***	0.06***	−0.03***	0.06***	1.01*
	2.96	4.19	−2.89	3.86	1.92
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
farm loans share	+ve	+ve	+ve	+ve	+ve
Observations	87,049	87,052	87,049	87,049	31,814
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 4: Banks' risk-taking This table shows the effect of the expansion of crop insurance on banks' risk-taking conditional on positive farm loan share. Columns (1), (2), and (3) show that a one standard deviation increase in insurance coverage and farm loan share after 1980 increased banks' return on loans and provisional losses share by 0.04 and 0.06 percentage points, respectively, while decreased return on assets by 0.03 percentage points. Columns (4) and (5) show that the same change in covariates increased charge-offs and Z-score by 0.06 and 1.01 percentage points, respectively. SEs clustered at county-level; t-stats reported under coefficients.

	Dependent variable:				
	return on loans	provisional losses share	return on assets	charge-offs share	Z-score
	(1)	(2)	(3)	(4)	(5)
insurance coverage	−0.02	0.05**	−0.05***	0.05**	
	−1.00	2.33	−3.78	2.06	
farm loans share Q3	0.05***	−0.05***	0.03***	−0.05***	
	4.77	−4.56	4.01	−4.42	
insurance coverage × farm loans share Q3	−0.04**	−0.003	0.003	−0.003	
	−2.52	−0.18	0.29	−0.18	
insurance coverage × 1(t > 1980)	−0.003	0.002	0.03	0.02	4.67***
	−0.11	0.08	1.52	0.52	3.44
farm loans share Q3× 1(t > 1980)	−0.02	0.12***	−0.03*	0.09***	−1.31
	−0.93	4.92	−1.93	3.85	−0.90
insurance coverage × farm loans share Q3× 1(t > 1980)	0.07***	0.06***	−0.03**	0.05**	0.06
	3.92	2.96	−2.16	2.36	0.07
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
ag exposure	ag banks	ag banks	ag banks	ag banks	ag banks
Observations	44,875	44,878	44,875	44,875	13,755
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 5: Ag banks' risk-taking This table shows the effect of the expansion of crop insurance on risk for ag banks. Columns (1), (2), and (3) show that a one standard deviation increase in insurance coverage and farm loan share after 1980 increased both—ag banks' return on loans and provisional losses share—by 0.07 and 0.06 percentage points, respectively, while return on assets decreased by 0.03 percentage points. Columns (4) and (5) show that the same change in covariates increased charge-offs by 0.05 percentage points and had no significant effect on the Z score. SEs clustered at county-level; t-stats reported under coefficients.

Column (1) in Table 6 shows banks' return on loans were not significantly affected by a one standard deviation increase in cooling degree days when complemented with a one standard deviation increase in insurance coverage after 1980. Critically, column (2) and (4) show that banks provisioned less for losses and charged off few loans by 0.05 and 0.06 percentage points respectively. As a result of provisioning less for potential losses, banks' return on assets increased by 0.04 percentage points. Column (5) shows there is no significant correlation between the joint effect of adverse weather shocks and insurance coverage on the Z-score after 1980. Table 7 confirms that these results extend to ag banks.

In conclusion, the results of our investigation show that despite adverse weather shocks, banks in counties with higher insurance coverage after the expansion of crop insurance made more farm loans (Table 2). Our results also show that banks used the insurance coverage to cover their downside risk (Table 6). They provisioned less to cover for potential losses and charged-off less exactly when affected by the adverse weather shock but with higher insurance coverage after the expansion. Return on loans were not significantly affected; the lower provisioning for potential losses is what increased return on assets which in turn leads to a muted correlation of the Z score with adverse weather shocks and insurance coverage. Overall, the expansion of crop insurance encouraged banks to make more—potentially riskier—farm loans. But focusing on the shock materializing suggests that insurance sufficiently compensated for loading on this risk.

	Dependent variable:				
	return on loans	provisional losses share	return on assets	charge-offs share	Z-score
	(1)	(2)	(3)	(4)	(5)
weather Q2	0.09***	0.003	0.03***	−0.01	
	8.87	0.48	7.08	−1.23	
insurance coverage	−0.01	0.02	−0.02**	0.03	
	−0.32	1.15	−2.31	1.44	
weather Q2 × insurance coverage	−0.0004	0.04***	−0.03***	0.03***	
	−0.03	4.28	−4.69	2.65	
weather Q2 × 1(t > 1980)	−0.16***	−0.12***	0.01	−0.11***	1.58**
	−11.60	−8.34	0.95	−7.62	2.46
insurance coverage × 1(t > 1980)	0.01	0.07***	−0.02	0.07***	4.73***
	0.50	3.34	−1.28	3.19	5.74
weather Q2 × insurance coverage × 1(t > 1980)	−0.004	−0.05***	0.04***	−0.06***	−0.72
	−0.26	−4.45	4.73	−3.70	−1.45
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
farm loans share	+ve	+ve	+ve	+ve	+ve
Observations	87,049	87,052	87,049	87,049	31,815
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 6: Banks' risk-taking and weather shocks This table shows the effect of weather shocks on banks' risk-taking conditional on positive farm loan share. Columns (1), (2), and (3) show that a one standard deviation increase in weather shock and insurance coverage after 1980 did not significantly affect return on loans, decreased provisional losses share by 0.05 percentage points, and increased return on assets by 0.04 percentage points. Columns (4) and (5) show that the same change in covariates reduced charge-offs by 0.06 percentage point and did not significantly affect Z-score. SEs clustered at county-level; t-stats reported under coefficients.

	Dependent variable:				
	return on loans	provisional losses share	return on assets	charge-offs share	Z-score
	(1)	(2)	(3)	(4)	(5)
weather Q2	0.08***	0.01*	0.02***	0.002	
	6.20	1.66	2.73	0.21	
insurance coverage	−0.05**	0.04**	−0.05***	0.04*	
	−2.06	2.03	−3.61	1.78	
weather Q2 × insurance coverage	0.01	0.03**	−0.02**	0.03**	
	0.41	2.36	−2.38	2.43	
weather Q2 × 1(t > 1980)	−0.10***	−0.13***	0.03**	−0.11***	4.09***
	−5.02	−5.63	2.29	−5.00	3.67
insurance coverage × 1(t > 1980)	0.02	0.01	0.02	0.02	4.96***
	0.93	0.45	1.33	0.76	3.65
weather Q2 × insurance coverage × 1(t > 1980)	−0.004	−0.04**	0.03***	−0.05***	−0.64
	−0.24	−2.47	2.75	−2.96	−0.77
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
ag exposure	ag banks	ag banks	ag banks	ag banks	ag banks
Observations	44,875	44,878	44,875	44,875	13,755
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 7: Ag banks' risk-taking and weather shocks This table shows the effect of weather shocks on ag banks' risk. Columns (1), (2), and (3) show that a one standard deviation increase in weather shock and insurance coverage after 1980 did not significantly affect return on loans, decreased provisional losses share by 0.04 percentage points, and increased return on assets by 0.03 percentage points. Columns (4) and (5) show that the same change in covariates reduced charge-offs by 0.05 percentage point and did not significantly affect Z-score. SEs clustered at county-level; t-stats reported under coefficients.

5.3 Bank Lending and Risk in Response to Acute Weather Events

Up to this point, we relied on the number of cooling degree days as our weather shock. In this section, we consider instead crop damages resulting from acute weather events. In contrast to cooling degree days which may be indicative of a bad crop season, crop damages is an ex post measure of the costs triggered by bad weather events.

Consistent with these differences, we find that banks' response on farm lending to acute weather shocks is muted.[20] We estimate Model 2a for banks with positive farm loan exposure and ag banks. Table 8 summarizes these results: one standard deviation increase in crop damages due to acute weather shocks and insurance coverage after 1980 does not affect farm loans as a share of total loans for either type of bank, see columns (1) and (3). The same change in covariates does not affect loans backed by farm real estate as a share of total loans for banks with positive farm loan exposure, but reduces loans backed by farm real estate as a share of total loans for banks by 0.22 percentage points, see columns (2) and (4).

Next, we turn to banks' risk-related outcomes. As one would expect, we find that acute weather shocks affect banks' risk in the same direction as cooling degree days for banks with positive farm loan exposure and ag banks, albeit at different levels of statistical significance, see Tables 9 and 10, respectively. Columns (1), (2), and (4) of Table 9 show that a one standard deviation increase in crop damages due to acute weather events and insurance coverage after 1980 reduced return on loans, provisional losses, and charge-offs as a share of all loans by 0.05, 0.06, and 0.08 percentage points, respectively. Columns (3) and (5) show that the same change in covariates has no statistically significant effect on return on assets or the Z-score, respectively, but the direction of the coefficients is the same as it was with cooling degree days.

Likewise, our results are robust if we zoom in exclusively on ag banks, see Table

[20]This difference in outcome relative to cooling degree days may be due to the distinct nature of the two types of shocks and how banks perceive farms' potential productivity as function of chronic versus acute risks.

	Dependent variable:			
	farm loan share Q3	farm RE-backed loans share Q3	farm loan share Q3	farm RE-backed loans share Q3
	(1)	(2)	(3)	(4)
weather shock Q2 + Q3	−0.07	0.04	−0.02	0.06
	−0.98	1.41	−0.17	1.38
insurance coverage	−0.57***	−0.18**	−0.45*	0.004
	−3.62	−2.31	−1.65	0.04
weather shock Q2 + Q3 × insurance coverage	0.02	0.12**	0.14	0.17**
	0.22	2.34	0.78	2.29
weather shock Q2 + Q3× 1(t > 1980)	−0.05	0.04	−0.11	−0.01
	−0.60	0.80	−0.83	−0.13
insurance coverage × 1(t > 1980)	0.48***	0.51***	0.50*	0.31**
	2.80	5.18	1.74	2.40
weather shock Q2 + Q3× insurance coverage × 1(t > 1980)	−0.06	−0.10	−0.10	−0.22**
	−0.51	−1.59	−0.51	−2.44
bank FE	Y	Y	Y	Y
county FE	Y	Y	Y	Y
year FE	Y	Y	Y	Y
ag exposure	+ve	+ve	ag banks	ag banks
Observations	40,410	40,410	21,625	21,625
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 8: Banks' exposure and acute weather shocks This table shows the effect of crop damages from acute weather shocks on banks' risk-taking. Columns (1) and (2) show that a one standard deviation increase in crop damages due to acute weather shocks and insurance coverage after 1980 did not significantly affect banks' farm loans and loans backed by farm real estate, respectively, conditional on having positive farm exposure. Column (3) shows the same result for farm loan share for ag banks only. Column (4) shows that ag bank reduced loans backed by farm real estate by 0.22 percentage points. SEs clustered at county-level; t-stats reported under coefficients.

10. Columns (1), (2), and (4) of Table 10 show that a one standard deviation increase in crop damages due to acute weather events and insurance coverage after 1980 reduced return on loans, provisional losses, and charge-offs as a share of all loans by 0.05, 0.06, and 0.07 percentage points, respectively. Columns (3) and (5) show that the same change in covariates has no statistically significant effect on return on assets or the Z-score, respectively, but the direction of the coefficients is again the same as it was with cooling degree days.

Together, these estimates when using crop damages due to acute weather events suggest that weather events have a muted impact on banks' loan making behavior but risk outcomes are similar to those using cooling degree days: they take on additional risk but are sufficiently compensated by insurance for this additional risk so the bank is not significantly riskier overall.

	Dependent variable:				
	return on loans	provisional losses share	return on assets	charge-offs share	Z-score
	(1)	(2)	(3)	(4)	(5)
weather shock Q2 + Q3	0.01	0.02*	−0.001	0.03**	
	0.38	1.87	−0.19	2.29	
insurance coverage	−0.004	0.01	−0.01	0.01	
	−0.13	0.45	−0.88	0.20	
weather shock Q2 + Q3 × insurance coverage	0.04*	0.03*	−0.01	0.05**	
	1.67	1.96	−0.99	2.45	
weather shock Q2 + Q3 × 1(t > 1980)	−0.06***	0.02	−0.02*	−0.01	−0.26
	−2.82	0.78	−1.91	−0.46	−0.30
insurance coverage × 1(t > 1980)	0.004	0.11***	−0.05**	0.12***	0.34
	0.11	3.03	−2.17	3.11	0.28
weather shock Q2 + Q3 × insurance coverage × 1(t > 1980)	−0.05**	−0.06***	0.02	−0.08***	−0.93
	−2.01	−2.65	1.37	−3.36	−1.01
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
farm loans share	+ve	+ve	+ve	+ve	+ve
Observations	37,802	37,803	37,802	37,802	17,073

Note: *p<0.1; **p<0.05; ***p<0.01

Table 9: Banks' risk-taking and acute weather shocks This table shows the effect of crop damages from acute weather shocks on banks' risk-taking conditional on positive farm loan share. Columns (1), (2), and (4) show that a one standard deviation increase in crop damages due to acute weather shock and insurance coverage after 1980 reduced return on loans, provisional losses share, and charge-offs by 0.05, 0.06, and 0.08 percentage points, respectively. Columns (3) and (5) show that the same change in covariates did not significantly affect return on assets and Z-score. SEs clustered at county-level; t-stats reported under coefficients.

	Dependent variable:				
	return on loans	provisional losses share	return on assets	charge-offs share	Z-score
	(1)	(2)	(3)	(4)	(5)
weather shock Q2 + Q3	0.01	0.01	0.01	0.02	
	0.81	0.71	0.80	1.32	
insurance coverage	−0.02	0.04	−0.04**	0.05	
	−0.60	1.29	−2.13	1.52	
weather shock Q2 + Q3 × insurance coverage	0.04*	0.03	−0.01	0.03	
	1.67	1.44	−0.62	1.31	
weather shock Q2 + Q3 × 1(t > 1980)	−0.06**	0.01	−0.01	−0.01	−0.63
	−2.49	0.21	−0.81	−0.43	−0.48
insurance coverage × 1(t > 1980)	−0.02	0.05	−0.01	0.04	−1.68
	−0.50	1.17	−0.33	0.90	−0.97
weather shock Q2 + Q3 × insurance coverage × 1(t > 1980)	−0.05*	−0.06**	0.02	−0.07**	−0.99
	−1.71	−2.08	0.84	−2.32	−0.80
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
ag exposure	ag banks	ag banks	ag banks	ag banks	ag banks
Observations	20,880	20,881	20,880	20,880	9,443

Note: *p<0.1; **p<0.05; ***p<0.01

Table 10: Ag banks' risk-taking and acute weather shocks This table shows the effect of crop damages due to acute weather shocks on ag banks' risk-taking. Columns (1), (2), and (4) show that a one standard deviation increase in crop damages due to acute weather shock and insurance coverage after 1980 reduced return on loans, provisional losses share, and charge-offs by 0.05, 0.06, and 0.07 percentage points, respectively. Columns (3) and (5) show that the same change in covariates did not significantly affect return on assets and Z-score. SEs clustered at county-level; t-stats reported under coefficients.

6 Conclusion

The significant extension of crop insurance in the U.S. in the 1980's was accompanied by an increase in agricultural lending an a decrease in the dependency of that lending on the vagaries of weather. While there is some evidence that on the margin banks were willing to take on riskier loans as a result, the net effect on bank riskiness was negligible, as the insurance arrangements themselves seem to have adequately protected banks against the additional risks.

In the current environment, increasing risks associated with changes in weather stemming from global warming have led private companies to tighten their willingness to provide insurance coverage. Meanwhile, pressure is rising for public insurance arrangements to take greater account of the costs of climate change and thus to put tighter restrictions on the use of insurance protection. If our results can be extrapolated, there are two sets of implications. First the reduction in insurance will cause banks to reduce their exposures to weather related risks. Second, the reduction in exposure will not have significantly offset the direct effect of increased risks on the overall riskiness of the banks – in other words the bank responses to changes in insurance availability cannot be relied on to offset underlying climate risks.

Our analysis has taken changes in insurance programs as exogenous. For specific government programs, this approach is likely to be a reasonable first step. However provision of insurance products by private financial entities will also respond to changes in risks and in availability of government subsidies. An analysis of the response of insurance companies themselves can also be carried out, in a manner parallel to the analysis we have made of the response of banks. While the capitalization of insurance companies would make them a less likely point of failure, the experience of the financial crisis has shown that risks of insurers can also serve as an independent source of financial stability. Finally, if capital is in limited supply overall in the economy, a potential mismatch in location of capital between banks and insurance companies, is a final source of potential instability. These additional channels merit examination as well.

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A Appendix

A.1 Policies Sold Count

The USDA Summary of Business Crop Insurance Experience 1948-1988 includes two measures of insurance coverage at the county-level: number of insured acres and the number of policies sold. While we have used the number of insured acres as our primary measure of insurance coverage, we test for robustness by using number of policies sold as an alternate measure. However, the two metrics are not perfect substitutes: given the wholesale restructuring of the federal crop insurance program in 1980, key features of insurance policies also change (see Section 3.2 for details). Consequently, number of acres insured is a more appropriate measure for assessing banks' exposure—and more commonly used in the literature—than the number of policies sold.

We find that almost all of our results in Section 5 hold when using number of policies sold instead of number of acres insured as a measure of insurance coverage. There are only two exceptions. First, column (3) in Tables A1 and A2 shows that while there is suggestive evidence that banks increased their farm loan share in response to a one standard deviation increase in cooling degree days and insurance coverage (i.e., number of policies sold) after 1980, the coefficient is not significant unlike column (3) in Tables 2 and 3. Second, column (4) in Table A5 shows suggestive evidence that banks reduced charge-offs when affected by a one standard deviation increase in cooling degree days and insurance coverage (i.e., number of policies sold) after, the coefficient is not significant unlike column (4) in Table 6. However, when we restrict the sample to ag banks only in Table A6, we see that the relationship holds at 5% significance level even with this alternate measure of insurance coverage.

	Dependent variable:			
	farm loan share Q3	farm RE-backed loans share Q3	farm loan share Q3	farm RE-backed loans share Q3
	(1)	(2)	(3)	(4)
weather Q2			-0.34^{***}	0.02
			-6.89	0.61
insurance coverage	-1.02^{***}	-0.34^{***}	-0.96^{***}	-0.35^{***}
	-9.66	-5.64	-8.99	-5.61
weather Q2 × insurance coverage			-0.08^{*}	0.04
			-1.67	1.33
weather Q2 × 1(t > 1980)			0.12^{**}	-0.01
			1.99	-0.34
insurance coverage × 1(t > 1980)	0.90^{***}	0.60^{***}	0.84^{***}	0.62^{***}
	7.84	9.17	7.27	9.20
weather Q2 × insurance coverage × 1(t > 1980)			0.04	0.09^{**}
			0.70	2.38
bank FE	Y	Y	Y	Y
county FE	Y	Y	Y	Y
year FE	Y	Y	Y	Y
ag exposure	+ve	+ve	+ve	+ve
Observations	95,150	95,150	95,150	95,150
Note:				*p<0.1; **p<0.05; ***p<0.01

Table A1: Banks' exposure to agriculture This table shows the effect of the 1980 federal crop insurance reform on banks' ag exposure. Columns (1) and (2) show that a one standard deviation increase in county-level insurance coverage after 1980 increased banks' farm loans and loans backed by farm real estate as a share of total loans by 0.90 and 0.60 percentage points, respectively. Column (3) indicates that weather shocks and insurance coverage jointly do not significantly effect banks' farm loan share. Column (4) shows that a one standard deviation increase in adverse weather and insurance coverage after 1980 increased banks' loans backed by farm real estate share by 0.09 percentage points. SEs clustered at county-level; *t*-stats reported under coefficients.

	Dependent variable:			
	farm loan share Q3	farm RE-backed loans share Q3	farm loan share Q3	farm RE-backed loans share Q3
	(1)	(2)	(3)	(4)
weather Q2			-0.45^{***}	0.05
			-5.89	1.30
insurance coverage	-1.16^{***}	-0.19^{**}	-1.14^{***}	-0.20^{**}
	-7.22	-2.41	-6.76	-2.56
weather Q2 × insurance coverage			-0.01	0.06
			-0.12	1.39
weather Q2 × 1(t > 1980)			0.28^{***}	-0.04
			2.86	-0.79
insurance coverage × 1(t > 1980)	1.12^{***}	0.44^{***}	1.11^{***}	0.46^{***}
	6.24	5.09	5.96	5.17
weather Q2 × insurance coverage × 1(t > 1980)			0.10	-0.005
			0.99	-0.09
bank FE	Y	Y	Y	Y
county FE	Y	Y	Y	Y
year FE	Y	Y	Y	Y
ag exposure	ag banks only	ag banks only	ag banks only	ag banks only
Observations	47,466	47,466	47,466	47,466
Note:				*p<0.1; **p<0.05; ***p<0.01

Table A2: Ag banks' exposure to agriculture This table shows the effect of the 1980 federal crop insurance reform on banks' ag exposure. Columns (1) and (2) show that a one standard deviation increase in county-level insurance coverage after 1980 increased banks' farm loans and loans backed by farm real estate as a share of total loans by 1.12 and 0.44 percetage points, respectively. Column (3) and (4) indicate that weather shocks and insurance coverage jointly do not significantly effect banks' farm loan share and loans backed by farm real estate share. SEs clustered at county-level; *t*-stats reported under coefficients.

	Dependent variable:				
	return on loans	provisional losses shares	return on assets	charge-offs share	*Z*-score
	(1)	(2)	(3)	(4)	(5)
insurance coverage	−0.004	0.04**	−0.03***	0.03*	
	−0.20	2.52	−2.92	1.86	
farm loans share Q3	0.05***	−0.02***	0.02***	−0.02**	
	5.37	−3.05	3.05	−2.20	
insurance coverage × farm loans share Q3	−0.01	0.0003	0.01	0.001	
	−0.47	0.03	0.85	0.13	
insurance coverage × 1(t > 1980)	0.03	0.03	−0.01	0.06**	6.18***
	1.19	1.44	−0.72	2.55	6.35
farm loans share Q3× 1(t > 1980)	−0.003	0.15***	−0.05***	0.12***	0.65
	−0.19	9.15	−5.00	7.81	0.83
insurance coverage × farm loans share Q3× 1(t > 1980)	0.04***	0.05***	−0.02**	0.04***	0.72
	3.10	3.30	−2.47	2.75	1.19
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
farm loans share	+ve	+ve	+ve	+ve	+ve
Observations	86,621	86,624	86,621	86,621	31,474

Note: *p<0.1; **p<0.05; ***p<0.01

Table A3: Banks' risk-taking This table shows the effect of the expansion of crop insurance on banks' risk-taking conditional on positive farm loan share. Columns (1), (2), and (3) show that a one standard deviation increase in insurance coverage and farm loan share after 1980 increased banks' return on loans and provisional losses share by 0.04 and 0.05 percentage points, respectively, while decreased return on assets by 0.02 percentage points. Columns (4) and (5) show that the same change in covariates increased charge-offs and *Z*-score by 0.04 and 0.72 percentage points, respectively, altought the latter is not statistically significant. SEs clustered at county-level; *t*-stats reported under coefficients.

	Dependent variable:				
	return on loans	provisional losses share	return on assets	charge-offs share	*Z*-score
	(1)	(2)	(3)	(4)	(5)
insurance coverage	−0.04*	0.05**	−0.05***	0.04	
	−1.87	2.27	−3.73	1.54	
farm loans share Q3	0.05***	−0.05***	0.03***	−0.05***	
	4.20	−3.99	3.94	−3.96	
insurance coverage × farm loans share Q3	−0.04**	0.01	0.01	0.01	
	−2.34	0.57	0.70	0.46	
insurance coverage × 1(t > 1980)	0.02	0.0002	0.02	0.04	6.17***
	0.80	0.01	0.97	1.17	4.14
farm loans share Q3× 1(t > 1980)	−0.01	0.13***	−0.03**	0.10***	−1.16
	−0.45	5.24	−2.32	4.02	−0.82
insurance coverage × farm loans share Q3× 1(t > 1980)	0.07***	0.05**	−0.03**	0.04*	−0.23
	3.97	2.23	−2.20	1.81	−0.23
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
ag exposure	ag banks	ag banks	ag banks	ag banks	ag banks
Observations	44,847	44,850	44,847	44,847	13,735

Note: *p<0.1; **p<0.05; ***p<0.01

Table A4: Ag banks' risk-taking This table shows the effect of the expansion of crop insurance on risk for ag banks. Columns (1), (2), and (3) show that a one standard deviation increase in insurance coverage and farm loan share after 1980 increased both—ag banks' return on loans and provisional losses share—by 0.07 and 0.05 percentage points, respectively, while return on assets decreased by 0.03 percentage points. Columns (4) and (5) show that the same change in covariates increased charge-offs by 0.04 percentage points and had no significant effect on the *Z* score. SEs clustered at county-level; *t*-stats reported under coefficients.

	Dependent variable:				
	return on loans	provisional losses share	return on assets	charge-offs share	Z-score
	(1)	(2)	(3)	(4)	(5)
weather Q2	0.09***	0.01	0.03***	−0.01	
	8.28	1.13	6.17	−1.09	
insurance coverage	−0.01	0.03*	−0.03**	0.03*	
	−0.68	1.92	−2.57	1.70	
weather Q2 × insurance coverage	−0.01	0.03***	−0.02***	0.01	
	−0.75	4.20	−3.65	0.48	
weather Q2 × 1(t > 1980)	−0.16***	−0.12***	0.01	−0.10***	1.29**
	−11.32	−8.26	1.15	−6.62	2.05
insurance coverage × 1(t > 1980)	0.03	0.03	−0.01	0.05**	6.15***
	1.43	1.53	−0.80	2.28	6.32
weather Q2 × insurance coverage × 1(t > 1980)	0.01	−0.05***	0.03***	−0.03	−0.74
	0.72	−4.50	3.95	−1.56	−1.28
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
farm loans share	+ve	+ve	+ve	+ve	+ve
Observations	86,621	86,624	86,621	86,621	31,475

Note: *p<0.1; **p<0.05; ***p<0.01

Table A5: Banks' risk-taking and weather shocks This table shows the effect of weather shocks on banks' risk-taking conditional on positive farm loan share. Columns (1), (2), and (3) show that a one standard deviation increase in weather shock and insurance coverage after 1980 did not significantly affect return on loans, decreased provisional losses share by 0.05 percentage points, and increased return on assets by 0.03 percentage points. Columns (4) and (5) show that the same change in covariates did not significantly affect charge-offs and Z-score. SEs clustered at county-level; t-stats reported under coefficients.

	Dependent variable:				
	return on loans	provisional losses share	return on assets	charge-offs share	Z-score
	(1)	(2)	(3)	(4)	(5)
weather Q2	0.07***	0.02**	0.02**	0.01	
	5.51	2.06	2.13	0.59	
insurance coverage	−0.05**	0.05**	−0.05***	0.04	
	−2.43	2.17	−3.52	1.47	
weather Q2 × insurance coverage	−0.01	0.02**	−0.02**	0.02**	
	−1.04	2.10	−2.06	2.08	
weather Q2 × 1(t > 1980)	−0.09***	−0.13***	0.03***	−0.12***	4.17***
	−4.69	−5.85	2.62	−5.22	3.85
insurance coverage × 1(t > 1980)	0.04	0.01	0.01	0.04	6.53***
	1.36	0.19	0.81	1.23	4.41
weather Q2 × insurance coverage × 1(t > 1980)	0.02	−0.03*	0.02**	−0.04**	−0.97
	1.11	−1.93	2.25	−2.52	−0.99
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
ag exposure	ag banks	ag banks	ag banks	ag banks	ag banks
Observations	44,847	44,850	44,847	44,847	13,735

Note: *p<0.1; **p<0.05; ***p<0.01

Table A6: Ag banks' risk-taking and weather shocks This table shows the effect of weather shocks on ag banks' risk. Columns (1), (2), and (3) show that a one standard deviation increase in weather shock and insurance coverage after 1980 did not significantly affect return on loans, decreased provisional losses share by 0.03 percentage points, and increased return on assets by 0.02 percentage points. Columns (4) and (5) show that the same change in covariates reduced charge-offs by 0.04 percentage point and did not significantly affect Z-score. SEs clustered at county-level; t-stats reported under coefficients.

A.2 Equity Ratio

In this section, we present results on banks' risk-related measures by splitting the sample of banks above and below the median equity ratio in the full sample. Tables A7 and A8 show that the results are more pronounced among banks with equity ratio below median, conditional on having positive farm loan exposure. Likewise, when isolating the effects of insurance using weather shocks, results are again more tightly estimate for banks with equity ratio below median, see Tables A9 and A10. These results indicate that banks with equity ratio below median took more risks once insurance was available and were compensated for the additional risk so that they were not riskier overall afterwards.

	Dependent variable:				
	return on loans	provisional losses shares	return on assets	charge-offs share	Z-score
	(1)	(2)	(3)	(4)	(5)
insurance coverage	0.02	0.09***	−0.05***	0.07***	
	1.07	4.08	−3.30	3.13	
farm loans share Q3	0.05***	−0.01	0.004	0.003	
	4.84	−0.66	0.59	0.21	
insurance coverage × farm loans share Q3	−0.004	−0.01	0.01	−0.0003	
	−0.28	−0.54	0.88	−0.02	
insurance coverage × 1(t > 1980)	0.0003	−0.01	0.005	0.03	5.82***
	0.01	−0.41	0.23	0.98	4.05
farm loans share Q3× 1(t > 1980)	−0.02	0.19***	−0.07***	0.14***	−1.28
	−0.99	6.69	−4.04	5.52	−0.96
insurance coverage × farm loans share Q3× 1(t > 1980)	0.05***	0.10***	−0.04***	0.09***	1.85*
	3.00	3.81	−2.94	3.33	1.82
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
farm loans share	+ve	+ve	+ve	+ve	+ve
capital ratio	< median	< median	< median	< median	< median
Observations	42,123	42,123	42,123	42,123	14,877
Note:					*p<0.1; **p<0.05; ***p<0.01

Table A7: Equity ratio below median banks' risk-taking This table shows the effect of the expansion of crop insurance on banks' risk-taking conditional on positive farm loan share for equity ratio below median. Columns (1), (2), and (3) show that a one standard deviation increase in insurance coverage and farm loan share after 1980 increased banks' return on loans and provisional losses share by 0.05 and 0.10 percentage points, respectively, while decreased return on assets by 0.04 percentage points. Columns (4) and (5) show that the same change in covariates increased charge-offs and Z-score by 0.09 and 1.85 percentage points, respectively, although the latter is not statistically significant. SEs clustered at county-level; t-stats reported under coefficients.

	Dependent variable:				
	return on loans	provisional losses shares	return on assets	charge-offs share	Z-score
	(1)	(2)	(3)	(4)	(5)
insurance coverage	−0.03	0.005	−0.01	0.005	
	−1.16	0.23	−0.93	0.23	
farm loans share Q3	0.05***	−0.03***	0.02***	−0.03***	
	3.33	−2.63	2.83	−2.82	
insurance coverage × farm loans share Q3	0.0001	−0.01	0.01	−0.01	
	0.004	−0.63	0.93	−0.78	
insurance coverage × 1(t > 1980)	0.05	0.06**	−0.02	0.06**	5.73***
	1.64	2.25	−1.07	2.49	5.57
farm loans share Q3× 1(t > 1980)	0.0005	0.13***	−0.05***	0.12***	1.75*
	0.02	7.29	−4.39	6.58	1.84
insurance coverage × farm loans share Q3× 1(t > 1980)	0.03	0.04**	−0.01	0.03	−0.22
	1.24	2.00	−1.22	1.57	−0.30
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
farm loans share	+ve	+ve	+ve	+ve	+ve
capital ratio	> median	> median	> median	> median	> median
Observations	44,345	44,345	44,345	44,345	16,635
Note:					*p<0.1; **p<0.05; ***p<0.01

Table A8: Equity ratio above median banks' risk-taking This table shows the effect of the expansion of crop insurance on banks' risk-taking conditional on positive farm loan share for equity ratio above median. Columns (1), (3), (4), (5) show that a one standard deviation increase in insurance coverage and farm loan share after 1980 increased banks' did not affect return on loans, return on assets, charge-offs, and Z-score. Column (2) shows that the same change in covariates increased provisional losses as a share of total loans by 0.04 percentage points. SEs clustered at county-level; t-stats reported under coefficients.

	Dependent variable:				
	return on loans	provisional losses share	return on assets	charge-offs share	Z-score
	(1)	(2)	(3)	(4)	(5)
weather Q2	0.10***	0.02**	0.02***	−0.001	
	7.82	2.38	2.81	−0.11	
insurance coverage	0.02	0.07***	−0.04***	0.07***	
	0.84	3.22	−2.67	2.89	
weather Q2 × insurance coverage	−0.02	0.03**	−0.02**	−0.01	
	−1.42	2.55	−2.47	−0.17	
weather Q2 × 1(t > 1980)	−0.16***	−0.14***	0.03***	−0.12***	2.53**
	−9.79	−5.81	2.60	−5.00	2.38
insurance coverage × 1(t > 1980)	−0.001	−0.02	0.003	0.02	5.49***
	−0.05	−0.49	0.17	0.57	3.79
weather Q2 × insurance coverage × 1(t > 1980)	0.02	−0.08***	0.04***	−0.03	−0.79
	1.15	−4.29	3.21	−0.93	−0.88
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
farm loans share	+ve	+ve	+ve	+ve	+ve
Observations	42,123	42,123	42,123	42,123	14,877

Note: *p<0.1; **p<0.05; ***p<0.01

Table A9: Equity ratio below median banks' risk-taking and weather shocks This table shows the effect of weather shocks on banks' risk-taking conditional on positive farm loan share for banks with equity ratio below median. Columns (1), (2), and (3) show that a one standard deviation increase in weather shock and insurance coverage after 1980 did not significantly affect return on loans, decreased provisional losses share by 0.08 percentage points, and increased return on assets by 0.04 percentage points. Columns (4) and (5) show that the same change in covariates did not significantly affect charge-offs and Z-score. SEs clustered at county-level; t-stats reported under coefficients.

	Dependent variable:				
	return on loans	provisional losses share	return on assets	charge-offs share	Z-score
	(1)	(2)	(3)	(4)	(5)
weather Q2	0.09***	−0.01	0.05***	−0.01	
	5.81	−0.54	5.62	−1.21	
insurance coverage	−0.04	−0.001	−0.01	0.003	
	−1.64	−0.07	−0.87	0.15	
weather Q2 × insurance coverage	0.01	0.02**	−0.02*	0.01	
	0.67	2.18	−1.86	0.67	
weather Q2 × 1(t > 1980)	−0.14***	−0.10***	−0.01	−0.09***	1.04
	−6.88	−5.68	−1.03	−4.91	1.35
insurance coverage × 1(t > 1980)	0.06**	0.06**	−0.02	0.06**	6.00***
	1.98	2.42	−1.13	2.41	5.89
weather Q2 × insurance coverage × 1(t > 1980)	−0.01	−0.03**	0.02*	−0.02	−0.36
	−0.79	−2.03	1.70	−1.29	−0.53
bank FE	Y	Y	Y	Y	Y
county FE	Y	Y	Y	Y	Y
year FE	Y	Y	Y	Y	Y
farm loans share	+ve	+ve	+ve	+ve	+ve
Observations	44,345	44,345	44,345	44,345	16,636
Note:					*p<0.1; **p<0.05; ***p<0.01

Table A10: Equity ratio above median banks' risk-taking and weather shocks This table shows the effect of weather shocks on banks' risk-taking conditional on positive farm loan share for banks with equity ratio above median. Columns (1), (2), and (3) show that a one standard deviation increase in weather shock and insurance coverage after 1980 did not significantly affect return on loans, decreased provisional losses share by 0.03 percentage points, and increased return on assets by 0.02 percentage points. Columns (4) and (5) show that the same change in covariates did not significantly affect charge-offs and Z-score. SEs clustered at county-level; t-stats reported under coefficients.