Credit Scoring Meets Agricultural Lending: Exogenous Shocks, Recovery and Access to Formal Credit

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Motivation

- Increasing use of credit scoring for credit allocation (Berger, Frame and Miller, 2005; de Janvry, McIntosh and Sadoulet, 2010)
- Theoretical arguments: mitigates moral hazard (Giné, Goldberg and Yang, 2012) and adverse selection (Pagano and Japelli, 1993)
- Most empirical evidence on credit scoring points to efficiency gains (Einav, Jenkins and Levin, 2012, 2013; Giné, Goldberg and Yang, 2012)

Motivation

- But credit scores are calculated using fixed borrower characteristics and information on prior repayment
  - Do not differentiate by reasons for default
  - Do not take into account information on exogenous shocks that affect the economic environment in which borrowers operate
- In the context of agricultural lending in developing countries:
  - Weather is an important determinant of productivity (Giné and Yang, 2009; Kaur 2015)
  - Temporary and exogenous shocks affecting farmer income are pervasive
  - Not incorporated in credit scores, yet observable (in principle)
- That the reason for default matters (at least for agricultural lending) has been known for a long time

Motivation

If any one owe a debt for a loan, and a storm prostrates the grain, or the harvest fail, or the grain does not grow for lack of water; in that year he need not give his creditor any grain, he washes his debt-table in water and pays no rent for his year

- Hammurabi's Code (c. 1760 B.C)

This Paper

- **Question**
  - *Can the combination of traditional credit scoring systems and situations where exogenous shocks are important lead to an inefficient allocation of capital?*
- Setting
  - Formal lending for coffee production in Colombia
  - Novel administrative data set with the near universe of formal loans to small farmers
  - Administrative data set with geographical location of coffee farmers' plots $\Rightarrow$ Allows precise measure of weather
- Proposes a model of borrower screening
  - Inclusion of observable information on exogenous shocks in credit scores reduces probability of lender mistakes
    - Inclusion error (lending to a un-profitable borrower)
    - Exclusion error (denying credit to a profitable borrower)

▸ Model

Preview of Findings

- Weather shocks cause worse concurrent loan outcomes
  - Probability of a period of 30 days past due $\Rightarrow \uparrow 22\%$
  - Probability of a bad score reported by the lender *to* credit bureaus $\Rightarrow \uparrow 20\%$
- For loan applications that follow a loan tenure with a shock
  - Scores reported *by* credit bureaus are lower
  - Probability of denial at least 12% larger
  - Effect is persistent: lasts at least two years
- Repayment recovers at most two years after the shock
  - Timing implies that the bank is not lending to farmers who could repay a second loan
  - Mechanisms: Productivity and income from coffee sales recover at most one year after the shock
- Evidence of a market failure
  - Farmers' access to credit declines because of exogenous shocks that do not reduce likelihood of future repayment

Related Literature and Contribution

- Broadly positive effects of credit scoring (Einav, Jenkins and Levin, 2012, 2013)
  - This paper documents a cost of the use of traditional credit scores
- Literature on effects of information sharing through credit bureaus and credit reports (de Janvry, McIntosh and Sadoulet, 2010; Giné, Goldberg and Yang, 2012)
  - This paper documents a cost of information sharing that does not differentiate among reasons of default
- Literature on long term effects of short term shocks. In macroeconomics (Blanchard and Summers, 1986; Ball 2014). In development economics (Rosenzweig and Wolpin, 1993)
  - This paper documents a new mechanism by which short term shocks can have long term consequences

Outline

- Background
- Data
- The Effect of Rainfall Shocks
  - On concurrent loan outcomes
  - On future access to credit
- Recovery
  - Recovery in Repayment Behavior
  - Timing of the Recovery and Implications for Credit Allocation
  - Recovery Mechanisms
    - Productivity of the coffee tree
    - Income from coffee production
- Conclusion and Policy Implications

Background

Credit in Colombia and the BAC

- Rural sector in Colombia under-supplied with capital
  - 84% of agricultural producers did not have machinery in 2013 (DANE, 2014)
  - 11% of agricultural producers demanded credit in 2013 (DANE, 2014)
- Formal loans are the main source of capital for rural households (Cadena and Quintero, 2015)
- Banco Agrario de Colombia (BAC) gives the bulk of loans to small farmers ▸ Pie Chart
- No insurance markets, at least for coffee production (Boucher and Moya, 2014)
- In the case of loans for coffee production
  - Short-term loans (one to two years): sustaining agricultural production (e.g. purchase fertilizer)
  - Long-term loans (five years or more): planting new trees, renovation of coffee plots

Background

BAC Application Process

Background

BAC Application Process

CIFIN Stage

- Farmer in BAC office
- Query from Credit Scoring Agency (CIFIN)

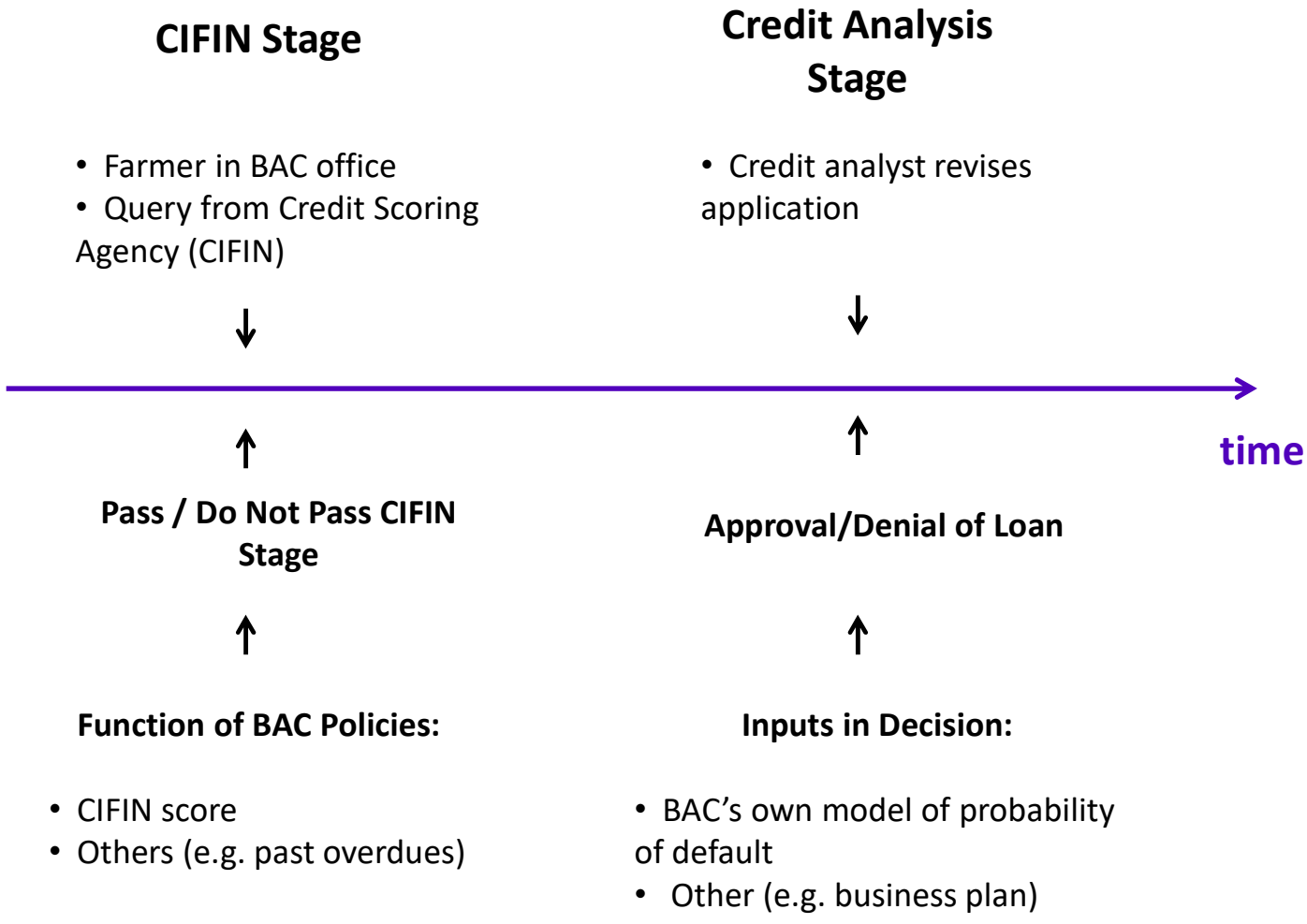
Pass / Do Not Pass CIFIN Stage

Function of BAC Policies:

- CIFIN score
- Others (e.g. past overdues)

Background

BAC Application Process



Background

Traditional Credit Scoring

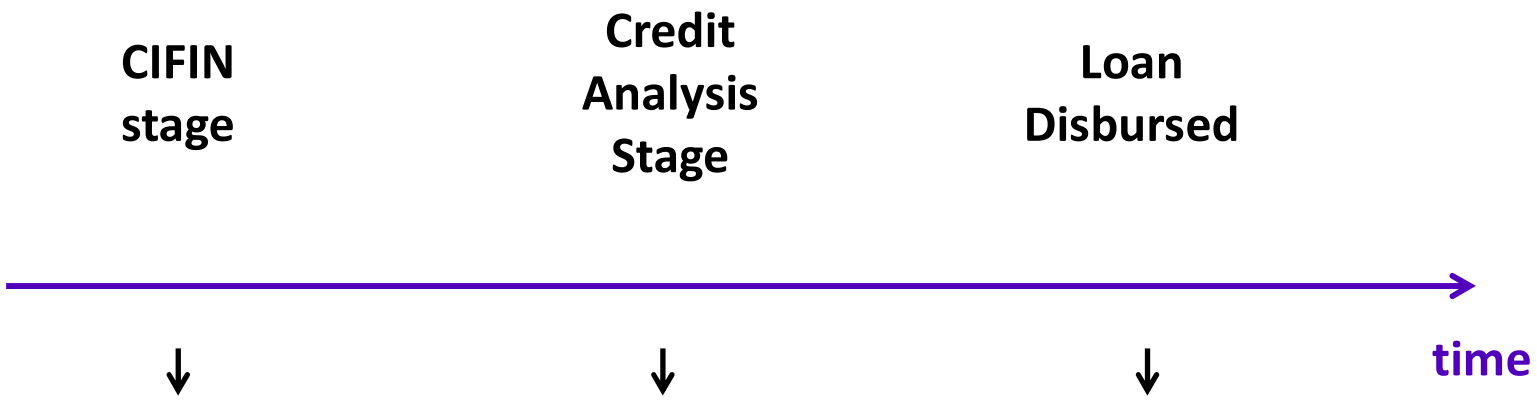
- Model of the probability of default (usually a logit)
  - Inverse of predicted probability is the credit score
  - Traditional right hand variables: credit history (and individual fixed characteristics)
- Most used: FICO in the US
  - Uses various measures of credit history, does not include income or assets (Keys et al., 2010)
- In the case of CIFIN and BAC models: they do not incorporate information on exogenous shocks

Outline

- Background
- **Data**
  - BAC Data
  - Farmers' Location and Rainfall Data
  - Rainfall Shock Definition
  - Estimation Sample
- The Effect of Rainfall Shocks
- Recovery
- Policy Implications and Conclusion

BAC Data

BAC Data



Data:

Universe of CIFIN queries (2010-2015):

- CIFIN Score
- Passed/ Did Not Pass Stage

Data:

Universe of Applications (2005-2015):

- Approved/Denied

Data:

Monthly Level:

- Days past due
- Loan Score

(reported monthly to credit bureau)

Loan Level:

- Maturity
- Destination

Data

Farmers' Location and Rainfall

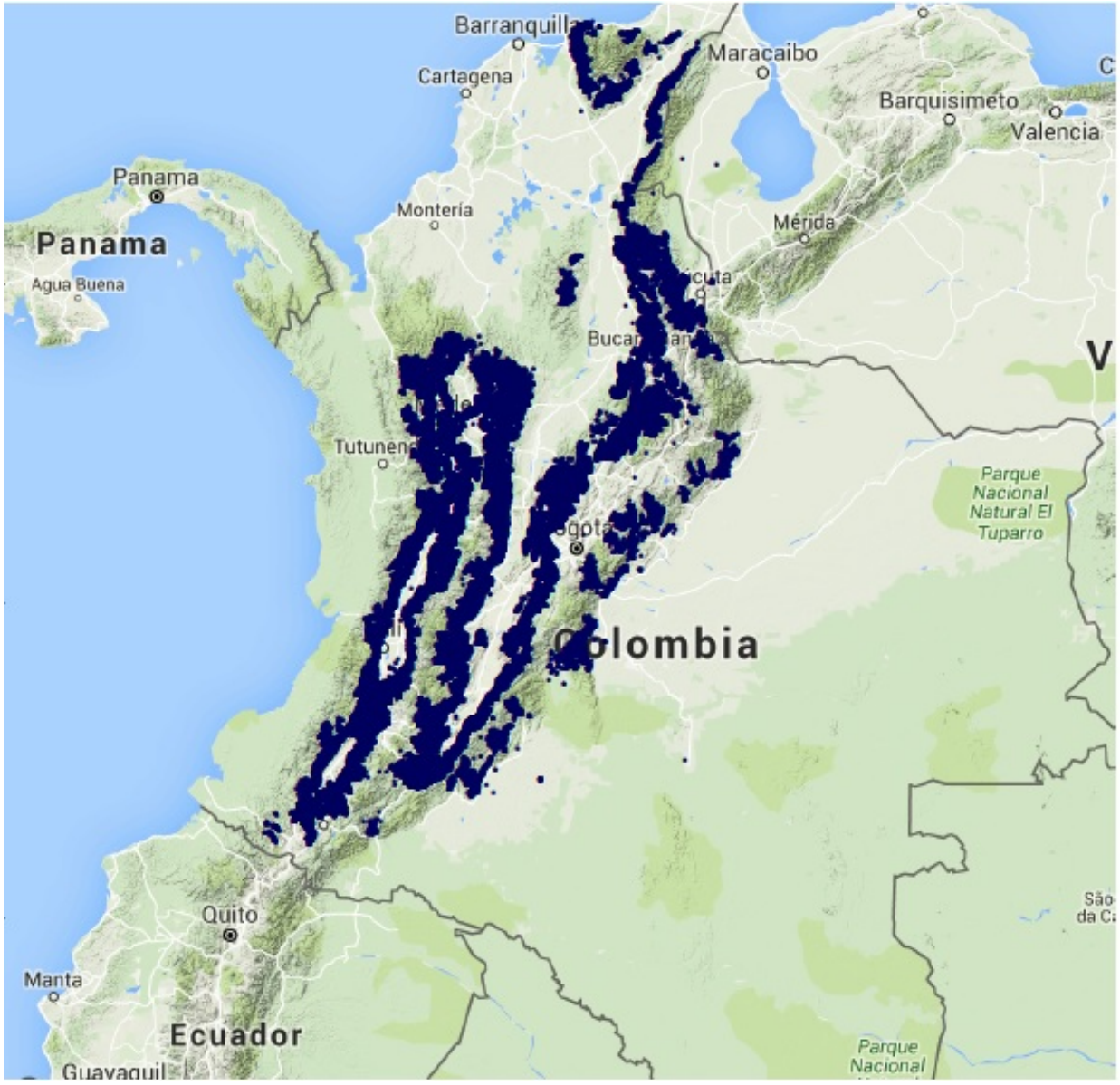
- Geographical location of farm from administrative data set on farmer plot characteristics (SICA)
  - Collected by the National Federation of Coffee Growers
- Link at the individual level BAC loans with SICA
  - Use individual identifiers to link with largest farm at time of loan disbursement
- Data from 1500 rainfall stations from 1982-2012 (IDEAM), monthly frequency
  - Link each farmer to the closest rainfall station, using SICA coordinates

Data

Coffee Farms Distribution

Data

Coffee Farms Distribution

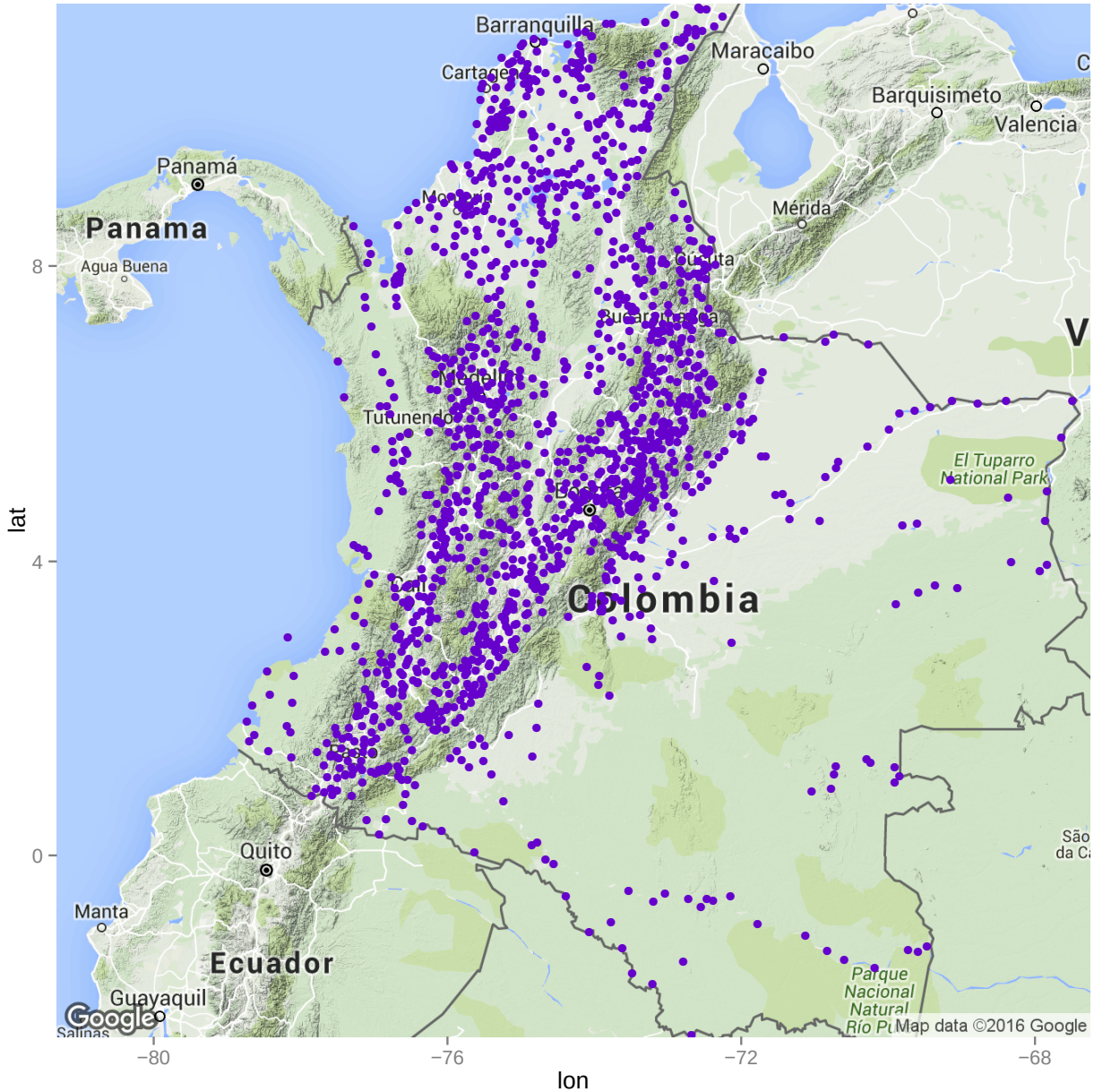


Data

Rainfall Stations Distribution

Data

Rainfall Stations Distribution



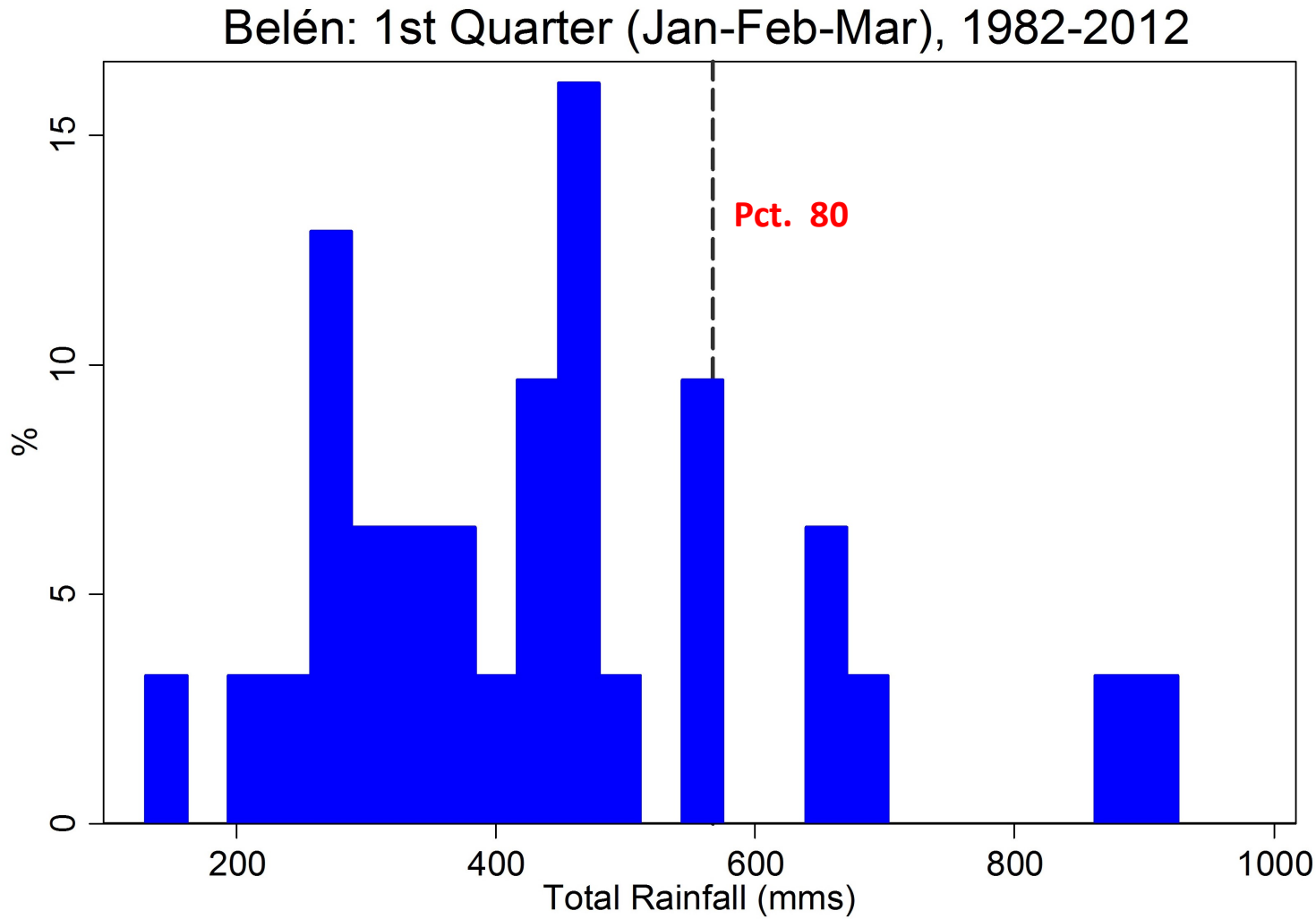
Data

Rainfall Shock Definition

- Definition in the spirit of Jayachandran (2006) and Kaur (2015)
- For each quarter of each rainfall station compute a rainfall distribution using data from 1982-2012

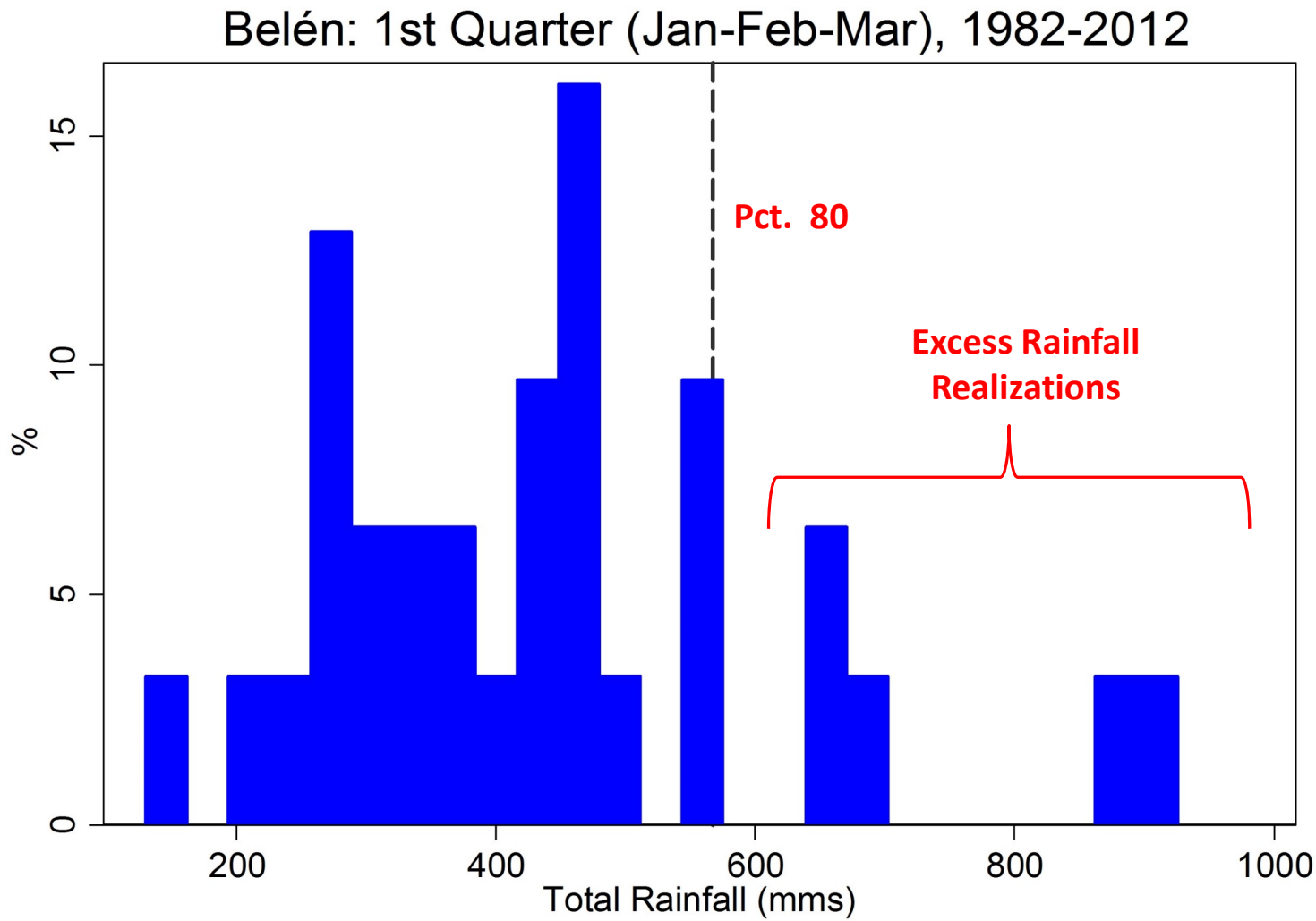
Data

Rainfall Shock Definition



Data

Rainfall Shock Definition



Data

Rainfall Shock Definition

- Definition of "rainfall shock" for a given year: two or more quarters of excess rainfall
  - Handle all dates at the quarterly frequency
  - Example: for a loan disbursed in 2008-2, a shock occurred in the first year after loan disbursement if two or more quarters among 2008-2, 2008-3, 2008-4 or 2009-1 were quarters of excess rainfall
- Definition accounts for some rainfall stations and some quarters being rainier than others
- Focus on excess rainfall: coffee is more sensitive to an excess of rainfall than to lack of rainfall
- Results are robust to different definitions of rainfall shock
  - Number of quarters of excess rainfall in a year
  - Use of the 90th percentile instead of the 80th percentile

Data

Estimation Sample

- Find the most recent loan disbursed in period 2008-2011
  - Law in 2008 that changed duration of negative records (up to four years)
  - Period contains an "El Niño" episode
- Find the next application after loan maturity
- Resulting sample: farmers who had a loan and applied for a new loan

Outline

- Background
- Data
- **The Effect of Rainfall Shocks**
  - On concurrent loan outcomes
  - On future access to credit
- Recovery
- Conclusion and Policy Implications

Effect of Rainfall Shocks on Concurrent Loans

Specification

- Estimate by OLS:

$$y_{ijm\tau} = \beta s_{j\tau} + \mu_{m\tau} + \delta_j + \epsilon_{ijm\tau}$$

Where:

- $y_{ijm\tau}$: Dummy equal to 1 if initial loan i, close to rainfall station j, of maturity m, originated in quarter τ was ever overdue by 30 days or more
- $s_{j\tau}$: Dummy equal to 1 if a rainfall shock occurred in the first year after loan disbursement
- $\mu_{m\tau}$: Quarter of origination $\times$ Maturity fixed effects
- δ_j: Rainfall station fixed effects
- $\epsilon_{ijm\tau}$: Error term

- Identification: $E[\epsilon_{ijm\tau}|s_{j\tau}, \mu_{m\tau}, \delta_j] = 0$
  $\Rightarrow$ Occurrence of shocks not systematically correlated with other time-varying factors affecting repayment

Effect of Rainfall Shocks on Concurrent Loans

Descriptive Statistics

	Mean	St. Dev.	Min	Pctl(25)	Median	Pctl(75)	Max
Maturity (years)	1.65	1.40	0.17	1.00	1.00	2.00	6.58
Interest Rate (annual)	10.67	2.72	2.47	9.50	10.02	12.54	43.98
Distance to Rainfall St.	6.54	3.98	0.04	3.86	5.96	8.37	38.13
Rainfall Shock, year 1	0.42	0.49	0	0	0	1	1
30 Days Overdue	0.14	0.35	0	0	0	0	1
BAC Score Fell to E	0.07	0.25	0	0	0	0	1

Notes: The data source is the BAC administrative data. Included loans are for coffee production, originated in the period of 2008-2011 and for which there is a subsequent application observed in the CIFIN Stage. There are 32,512 observation in the main estimation sample.

Effect of Rainfall Shocks on Concurrent Loans

Lower Repayment

	Baseline			Heterogeneous Effects	
	30 Days Overdue		60 Days Overdue	Dist.to Stat. < Median	Maturity: One Year
Rainfall Shock, year 1	0.034***		0.022***	0.017*	0.032***
	(0.007)		(0.006)	(0.009)	(0.008)
# Excess Rainfall Qrts., year 1		0.016***			
		(0.004)			
Mean (control group)	0.155		0.117	0.11	0.12
Mean (all obs.)		0.142			
Origin Date * Maturity FE	Y	Y	Y	Y	N
Origin Date FE	N	N	N	N	Y
Observations	32,512	32,512	32,512	16,590	28,047
Adjusted R^2	0.125	0.124	0.114	0.121	0.138

Notes: Standard errors clustered at the rainfall station level reported in parentheses. All regression include rainfall station fixed effects. *p<0.1; **p<0.05; ***p<0.01.

Effect of Rainfall Shocks on Concurrent Loans

Lower Reported Scores to Credit Bureaus

	Score Fell from A	Score Fell to E
Rainfall Shock, year 1	0.029^{***}	0.017^{***}
	(0.007)	(0.005)
Mean (control group)	0.150	0.085
Observations	32,512	32,512
Adjusted R^2	0.16	0.075

Notes: Standard errors clustered at the rainfall station level reported in parentheses. Both regressions include Date × Maturity and Rainfall Station fixed effects. $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$.

Effect of Rainfall Shocks on Subsequent Applications

Specification

- For the first application after loan maturity
- Estimate by OLS

$$x_{ijm\tau} = \alpha s_{j\tau} + \mu_{m\tau} + \delta_j + \epsilon_{ijm\tau}$$

Where:

- $x_{ijm\tau}$: CIFIN Score, Dummy for Denial at CIFIN Stage, Dummy for Denial at Analysis Stage

Effect of Rainfall Shocks on Subsequent Applications

Lower Scores & Higher Denial

	Applied New Loan	Initial Loan Overdue	CIFIN Score	CIFIN Denial	Analysis Denial
Rainfall Shock, year 1	-0.005	0.034***	-5.747***	0.015***	0.017***
	(0.005)	(0.007)	(1.96)	(0.005)	(0.007)
Sample	Initial Loans	Main Sample	Main Sample	Main Sample	Up to Analysis
Mean (control group)	0.816	0.21	925	0.119	0.173
Observations	51,102	32,512	31,939	32,512	24,083
Adjusted R^2	0.21	0.13	0.074	0.048	0.019

Notes: Standard errors clustered at the rainfall station level reported in parentheses. All regressions include Date × Maturity and Rainfall Station fixed effects. *p<0.1; **p<0.05; ***p<0.01.

Effect of Rainfall Shocks on Subsequent Applications

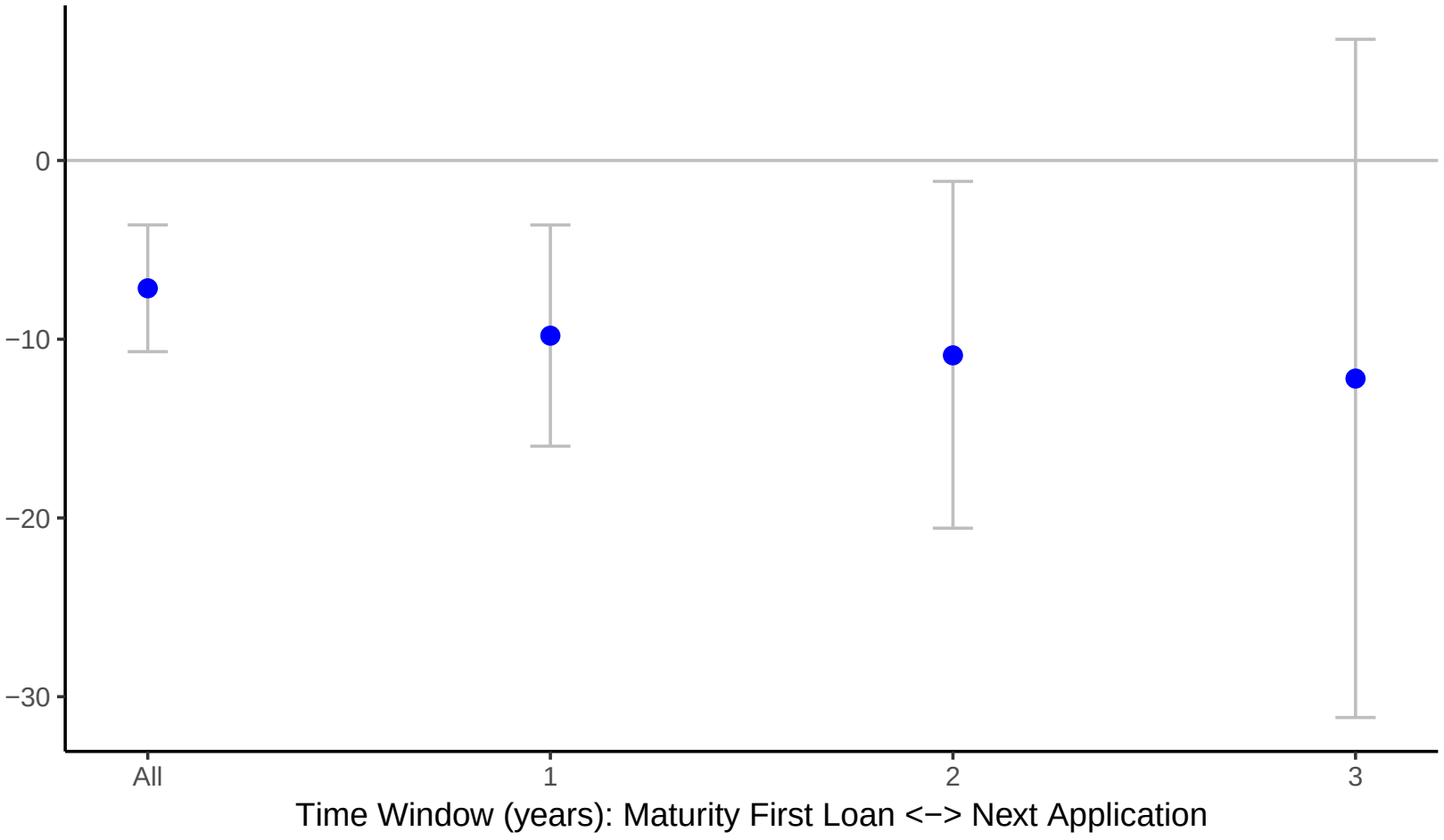
Lower Scores & Higher Denial (initial loan: 1 year maturity)

	Applied New Loan	Initial Loan Overdue	CIFIN Score	CIFIN Denial	Analysis Denial
Rainfall Shock, year 1	-0.003	0.024***	-7.148***	0.019***	0.019***
	(0.009)	(0.006)	(2.155)	(0.007)	(0.009)
Sample	Initial Loans	Main Sample	Main Sample	Main Sample	Up to Analysis
Mean (control group)	0.835	0.149	941	0.109	0.16
Observations	28,177	20,549	20,161	20,549	16,638
Adjusted R^2	0.28	0.152	0.049	0.059	0.019

Notes: Standard errors clustered at the rainfall station level reported in parentheses. All regressions include Date × Maturity and Rainfall Station fixed effects. *p<0.1; **p<0.05; ***p<0.01.

Effect of Rainfall Shocks on Subsequent Applications

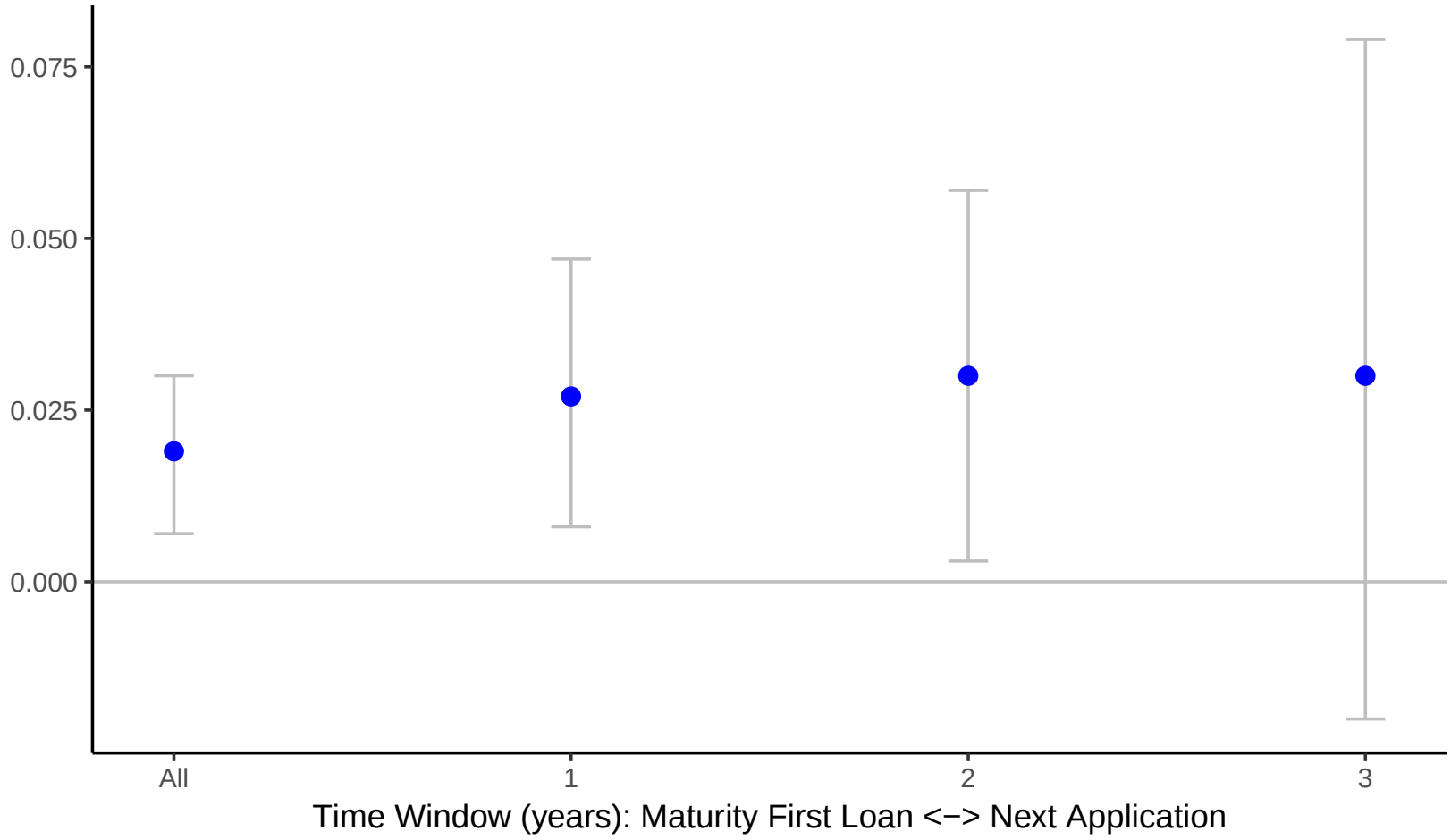
Persistence



Estimated Effect on CIFIN Score

Effect of Rainfall Shocks on Subsequent Applications

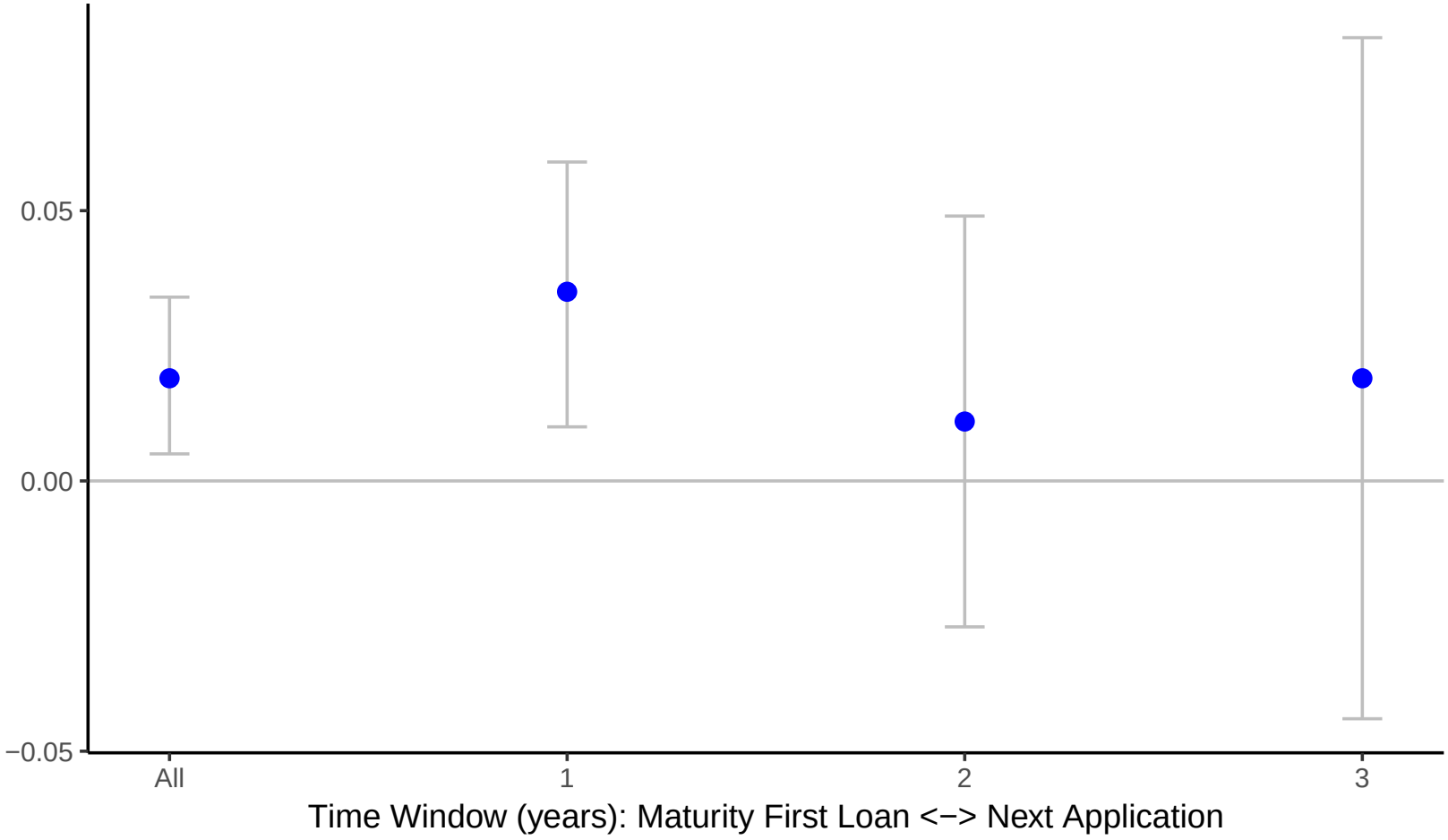
Persistence



Estimated Effect on Denial (CIFIN Stage)

Effect of Rainfall Shocks on Subsequent Applications

Persistence



Estimated Effect on Denial (Analysis Stage)

Outline

- Background
- Data
- The Effect of Rainfall Shocks
- **Recovery**
  - Recovery in Repayment Behavior
  - Timing of the Recovery and Implications for Credit Allocation
  - Recovery Mechanisms
    - Productivity of the coffee tree
    - Income from coffee production
- Conclusion and Policy Implications

Recovery in Repayment Behavior

- Does repayment behavior recover?
  - Or, do shocks during first loan affect repayment of next loan?
- Fundamental problem: rainfall shocks cause higher rates of denial of subsequent loan applications
  - Sample of farmers who get a second loan is selected
  - Repayment of farmers who do not get a loan is not observed
- Solution:
  - Recovery in long term loans
  - Recovery in high ex-ante credit score borrowers ▸ Appendix

Recovery in Repayment Behavior

Long Term Loans

- Use a sample of loans with maturities of five or more years
- Estimate by OLS:

$$y_{kij\tau} = \beta_k s_{j\tau} + \psi_\tau + \iota_j + \nu_{kij\tau}$$

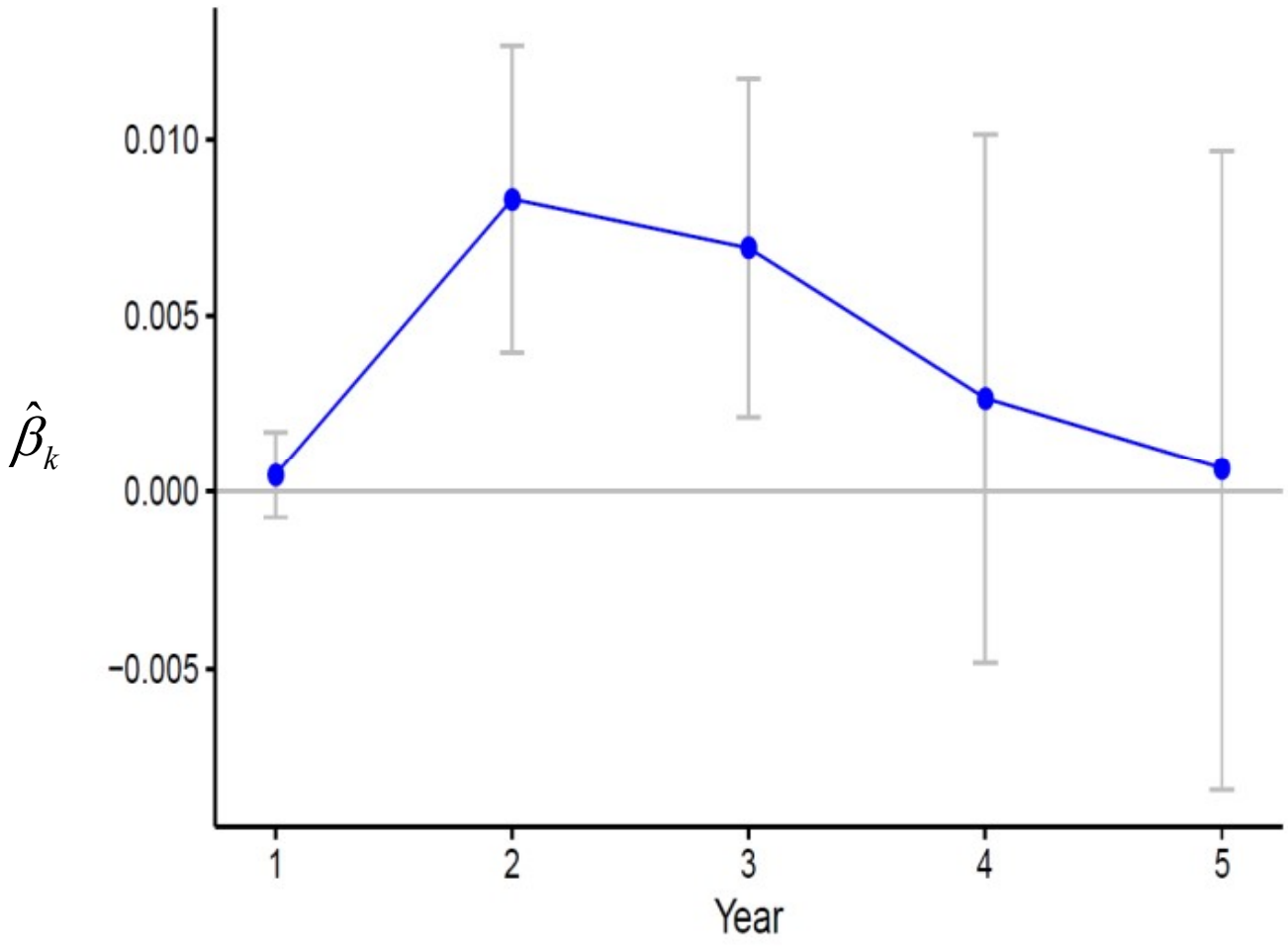
Where:

- $y_{kij\tau}$: Dummy equal to 1 if loan i ever entered into a period of 30 days past due at age k (in years)
- $s_{j\tau}$: Dummy equal to 1 if a rainfall shock occurred in the first year after loan disbursement

- Plot β_k for k in $\{1,2,3,4,5\}$

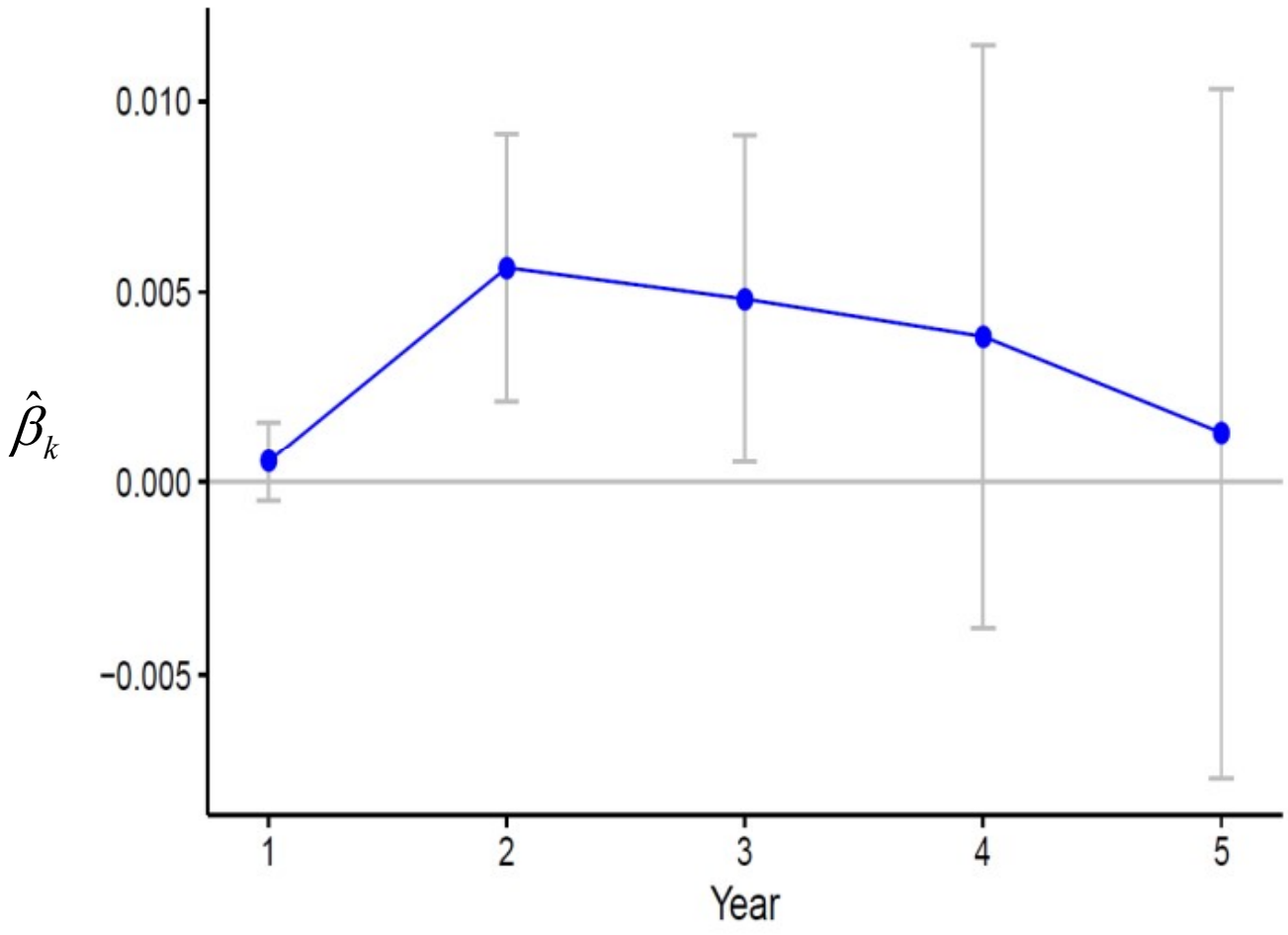
Recovery in Repayment Behavior

Long Term Loans (all loans)



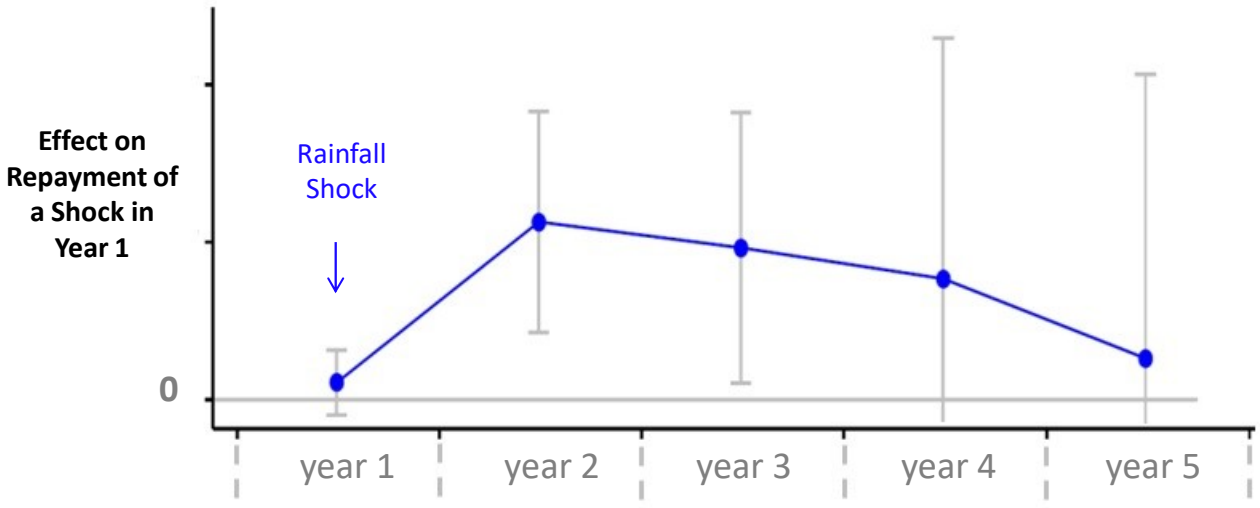
Recovery in Repayment Behavior

Long Term Loans (restructured loans omitted)



Timing of Recovery and Credit Allocation

Timing of Recovery and Credit Allocation



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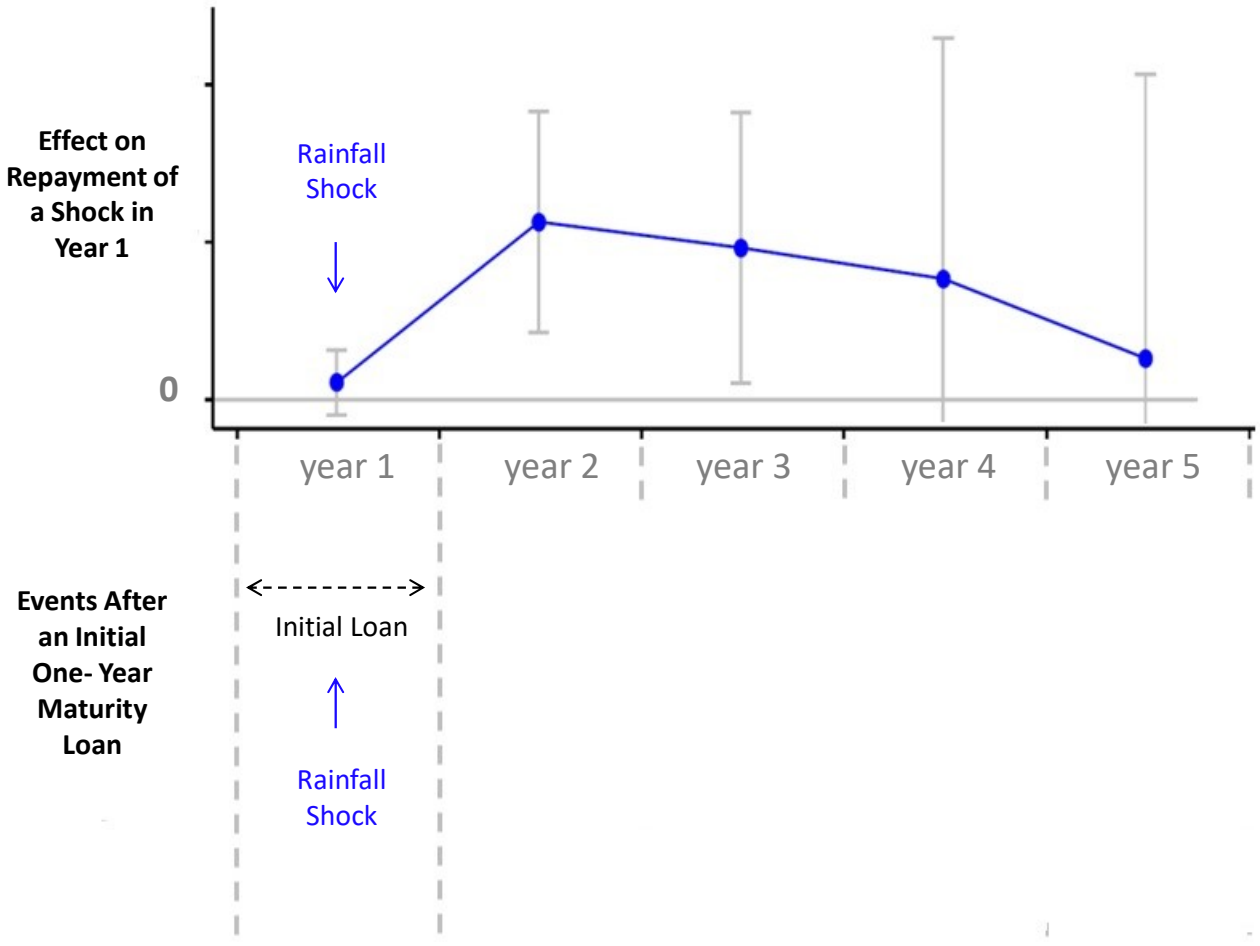

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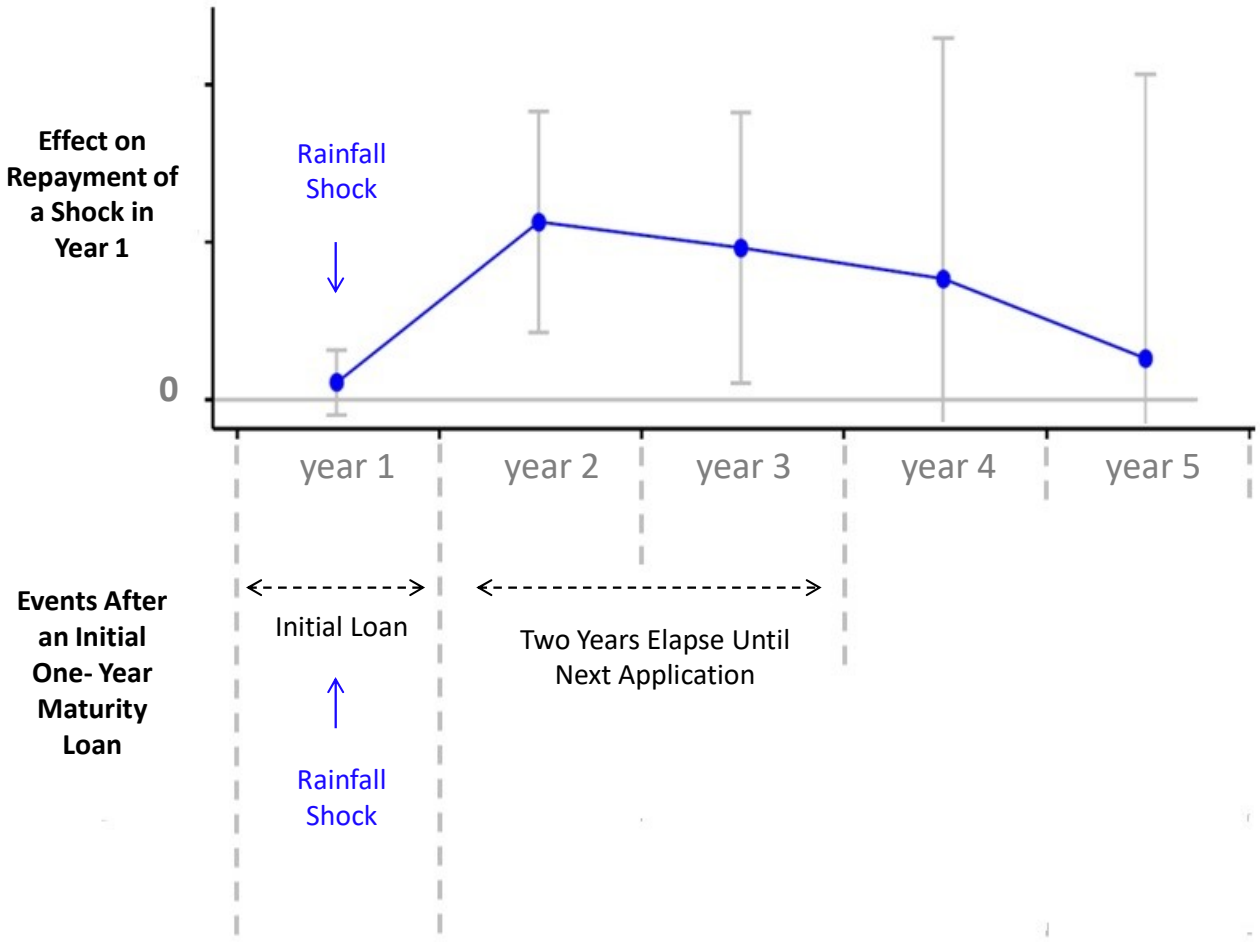
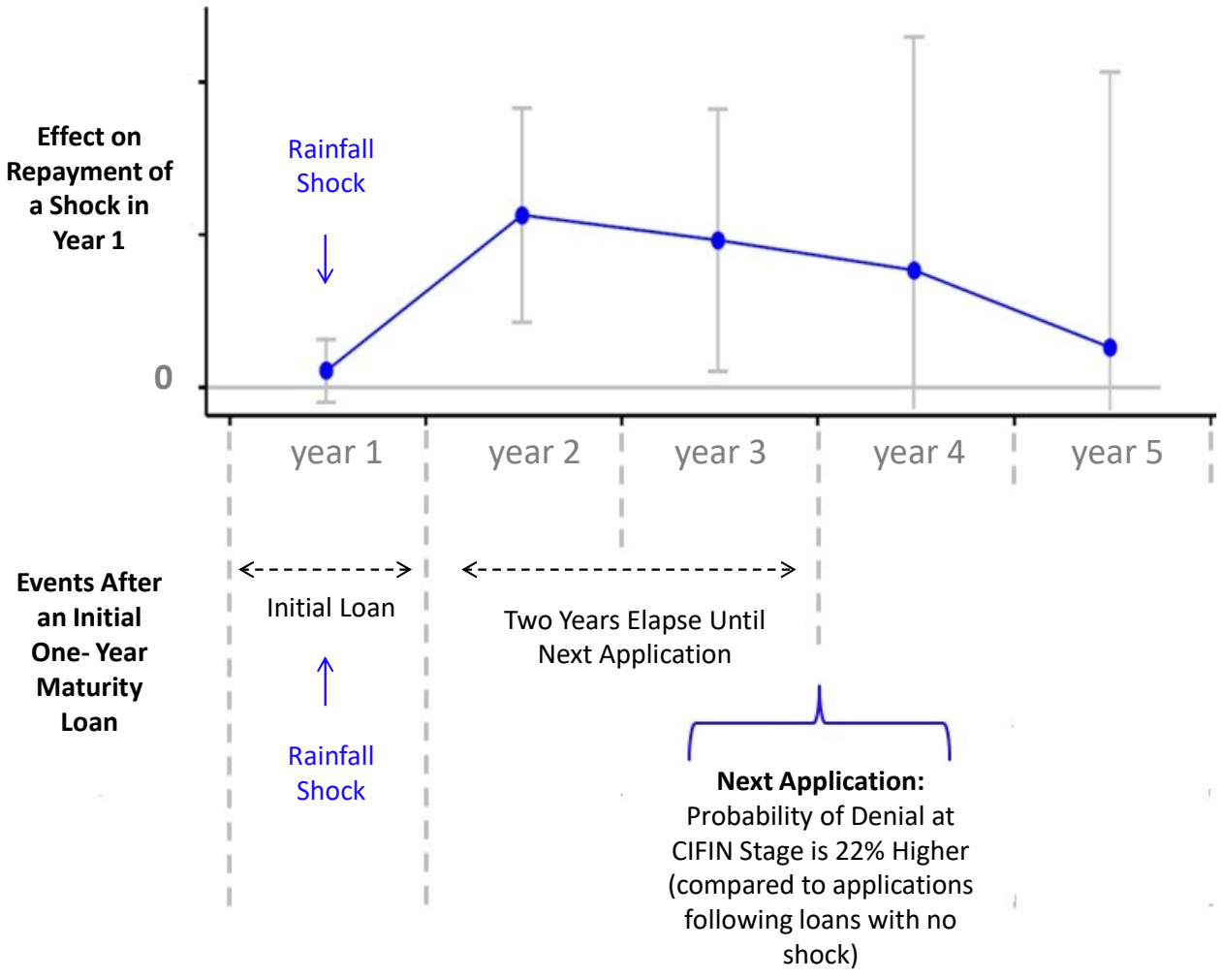


Timing of Recovery and Credit Allocation



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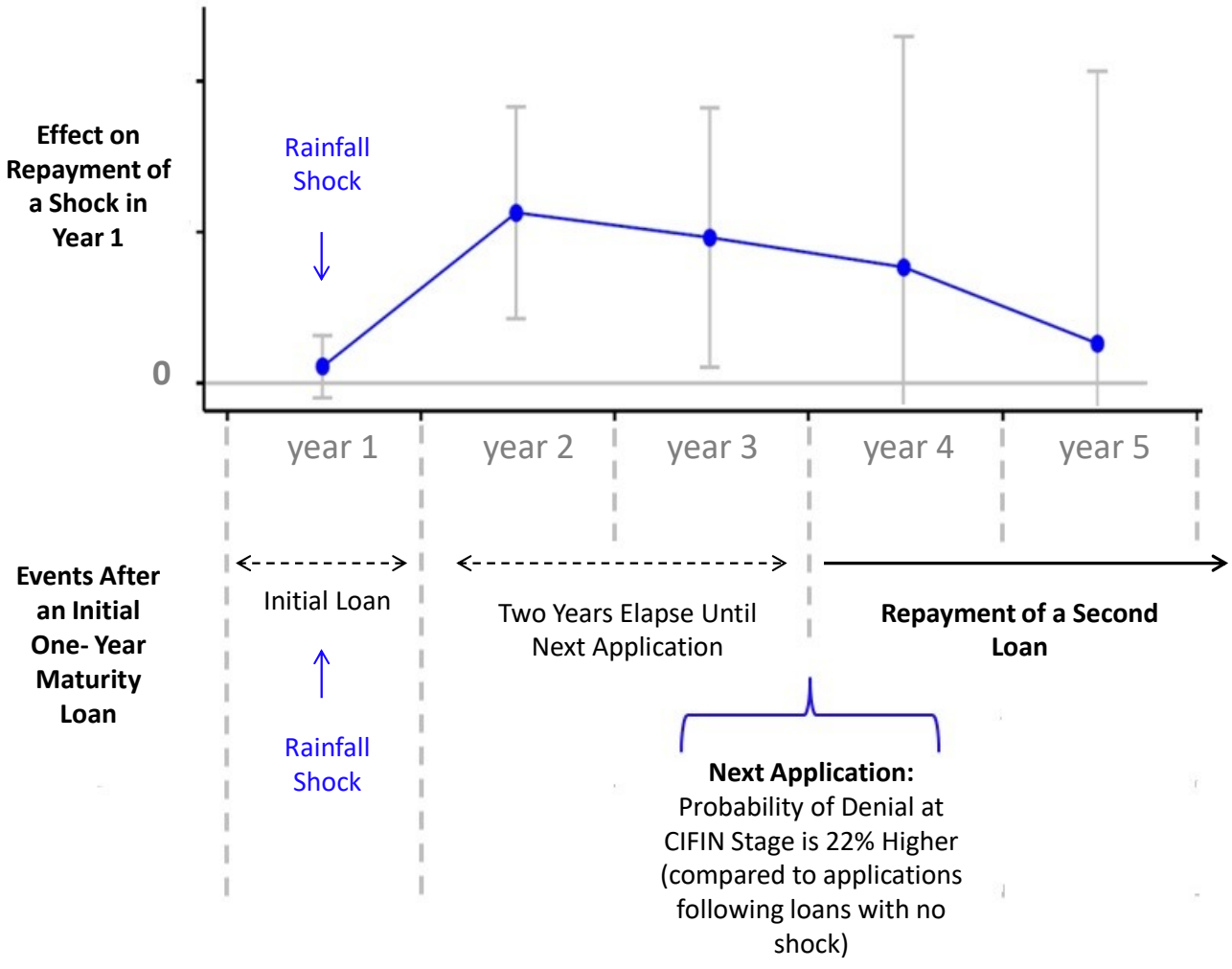
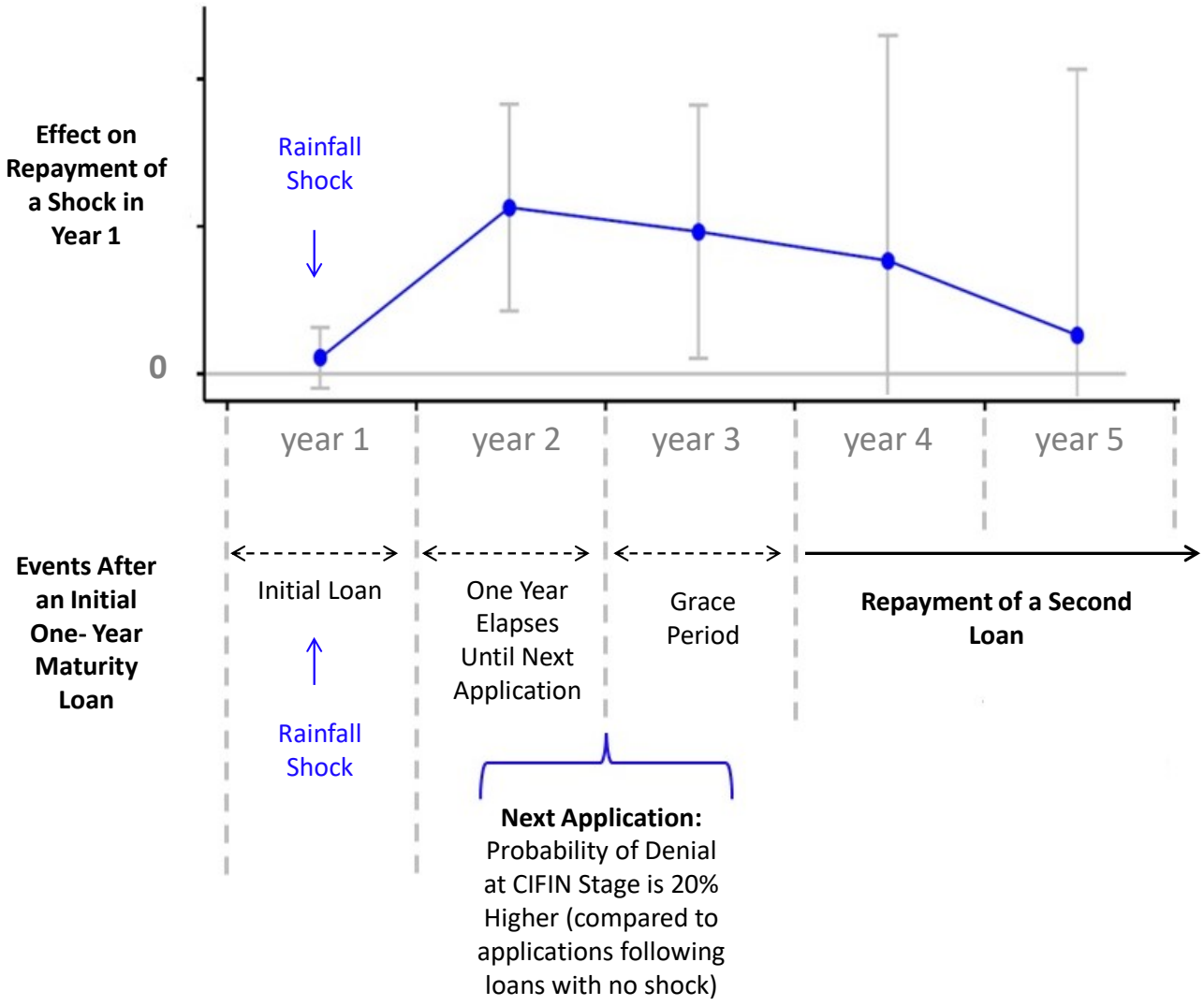


Timing of Recovery and Credit Allocation

One Year Time Window and Grace Period



Recovery Mechanisms

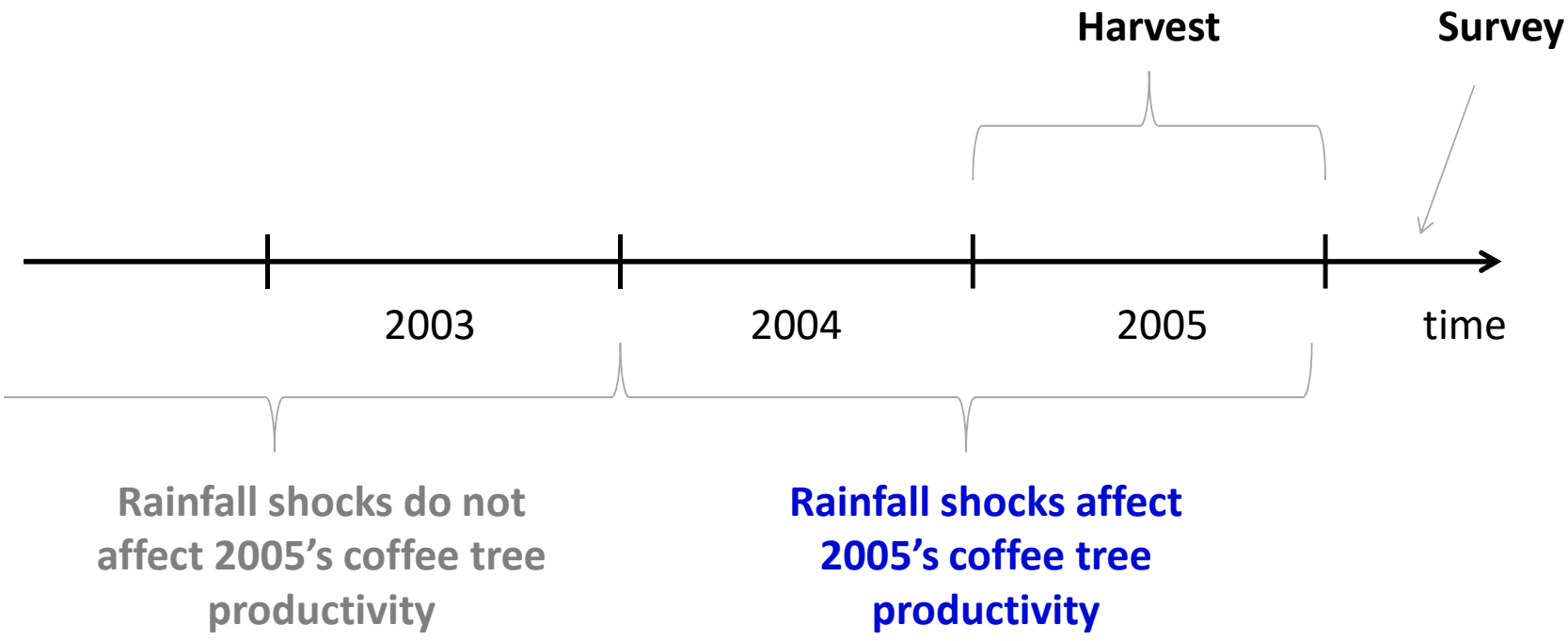
Productivity of the Coffee Tree

- Large agronomic literature on coffee production
- Periods of excessive rainfall affect productivity of the coffee tree if they occur up to one year before harvest ▸ Details
- Once weather returns to normal, the productivity of the coffee tree returns to normal

Recovery Mechanisms

Income From Coffee Sales

- Data: Representative survey of small coffee farmers in 2006 with information on coffee sales
- Asks about coffee sales in previous year (2005)



Recovery Mechanisms

Income From Coffee Sales

- Estimate by OLS:

$$r_{itjc} = \alpha_0 + \alpha_1 s_{t-1,j} + \alpha_2 s_{t-2,j} + \alpha_3 s_{t-3,j} + Z_i'\rho + \phi_c + u_{itjc}$$

Where:

- r_{itjc}: Amount of coffee sold in 2005 per-hectare cultivated with coffee (farmer i, close to rainfall j, in coffee growing region c)
- $s_{t-1,j}$: Dummy equal to 1 if a rainfall shocks occurred in 2005 or in 2004. $s_{t-2,j}$ and $s_{t-3,j}$ defined analogously for periods 2002-2003 and 2000-2001
- Z_i: Vector of individual controls
- ϕ_c: Coffee-region fixed effects
- u_{ijc}: Error term

Recovery Mechanisms

Income From Coffee Sales

- Identification: $s_{t-1,j}$, $s_{t-2,j}$ and $s_{t-3,j}$ are uncorrelated with the error term
  - Shocks are as good as random in the cross-section

- Support of this claim
  - Shocks definition: has already taken out a rainfall-station fixed-effect effectively
  - Shocks are distributed across the country ▸ Map
  - No large differences in covariates between farmers with $s_{t-1,j} = 1$ and farmers with $s_{t-1,j} = 0$ ▸ Balance Test
  - Coefficients are stable across specifications with different set of covariates

Recovery Mechanisms

Income From Coffee Sales

	Controls (none)	Controls (pred.)	Controls (all)
Rainfall Shock 04-05	-7.67**	-7.46**	-6.43**
	(3.52)	(3.49)	(2.92)
Rainfall Shock 02-03	3.75	3.64	6.15
	(4.70)	(4.61)	(5.46)
Rainfall Shock 00-01	3.82	4.30	2.96
	(5.22)	(5.19)	(5.73)
Mean (control group)	23.9	24.2	24.3
Observations	1,296	1,256	1,242
Adjusted R^2	0.048	0.053	0.100
p-value S. 04-05 = S. 03-02	0.092	0.097	0.063
p-value S. 04-05 = S. 00-01	0.119	0.109	0.201

Notes: All regression include a constant term and coffee region fixed effects. Predetermined controls include: Farm area, household size, education, gender. Non-predetermined controls include: density, average age of the plot, sun exposed dummy and coffee variety dummies. Standard errors clustered at the rainfall station level reported in parentheses. $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Outline

- Background
- Data
- The Effect of Rainfall Shocks
- Recovery
- **Conclusion and Policy Implications**

Conclusion

- This paper documents a market failure resulting from the use of traditional credit scores in agricultural lending
  - Farmers are excessively penalized for exogenous shocks that do not reduce repayment of future loans
- Paper involves a single bank
  - According to CIFIN in at least five other countries in Latin America institutions lending to farmers consult credit histories
  - Consulting credit histories and using credit scoring is considered good banking practice (de Olloqui, 2013)
- Why do banks not take shocks into account?
  - Technological constraints only recently allowed for measures of shocks at low cost with the level of precision needed for credit scores
  - Inertia of banking practices: credit scoring institutions in developing countries do what others do in developed countries
  - Banks omitting information on the sources of default not unique to my setting (Garmaise and Natividad, 2016)

Policy Implications

- Verifiable information on individual level shocks should be incorporated into credit scores
  - Case of Colombia, where this information is available at least for some crops
- For scenarios where the information is not available
  - Geo-reference farmers and establish close rainfall stations
  - Keep detailed records of weather events
- The mechanisms outlined here might apply to other credit markets
  - Firm closings and massive layoffs

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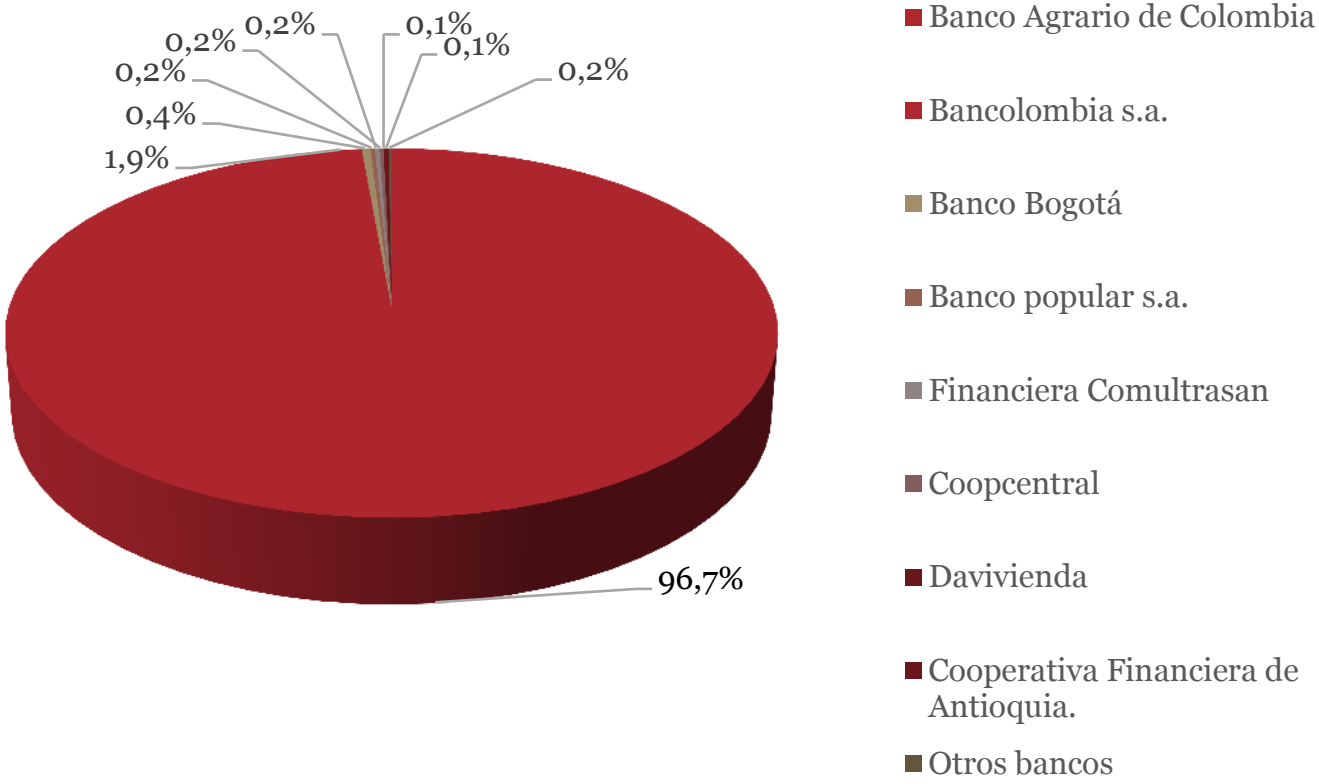
Thank You!

APPENDIX

Source of Formal Loans to Small Farmers in 2013



Fuente: MADR/FINAGRO

back

Recovery in Repayment Behavior

High Ex-ante Credit Score Borrowers

- Sample of farmers in the top quartile of the CIFIN score distribution (1st loan)
- Estimate effect of a shock in first loan on repayment of next loan
  - In this sample selection is less of a concern
  - High credit score farmers are likely to get a second loan even if they get a shock during the first loan

Recovery: Repayment

High Ex-ante Credit Score Borrowers

	1st Loan Overdue	CIFIN Denial	Analysis Denial	2nd Loan Overdue
Rainfall Shock	0.014**	0.011	0.012	0.033
	(0.008)	(0.012)	(0.022)	(0.021)
Mean (control group)	0.013	0.055	0.141	0.063
Observations	2,681	3,785	3,141	2,550
Adjusted R^2	0.028	0.078	0.025	0.043

Notes: Sample of first loan corresponds to the most recent loan originated in 2010-2011. Standard errors clustered at the rainfall station level are reported in parentheses. All regressions include Date $\times$ Maturity and Rainfall Station fixed effects. $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

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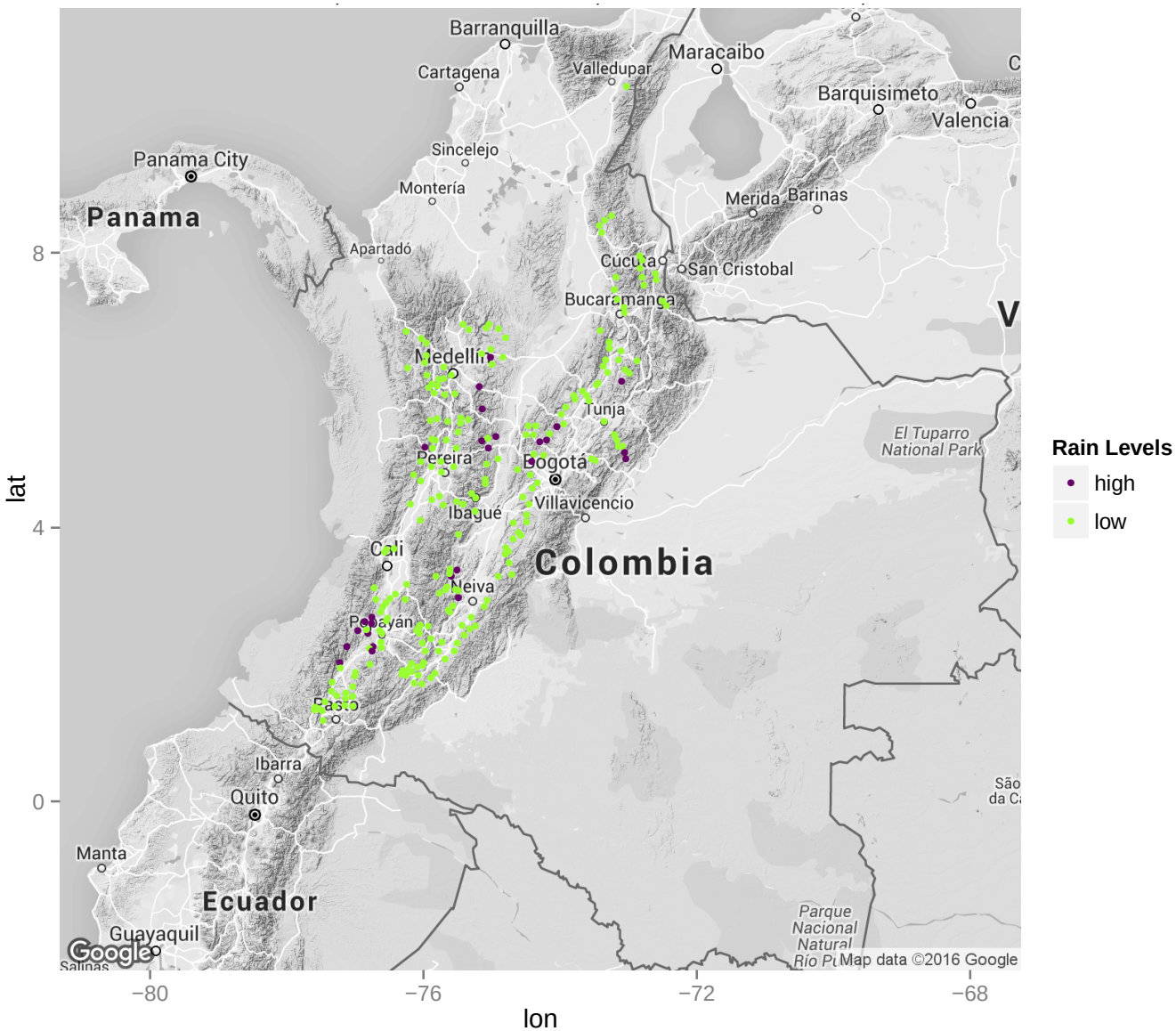
Distribution of Shocks Across Space (2004-2005)



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Covariate Balance

	$s_{t-1,j} = 0$	$s_{t-1,j} = 1$	p-value	
Household Size	3.93	4.10	0.300	
Education	0.99	0.89	0.060	*
Gender	1.18	1.16	0.597	
Coffee Area	3.1	2.8	0.204	
Density	4323	4030	0.059	*
Average Age	8.3	8.7	0.540	
Farm Area	5.8	5.7	0.840	
Sun Exposed	0.19	0.24	0.130	

Notes: The data comes from the MLYCC survey. The reported p-value corresponds to a test where the null hypothesis is equality in means across the group of farms with $s_{t-1,j} = 1$ and group of farms with $s_{t-1,j} = 0$. *p<0.1; **p<0.05; ***p<0.01

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Coffee Tree Productivity Details

- Two phases of fruit growth that are affected by excessive rainfall:
  - **Flowering Phase** (3 to 5 months): high levels of rainfall hinder development of the flower
  - **Fruit Development Phase** (6 to 7 months): lack of solar radiation hinders development of the fruit
    - Periods of high rainfall are correlated with low solar radiation in coffee regions (Turbay et al. 2014)
  - Periods of excessive rainfall affect productivity of the coffee tree if they occur up to one year before harvest

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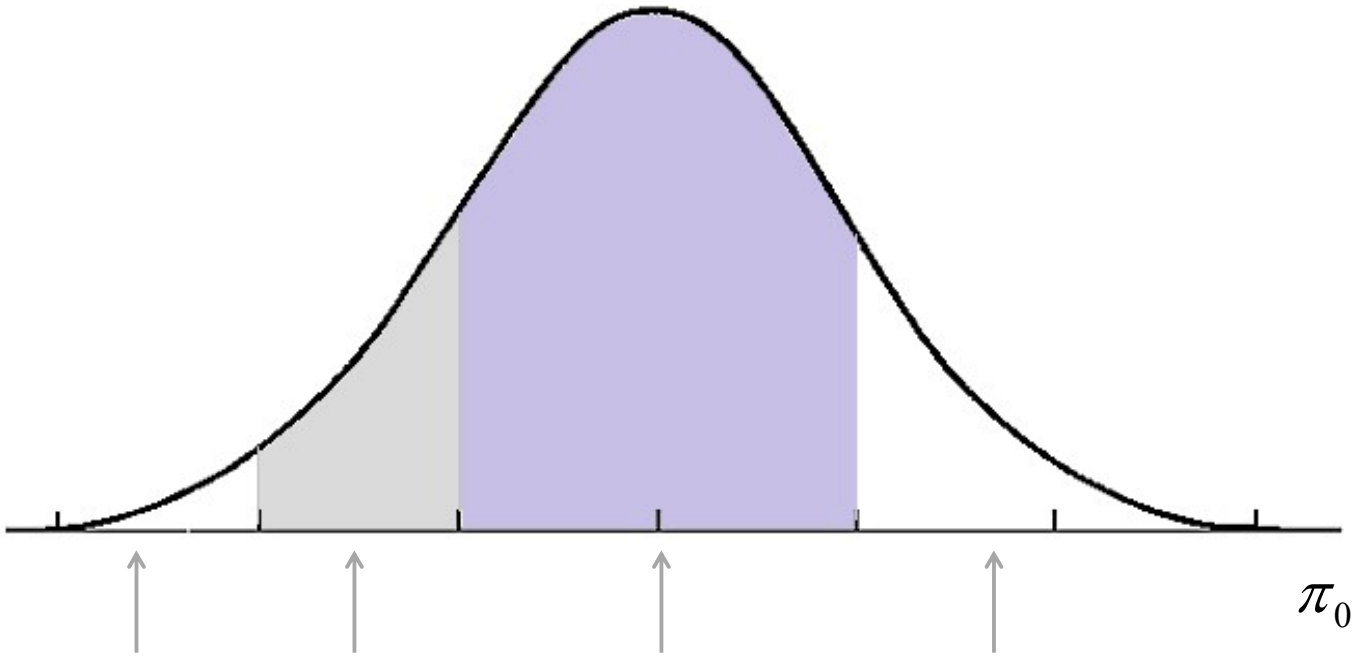
Type Distribution and Recovery



Never pay

Pay if no shock. If shock do not pay. Never recover. => **Cannot** pay future loans

Pay if no shock. If shock do not pay. Recover => **Can** pay future loans

Always pay

A Model of Borrower Screening

Setup

- Borrower has a loan in period $t-1 \Rightarrow$ Repayment: π_{t-1}
- Applies for a new loan for period t
- Lender decides if he grants the loan for period t
- Borrower profitability: π_0, unobserved by the lender

- Repayment of borrower in $t-1$:

  $\pi_{t-1} = \pi_0 + z + \epsilon$
  - z is a "rainfall shock" (independent of π_0) and potentially observable by the lender
  - ϵ: independent of π_0 and z. Unobservable to the lender
  - Assume: lender knows the process generating π_{t-1} but does not observe any of its components

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A Model of Borrower Screening

Setup

- Assume: $z \sim N(0, \sigma_z^2)$ and $\epsilon \sim N(0, \sigma_\epsilon^2)$
- Assume: no uncertainty in the repayment of second loan (once the lender has made his decision) so that $\pi_t = \pi_0$
- Lender makes a positive profit in the second loan if $\pi_0 > 0$ and negative one if $\pi_0 < 0$
- Credit Score:
  - Lender makes a prediction of π_t based on past repayment, π_{t-1}.
  - When the rainfall shock is not observed: $E[\pi_t|\pi_{t-1}] = \pi_{t-1}$
  - Lender grants the loan if: $E[\pi_t|\pi_{t-1}] \geq 0$

A Model of Borrower Screening

Probability of Lending to an Unprofitable Borrower, z Unobserved

- Assume z is not observed by the lender
- P_u: probability that loan is granted to unprofitable borrower
- $P_u = P(\pi_{t-1} \geq 0) = P(\pi_0 + z + \epsilon \geq 0)$ given $\pi_0 < 0$.
  - $z + \epsilon$ is distributed $N\left(0, \sigma_z^2 + \sigma_\epsilon^2\right)$ since z and ϵ are independent
  - $P(\pi_0 + z + \epsilon \geq 0) = P(z + \epsilon \geq -\pi_0) = P(z + \epsilon \leq \pi_0)$
  - $P_u = \Phi\left(\frac{\pi_0}{\sqrt{\sigma_z^2 + \sigma_\epsilon^2}}\right)$
  - Increasing in $\sqrt{\sigma_z^2 + \sigma_\epsilon^2}$ given that $\pi_0 < 0$

A Model of Borrower Screening

Probability of Lending to an Unprofitable Borrower, z Observed

- Assume z is observed by the lender
- Lender discounts the credit score:
  - $E[\pi_t|\pi_{t-1}, z] = E[\pi_t|\pi_{t-1}] - z = \pi_0 + \epsilon$
- $P_u = \Phi\left(\frac{\pi_0}{\sigma_\epsilon}\right)$ with $\pi_0 < 0$

A Model of Borrower Screening

Result

- P_u if z is unobserved:

$$P_u = \Phi\left(\frac{\pi_0}{\sqrt{\sigma_z^2+\sigma_\epsilon^2}}\right) \text{ with } \pi_0 < 0$$

- P_u if z is observed and incorporated in the credit score:

$$P_u = \Phi\left(\frac{\pi_0}{\sigma_\epsilon}\right) \text{ with } \pi_0 < 0$$

- First expression is larger than the second one as long as $\sigma_z^2 > 0$