

Contagion of bank failures through the interbank network in Argentina

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Why do banks fail?

Contract theory: capital structure

The equity buffer e_i

“Virtually all [empirical] studies find that low capital ratios raise the probability of bank failure.”

Berger & Roman (2020)

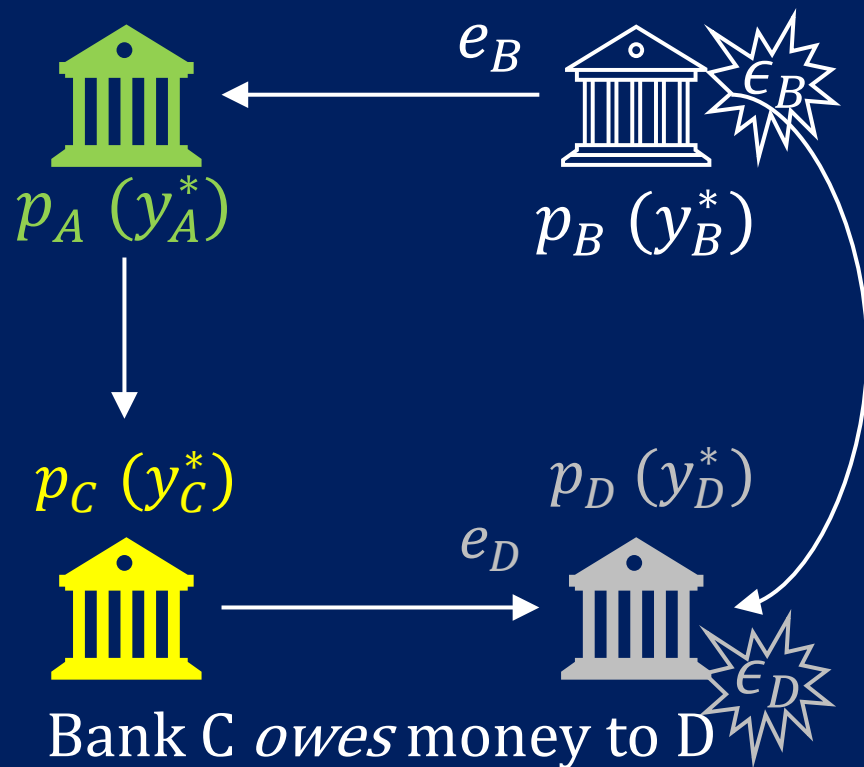
Virtually all such studies assume independent and thus isolated banks.

Network theory: Contagion in financial networks

Why do banks fail?

Network theory: Contagion in financial networks

Arrows describe cash-flow direction when the market clears



Allen & Gale (2000)

- The structure matters for the propagation of shocks.
- The more links the better

Gai & Kapadia (2010)

- Sometimes less links is better.
- Robust-yet-fragile systems

The spatial approach

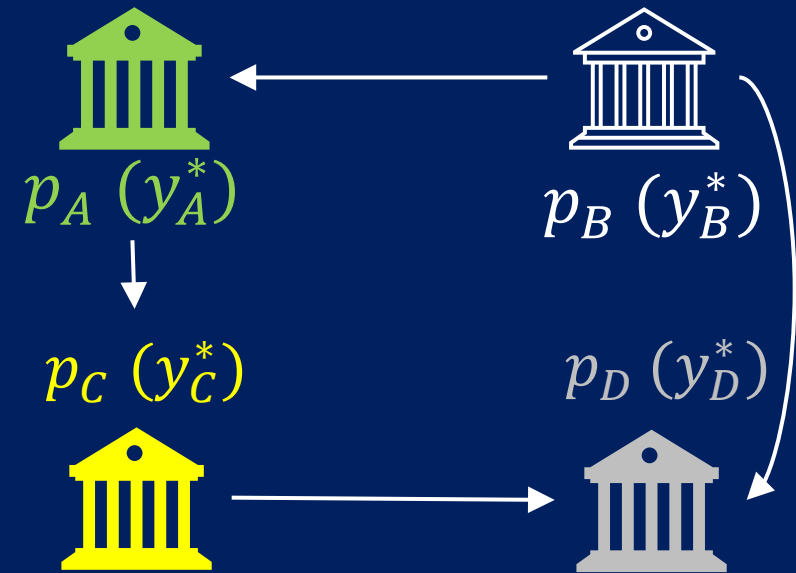
Network data

The *in degree*_{*i*} of node *i*

$$p_i \propto \text{in degree}_i$$

The spatial approach

The weight matrix



Bank C *owes* money to D

$W =$
Borrower \rightarrow

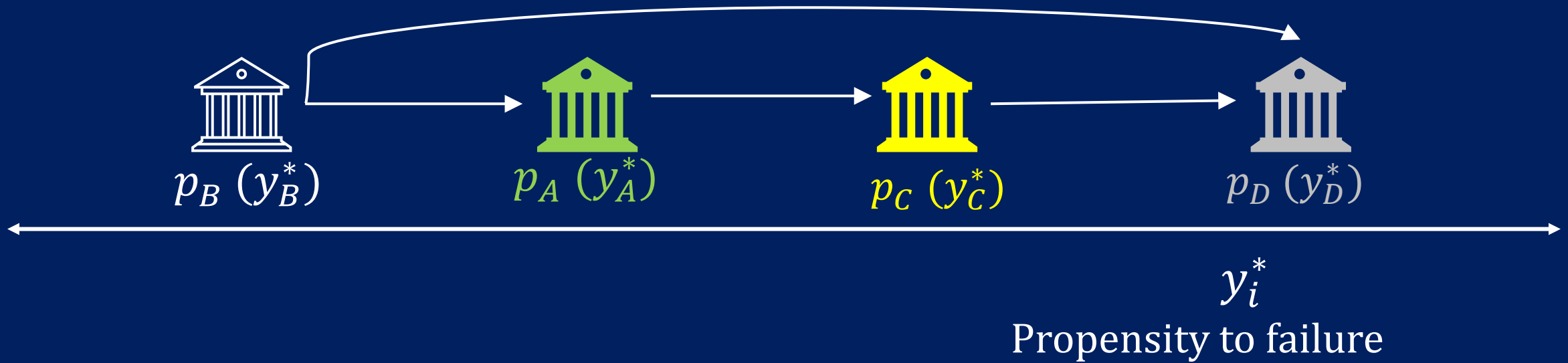
	Bank A	Bank B	Bank C	Bank D
Bank A	0	0	0.2	0
Bank B	0.1	0	0	0.3
Bank C	0	0	0	0.4
Bank D	0	0	0	0

- $w_{C,D} = \frac{\text{Loan \$}}{\text{Total loans D \$}}$
- Main diagonal is 0

The spatial approach

Spatial autoregressive process (SAR)

The latent variable is spatially correlated



$$\mathbf{y}^* = \rho \mathbf{W} \mathbf{y}^* + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \quad \boldsymbol{\varepsilon} \sim \mathcal{N}(\mathbf{0}, \mathbf{I}_N)$$

- \mathbf{W} main diagonal is 0
- The scalar $|\rho| \in (0,1) \approx$ a correlation coefficient

The spatial approach

Spatial autoregressive process (SAR)

$$\mathbf{y}^* = \rho \mathbf{W} \mathbf{y}^* + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \quad \boldsymbol{\varepsilon} \sim \mathcal{N}(\mathbf{0}, \mathbf{I}_N)$$

$$\mathbf{y}^* = (\mathbf{I}_N - \rho \mathbf{W})^{-1} \mathbf{X}\boldsymbol{\beta} + (\mathbf{I}_N - \rho \mathbf{W})^{-1} \boldsymbol{\varepsilon}$$

$$(\mathbf{I}_N - \rho \mathbf{W})^{-1} \approx \mathbf{I}_N + \rho \mathbf{W} + \underbrace{\rho^2 \mathbf{W}^2}_{\substack{\text{Higher-order} \\ \text{effects}}} + \rho^3 \mathbf{W}^3 + \dots$$

$$\mathbf{W}^2 \equiv \mathbf{W} \times \mathbf{W}$$

- The “friends of your friends”

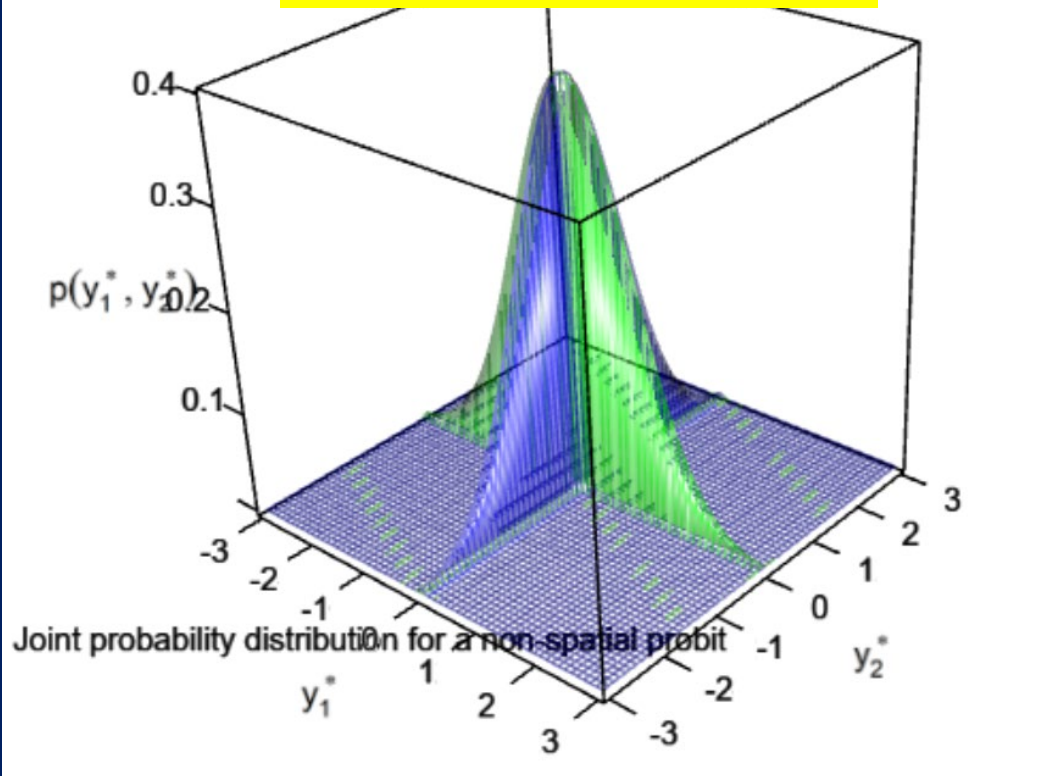
Feedback effects

Higher-order effects

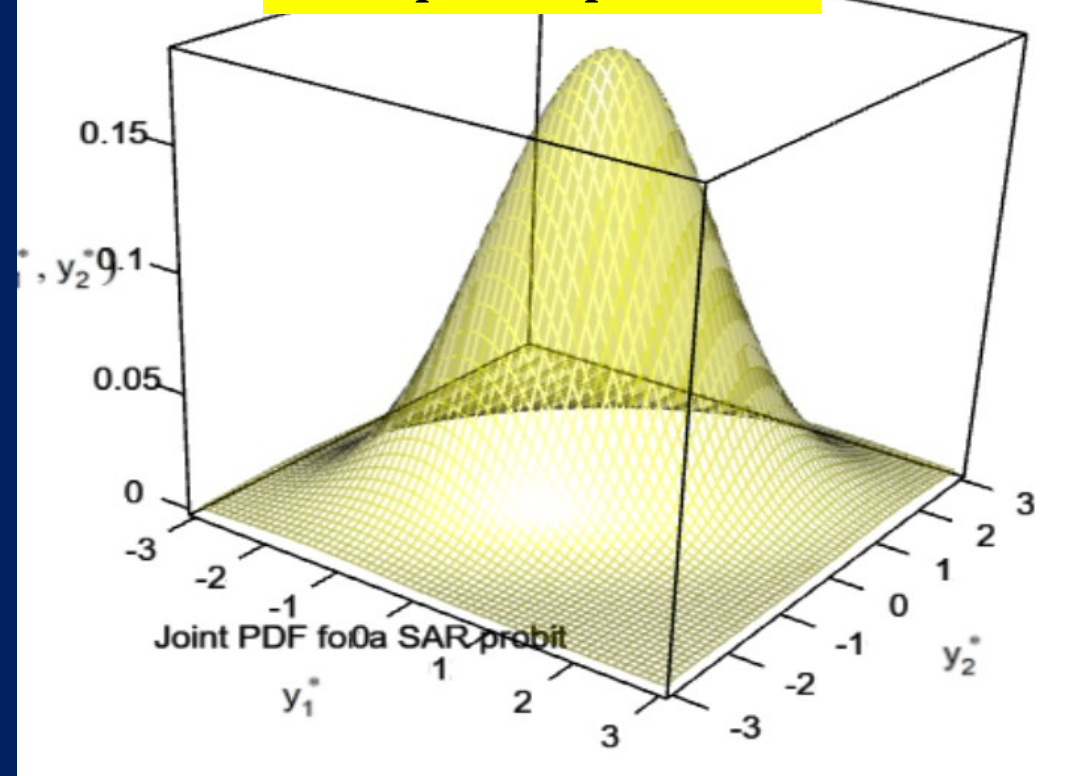
The joint probability of \mathbf{y}^* and \mathbf{y}

The problem with $N = 2$

\mathcal{L} non-spatial probit



\mathcal{L} spatial probit



Numerical integration

Simulation

Analytical approximation

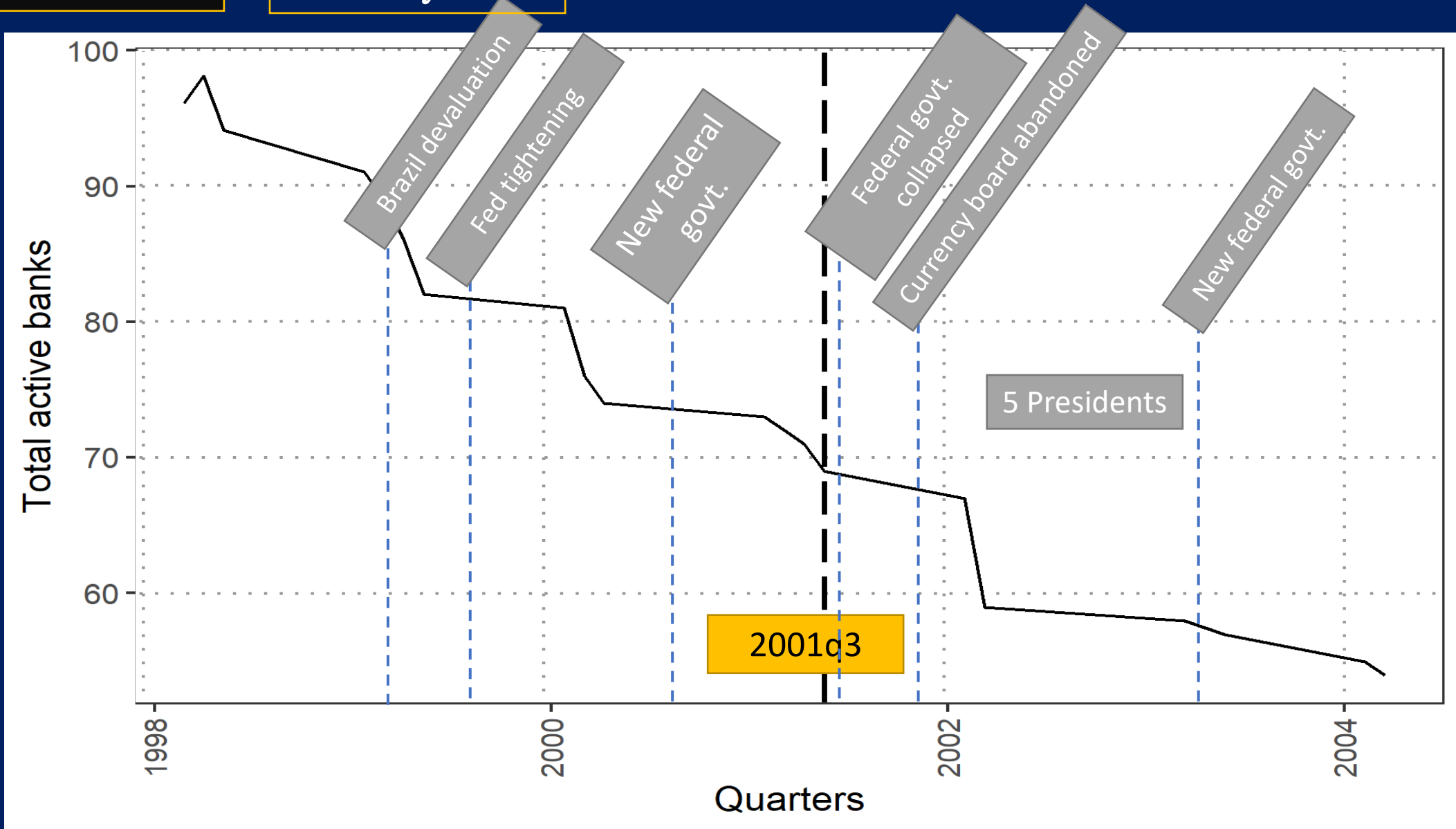
Martinetti & Genieaux (2017), *Approximate likelihood estimation of spatial probit models*

Sample description

$$\mathbf{y}_t^* = \rho \mathbf{W}_{t-1} \mathbf{y}_t^* + \mathbf{X}_{t-1} \boldsymbol{\beta} + \boldsymbol{\varepsilon}_t$$

Historical context

Currency board

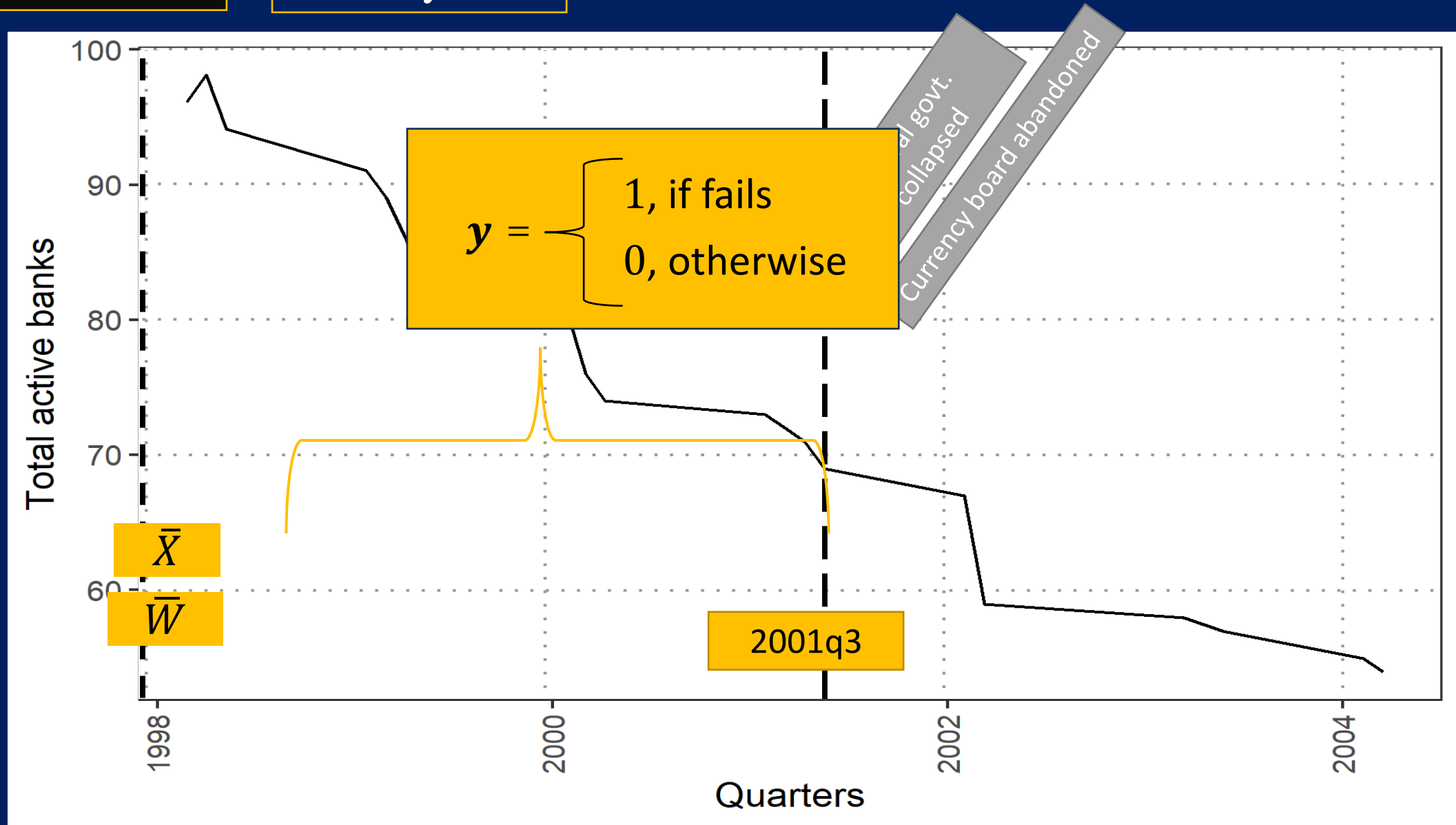


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$$\mathbf{y}_t^* = \rho \mathbf{W}_{t-1} \mathbf{y}_t^* + \mathbf{X}_{t-1} \boldsymbol{\beta} + \boldsymbol{\varepsilon}_t$$

Historical context

Currency board



The Network

$$\mathbf{y}_t^* = \rho \mathbf{W}_{t-1} \mathbf{y}_t^* + \mathbf{X}_{t-1} \boldsymbol{\beta} + \boldsymbol{\varepsilon}_t$$

Credit registry

Central Bank *Central de Deudores*

# Links	# lender banks	# borrower banks	Avg loan size
584	61	72	1.52

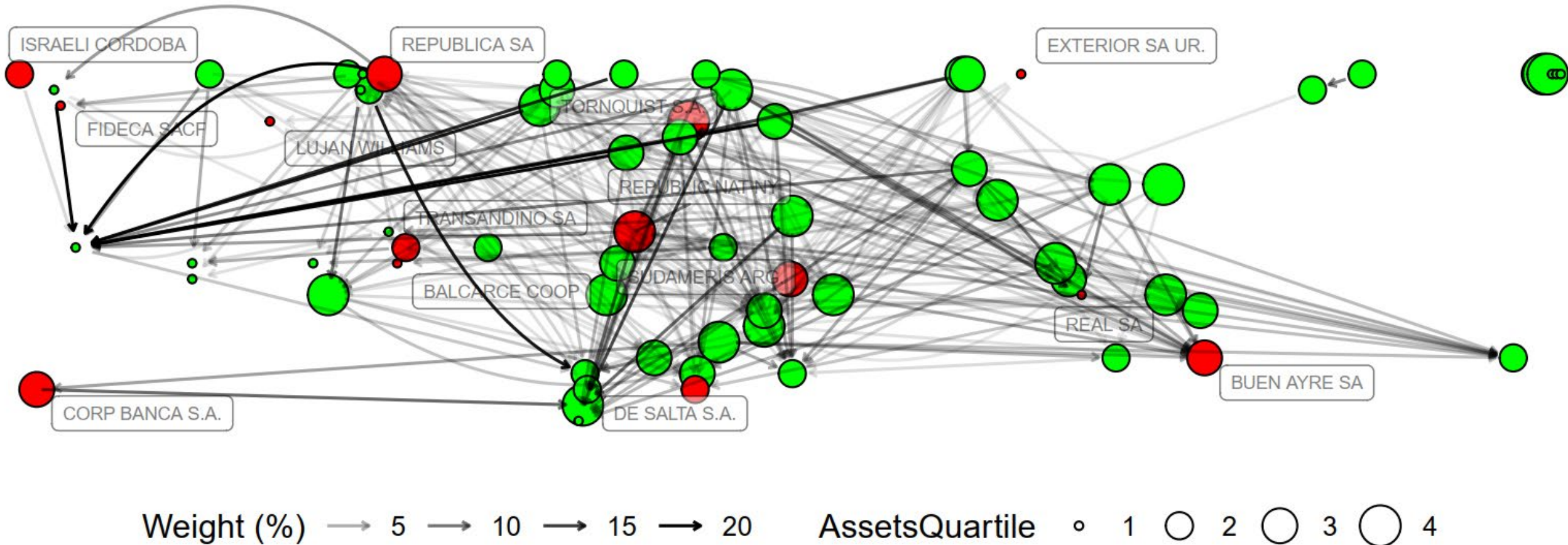
- Links are from borrower to lender.

The Network

$$\mathbf{y}_t^* = \rho \mathbf{W}_{t-1} \mathbf{y}_t^* + \mathbf{X}_{t-1} \boldsymbol{\beta} + \boldsymbol{\varepsilon}_t$$

# Links	# lender banks	# borrower banks	Avg loan size
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- 70% of failing banks were directly connected before the crisis

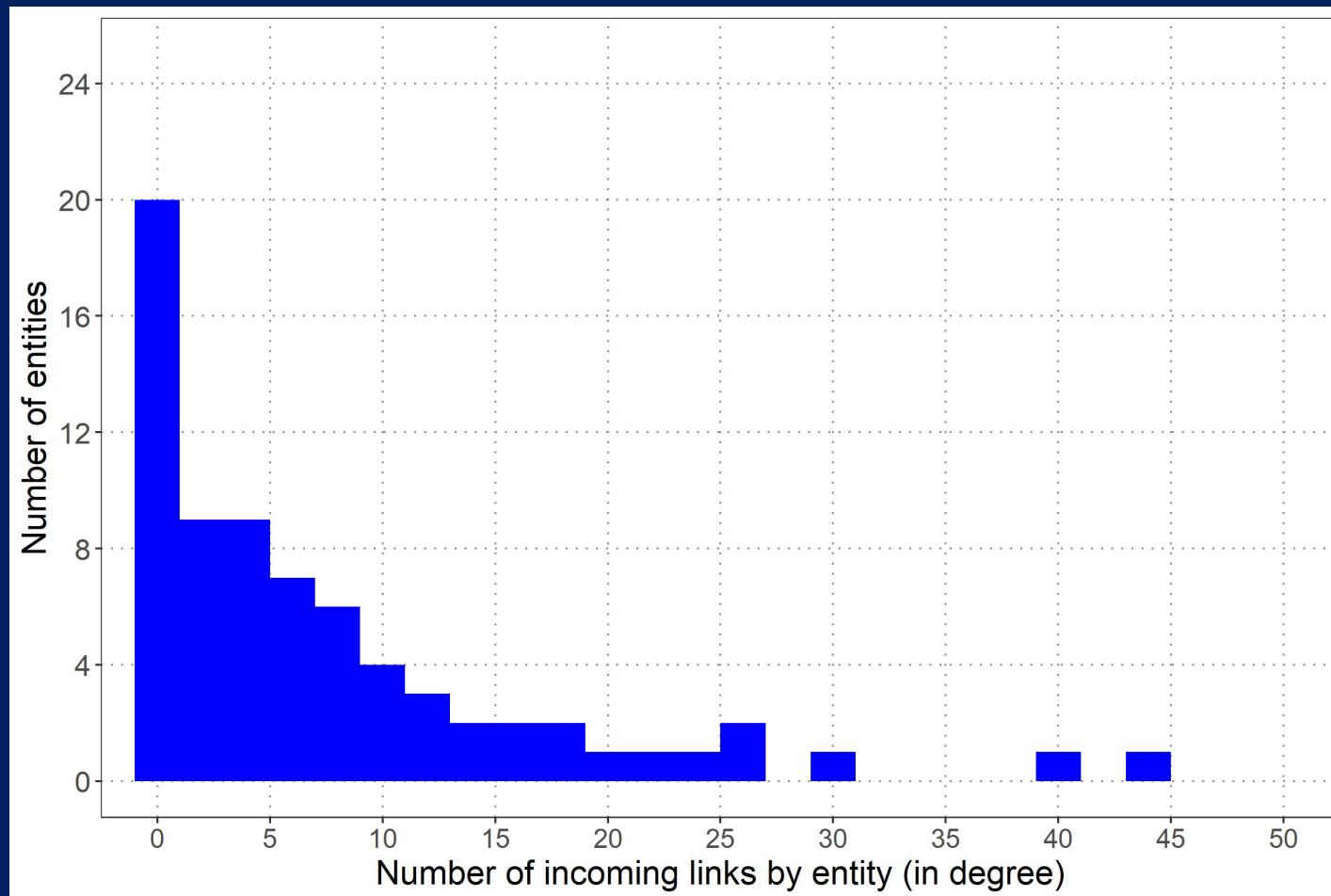


The Network

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# Links	# lender banks	# borrower banks	Avg loan size
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In-degree distribution (# assets)



Is there network contagion?

$$y_t^* = \rho W_{t-1} y_t^* + X_{t-1} \beta + \varepsilon_t$$

Coefficient estimates

Cross-section

PREDICTOR / MODEL	Predicted variable:= 1(<i>failure</i>)	
	Probit	SAR probit
Size		
Logarithm of Assets	-0.40**	-0.47***
Asset-side risk		
Non-performing loans	0.03	-1.13
Lending rate	0.96	1.01
Lending in USD	1.68	2.83
Funding		
Equity-to-Assets (%)	-4.94**	-4.20**
Spatial		
ρ		-0.53**

Panel sample - Pool

Number of observations is 72; *** p<1%, ** p<5%, * p<10%,

Is there network contagion?

$$y_t^* = \rho W_{t-1} y_t^* + X_{t-1} \beta + \varepsilon_t$$

Panel sample - Pool

With quarter fixed effect.

PREDICTOR / MODEL	Predicted variable:= 1(<i>failure</i>)			
	LPM	SAR LPM	Probit	SAR Probit
Size				
Logarithm of Assets	-0.01*	-0.01	-0.15	-0.04
Asset-side risk				
Non-performing loans	0.001	0.001	0.001	0.001
Lending rate	-0.001	-0.001	-0.02	-0.006
ROA	-0.001***	-0.001***	-0.04***	-0.02*
Funding				
Log of equity-to-Assets	-0.02**	-0.02*	-0.29**	-0.15.
Spatial				
ρ		-0.71**		-0.32***
In-degree	0.001	0.000	-0.001	0.006

Number of banks is 97. Number of observations is 938. *** p<1%, ** p<5%, * p<10%, . p<15%

The network dampens shocks

$$\mathbf{y}_t^* = -0.53W_{t-1}\mathbf{y}_t^* + X_{t-1}\boldsymbol{\beta} + \boldsymbol{\varepsilon}_t$$

$$\hat{\rho} = -0.53$$

$$\mathbf{y}^* = \cdots (\mathbf{I}_N - \rho W)^{-1} \boldsymbol{\varepsilon}$$

with $W\mathbf{1}_N = \mathbf{1}_N$.

$$(\mathbf{I}_N - \rho W)^{-1} \approx \mathbf{I}_N + \rho W + \rho^2 W^2 + \cdots$$

The network multiplier

$$\frac{1}{1 - \rho} = 0.65 < 1$$

- $\rho < 0 \rightarrow$ “substitution effect” of failures

Is there network contagion?

$$\mathbf{y}_t^* = -0.53W_{t-1}\mathbf{y}_t^* + X_{t-1}\boldsymbol{\beta} + \boldsymbol{\varepsilon}_t$$

Yes. The failure of a bank *reduces* its neighbors failure probability

Why?

A bank failure increases liquidity

- On the asset side of the failing bank (Diamond & Rajan 2001)
- In the system through the Deposit Insurance Corporation

The network funnels this extra liquidity to neighbor banks

Is there network contagion?

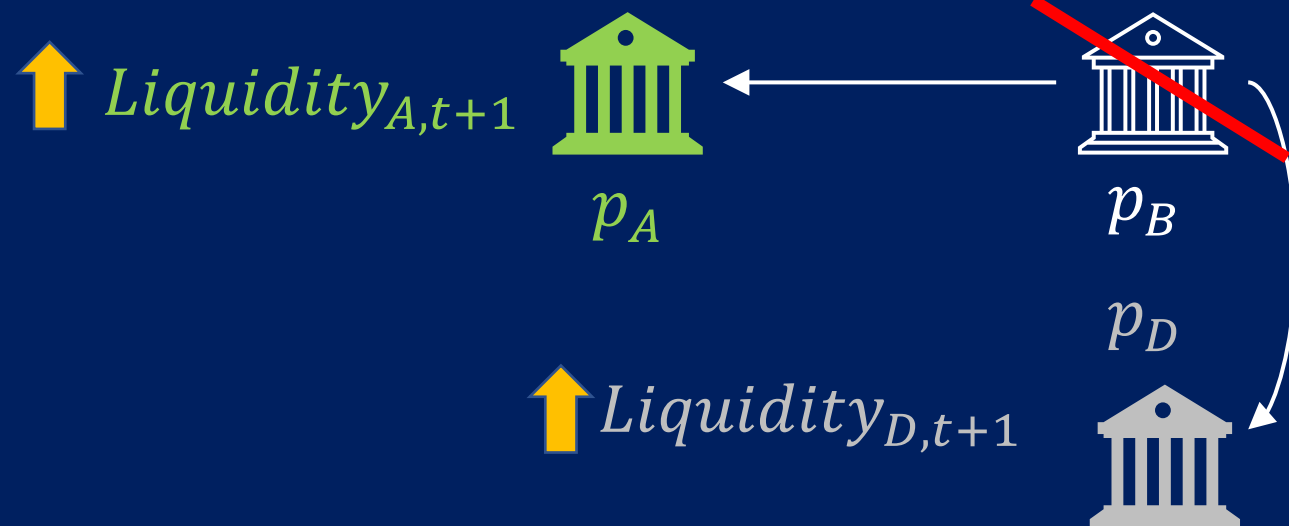
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Yes. The failure of a bank *reduces* its neighbors failure probability

The network funnels this extra liquidity to neighbor banks

After a failure surviving neighbours (lenders) increase

- liquid assets by 5%
- deposits by 0.5%



Who buys a failing bank?

50% the failing banks were bought by their neighbors in the network

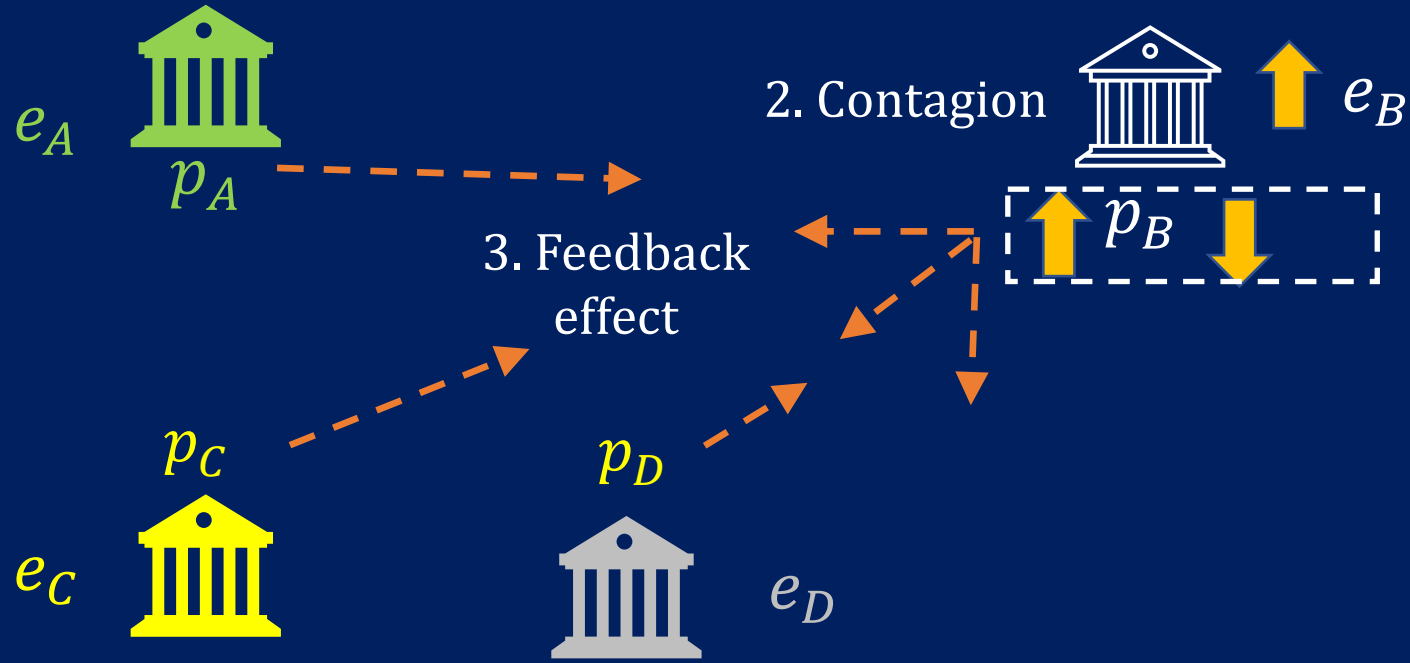
The network *protects* the banking system

Consequences of network contagion

The direct marginal effect of equity

$$E \left[\frac{\partial p_i}{\partial x_{i,e}} \right]$$

Own spillover effect	SAR Probit			Probit
	Direct	Indirect	Total	
Equity-to-Assets	-0.84		-0.54	-1.08



- 1. Bank B increases equity
- 4. Direct effect on B

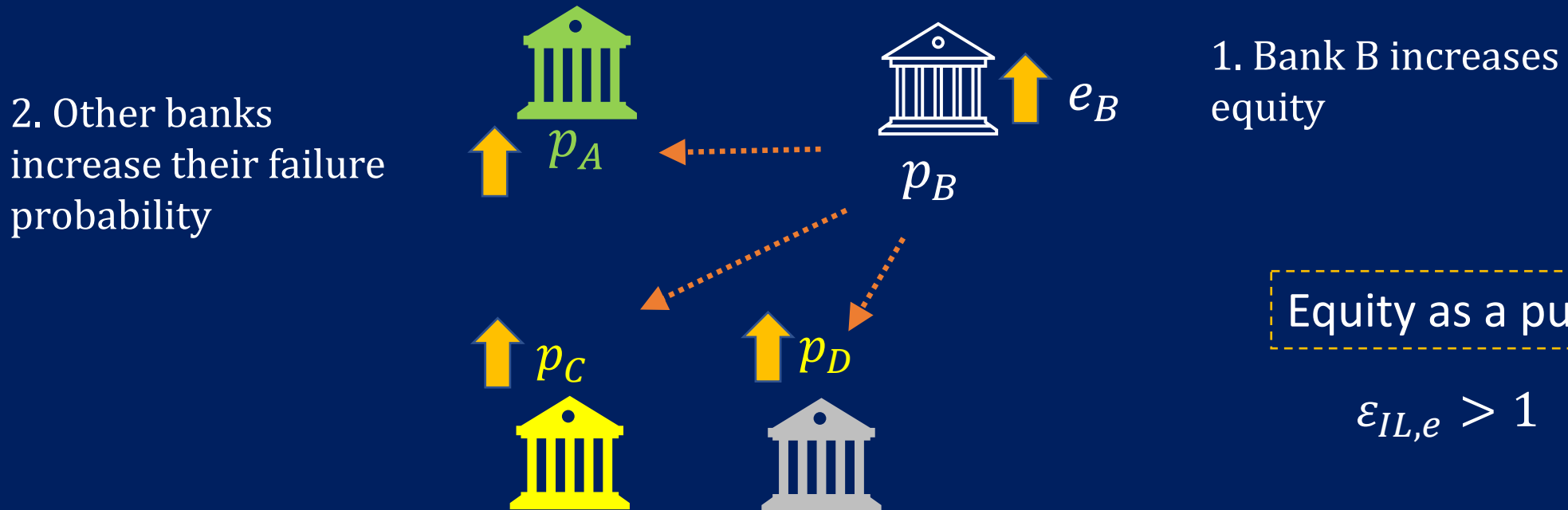
Consequences of network contagion

The indirect marginal effect of equity

$$E \left[\frac{\partial p_i}{\partial x_{j,e}} \right]$$

Spillover effect

	SAR Probit		Total	Probit
	Direct	Indirect		
Equity-to-Assets	-0.84	0.30	-0.54	-1.08



Consequences of network contagion

The total marginal effect of equity

Equity-to-Assets	SAR Probit		Total	Probit
	Direct	Indirect		
	-0.84	0.30	-0.54	-1.08

Equity is 50% less effective when banks are interconnected

$$E \left[\frac{\partial p_i}{\partial x_{i,e}} \right] + E \left[\frac{\partial p_i}{\partial x_{j,e}} \right] = E \left[\frac{\partial p}{\partial x_e} \right]$$

Consequences of network contagion

The total marginal effect of lending in USD

	SAR Probit		Total	Probit
	Direct	Indirect		
Equity-to-Assets	-0.84	0.30	-0.54	-1.08
Lending in USD	0.56	-0.20	0.37	0.37

Lending in the USD is the same?

$$E \left[\frac{\partial p_i}{\partial x_{i,e}} \right] + E \left[\frac{\partial p_i}{\partial x_{j,e}} \right] = E \left[\frac{\partial p}{\partial x_e} \right]$$

Strategic interactions:
Farhi & Tirole (2012)

Conclusions & further agenda

Network

Complete and observable network of interbank linkages

The spatial approach

Captures feedback and higher-order effects
Separately identifies spillover effects

Results

The network protected the banking system

Equity buffers are 50% less effective

Lender banks become more liquid after their borrowers fail

Failing banks were bought by their lenders in the network

Credit supply?

The Network

$$\mathbf{y}^* = \rho \mathbf{W} \mathbf{y}^* + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}$$

Interbank loans

(Overnight) Interbank market

Forte (2020)

Balance sheet

Veld Lelyveld (2014)

Credit registry

Central Bank *Central de Deudores*

$\mathbf{W} =$

	Bank A	Bank B	Bank C	TOTAL
Bank A	0	?	?	100
Bank B	?	0	?	120
Bank C	?	?	0	15

TOTAL	60	25	150	0
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The Network

$$y^* = \rho W y^* + X\beta + \varepsilon$$

Credit registry

Central Bank *Central de Deudores*

Links weighted from the lender bank perspective



Date	Lender bank name	Lender bank ID	Debtor TFN	Debtor name	Debtor bank ID	Loans ARS\$
1998m7	CREDICOOP COOP.LTDO.	191	30500000747	BANCO COMERCIAL DE TRES ARROYO	107	0.60
1998m7	BANSUD S.A.	67	30500000747	BANCO COMERCIAL DE TRES ARROYO	107	13.00
1998m7	BANKBOSTON, NATIONAL ASSOCIA...	15	30500000747	BCO DE TRES ARROYOS	107	0.20
1998m7	MORGAN GUARANTY TRUST CO OF ...	165	30500001735	BANCO DE GALICIA Y BUENOS AI...	7	0.00
1998m7	RIO DE LA PLATA S.A.	72	30500001735	BANCO DE GALICIA Y BS AS	7	861.00
1998m7	NAZIONALE DEL LAVORO S.A.	265	30500001735	BANCO DE GALICIA Y BUENOS AIR...	7	20,003.50
1998m7	REAL DE ARGENTINA S.A.	167	30500001735	BANCO DE GALICIA Y BS AS	7	2,500.40
1998m7	BANK OF AMERICA S.A.	3	30500001735	BCO DE GALICIA Y BUENOS AIRES	7	4,568.70
1998m7	DE GALICIA Y BUENOS AIRES	7	30500001735	BCO GALICIA Y BS AS SOC DEP F...	7	92.00
1998m7	QUILMES S.A.	43	30500001735	BANCO DE GALICIA Y BUENOS AIRE	7	91.40
1998m7	MBA BANCO DE INVERSIONES S.A.	312	30500001735	BANCO DE GALICIA Y BUENOS AIR...	7	0.00
1998m7	B.I.CREDITANSTALT S.A.	147	30500001735	BANCO DE GALICIA Y BUENOS AIR...	7	0.00
1998m7	DO BRASIL S.A.	46	30500001735	BANCO DE GALICIA Y BUENOS AIR...	7	18.30

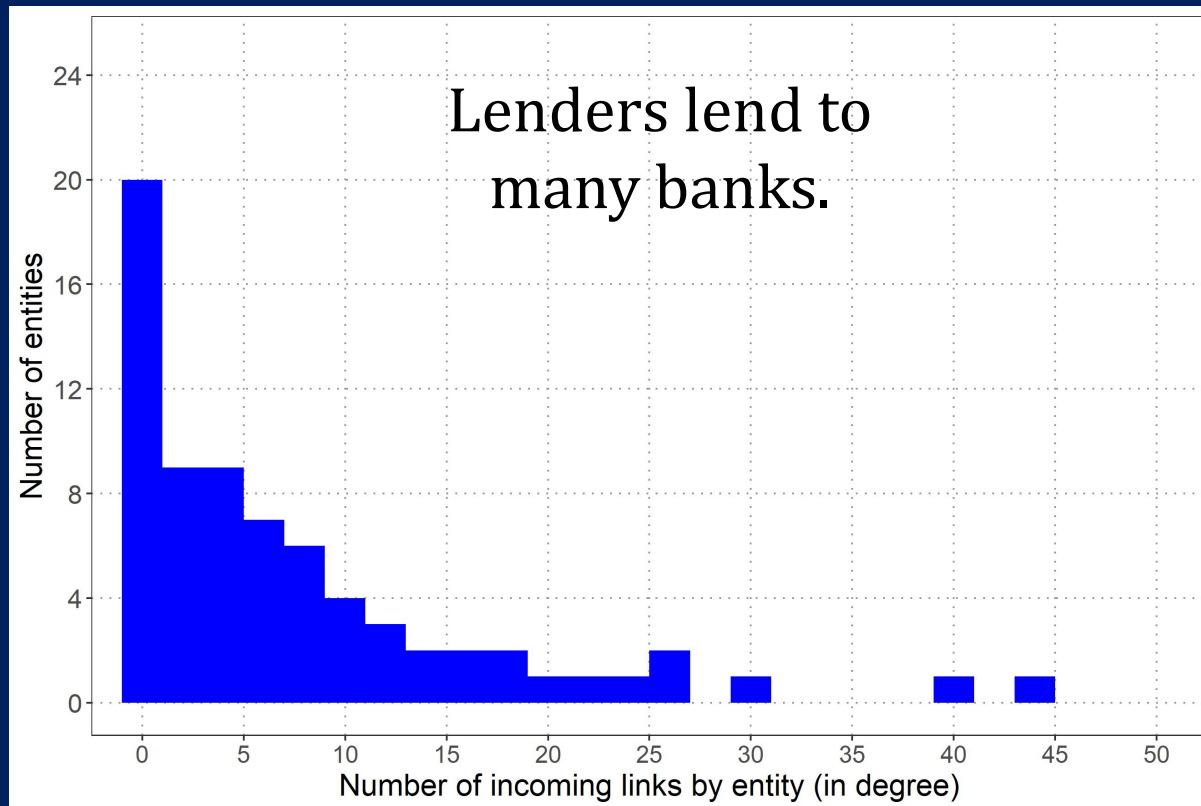
The Network

$$\mathbf{y}^* = \rho \mathbf{W} \mathbf{y}^* + \mathbf{X} \boldsymbol{\beta} + \boldsymbol{\varepsilon}$$

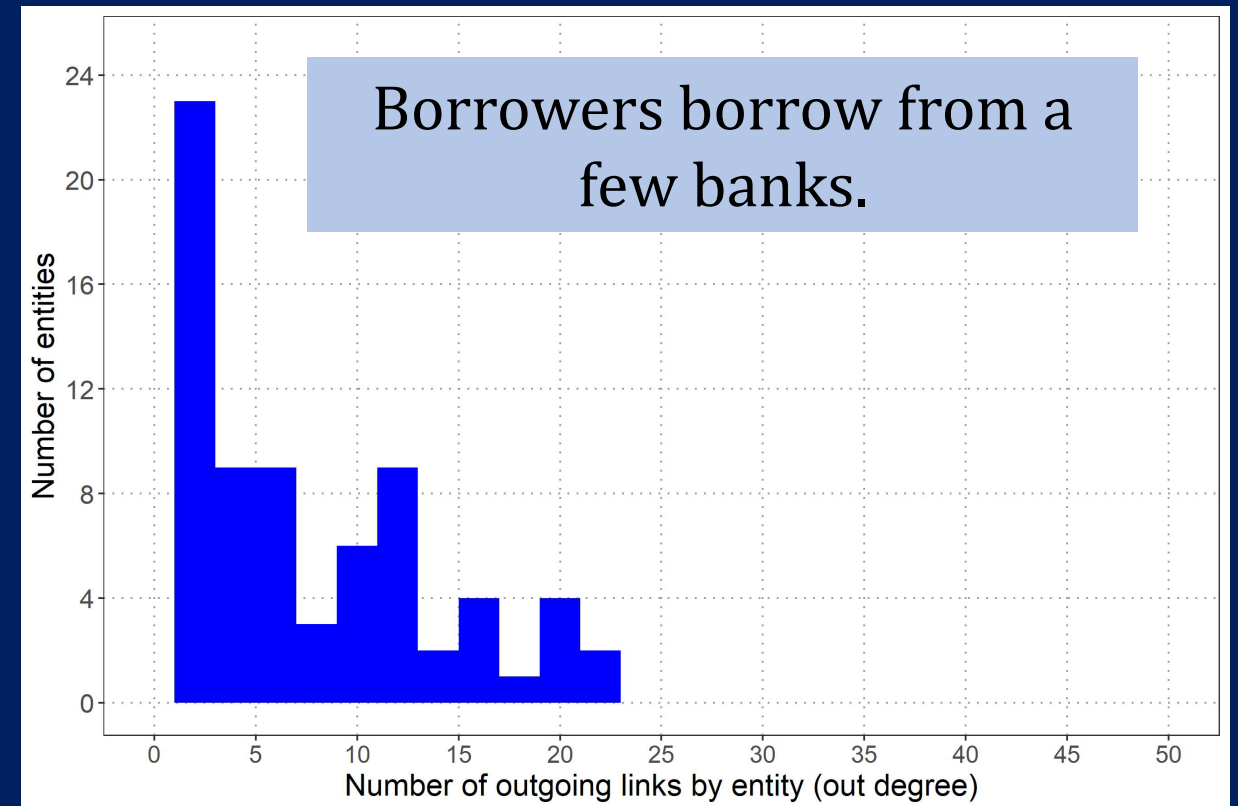
Links are from borrower to lender

# Links	# lender banks	# borrower banks	Avg loan size (% lender total loans)
584	72	61	1.52

In-degree distribution (# assets)



Out-degree distribution (# debts)



Sample description

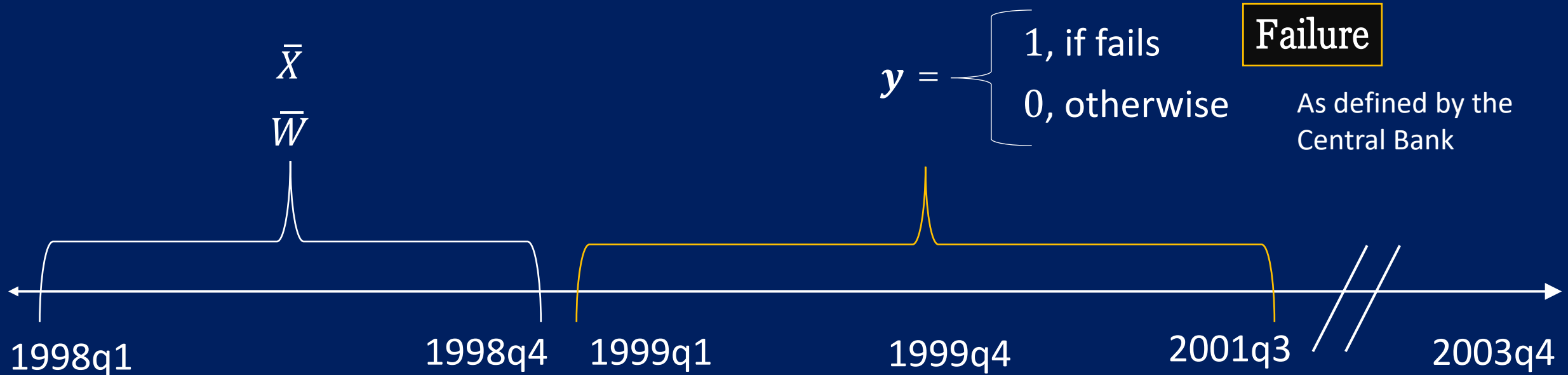
$$\mathbf{y} = \rho \mathbf{W} \mathbf{y} + \mathbf{X} \boldsymbol{\beta} + \boldsymbol{\varepsilon}$$

Entities

- Active at 1997q4
- Local private
- Complete observations
- In the network

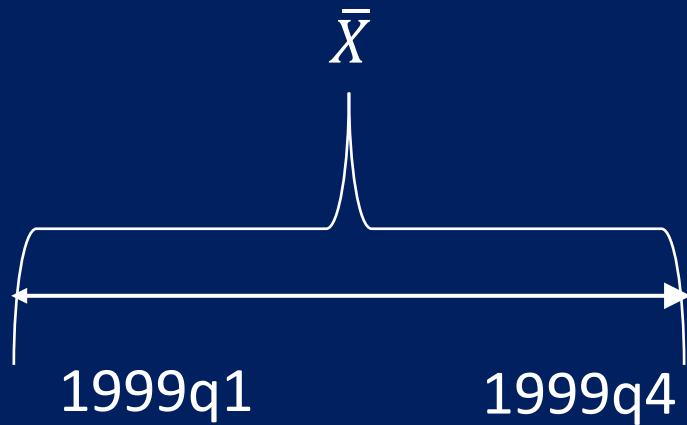
N	72
Failure rate	0.19

Time



$$y = \rho W y + X\beta + \varepsilon$$

Sample description



- Annual predictors: within average for **1998**
- Failure between 1999q1 y 2001q3

N	72
Failure rate	0.19

Predictor	Mean	Coef. of variation
Size		
Assets in ARS \$ (mill)	1,341	1.9
Credit risk		
Non-performing assets (%)	7.66	0.71
Lending rate (%)	23.3	0.4
Lending to Public Sector (%)	4.19	1.9
Lending in USD (%)	57.8	0.4
Loans-to-Assets (%)	51.1	0.3
Funding		
Equity-to-Assets (%)	15.8	0.7
Return-on-Assets (%)	0.9	3.1
Deposit rate (%)	5.20	0.56