Contagion of bank failures through the interbank network in Argentina

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Australian Conference of Economists
Brisbane, July 2023

Research supported through an Australian Government RTP Scholarship, the University of Western Australia Dean's Excellence PhD Scholarship and the ARC grant DP200101498: “Selection of mixed strength moment restrictions and optimal inference”

Introduction

Why study bank failures?

Doerr et al (2022), *Financial Crisis and Political Radicalization: How Failing Banks Paved Hitler's Path to Power*

Why do banks fail?

Contract theory. Focus on equity (*financial* capital)

Capital regulation (Basel)

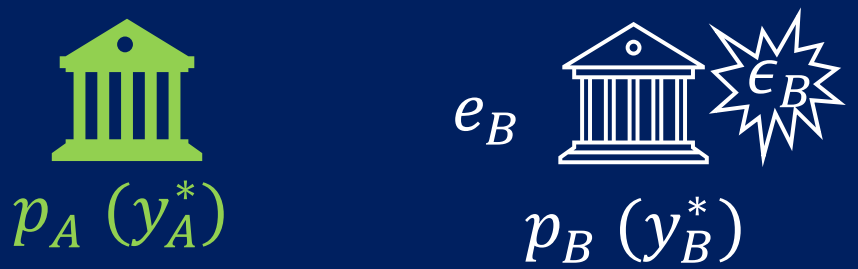
Network theory. Focus on the interconnectedness of the banking system

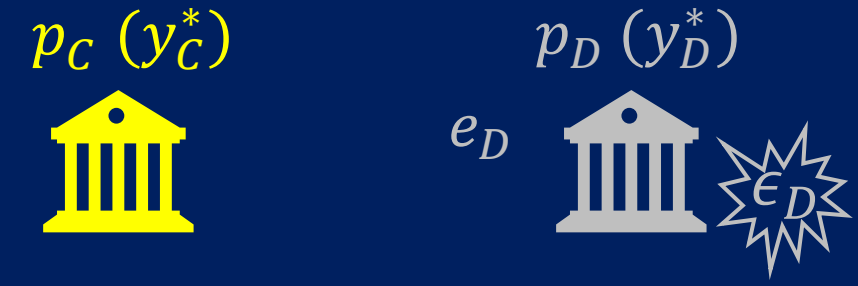
- Is there network contagion?
- If so, is capital regulation effective?

Why do banks fail?

Contract theory: capital structure

- **Propensity** to failure y_i^* for bank i depends on equity e_i
- **Probability** of failure $p_i(y_i^*)$ for bank i





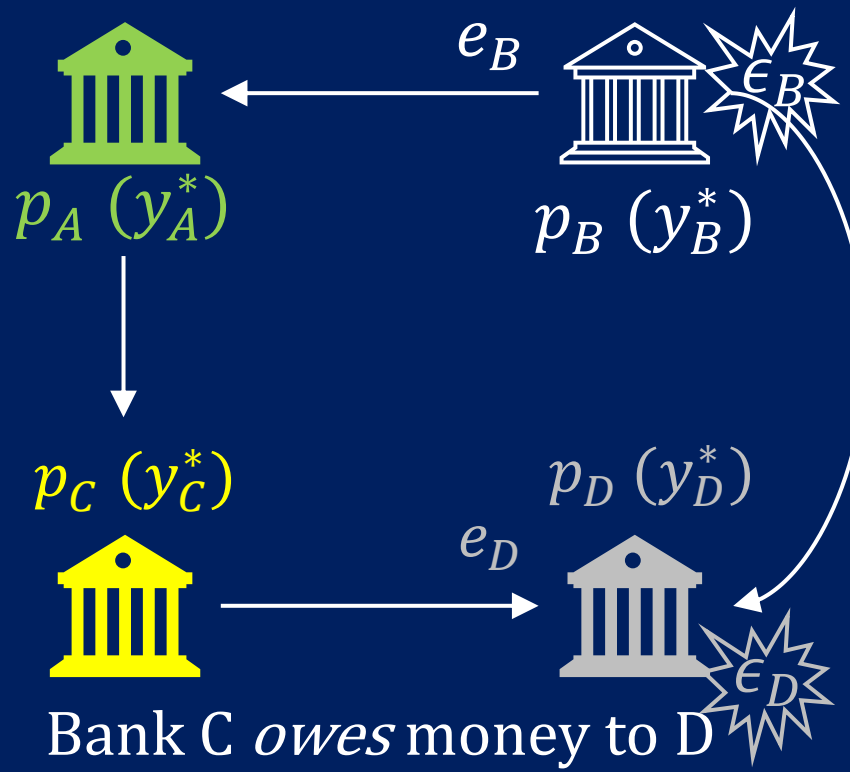
The equity buffer e_i

"Virtually all such [empirical] studies find that low capital ratios raise the probability of bank failure."
Berger & Roman (2020)

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

The $in\ degree_i$ of node i

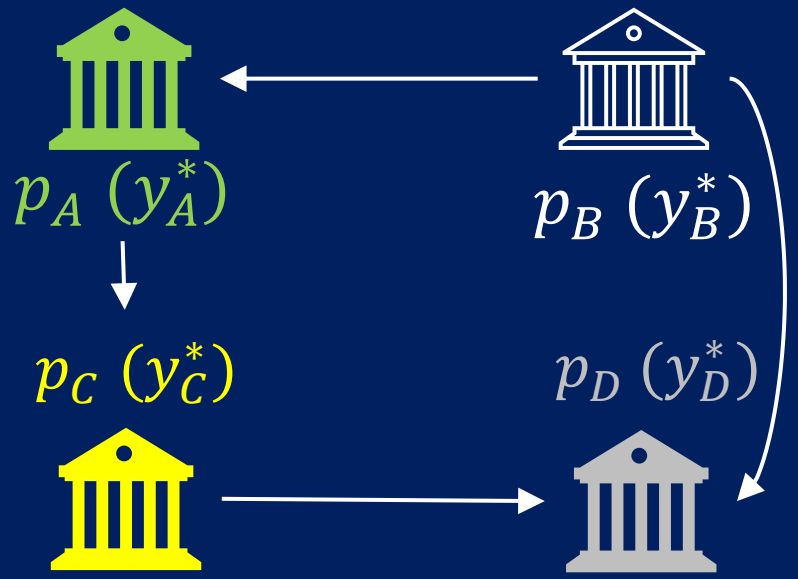
$p_i \propto in\ degree_i$

Virtually all such studies assume independent and thus isolated banks.

Network data

The spatial approach

The weight matrix



Bank C *owes* money to D

W =

Borrower →

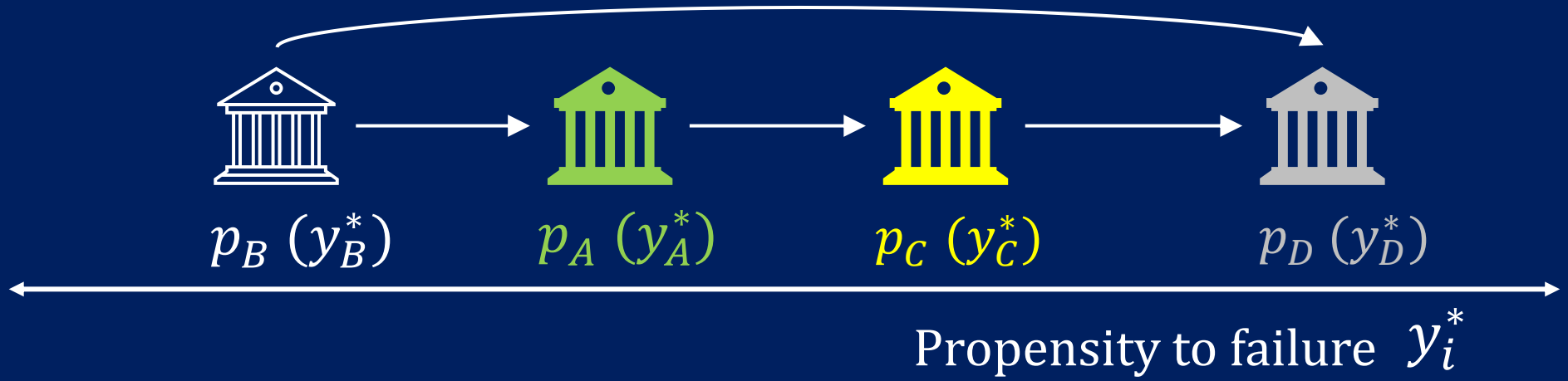
	Bank A	Bank B	Bank C	Bank D
Bank A	0	0	0.2	0
Bank B	0.1	0	0	0.3
Bank C	0	0	0	0.4
Bank D	0	0	0	0

$$w_{C,D} = \frac{Loan\ \$}{Total\ loans\ D\ \$}$$

Main diagonal is 0

The spatial approach

Spatial autoregressive process (SAR)



The latent variable is spatially correlated

- System of equations
- W main diagonal is 0
- The scalar $\rho \in (0,1) \approx$ a correlation coefficient

$$\mathbf{y}^* = \rho \mathrm{W}\,\mathbf{y}^* + \mathrm{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \qquad \boldsymbol{\varepsilon} \sim \boldsymbol{\mathcal{N}}(\mathbf{0}, \mathrm{I_N})$$

Feedback effects

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

$$\approx \mathrm{I}_N + \rho W + \rho^2 \underbrace{W^2} + \rho^3 W^3 + \cdots .$$

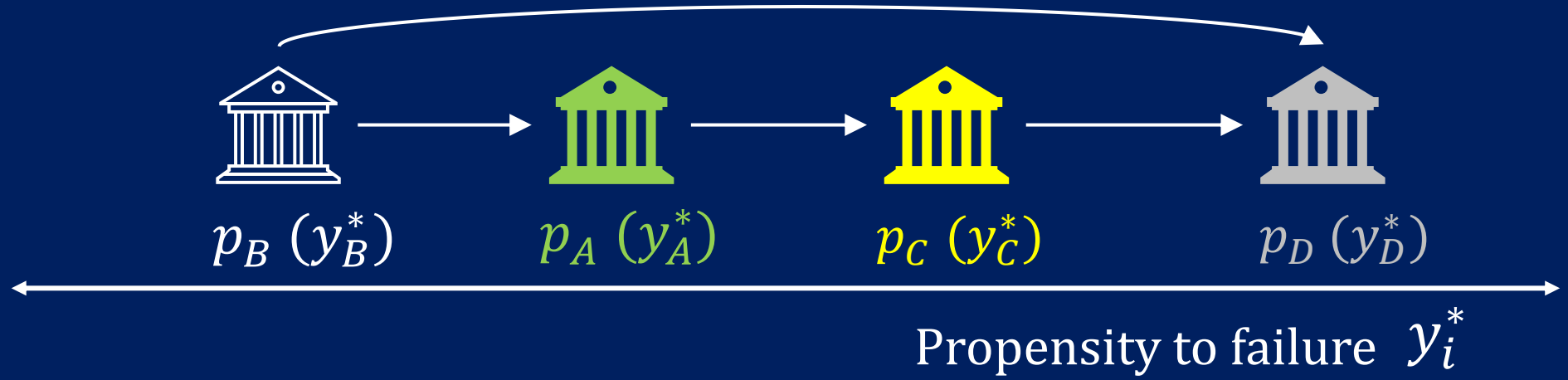
Higher-order effects

$$W^2 \equiv W \times W$$

- "The friends of your friends"

The spatial approach

The spatial probit model



The latent variable is spatially correlated

$$\mathbf{y}^* = \rho \mathrm{W}\, \mathbf{y}^* + \mathrm{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \qquad \boldsymbol{\varepsilon} \sim \mathcal{N}(\mathbf{0}, \mathrm{I_N})$$

$$p_i = \int^{N} \phi(\widehat{\boldsymbol{y}^*}) d\boldsymbol{u}$$

The joint probability of $\boldsymbol{y}^*$ and $\boldsymbol{y}$

It is N-dimensional!

The observable variable

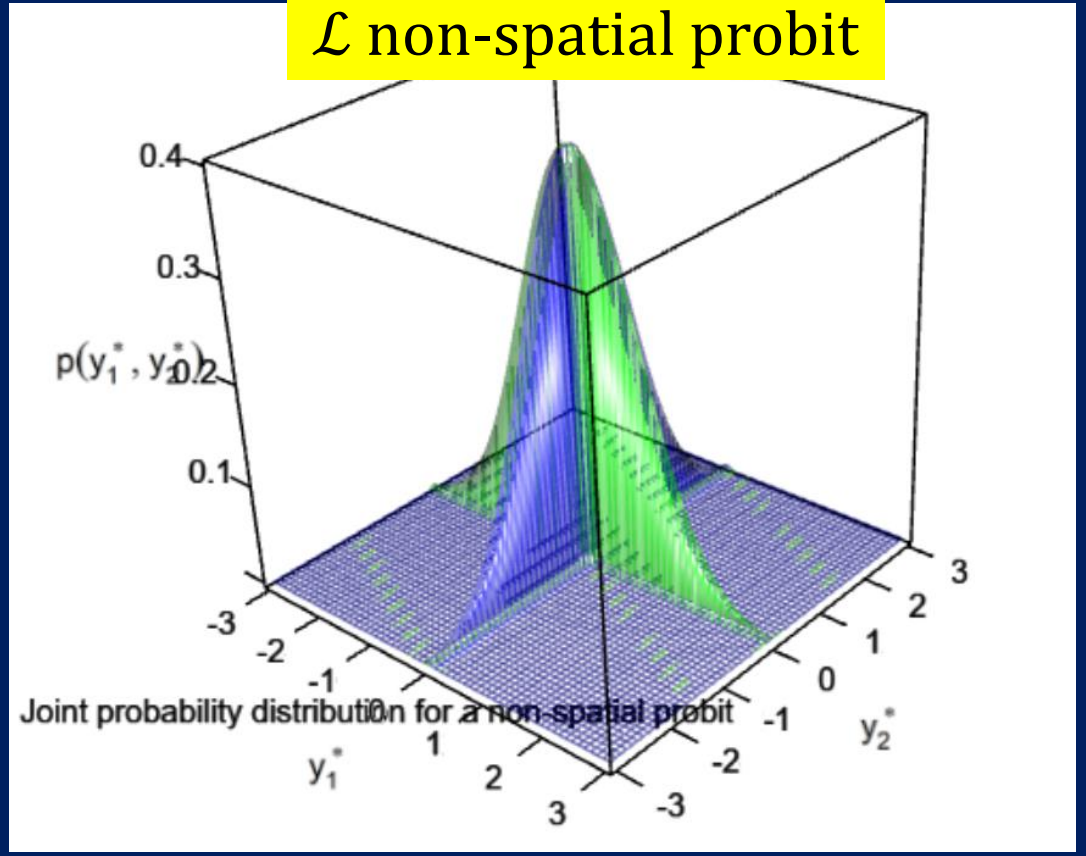
$$y_i = \begin{cases} 1, \text{ with probability } p_i \\ 0, \text{ with probability } 1 - p_i \end{cases}$$

The spatial approach

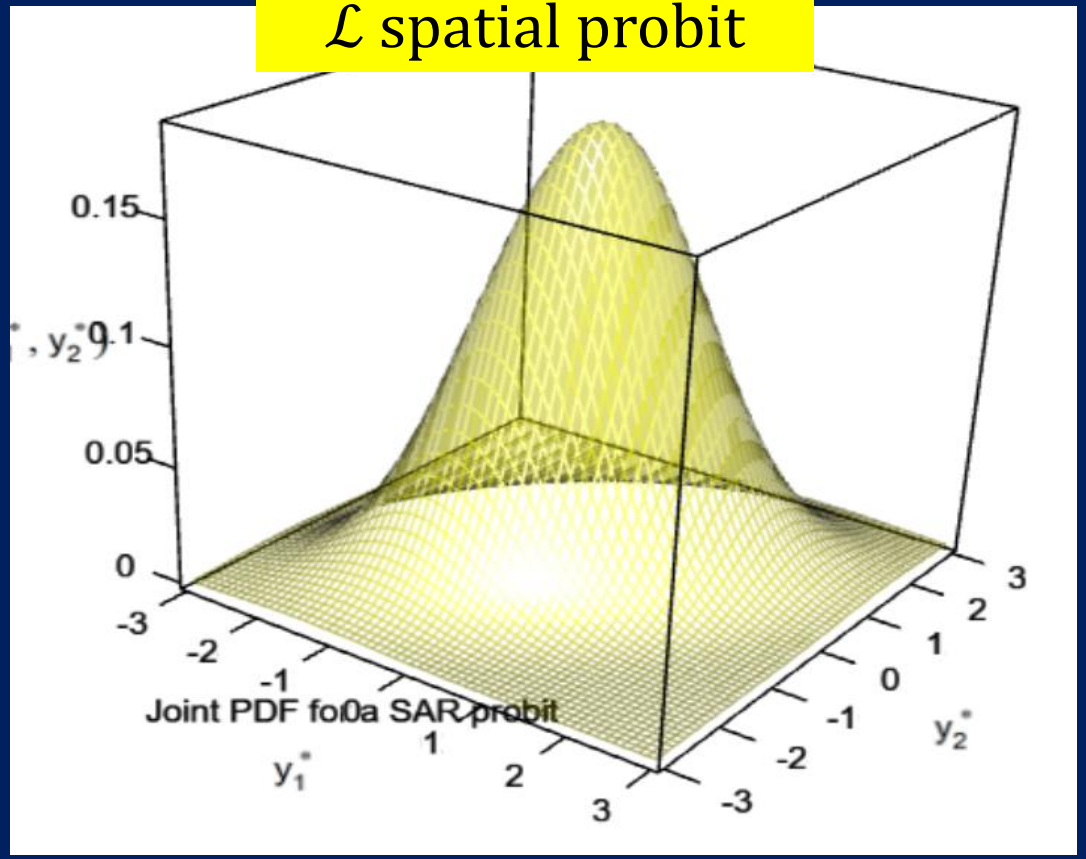
The joint probability of $\boldsymbol{y}^*$ and $\boldsymbol{y}$

The problem with $N = 2$ $\max_{\boldsymbol{\beta}, \rho} \mathcal{L}(\boldsymbol{\beta}, \rho, W)$

$\mathcal{L}$ non-spatial probit



$\mathcal{L}$ spatial probit



Numerical integration

Simulation

Analytical approximation

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

The Network

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

Interbank loans

(Overnight) Interbank market

Forte (2020)

Balance sheet

Veld Lelyveld (2014)

Credit registry

Central Bank *Central de Deudores*

Links weighted from the lender bank perspective

$W =$

	Bank A	Bank B	Bank C	Bank D	TOTAL
Bank A	0	0	?	0	$20
Bank B	?	0	0	?	$40
Bank C	0	0	0	?	$40
Bank D	0	0	0	0	0
TOTAL	$10	0	$20	$70	$100

The Network

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

Links are from borrower to lender

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

Most loans are small

70% of failing banks were directly connected before the crisis

Interactive Network

Sample description

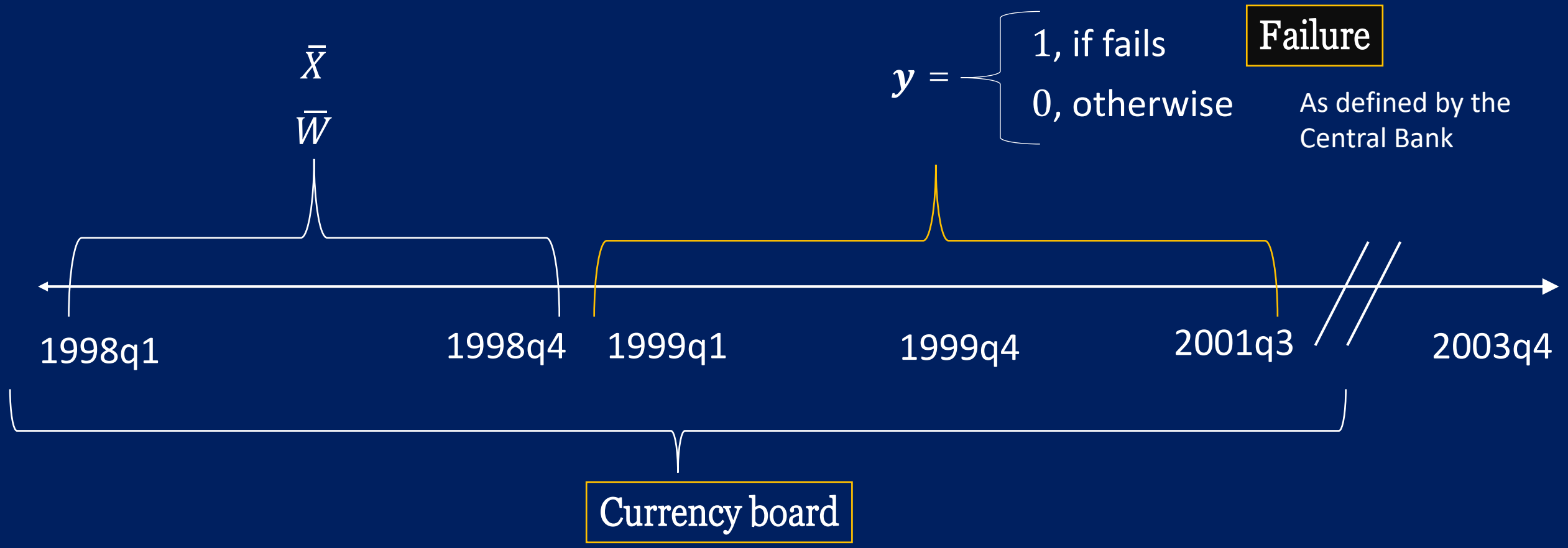
$$y = \rho W y + X\beta + \varepsilon$$

Entities

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

N	72
Failure rate	0.19

Time



Is there network contagion?

Coefficient estimates

	Predicted variable:= $\mathbf{1}(failure)$	
PREDICTOR / MODEL	Probit	SAR probit
Size		
Assets in ARS $ (mill)	-0.40**	-0.47***
Asset-side risk (%)		
Non-performing assets	0.03	-1.13***
Lending rate	0.96	1.01***
Lending to Govt	-6.00	-1.73***
Lending in USD	1.68	2.83***
Loans-to-Assets	-0.07	-0.55***
Funding (%)		
Equity-to-Assets	-4.94**	-4.20***
Spatial		
ρ		-0.53***

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

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

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

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

Is there network contagion?

$$\mathbf{y}^* = -0.53\,\mathrm{W}\,\mathbf{y}^* + \mathrm{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}$$

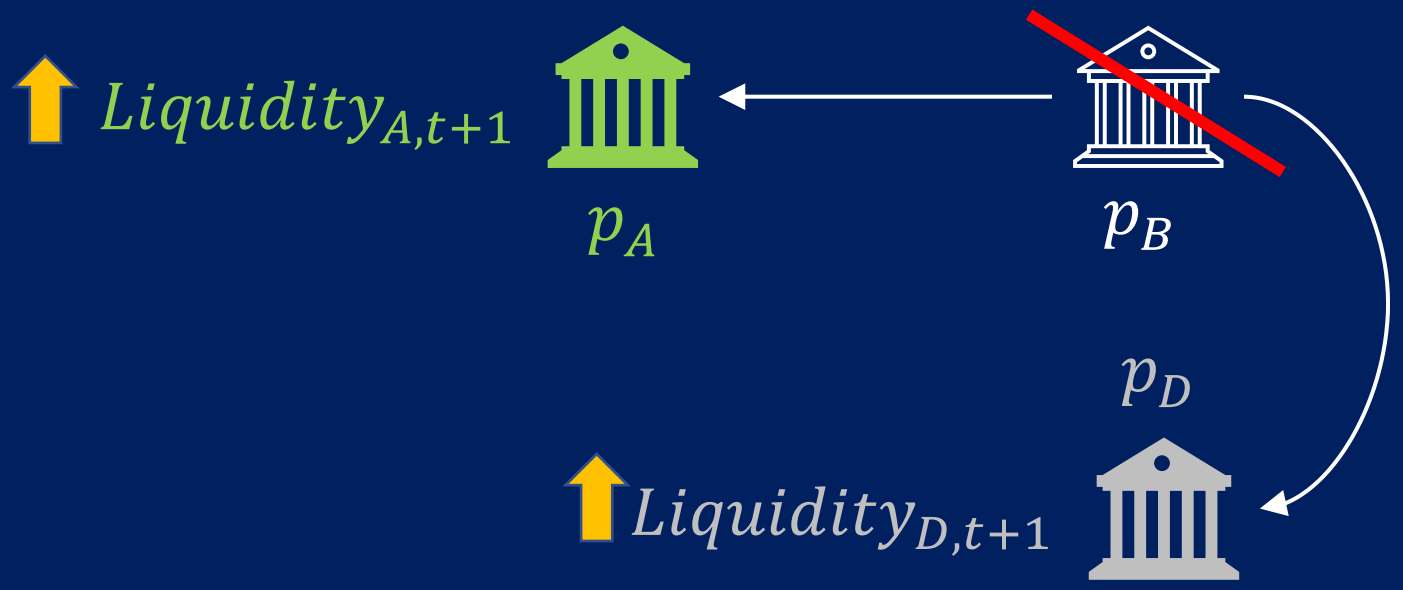
Yes. The failure of a bank *reduces* its neighbors failure probability

Why?

A bank failure increases liquidity in the system (Diamond & Rajan 2001)

The network facilities the redistribution of this extra liquidity among surviving banks

On average surviving neighbours (lenders) increase their liquid assets by 5% and their deposits by 0.5% the quarter after a failure



The network *protects* the banking system. But not necessarily the macroeconomy!

Conclusions & further agenda

Network

Complete and observable network of interbank linkages

The spatial approach

Captures feedback and higher-order effects

Separately identifies spillover effects (*Not presented!)*

Results

70% of failing banks were directly connected

Evidence of network contagion is economically and statistically significant

Lender banks become more liquid after their borrowers fail

Equity buffers are 50% less effective in a model allowing connections between banks

Further agenda

The Australian interbank network and its macrofinancial implications

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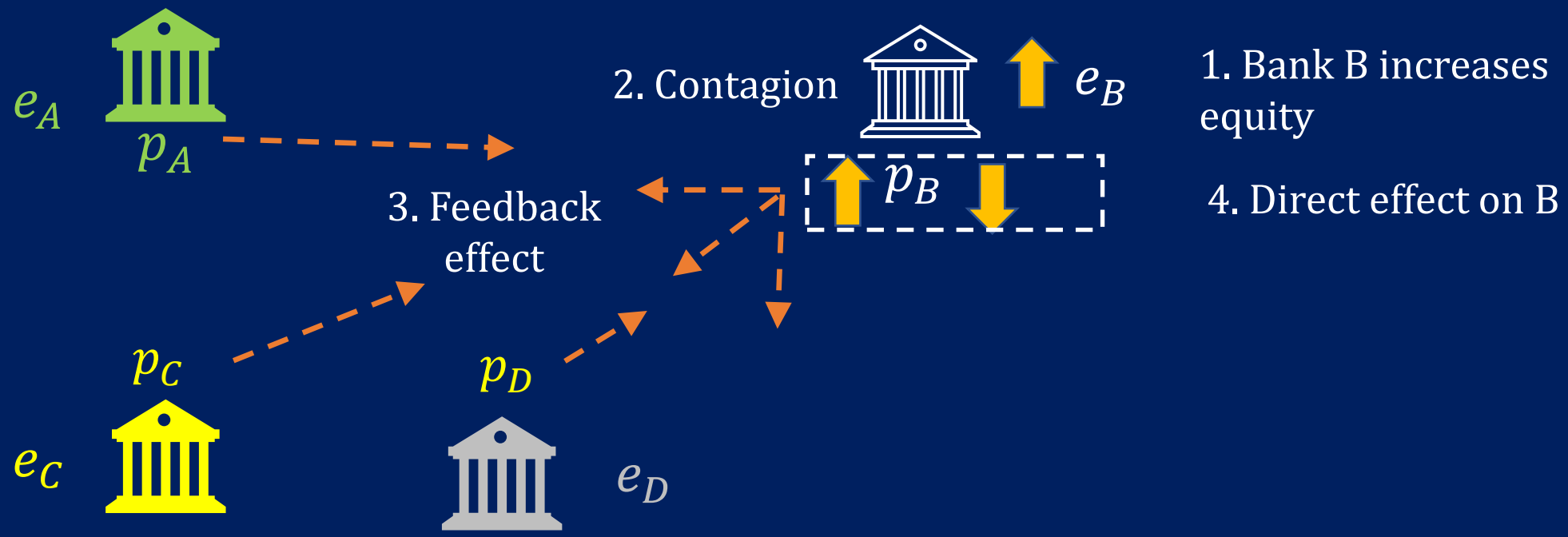
Consequences of network contagion

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



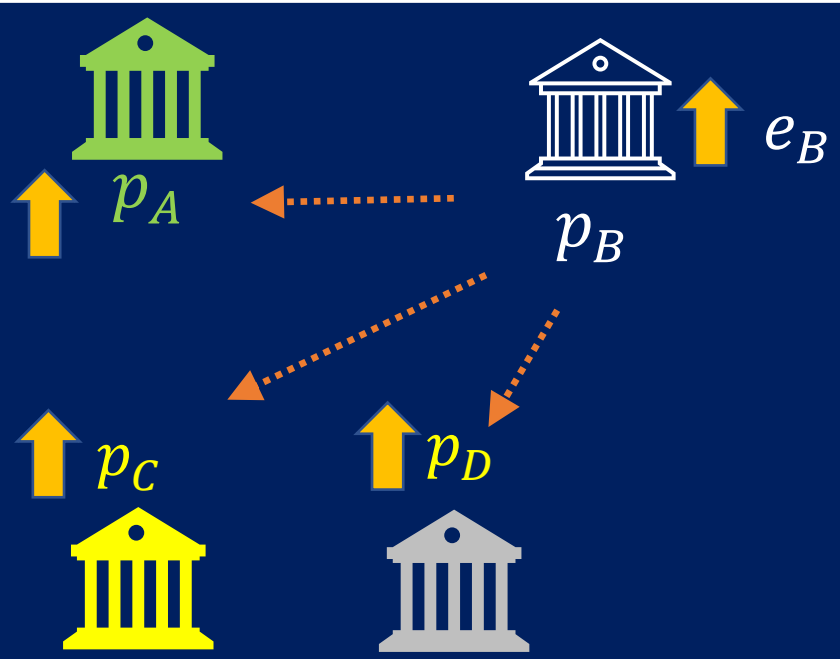
Consequences of network contagion

The indirect marginal effect of equity

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

Spillover / Vulnerability effect

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



2. Other banks increase their failure probability

1. Bank B increases equity

Equity as a public good

Strategic interactions I

Consequences of network contagion

The total marginal effect

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

Equity is 50% less effective when banks are interconnected

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

Lending in USD has the same marginal effect in both the spatial and no spatial model

but the reasons are very different!

In the spatial, when other banks increase their lending in USD it *benefits* you. "Positive" spillover.

Strategic interactions II: Farhi & Tirole (2012)

$$R_e = \left[\frac{\partial Pr(\boldsymbol{y}=1)}{\partial x_e'}\right] = \text{diag}[\phi(\boldsymbol{\eta})]\,(I_N - \rho W)^{-1}\,\beta_e.$$

$$= \begin{bmatrix} \frac{\partial \mathbb{E}y_1}{\partial x_{1,k}} & \cdots & \frac{\partial \mathbb{E}y_1}{\partial x_{i,k}} & \cdots & \frac{\partial \mathbb{E}y_1}{\partial x_{N,k}} \\ \cdots & & & & \\ \frac{\partial \mathbb{E}y_i}{\partial x_{1,k}} & \cdots & \frac{\partial \mathbb{E}y_i}{\partial x_{i,k}} & \cdots & \frac{\partial \mathbb{E}y_i}{\partial x_{N,k}} \\ \cdots & & & & \\ \frac{\partial \mathbb{E}y_N}{\partial x_{1,k}} & \cdots & \frac{\partial \mathbb{E}y_N}{\partial x_{i,k}} & \cdots & \frac{\partial \mathbb{E}y_N}{\partial x_{N,k}} \end{bmatrix}$$

Sample description

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

Historical context

Currency board