OFFICE OF FINANCIAL RESEARCH

The Multilayer Structure of the Financial System

Dror Y. Kenett

Views expressed in this presentation are those of the speaker(s) and not necessarily of the Office of Financial Research.

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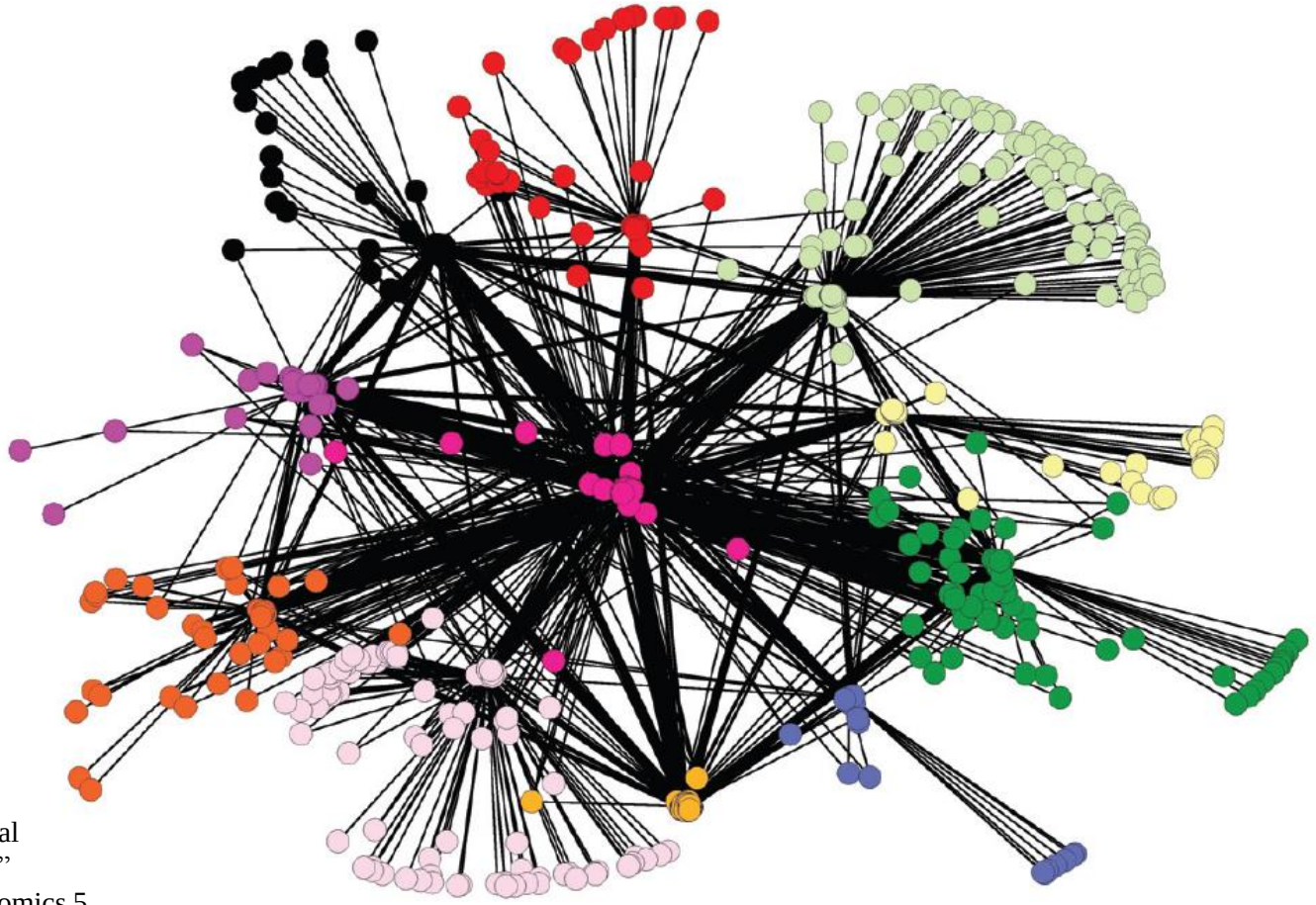
Austrian interbank network



Source: Martin Summer. «Financial Contagion and Network Analysis." Annual Review of Financial Economics 5, 277-297, 2013.

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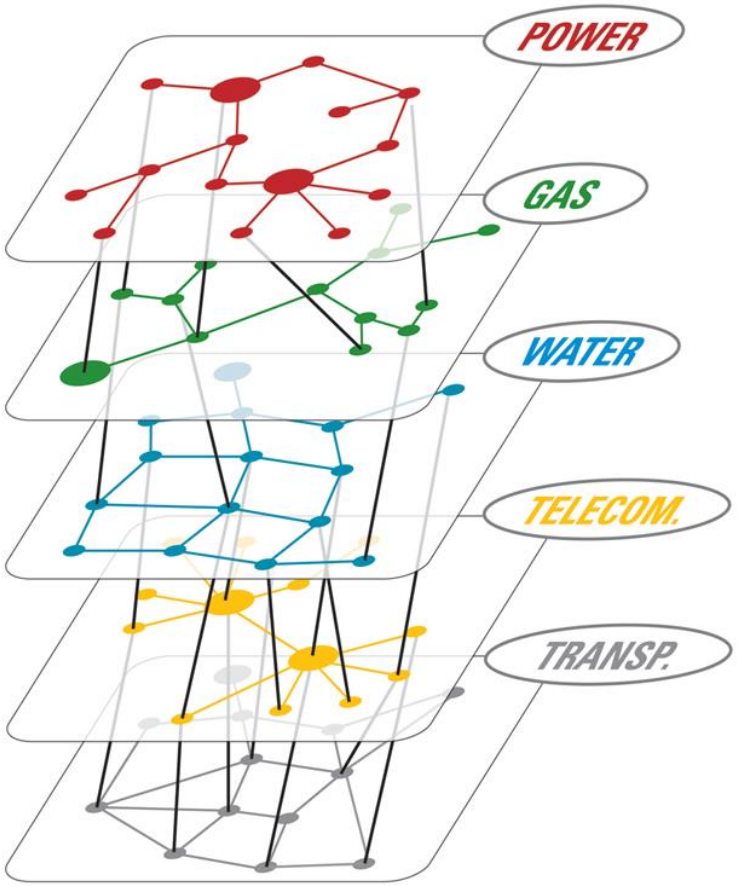
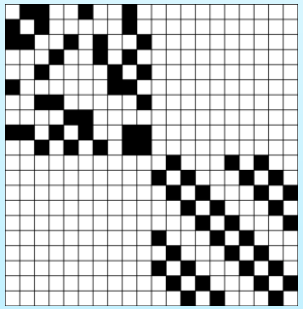
What is a multilayer network?

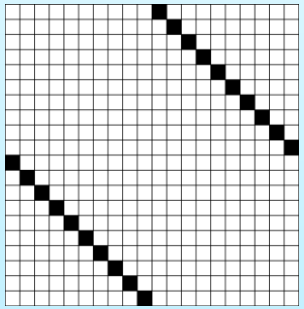


Connectivity

Dependency

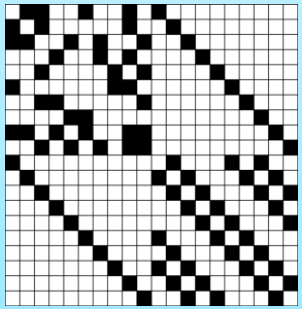
Adjacency matrix





Interconnected Networks:

Adjacency matrix



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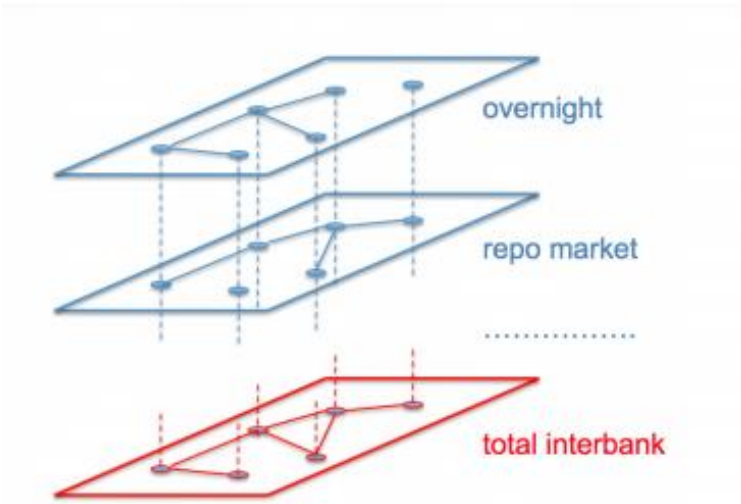
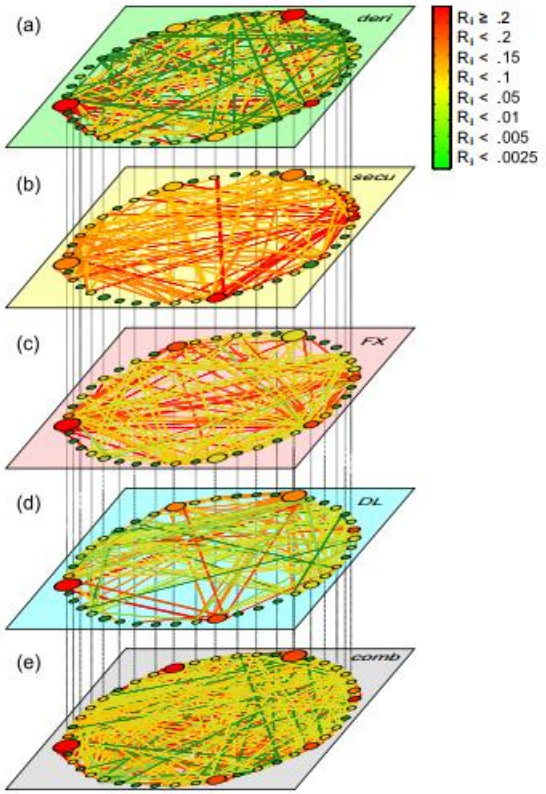
Multilayer interbank networks



Source: Leonardo Bargigli, Giovanni Di Iasio, Luigi Infante, Fabrizio Lillo, Federico Pierobon. «The multiplex structure of interbank networks". Quantitative Finance 15(4), 673-691, 2015.



Source: Sebastian Poledna, José Luis Molina-Borboa, Serafín Martínez-Jaramillo, Marco van der Leij, Stefan Thurner. "The multi-layer network nature of systemic risk and its implications for the costs of financial crises". arXiv:1505.04276, 2015.

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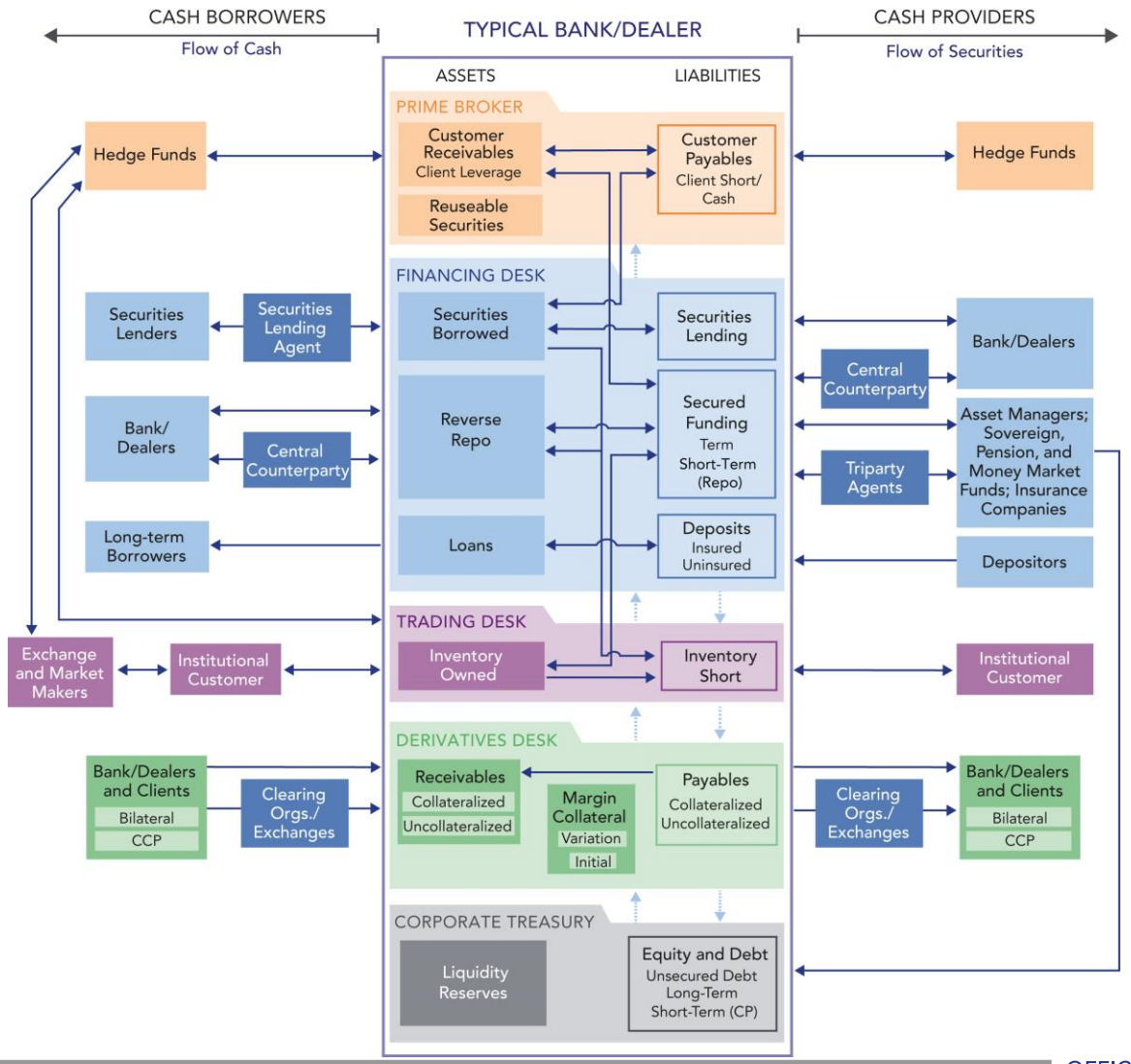
Mapping the financial system



Source: Richard Bookstaber, Dror Y Kenett. "Looking Deepr, Seeing More: A multilayer Map of the Financial System." OFR Brief 16-06.

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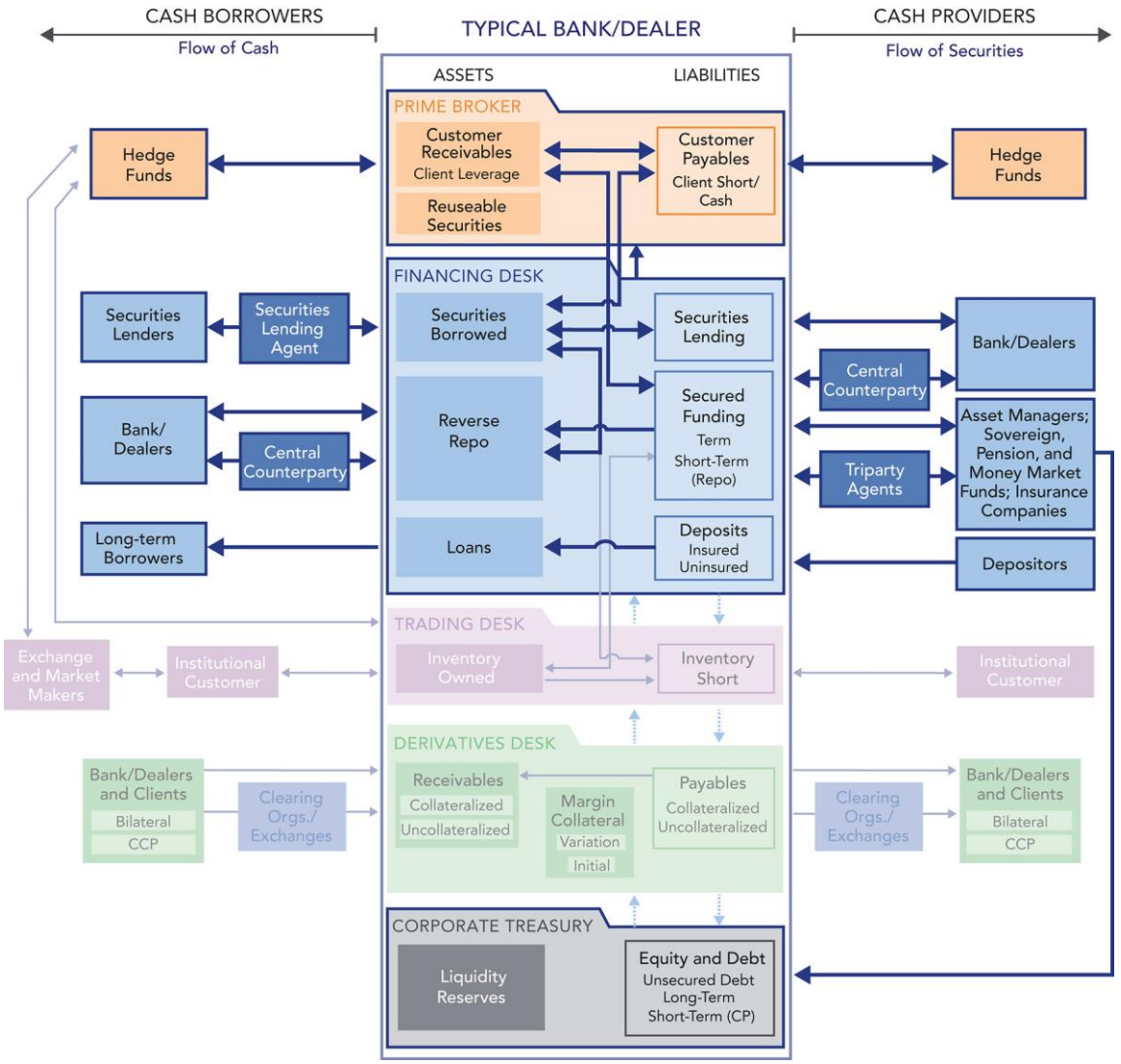
Funding layer



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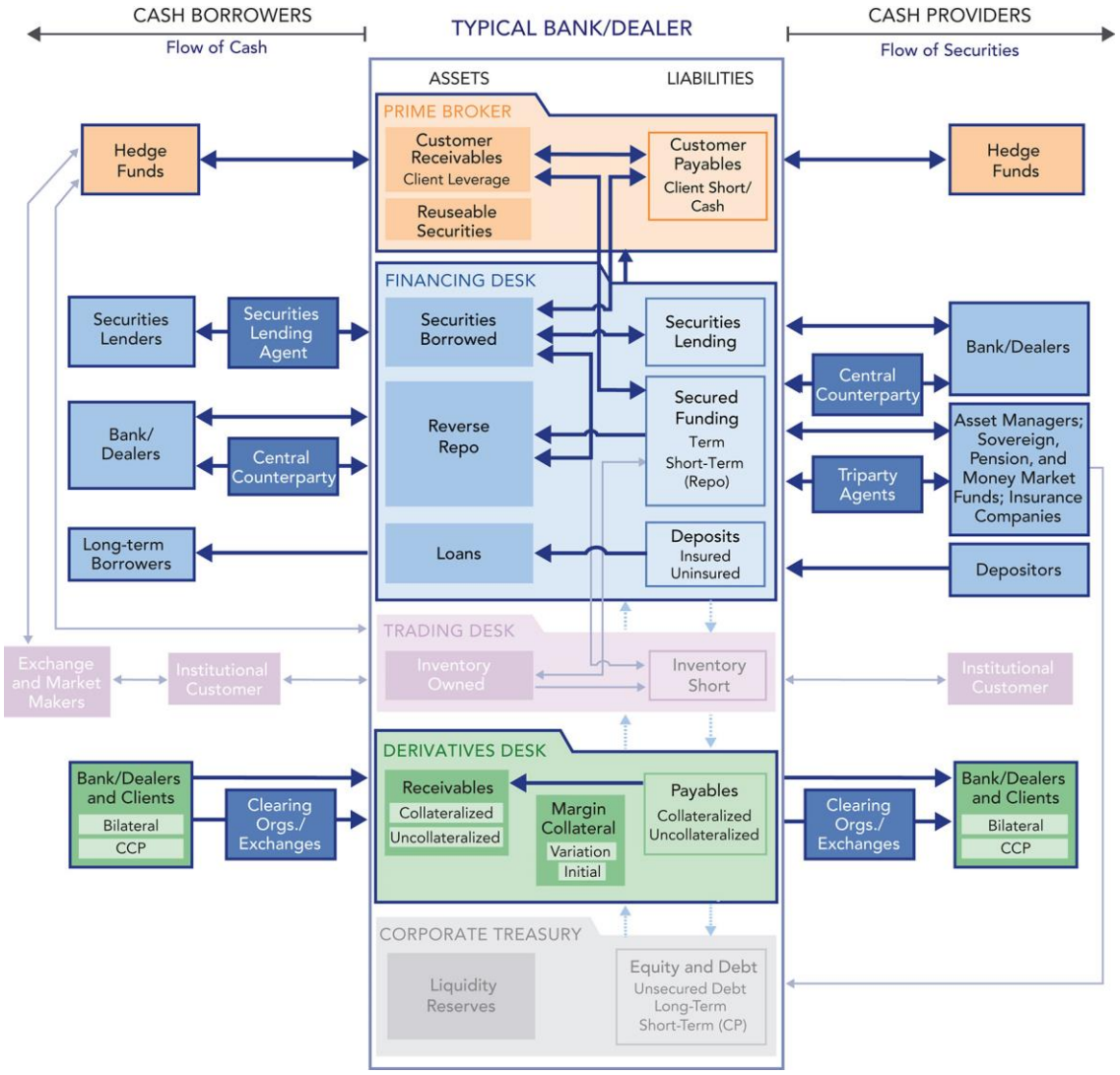
Collateral layer



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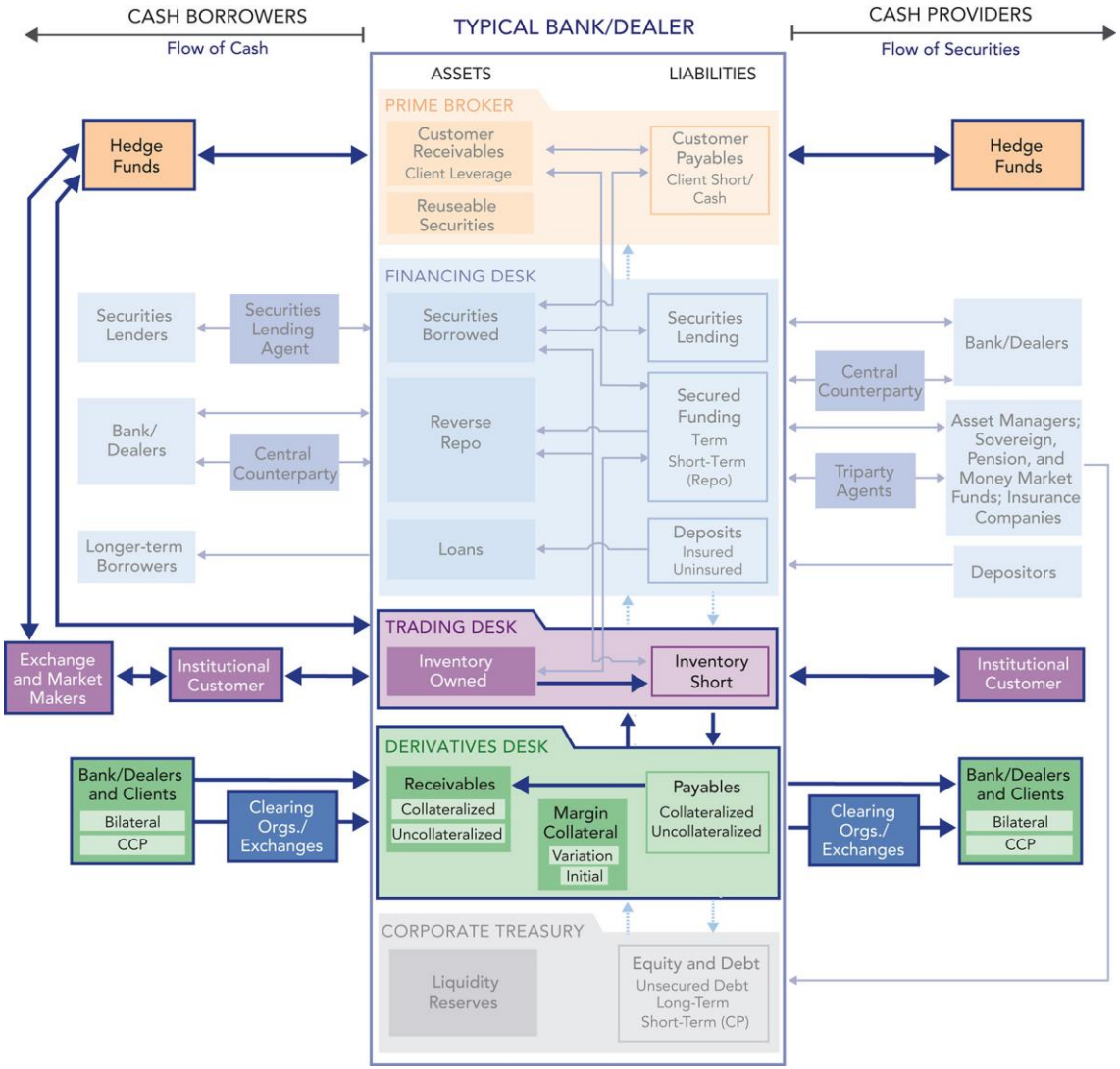
Asset layer



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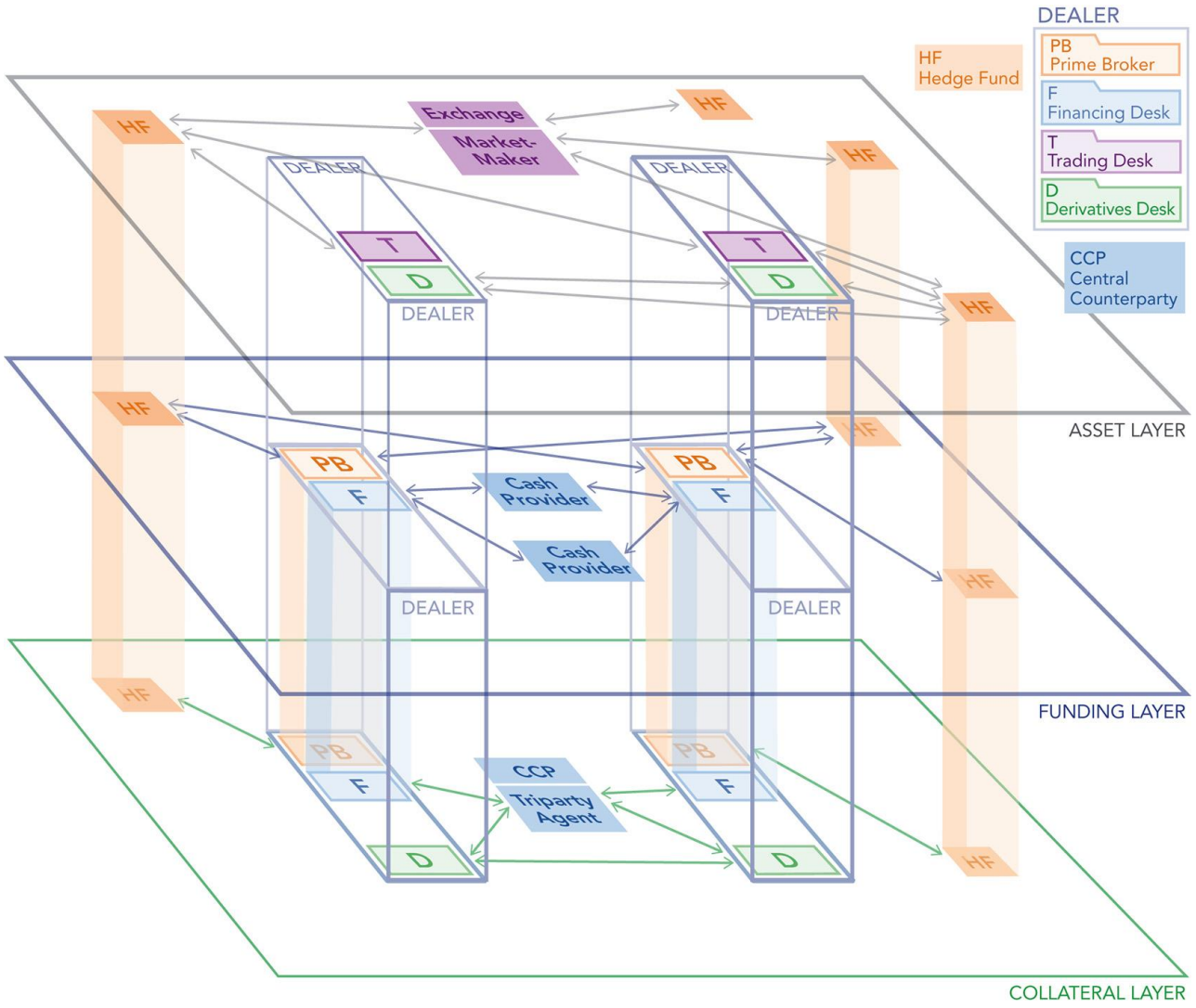
Multilayer structure



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		Node		Function			Primary regulator
Layer	Agent	Core	Periphery	Supplier	Intermediary	User	
Asset	Hedge Funds		X	X		X	SEC, CFTC
	CAsset Managers		X	X		X	SEC
	Bank/Dealer Market Makers	X			X		OCC, FED, SEC
	Bank/Dealer Derivatives	X			X		OCC, SEC
	Exchanges and non-bank Market Makers	X			X		SEC, CFTC, SRO
Funding	Hedge Funds		X			X	SEC, CFTC
	Cash providers (pension funds, insurance companies)		X	X			Department of Labor, State Insurance Departments, FIO
	Bank/Dealer Finance Desk	X			X		OCC, FED
	Bank/Dealer Prime Brokerage	X			X		SEC
Collateral	Cash providers (pension funds, insurance companies)		X	X			Department of Labor, State Insurance Departments, FIO
	Derivatives		X	X		X	CFTC
	Bank/Dealer Financial Desk	X		X		X	OCC, FED
	Central Counterparties (CCPs)	X			X		SEC, CFTC, FED
	Tri-party Repo Agents	X			X		FED

Source: Author's analysis

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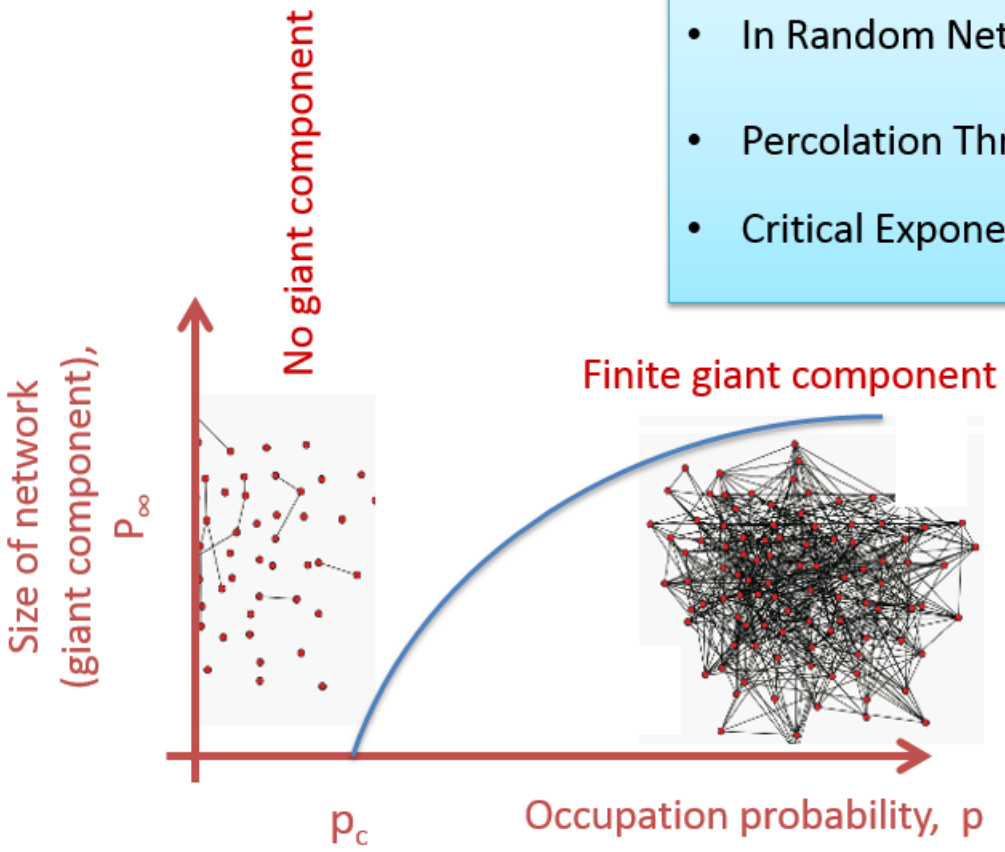
Percolation – a framework for stress testing networks

- Second Order Phase Transition
- In Random Networks (ER) - $P_\infty = p(1 - e^{-kP_\infty})$
- Percolation Threshold – p_c
- Critical Exponents – $P_\infty(x)_{x \to p_c} = A(x - p_c)^\beta$



Source: Author's analysis

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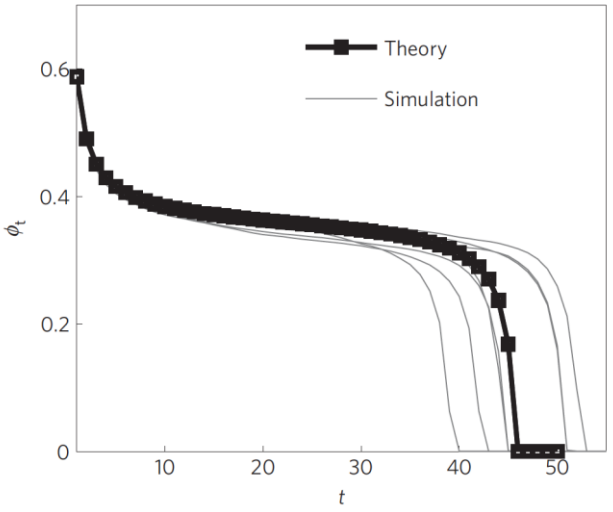
Analytic solutions for dynamical process

$$
\begin{aligned}
y'_1 &= p_1 \\
f'_1 &= p_2[1 - q_2(1 - p_1 g_1(y'_1))] \\
y'_2 &= p_1[1 - q_1(1 - p_2 g_2(f'_1))] \\
&\vdots \\
y'_t &= p_1[1 - q_1(1 - p_2 g_2(f'_{t-1}))] \\
f'_t &= p_2[1 - q_2(1 - p_1 g_1(y'_t))]
\end{aligned}
$$

$$
P_{¥,i} = x_i g_i(x_i)
$$

At steady state:

$$
\begin{cases}
x_1 = p_1 q_1 P_{\infty,2}(x_2) + p_1(1 - q_1) \\
x_2 = p_2 q_2 P_{\infty,1}(x_1) + p_2(1 - q_2)
\end{cases}
$$



Source: Parshani et al., PRL 105, 048701 (2010).

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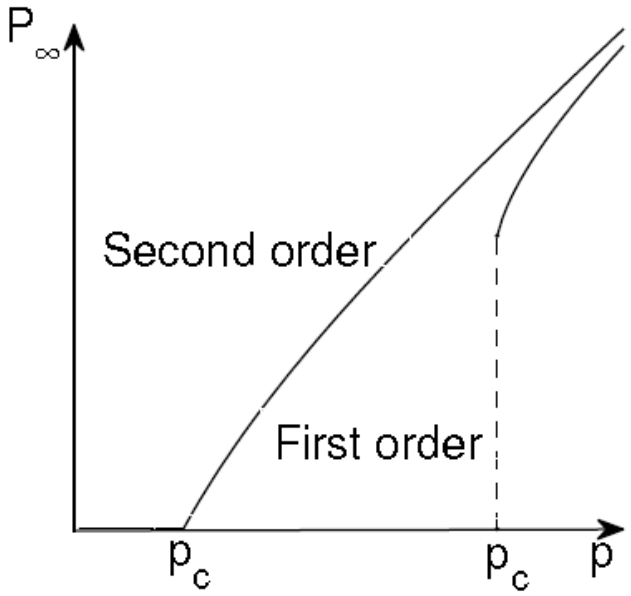
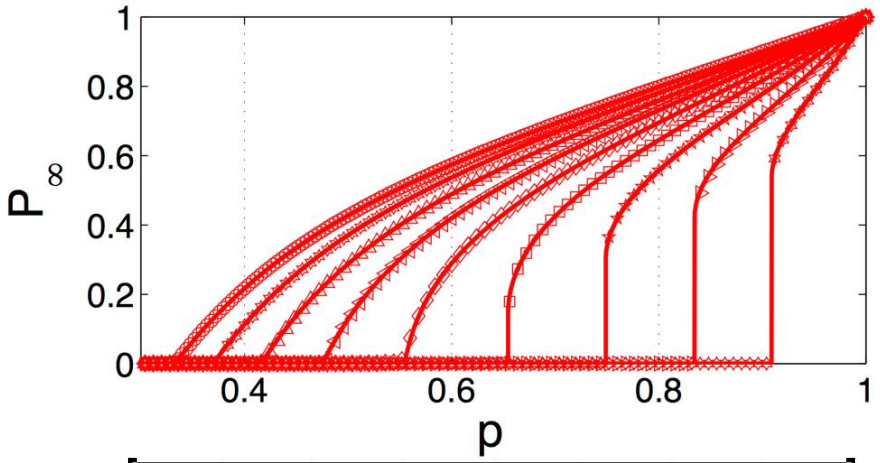
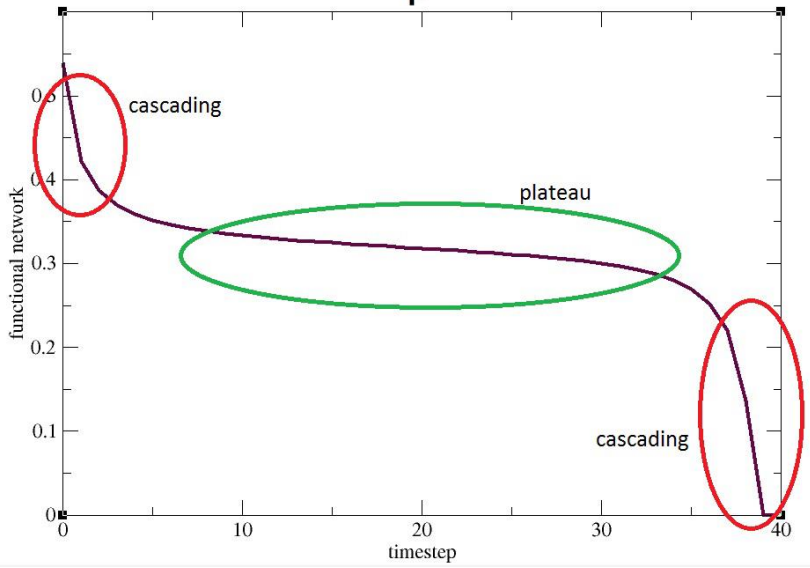
Cascading failures in multilayer networks







Source: Author's analysis

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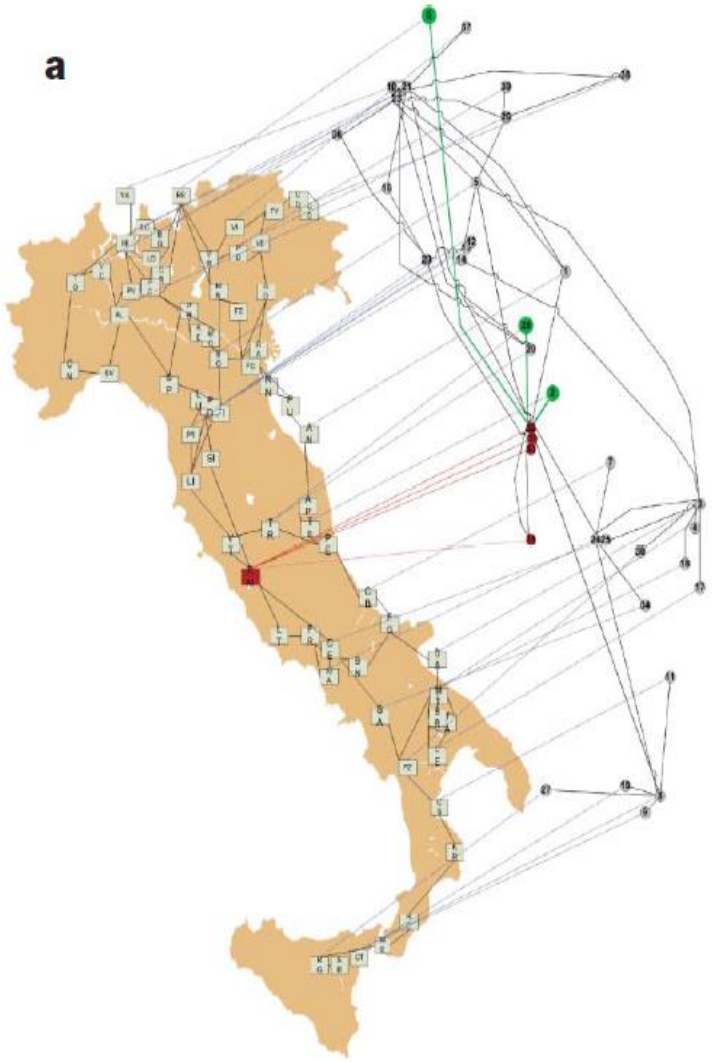
Cascading failures in multilayer networks



Source: Buldyrev et al, Nature 464, 7291 (2010)

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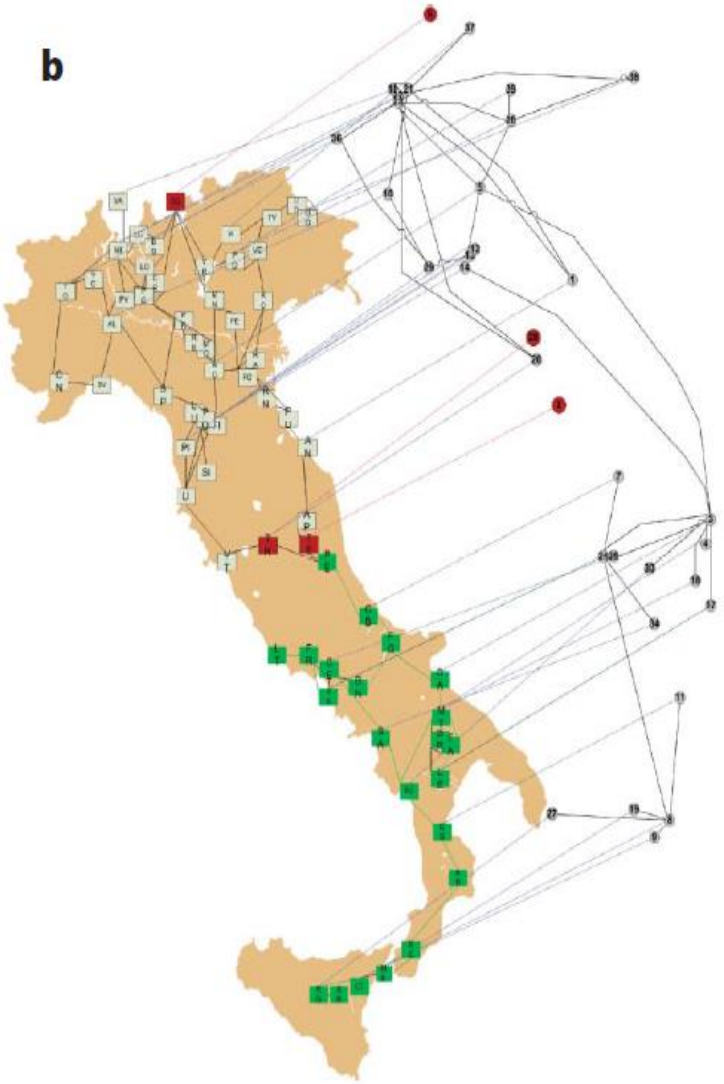

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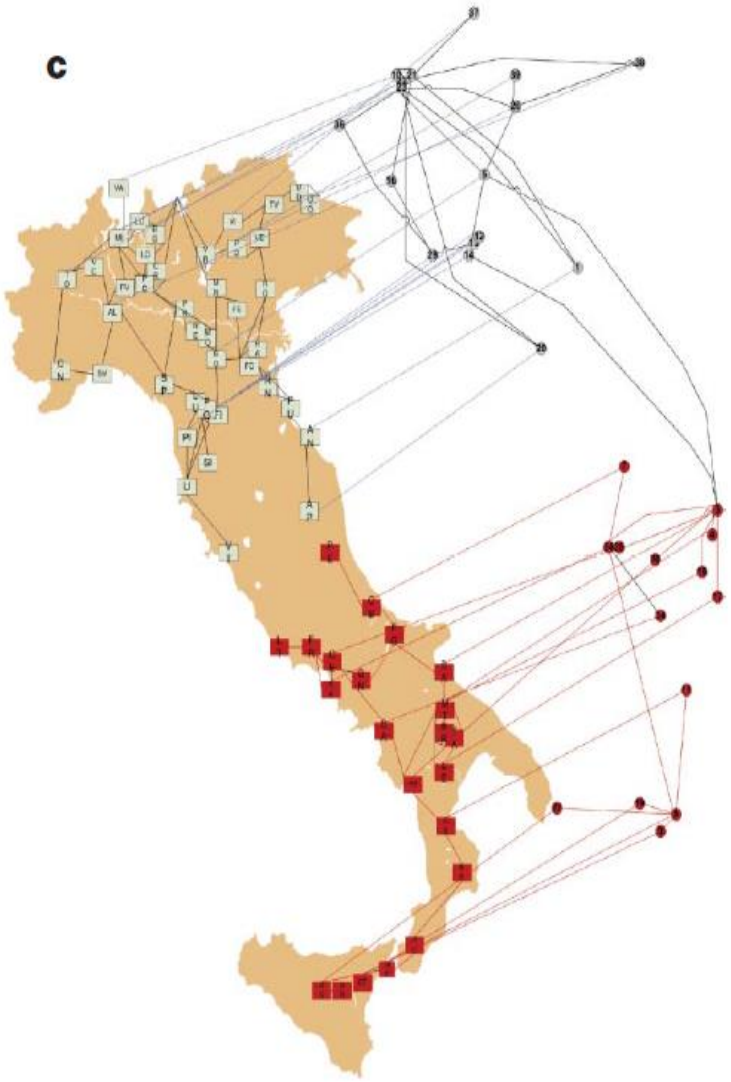

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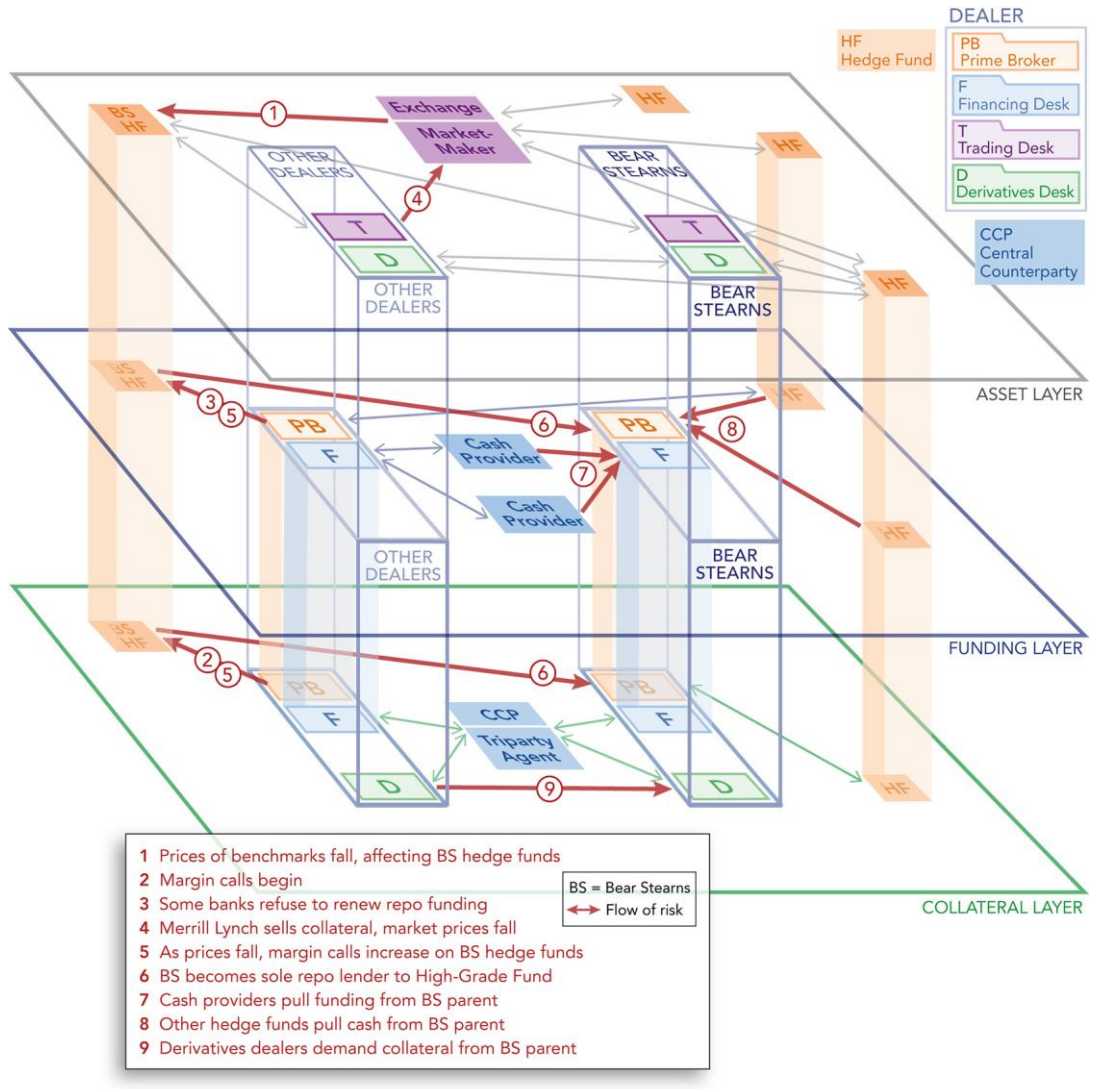
Multilayer structure



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Applications and Challenges

- Obtaining and tying together different data sources and using them to calibrate the interaction between nodes in different layers. Detailed counterparty position level transaction data is needed.

- Understanding the financial system as a multilayer network results in the need to modify contagion models for the financial system, considering the spread of shocks within and between the different layers. These new models should lead to the development of a new class of stress tests, and ultimately to a new class of intervention strategies for the management of financial crises.

- Rethinking how financial institutions are defined, according to their activity in the different layers. This will require rethinking regulation and monitoring policies, and provide new definitions into systemically important financial institutions.

- Providing quantitative evidence for the effect of integration versus segregation in the financial system. This is becoming increasingly important considering how financial institutions, are branching out into new financial activities.

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Thank You.

Questions?

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