

The Architecture of Economic Systems: A Risk Perspective

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Outline

1. Design on risk-robust system
2. Economic architecture—main elements
3. Motivations
4. Some general principles
5. A special case with general results
6. Some more general results
7. Next stages in risk programming

Economic architecture

- Designing an economic system (rules of the game, institutions) with good risk properties:
 - Limiting exposure to exogenous risk
 - Preventing build up/creation of endogenous risk
 - Improving automatic stabilizers/reducing automatic destabilizers
 - Improving social insurance to mitigate consequences of risk
- This lecture focuses on one important aspect of economic architecture:
 - How the design of the “network”—the relations among the firms within the country, and especially the banks—affects the *systemic stability of the system*
 - Resulting in the transmission of a shock from one firm to another
 - Potentially leading to a disastrous cascade—systemic risk
- Similar issues arise in analyzing the consequences of linkages among countries

The design of an economic system

- Affects the risks to which a country is exposed
- The extent to which those risks are amplified and shocks can persist
- The impact of the shock on individuals

Exogenous risk

- For developing/small countries, most shocks come from the outside
 - Flows of foreign capital
 - Terms of trade shocks
- Terms of engagement with the external world affect exposure to shocks
 - Capital market liberalization has exposed countries to more (even though it was supposed to enable countries to “diversify” risks)
 - Tariffication has exposed countries to more risk
 - Financial market liberalization may have spread risk in the 2008 crisis

Broader context: some “reforms” have moved in the wrong direction

- Changes in our economic system may have dampened automatic stabilizers
 - Move from defined benefit to defined contribution pension system
- There are also automatic destabilizers
 - Balanced budget laws
 - Capital adequacy requirements without forbearance

Coping with risk

- Major role of social insurance/social protection
- In general, markets don't provide adequate insurance
- Design of a good insurance system is complicated
- Can also serve as automatic stabilizer
- Again, reforms may have moved in the wrong direction, weakening capacity to cope, and therefore undermining welfare
 - Even if GDP goes up
 - GDP is not a good measure of well-being

Origins of interest

- East Asia crisis (1997-1998)
 - 70% of firms in Indonesia went into default, more than 50% in Korea, almost 50% in Thailand
 - Hard to establish value of any firm—depended on what they received from those who owed them money, and that depended on how much their debtors received from those who owed them money
 - Complex general equilibrium problem

Severe consequences

- Paralysis
- Costly delay in restructuring
- Proposals: Super-Chapter 11 (Miller-Stiglitz)

Post-East Asia crisis

- Work developing general equilibrium theory of credit (Greenwald-Stiglitz, Allen-Gale)
 - Bankruptcy cascades
 - Multiple equilibria
 - Architecture mattered
 - Limited data available at time on credit interlinkages (Japan)
 - Some architectures better able to absorb small shocks
 - Some architectures more resilient to large and correlated shocks

Also highlighted inconsistency of former approaches

- Emphasized importance of diversification before a crisis
- But emphasized contagion after crisis
- Contagion exacerbated by greater linkages
- Needed a coherent approach taking both sets of effects into account
 - Optimal degree, form of diversification?
 - Were there corner solutions—full or no diversification? Under what conditions?

Digression on language

- “Contagion”
 - Concept borrowed from epidemiology
 - Response to the spread of diseases is not “diversification” but “isolation,” quarantine
 - The spread of disease is a multiplicative process

Some general principles

- Privately profitable contracts (linkages) may not be socially desirable (application of Greenwald-Stiglitz 1986 theorem)
 - May be desirable to discourage, prevent some kinds of interlinkages
- There is a general equilibrium moral hazard problem if there is not a full disclosure of everyone in the networks' financial position/risks
 - Obviously impossible
 - Undermines principles of decentralizability

Systemic risk—collapse of a series of financial institutions

- **Systemic risk** involves the behavior of the system as a whole
- Linking that behavior to the behavior of the elements and the network design
 - Many different architectures, rules governing structures
 - Circle; Main Bank with Periphery Bank; Main Banks can be linked to each other in multiple ways; complete linkages
- There are important externalities
 - Presence of externalities explains why representative firm models don't work
 - Excessive borrowing or interconnectivity can make the *system* more volatile
 - More vulnerable to shocks, whether endogenous or exogenous
 - Each market participant ignores these effects

- Understanding market failure (simple moral hazard problem)
 - Debt not observable; an increase in debt leads to increased risk of default against lender; but, depending on the network, that can lead to an increase in probability of default by lender against his lenders
 - Price system working only imperfectly: full price system would require interest rate charged to be related to all loans—and to the financial situation of all who owe money to the firm
- Structure and policy matters
 - Who can be linked to whom; limits on lending, borrowing
 - **Circuit breakers can help prevent cascades**
 - Can capital controls be thought of in an analogous way

- Information requirements also are affected by architecture
 - With clearing houses, only need to know that the clearing house can make full financial obligations—much less information required
 - Clearing houses can increase information transparency—which banks don't like
- “Free market” networks may exhibit excessive systemic instability
- IMPLICATION: IMPORTANT ROLE FOR GOVERNMENT IN OVERSIGHT AND MANAGEMENT OF NETWORK
- RESEARCH PROGRAM TRYING TO UNDERSTAND HOW TO DO THIS BETTER

Approaching these questions through network analysis

- **Why networks, and network analysis, matter**—including for macro-economic analysis
 - *The presence of externalities provides one of the important reasons for understanding the micro-structure of the financial sector*
 - *—in the **presence of externalities, the system behaves differently than it would if there were a single “agent”***
 - *Another reason that the representative agent model is so misleading*
- Financial market spillovers—bankruptcy cascades, contagion
- Broader macro-economic externalities—balance sheet effects interact with collateral effects to give rise to costly macro-economic fluctuations

Some general principles

- Nature of impacts depends on conservation of losses vs. amplification, on convexity or concavity of relevant functions
 - In epidemiology, “contagion” entails amplification
 - Real bankruptcy costs imply that the system is not conservative
 - Processes with trend reinforcement exhibit similar properties
 - Negative balance sheet shocks force borrowers to pay higher interest rates
 - In conservative systems with concave loss functions, spreading risks typically is welfare-enhancing
 - In non-conservative system (and most systems are not conservative), it may well not be

An analogous problem

- With an integrated electric grid, the excess capacity required to prevent a blackout can be reduced
 - Alternatively, for any given capacity, the probability of a blackout can be reduced
- But a failure in one part of the system can lead to system-wide failure
 - In the absence of integration, the failure would be geographically constrained
- Well-designed networks have circuit breakers to prevent the “contagion” of the failure of one part of the system to others

Some general principles

- In conservative systems, depending on contractual arrangements, there can be multiple or no equilibria
- Multiple equilibria raise difficult questions about regulatory oversight and bankruptcy procedures: outcomes can be sensitive to order of filing
- No equilibria are perhaps even more philosophically troubling—can arise with poorly designed derivatives

Some general principles (cont.)

- Systemic risk
- Not just a matter of “too big to fail”
 - Too “central” to fail
 - Too interlinked to fail
 - Too correlated to fail
- What can we say about good architecture design?
- Do more linkages stabilize the system and reduce systemic risk?
- How do we avoid banks that are too correlated to fail?
- This lecture will focus on a narrower question: are more interlinked institutions (countries) likely to exhibit greater stability?
 - First: recapitulation of central results

Summary of the main insights from network analysis

- Full interconnectedness/complete diversification is not optimal
 - Tradeoff depends on various parameters
- There is no single optimal architecture
 - Systemic risk depends on the interplay of topology (architecture), capital buffers, asset market liquidity, and correlations
- Systemic importance of institutions involves more than bank size
 - Banks can be too interconnected, too central, or too correlated to fail

Summary of the main insights from network analysis

- Systemic risk can be measured and monitored (won't cover this here)
- Containing systemic risk implies that it may be desirable to limit interconnectedness, complexity (of structure and instruments), and correlations to construct a richer ecology of financial institutions (not just universal banks)
- There is an *international* network of TBTF institutions that are too interconnected to fail. But we have *national* authorities. Moral hazard in a network context. Cross-boundary externalities have yet to be adequately dealt with
- The IMF has, however, recognized that cross-border capital flows more generally have to be managed
 - Most important exception to the principle of national treatment

The financial system as a network

- The financial system can be seen as a multi-level network
 - It is a collection of actors and relations. Several types of actors and links.
 - Note: financial networks not only entail direct linkages (contracts), they also encompass bank-asset and bank-firms linkages
- We argue that thinking of the financial system as a (multi-level) network:
 - Improves our understand of how it functions both within countries and at a macro-economic level
 - Provides insights into long standing issues
 - Role of capital controls
 - Role of clearing houses
 - Allows us to better design policies that make the financial system better serve its social function

Simple example

$$(1) Q_i = F(S_i), F' > 0, F'' \leq 0$$

In autarky,

$$(2) S_i = \hat{S} + \varepsilon_i$$

where $E(\varepsilon) = 0$ and $\text{Var}(\varepsilon) = \sigma_i^2$.

We normalize by choosing our units so that $\hat{S} = 1$

Simple example (cont.)

- Polar case where there is no value of risk diversification—the production is linear in S , provided S is greater than some critical number S^* , at which point system failure occurs, and a loss of $-C$ occurs. The main concern then is to minimize the losses from system failure

Simple example (cont.)

- Assume that $S_i = -\alpha_1$ with probability p , α_2 with probability $1 - p$, such that

$$p\alpha_1 = (1 - p)\alpha_2$$

i.e. expected output without bankruptcy costs is zero, but if $S \leq 0$, the country goes bankrupt, with output $-C$, where $C < \alpha_1$.

- Prior to liberalization, expected output is

$$-pC + (1 - p)\alpha_2 = p(\alpha_1 - C)$$

- Assume $N = 2$, and there is full liberalization
 $\alpha_2 < \alpha_1$, (so from above equation, $p < .5$)
- We focus on this case—small probabilities of “disaster”

Full liberalization is unambiguously welfare decreasing

- With liberalization (complete risk sharing)

$$p \left(\sum S_i / 2 < 0 \right) = 1 - (1 - p)^2$$

i.e. *both* countries go bankrupt if only one country has a bad outcome, and expected output (per country) is

$$(1-p)^2 \alpha_2 - C (1 - (1-p)^2) < -pC + (1 - p) \alpha_2$$

- Basic insight: even with mean preserving reductions in risk associated with risk pooling, the probability of any particular country falling below the bankruptcy threshold may increase with economic integration
 - And because of the non-conservative system, the more banks that fall below the threshold, the greater the societal loss

Some general results

- Full integration never pays if there are enough countries
- Optimal-sized clubs
- Restrictions on capital flows (circuit breakers) are desirable

Simple intuition: limited risk sharing may increase losses

- Assume that country has a loss of L , and that it has contracts that share that loss with n other countries ($\sum L_i = L$)
- Assume the cost to each is linear in L_i , the loss it absorbs, provided $L_i < L^*$, but is C for $L_i > L^*$, where we assume C is large, and $> L$

Simple intuition: Large losses may lead to systemic crises (cont.)

- Assume L is a random variable (n is fixed)
- So long as L is small enough, diversification pays
- But if L is large, there are large losses from the contagion, as many countries (banks) go into bankruptcy.
- If n is increased (a higher degree of diversification), and L is large, more banks will go into bankruptcy
 - Total societal costs are increased
- There is a trade-off—diversification helps with small L , hurts with large L
 - The ability to absorb small shocks is enhanced; the effects of large shocks is increased
- There is an optimal degree of diversification

Uncertainty and amplification

- Assume that there is risk about how a loss is divided
 - The risk is divided among n countries, $n < n^*$
 - But it is not known which countries
 - Hence, each country now faces a risk of a loss of $-C$ with probability n/N , where N is the total number of banks
 - With risk neutrality, the market value of each will be decreased by nC/N
 - With risk aversion, the reduction in market value is greater
 - Each will find it more difficult to raise capital
- This in turn will have its own amplification effect: uncertainty can amplify the amplifications

Summary

- Impact of shocks depends on the size of shocks, the correlation among the shocks, how the shocks are distributed,
- And the architecture of the “network”

- Banking systems have evolved into a few concentrated nodes; big nodes interlinked
 - Good for absorbing small shocks
 - Bad for systemic risk in the face of large and correlated shocks

More general network result:

Role of link density

- Density increases resilience in the absence of amplifications
- There is a size effect (not a fundamental effect) that implies that denser networks are less resilient than sparse one when shocks are large enough/hit enough banks. If exposure could be made smaller, shocks would vanish
- The robust yet fragile conjecture has more substance, but in relation to amplifications
- In the presence of amplifications, density increases instability

This can be viewed as the *beginning* of an analysis

Levels of analysis

1) Describing different patterns of credit interlinkages (the architectures)

- Observing changes in these structures, differences among structures in different countries

2) Analyzing each (observed or potential) architecture in terms of how it responds to different kinds of shocks, *given a set of contracts and portfolios*

- Analyzing how we can quantitatively assess systemic risks
- Analyzing particular architectures—clearing houses vs. bilateral contracts
- Analyzing equilibrium valuations
- Analyzing probabilities of bankruptcy

Next stage: making contracts endogenous

Next level of analysis

3) Analyzing each architecture in terms of how it responds to different kinds of shocks *taking contracts and investments (loans) as endogenous*, given a particular set of rules of the game

- Need a theory of behavior of financial agents (banks)
 - How they form expectations
 - Agency issues

Incentives make matters worse

- Large “too-big-to-fail” institutions have an **incentives** to engage in **risk-taking**
 - “Heads I win, tails you lose”
 - But the system **evolves** towards too-big institutions. Because they are implicitly guaranteed, they can get access to capital at lower rates
 - In many cases they can become so large that they have market power
 - And even worse, political power—incentives and means to shape regulations
 - Can even become “too big to be held accountable,” to be subject to effective judicial disciplines
 - There are incentives to be “**too interlinked to fail**,” “**too correlated to fail**”
 - Hence market structure that evolves on its own is likely to entail **excessive systemic risk**

Incentives and information asymmetries make matters worse

- Markets make money out of complexity
 - Create information asymmetries
 - Lack of transparency enhances profits, but erodes systemic performance
- Securitization forced reliance on others to monitor and assess risk
 - And reduced the incentives for originators to monitor risk
 - Created a public good out of information associated with lending
 - But credit rating agencies and investment banks putting together securitization packages had flawed incentives
 - Attempts to have efficient “delegated” responsibilities through putback mechanisms failed because of fraud and difficulties of enforcement
 - And exploited ignorance/flawed incentive structures of managers of pension and other funds
 - Who had to maximize returns given the ratings of the rating agencies
- Structured financial products made matters even worse

Next levels of analysis

4) Analyzing the consequences of the different rules of the game

- The behavior of banks or other financial institutions, and therefore of the system as a whole, is dependent on the rules of the game (the regulations, the bailout policy, etc.)
- Viewing the architecture itself as endogenous
- Incentives to be too big to fail, too correlated to fail, too interconnected to fail
- Effects of different restrictions (e.g. on naked CDs's, on universal banking, and on trading through clearing houses)
- There needs to be an underlying theory of the behavior of financial agents

Next levels of analysis (cont.)

5) Normative questions: optimal design and the instruments by which that can be achieved

- Analysis of alternative objectives
- Analysis of exposure to shocks
- Given objectives and shocks, what rules, regulations, restraints, taxes are desirable

6) Interactions between financial sector and real sector

- Trade and production networks
- When do shocks get dampened, and when do they get amplified?

7) Political economy

- Analysis of the political forces determining the rules of the game

- We argue that thinking of the financial system as a (multi-level) network:
 - Improves our understand of how it functions both within countries and at a macro-economic level
 - Allows us to better design policies that make the financial system better serve its social function
- **Networks matter for estimating systemic risk** and the **systemic importance** of financial institutions (regulatory debate on TBTF). No networks → wrong estimates
- **Networks matter for estimating of prudential policies. E.g.:**
 - More network density → more systemic risk (with amplifications, always)
 - Interplay capital buffers, correlations, and network topology
 - Role of correlations, procyclicality
 - No networks → wrong policies
- Step towards **policy makers' uptake of network-based tools**

Further analysis systemic risk

- TREND REINFORCEMENT
- BANKRUPTCY CASCADES

Trend reinforcement

- Negative shocks move us down further (equity depletion)
 - Modeling using stochastic differential equations, with the probability that at any given time an agent goes bankrupt, modeled as problem in first passage time
- With trend reinforcement, there is an optimal degree of diversification
 - Battiston, Stefano, Domenico Delli Gatti, Mauro Gallegati, Bruce Greenwald, and Joseph E. Stiglitz, “Liaisons Dangereuses: Increasing Connectivity, Risk Sharing, and Systemic Risk,” paper presented to the Eastern Economic Association Meetings, February 27, 2009, New York, NBER Paper No.

Financial interlinkages and bankruptcy cascades

- Bankruptcy cascades (Greenwald and Stiglitz, 2003; Gale and Allen, 2001)
 - The bankruptcy of one firm affects the likelihood of the bankruptcy of those to whom it owes money, its suppliers, and those who might depend upon it for supplies; and so, actions affecting its likelihood of bankruptcy have adverse effects on others
- The “architecture” of the credit market can affect the risk that one bankruptcy leads to a sequence of others
 - If A lends to B, B lends to C, and C lends to D, then a default in D can lead to a bankruptcy cascade
 - On the other hand, if lending all goes through a sufficiently well-capitalized clearing house (a bank), then a default by one borrower is not as likely to lead to a cascade
 - But a very large shock that leads to the bankruptcy of the “clearing house” can have severe systemic effects

- Further externalities are generated as a result of *information costs and imperfections*.
 - If unit *i* doesn't fully know other units' characteristics—including the relationships (contracts) of those with whom it engages in a relationship, including all the relationships with whom those are engaged, *ad infinitum*—it cannot know the risks of the other units honoring their contract
 - Explains some of the adverse effects of non-transparent, over-the-counter credit default swaps

Asymmetric patterns

- Our canonical model also assumed symmetric relationships in which all ties/contracts were identical
- In the presence of convexities, such symmetric arrangements often characterize optimal designs
- But that is not so in the presence of non-convexities, and there are many alternative architectures
 - For instance, a set of countries (banks) can be tightly linked (a “common financial market”) to each other, but the links among financial markets may be looser. The former is designed to exploit the advantages of risk diversification, the latter to prevent the dangers of contagion
 - Circuit breakers might be absent in the former but play a large role in the relations among the “common markets”
- Different architectures may lead to greater ability to absorb small shocks but less resilience to large shocks

- Reducing the set of admissible relationships and behaviors can have benefits
 - Reducing the scope for these uncertainties
 - Reducing the potential for information asymmetries
 - Reducing the burden on information gathering
- In large non-linear systems with complex interactions, even small perturbations can have large consequences
 - Understanding these interactions is a major research agenda
- **Broader research agenda: design of optimal networks, circuit breakers, optimal degree and form of financial integration**
- Beginning of large literature

New important application of network analysis: climate risk

- If we are successful in limiting the increase of the earth's temperature to 2 degrees Celsius, then we will not be able to use all of the global "reserves" of oil and gas (let alone coal) that have already been discovered
- Stranded assets
 - "Zero value"
 - But market does not currently value them at zero
- When the market discovers that they are worthless, there will be large changes in values of companies that own these assets
 - Markets are often short sighted—have not yet fully taken on board the implications of climate change
 - The adjustment could occur slowly
 - But it could also happen suddenly—"herding behavior"

Some evidence that market is beginning to realize “climate risk”

- By some accounts, the value of reserves (overvalued as they are) exceeds the value of the corporations that own them
 - Consistent with “agency” perspective
 - Managers of oil companies will dissipate value as they continue to explore for additional oil
 - Marginal value of discoveries likely to be considerably less than the cost of exploration
 - Explains the negative “residual” value of corporations
 - Market value maximization would entail stripping out reserves from corporations

The real challenge: highly interdependent financial markets

- Banks lend to corporations
- Corporations own shares in other corporations
- Banks and corporations have a wide range of interdependencies with producers of fossil fuels
- Decrease in value of fossil fuel companies—with many bankruptcies—will have *systemic* effects
- Analyzing the systemic effects is important

Concluding comments

- We now know that understanding the functioning of the financial system is crucial for understanding macro-economic behavior
- This is part of an attempt to better understand the functioning of the financial system, and the relationship between the financial system and the real economy
- Especially relevant for understanding critical issues of *systemic* risk
- These current issues could not be addressed by old models
 - And especially by DSGE models
- This work is at the heart of efforts to prevent another major financial and economic crisis
 - Reforms in the structure of the financial market
 - Reforms in the regulation of the financial market

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