Global Financial Systems
Chapter 15
Dangerous Instruments

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To accompany
Global Financial Systems: Stability and Risk
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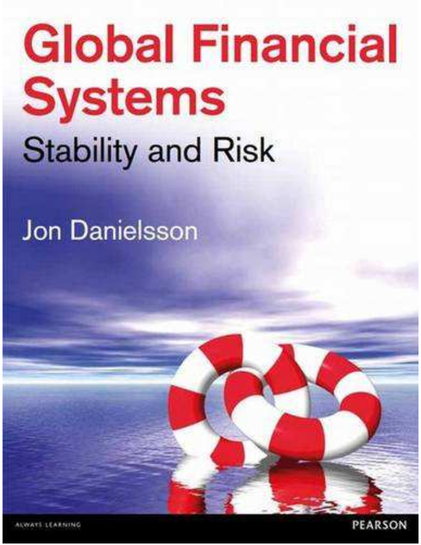
Book and slides



- Updated versions of the slides can be downloaded from the book web page `www.globalfinancialsystems.org`

Complexity and Derivatives

Complexity kills

- Before 2007 complexity was considered good
- It was very profitable (why?)
- And the dangers not recognized
- The crisis caused counterparties is to assume the worst
- And institutions to not understand their positions
- Ignores liquidity, nonlinear dependence and even fat tails

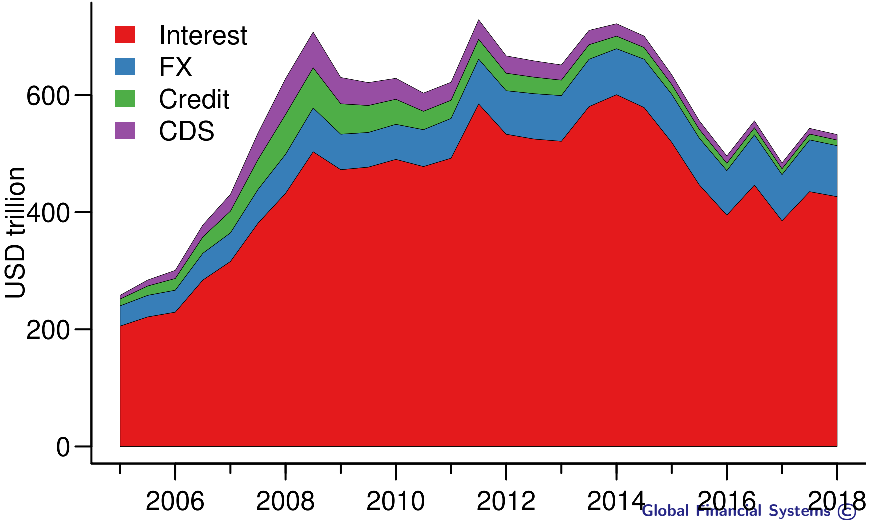
Derivatives

"Derivatives are financial weapons of mass destruction, carrying dangers that, while now latent, are potentially lethal."

Warren Buffett

Notional amounts

total or face amounts, used to calculate payments, USD trillion

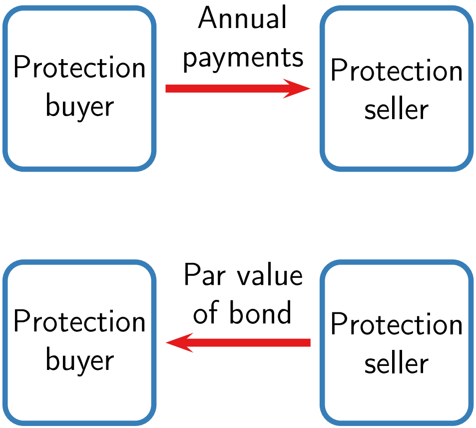


Credit Default Swaps — CDSs

"catastrophic enabler of the dark forces that have swept through financial markets".

"They are, says a former securities regulator, a 'Ponzi Scheme' that no self–respecting firm should touch."... "Alan Greenspan, who used to be a cheerleader, has disowned them in 'shocked disbelief'. They have even been ridiculed on 'Saturday Night Live', an American TV show."

Simple CDS payment flow



CDS

Over–the–counter (OTC) transaction involving two counterparties:

The Protection Buyer

1. Pay premium
2. Receive default payment if credit event occurs
3. Sells/hedges *credit* risk
4. Equivalent to selling a bond

The Protection Seller

1. Receive premium
2. Pay default payment if credit event occurs
3. Buys/take on *credit* risk
4. Equivalent to buying a bond

Terminology

Reference entity The legal entity which borrows money;

Reference obligation Any debt or obligation that is "referenced" in the transaction;

Notional principle Quantity upon which interest or other payments are computed;

Credit event Any event that happens in respect of the reference entity that triggers payment under the CDS, this includes bankruptcy, restructuring, repudiation of debt.

An example

5 Year CDS on \$100 million principal, starting in 1 Sep 2013 whereby the buyer agrees to pay 90 bps (CDS spread) annually

- If no default, the buyer receives zero payoff
- And pays \$900,000 on September 1 on 2014, 2015, 2016, 2017, and 2018
- If there is a credit event, and *physical settlement*
    - buyer receives \$100 million
- If *cash settlement*, supposing recovery value is \$35 per \$100 of face value
    - buyer receives \$65 million

Why use CDSs?

- To manage and hedge credit risk better, CDSs reduce the impact of a loss on a single party
- CDSs permit risk–taking in a tailored way, users can choose whether to increase or decrease exposures to countries, market sectors, etc.
- Firms can earn premium from parties who want credit exposure without owning the assets
- To provide access to exposures that would not otherwise be available

Risks of CDSs

- Protection buyer faces *counterparty risk* on the performance of the protection seller
- The value of the CDS contract can change without a credit event
- Protection seller faces liquidity risk on any margin requirements generated by any CDS spread moves
- CDS spreads depend on the perceived probability of default, arguably some will have more information to estimate this probability than others
- Creating *information asymmetry*

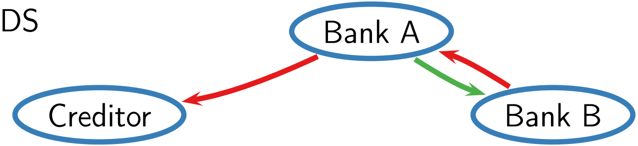
CDS network risk creation

1: Initial exposure

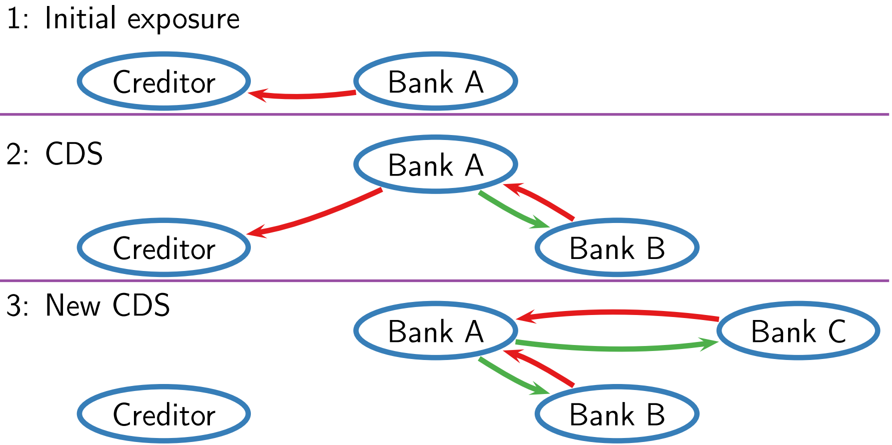
CDS network risk creation

1: Initial exposure

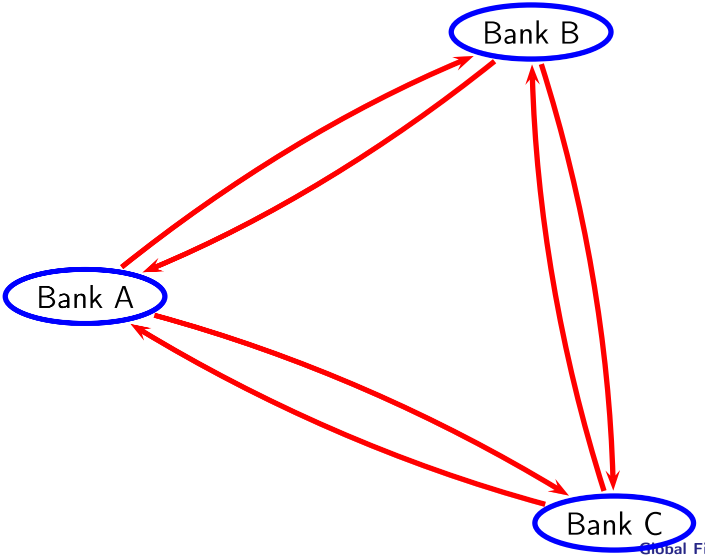
2: CDS



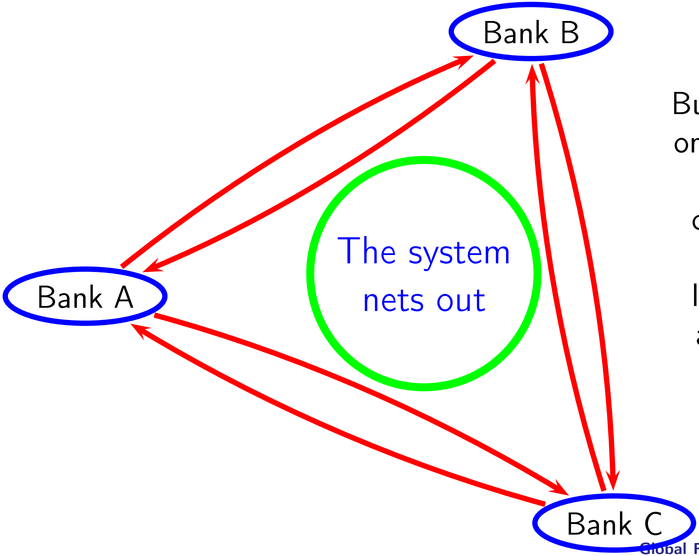
CDS network risk creation



Netting out



Netting out



But each bank only knows its own obligations.

Information asymmetry

Main problem with CDSs

- Because they are bespoke and OTC it is hard to *net positions* — i.e., aggregate positions to find the net exposure
- This means that a bank can have a large *gross* position, but *zero net exposure*
- Lehmans came close to that
- However, the net exposure is only found out after failure
- This problem can be solved by CCPs

Naked CDSs

- Trading CDSs for purely speculative reasons without owning the underlying asset
- Insurable interest is missing
- What might happen if a person could buy fire insurance on their neighbor's house

"I think that derivative products like the CDS on sovereign debt have to be at least very, very regulated, rigorously regulated, limited or banned"
Christine Lagarde, former French minister and now the managing director of the International Monetary Fund (IMF)

Collateralized Debt Obligations

CDOs

From BBC programme, for the love of money

last days of lehmans

Introduction

- Debt security whose underlying is a portfolio of risky bonds or loans, held by a SPV (or trust)
- SPV allocate interest and principal repayments to prioritized tranches, perhaps
  - Super senior (AAA)
  - Senior notes (AA)
  - Mezzanine (A to BB)
  - Equity (unrated)
- This structure created AAA rated securities from risky collateral by repackaging risks

Alchemy

noun

the medieval forerunner of chemistry, based on the supposed transformation of matter. It was concerned particularly with attempts to convert base metals into gold or to find a universal elixir.

figurative a process by which paradoxical results are achieved or incompatible elements combined with no obvious rational explanation: his conducting managed by some alchemy to give a sense of fire and ice.

Binomial coefficient

- Suppose we have three bonds ($n = 3$) A, B, C each with default probability $p = 0.1$, with independent defaults
- What is the chance that exactly $k = 2$ with default
  - We can get A, B or A, C or B, C i.e. (*Binomial coefficient*)

$$\binom{3}{2} = 3, \quad \binom{n}{k} = \frac{n!}{k!(n-k)!}$$

- But how to get the probabilities? The outcomes are *binomially distributed*

Binomial distribution

- Probability of exactly *k* outcomes in a sample of size *n* when the *independent* probabilities are *p* is

$$y = g(k|n,p) = \binom{n}{k} p^k (1-p)^{n-k} \tag{1}$$

which gives in the example on the last slide 2.7%

- In our case, we are more interested in *at least k* defaults in a sample of n, i.e., the *cumulative distribution*

$$G(k|n,p) = \sum_{i=0}^{k} \binom{n}{i} p^i (1-p)^{n-i}$$

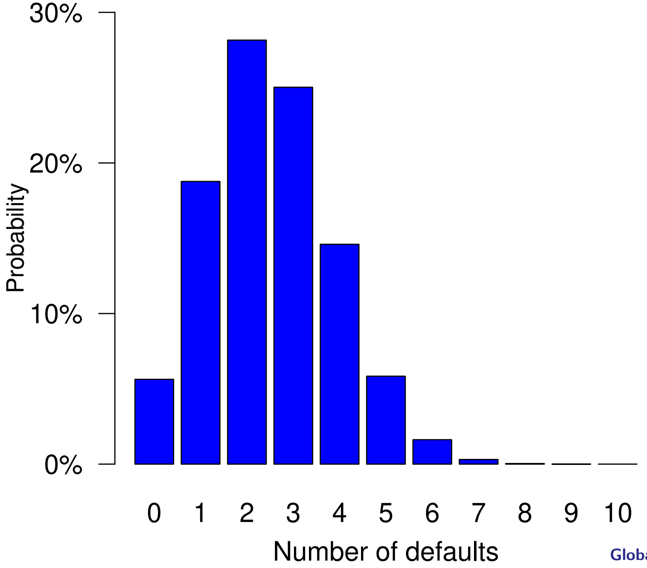
Probability of defaults

number of defaults	probability of defaults	cumulative probability
0	0.729	0.729
1	0.243	0.972
2	0.027	0.999
3	0.001	1.000

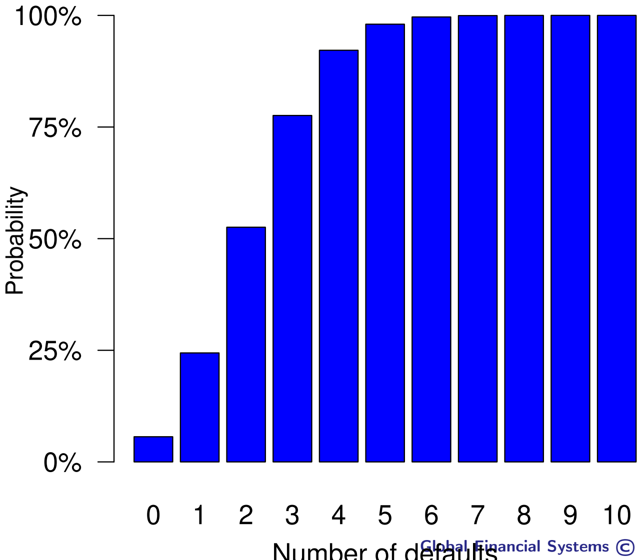
Example CDO

- A SPV buys 10 bonds
- Each bond has 1 year maturity, with face value of $10 million
    - so the SPV holds $100 million
- Bonds have 12% annual interest
- Default probability on each bond is *25%*, recovery is zero if default

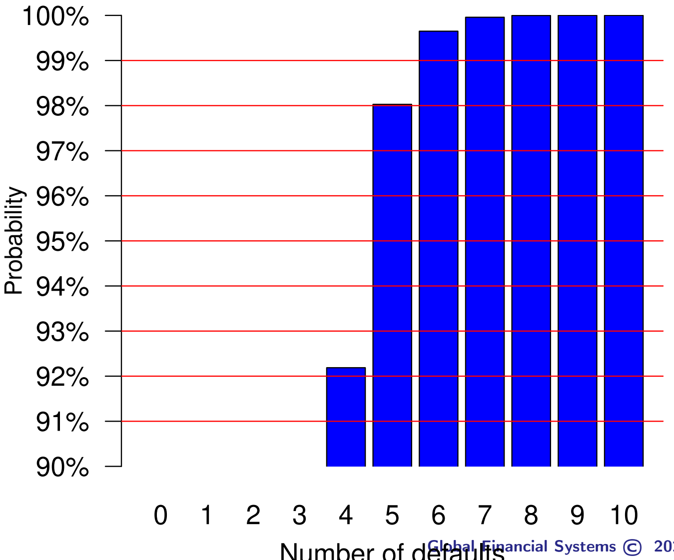
Distribution of defaults



Cumulative defaults



Cumulative defaults (top 10%)



Defaults and probabilities

number of defaults	probability of defaults	cumulative probability	cumulative probability from largest to smallest
0	0.05631	0.05631	1.00000
1	0.18771	0.24403	0.94369
2	0.28157	0.52559	0.75597
3	0.25028	0.77588	0.47441
4	0.14600	0.92187	0.22412
5	0.05840	0.98027	0.07813
6	0.01622	0.99649	0.01973
7	0.00309	0.99958	0.00351
8	0.00039	0.99997	0.00042
9	0.00002861	0.99999905	0.00002956
10	0.00000095	1.00000000	0.00000095

Benchmark

- Benchmark: corporate bond default probabilities (p) and interest

  AAA has $p = 0.3\%$, interest 6%
  BBB has $p = 7\%$, interest 8%

- For simplicity we assume that if the benchmark corporate bond defaults there is no recovery, so for a \$1 million AAA bond we get:

$$\text{payment} = \begin{cases} \$60,000 + \text{principal (\$1mn)} & \text{with probability } 99.7\% \\ 0 & \text{with probability } 0.3\% \end{cases}$$

- The probability of all 10 bonds defaulting is 9.54×10^{-7}
- The probability of 9 or 10 bonds defaulting is $9.54 \times 10^{-7} + 2.86 \times 10^{-5}$
- The probability of 8 to 10 bonds defaulting is $4.158 \times 10^{-4} < 0.003$
- The probability of 7 to 10 bonds defaulting is $0.00351 > 0.003$.

$$\Pr[8 \text{ to } 10 \text{ defaults}] < \Pr[\text{AAA defaulting}] < \Pr[7 \text{ to } 10 \text{ defaults}]$$

- The probability of getting \$3.6 million ($3 \times 10 \times 0.12$) in interest payments from the SPV, 99.958% is higher than the probability of getting paid from the AAA bond, 99.3%
- The the probability of getting \$4.8 million ($4 \times 10 \times 0.12$) in interest payments from the SPV, 99.65%, is lower than the AAA default probability
- We conclude that the payment flow from the first 3 bonds to pay out gets a AAA rating

Tranches

rating	interest rate	number of bonds	value of bonds	interest payment
AAA	6%	3	$30mn.	$1.8mn.
BBB	8%	2	$20mn.	$1.6mn.

Tranches

rating	interest rate	number of bonds	value of bonds	interest payment
AAA	6%	3	\$30mn.	\$1.8mn.
BBB	8%	2	\$20mn.	\$1.6mn.
		10	\$100mn.	\$12mn.

Tranches

rating	interest rate	number of bonds	value of bonds	interest payment
AAA	6%	3	$30mn.	$1.8mn.
BBB	8%	2	$20mn.	$1.6mn.
Equity	17.2%	5	$50mn.	$8.6mn.
		10	$100mn.	$12mn.

Example CDO structure

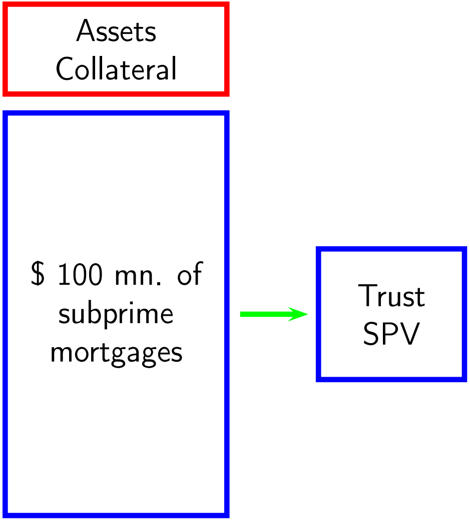
Assets
Collateral

Example CDO structure

Assets
Collateral

$ 100 mn. of subprime mortgages

Example CDO structure



Example CDO structure

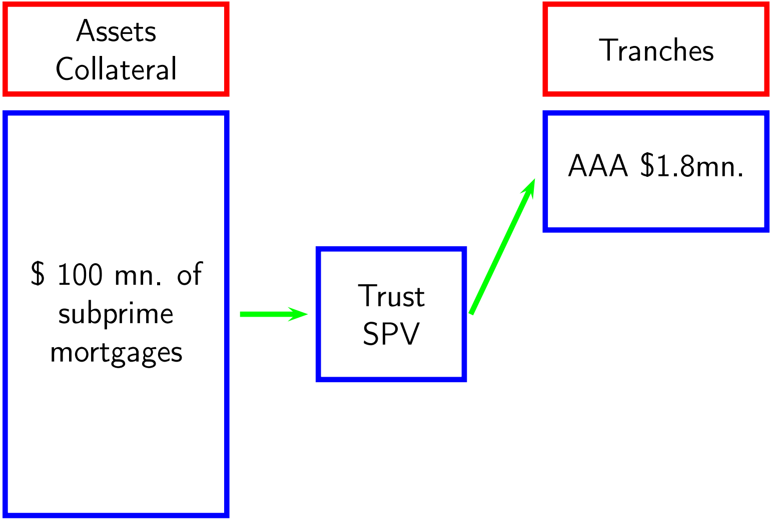
Assets
Collateral

Tranches

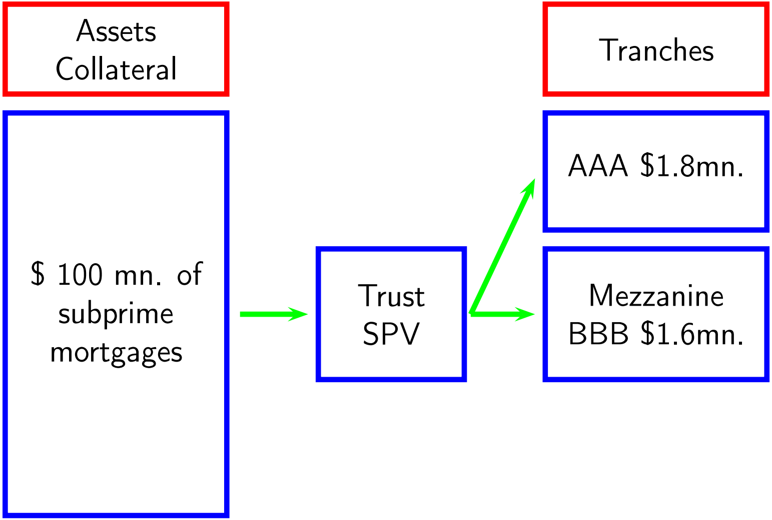
$ 100 mn. of subprime mortgages

Trust
SPV

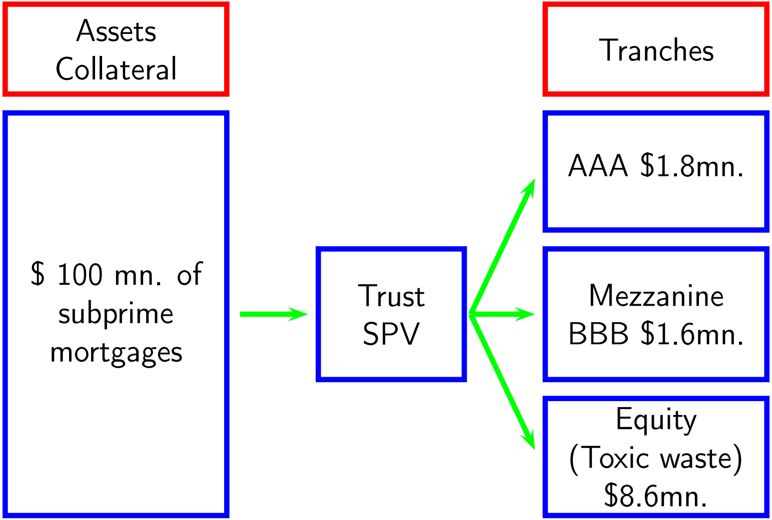
Example CDO structure



Example CDO structure



Example CDO structure



Conclusion

- We were able to take
- \$100 million of high–risk subprime mortgages
  - with 25% default probability
- And create AAA assets
- It's like magic
- What could possibly go wrong?

Correlations

Correlated defaults

- The approach above assumed that defaults were independent events
  - I may get sick, loose my job and not pay my mortgage but that does not mean anybody else will default
  - this is often a correct assumption in boom times
- In economic downturns defaults become correlated
  - the factory closes, everybody looses their job and hence default
  - mortgage default correlations dependent on the business cycle

Mispricing

- Time–varying default correlations are hard to model, lack of data
- Rating agencies used over optimistic assumptions
- And allowed banks to adjust the structure of the CDO until the desired ratings were achieved — *datamining in the negative sense*
- Reliability of sophisticated models *decreases* with complexity

Defaults and correlations

- If we assume *independent* defaults, we can use the binomial distribution
- Increasing correlation increases risk of all tranches
- It is mathematically straightforward to add correlations
- For example with the infamous David *Li's Gaussian copula*

David Li's Gaussian copula

- David Li proposed in 2000 a method for calculating correlated defaults
- It assumes that defaults are correlated in the same way as the *multivariate normal distribution*
- Hence the *Gaussian copula*

Gaussian copula implemented

- X is standard normally distributed, i.e.,

$$X \sim \mathcal{N}(0,1)$$

- Probability of default is p
- Default happens if the outcome of the random variable is below the inverse normal distribution at the probability p, i.e., if

$$x \leq \Phi^{-1}(p) \equiv Q$$

$$\begin{array}{ll} \text{if } x \leq Q & \text{default} \\ \text{if } x > Q & \text{no default} \end{array}$$

- Suppose we have N assets
- X is a $N \times 1$ vector, with each element corresponding to an asset
- Therefore, X has the distribution

$$X \sim \mathcal{N}(0, \Sigma)$$

where Σ is the covariance matrix

Factor structure

$x_i = \sqrt{\rho} f + \sqrt{1-\rho} z_i$	outcome for bond
$F \sim \mathcal{N}(0,1)$	common factor
$Z_i \sim \mathcal{N}(0,1)$	idiosyncratic shock

Where the factor is F, within individual outcome f, whilst the idiosyncratic shock is Z_i with an individual outcome z_i, and correlation ρ

We then have that the probability of default *conditional* on the factor f is:

$$\Pr(x_i < Q|f)$$

$$\begin{aligned}\Pr(x_i < Q|f) =& \Phi\left(\frac{Q - \sqrt{\rho} f}{\sqrt{1-\rho}}\right)\\ =& \Phi\left(\frac{\Phi^{-1}(p) - \sqrt{\rho} f}{\sqrt{1-\rho}}\right)\\ =& p|f\end{aligned}$$

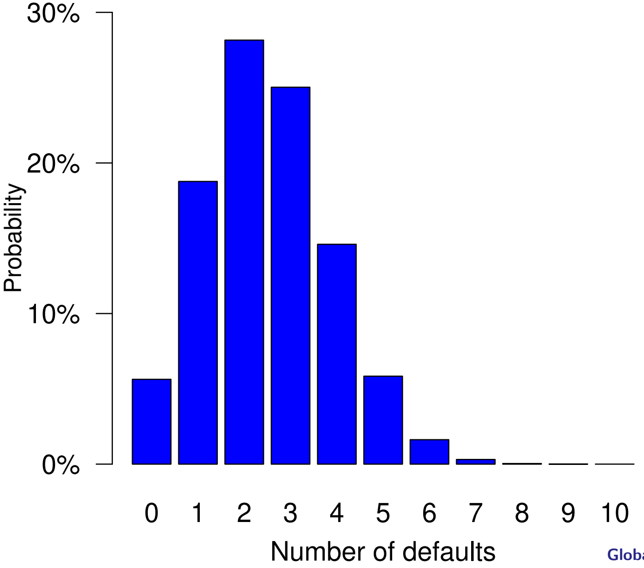
What about f?

$$g\left(k|n,p,f\right) = \binom{n}{k} (p|f)^k (1-p|f)^{n-k}$$

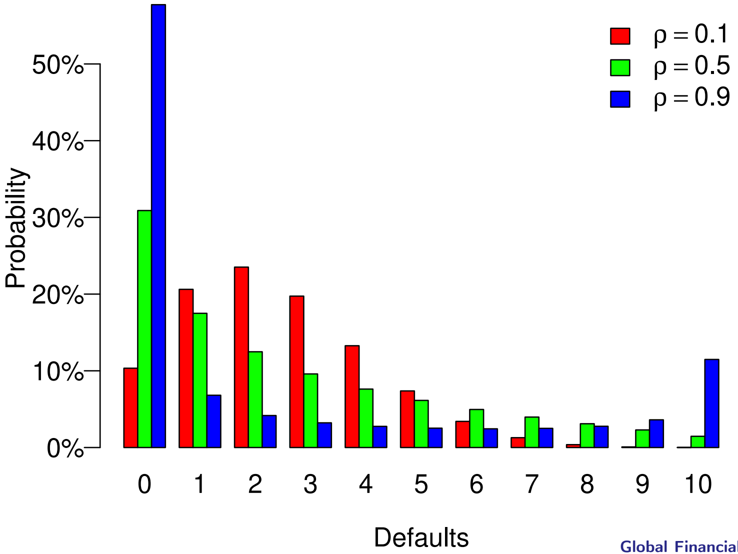
Integrate over the density of the factor, in our case the normal or $\phi()$:

$$\int_{-\infty}^{\infty} g\left(k|n,p,f\right) \phi(f) df$$

Distribution of defaults, $\rho = 0$



Correlations



Impact of Correlation on Defaults

ρ	probability of defaults	
	8–10	6–7
0%	0.04%	1.93%
20%	1.46%	6.84%
40%	4.77%	8.83%
60%	9.15%	8.59%
80%	14.47%	6.70%
100%	25.00%	0.00%

The First Phase of the Crisis

The 2007–2009 Crisis

Ratings of CDOs vs. corporates

- 80–year history of corporate ratings
  - in a recession *flight to quality* — spreads on highest ratings narrow
  - defaults on highest ratings idiosyncratic events
- 15–year history of CDO ratings
  - concentrate economic risk
  - CDOs are like "*economic catastrophe bonds*" — see next slide

CDOs like economic catastrophe bonds

- Such bonds pay out if things go well, but allow borrower to defer or cancel payment if a disaster happens
- Most AAA corporates are the opposite
  - because of flight to quality, their spreads narrow in crisis
  - only AAA to default in crisis was AIG
- CDOs are the opposite
  - their risk only becomes apparent during downturns
- Therefore, they have been said to be like economic catastrophe bonds

Resecuritisation — CDO^2

- Enormous demand for CDOs tranches
  - after all, who can resist something with AAA risk by paying 2% more
- Market responds by *specifically demanding high risk assets*
  - banks came to the Icelandic banks when they were the riskiest in the world and *asked them to issue debt*!
- Another trick was to use CDO tranches as inputs into CDOs — CDO^2 — and even again CDO^3

Optimization

- Some CDO tranches are more valuable than others
- Optimizing the CDO structure — software from rating agencies
- Optimization is same as minimizing quality of the asset pool
- The cheapest way to optimize is to use assets with higher loss given default and higher default correlations than assumed in the modeling
- Because they are cheaper
- Affects the value of all tranches
- High demand for high risk — low recovery assets — *garbage*

Was it a "subprime crisis"?

- In the beginning subprime was blamed
- But it was only the instrument — need for high risk fixed–income assets
- Subprime–securitization–CDO boom was demand driven
- It was a classic bubble

Off Balance Sheet Vehicles and the Crisis

Conduits

- A SPV usually is "sponsored" by a single bank which retains a slice of equity
- It issues asset–backed commercial paper (ABCP) to fund purchases of longer term ABS
- But ABCP is a *short–term debt instrument* (90 days or less), needs to be rolled over regularly
- Overcollateralization and liquidity facility from sponsor ensures good ratings for the ABCP
- Conduits profit from maturity and credit spread

Why do conduits?

- Sponsoring bank earns fees by guaranteeing low cost borrowing
- Assuming the ABCP markets would always function
- Nice fat steady fees at no risk
- Except, ignores *liquidity risk*
- Popular with unsophisticated midsize European banks
    - Like German Landesbanks

The canary in the coalmine dies

RIP IKB July 2007

- Conduits €10 billion, (20% of IKB balance sheet)
- IKB 38% government–owned
- Bailout: €9 billion – until now (€125 per German)
- BaFin asleep
- IKB later made name for itself by transferring money to Lehman's — after the latter defaulted

Shadow banks

	Old Style Bank	Conduit
Equity Capital	Shareholders	Sponsor
Debt	Short–term deposits	Short–term ABCP
Assets	Long–term loans	Long–term loans

- In good times, these structures allows banks to enhance earnings without holding the assets themselves
- They are off balance sheet, enabling risk to be hidden from shareholders and regulators