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Lecture Note 9.1: Asset-backed Securities

Introduction:

Today we continue our examination of credit-based products to consider the universe of *asset-backed securities* (ABS).

Securitization of cash-flows is a very important tool of financial engineering. To understand why, we need to start by examining the constraints of loan originators. Our discussion will show us how particular contract forms in ABS evolved.

Then we turn to the the topic of modeling ABS. We will see that different structures allow us to use different sets of tools. In some cases, our valuation models cannot give us no-arbitrage prices. But in many cases the models are still extremely useful.

Outline:

I. The Problem; The Solution.

II. Securitization with Large Pools.

III. Unhedgeable Repayment Risk.

IV. Example: Guaranteed Mortgage-Backed Securities.

V. CDOs.

VI. Summary.

I. The Problem.

- The vast majority of financing activity through out the world consists of small loans (less than $5 million, say) to companies and individuals.

- From the point of view of the lenders, these are all primary securities in the sense that their underlying default risks are particular to individual borrowers and cannot be hedged.

- The logic of diversification suggest that markets as a whole should not care about idiosyncratic exposures to the extent that they represent an infinitessimal contribution to the risk of a well-diversified investor.
  - ▶ Diversified investors are *neutral with respect to idiosyncratic risk.*

  - ▶ So they charge interest that is proportional to the true probability of default, without any additional risk premium.

- On the other hand, these loans are <u>not</u> made by diversified investors. They are made by individual banks.
  - ▶ Non-diversified investors are *NOT* neutral with respect to idiosyncratic risk.

  - ▶ They will demand extra compensation for bearing it.

- Do banks – or bank owners – care about idiosyncratic risk?

- If the banks themselves have access to competitive finance from perfect markets, then their own cost of capital should not depend on the idiosyncratic risks they bear.

- In practice, though, capital markets do impose limits on the idiosyncratic risk banks can hold in their loan portolios.
  - ▶ Banks rely on customer deposits that governments guarantee. Governments impose capital charges that are directly tied to total default risk.
  - ▶ Another constraint comes from *asymmetric information*.
    - ∗ Banks know more about their asset values (i.e. the quality of their borrowers) than markets do.
    - ∗ Public markets will effectively punish them for this: they will assume that loan originators will seek external capital when their private information is worse than the market knows.
- If external finance can be limited or expensive, and if liquidation would be costly to bank investors (e.g. when loan losses are large and cannot be funded), then banks themselves will rationally behave as if they are *averse to idiosyncratic risk*.
  - ▶ Their loans will impound an additional risk premium in excess of the default probability.
- In a competitive market, any bank that can overcome this problem will be able to provide cheaper loans and gain a competitive advantage.
- So the question is: how to get the market-priced funds (which don't penalize idiosyncratic risk) through to the borrowers?

- One answer is to sell the loans to large well-diverisified investors.
  - Even if we can't sell each loan to the whole public, all it should take is one (non-constrained) buyer that is large enough to not price the idiosyncratic risk of each borrower.

- Of course, large buyers will also find it costly to transact in lots of tiny assets. So it might make sense for the bank to sell groups of loans together.

- It is only one further step from here to recognize that if the set of loans is big enough, then the whole collection could be sold as a public security.
  - Achieving this often requires grouping the loans from multiple banks into a pool.
  - The pool is held by a separate legal entity, whose cash-flows are then passed straight to the security owners.

- In this case, the size itself may achieve a further goal: *the pool itself may be well-diversified.*
  - If there are enough names that individual risk contributions average out, the pool cash-flows may now only be functions of aggregate economic factors.
  - But note that this is not a requirement for the pooling to achieve its objective: even if the issue is still subject to idiosyncratic risks, if it is priced by the market as a whole, those risks will not affect the required rate of return.

- For asset-backed finance to work, however, there is a crucial requirement: the act of selling the loan (to the pooling entity) must not *by itself* lower the loan's value.
  - ▶ If the borrower's performance depends on the actions of the originating bank – perhaps through advice and access to other financial products – then taking away the incentive to provide those services may degrade the loan's outcome.
  - ▶ Similarly, the bank may not have the same incentives in a loan foreclosure if it is not protecting its own investment.
  - ▶ For these reasons, spelling out the *loan servicing agreement* is a key step in the contract design.
- What about the asymmetric information problem?
  - ▶ How can the market know that the loans being put into the pool are not the ones that are most likely to underperform?
  - ▶ There are a couple of potential mechanisms to deal with this.
    - ∗ The pool may have the right to put individual loans back to the originator if they are later found to be of lower quality than reported.
    - ∗ The originator may be required to retain an interest in the loan performance by buying some fraction of the pool. If the originator holds the most exposed piece of credit risk, that is a strong incentive to monitor quality level.

- This discussion illustrates that contract design is an important component of financial engineering.
  - ▶ Understanding how people value risks requires identifying the constraints under which they operate.

- Now let's think about how we can apply the tools of financial engineering to model ABS products.

II. Securitization of Large Pools.

- An important segment of the asset-backed finance market deals with pools of loans whose principal payments include a lot of default risk. Examples include:

(A) Small-business loans or lease payments;

(B) Credit-card debts;

(C) Automobile loans;

(D) Commercial property mortgages;

(E) Sub-prime residential mortgages.

- The presence of default risk motivates <u>tranching</u> as a mechanism to isolates those risks.
  - ▶ Tranching just means that the entity that owns the pool sells different claims on the cash-flows (different classes of bonds) whose priority in receiving repayments is strictly determined.
    - ∗ The tranches are thus indexed by their seniority: from super-senior down to junior.
    - ∗ The bottom tranche is usually called the "equity" tranche. Technically it is still a bond. But, like stock, it only gets the rights to residual cash-flow after everybody else has been paid.
    - ∗ If any of the underlying loans defaults, the principle amount of the loan is deducted from the most junior tranche, and the recovery amount (if any) goes to the most senior.

- $*$ This process can lead to both the highest and lowest tranches evaporating.
  - The highest tranche can have its principal entirely repaid early.
  - The lowest tranche can be entirely wiped out.

  Of course, when either of these events happen, the next-most junior/senior tranches inherit the rights/obligations.

- ▶ A typical *collaterlized loan obligation* (CLO) might have 10 tranches.
  - $*$ This allows the underwriter of the CLO the ability to fine-tune the bonds to meet the demands of underlying investors
- ▶ It would not be unusual for the top 80% or more of the principal to get rated AAA or AAA+.
- ▶ Tranching can thus manufacture almost riskless assets from very risk ones.

- Sometimes the rules governing what actually happens with the loans in the pool can be quite complex.
  - ▶ First, the life-span of the loans could in theory be up to 30 years or as little as 1 year. Within a pool, the top tranche might get repaid within 90 days (an example of *asset-backed commercial paper*).

- Second, default timing and realization of recoveries are less straightforward: delinquent loans stay in the pool and the omitted principal payments are written down as they occur.
- Third, the loans often have diverse and non-standard features, like adjustable rates or the option of the borrower to defer principal repayment.
- Fourth, it is not uncommon for the issuer to obtain third-party guarantees similar to government agency ones for some portion of the principal.

- Despite this complexity, it is usually possible to express the cash-flows that each tranche will receive as a straightforward function of the interest payments, principal pre-payments, defaults, and recoveries of the individual loans.
- In general, these cash-flow streams represent *unhedgeable* risks.
- However, there is an important special case where this is not true.
- If the pool is large and diversified enough, then it may be the case that the default rates and prepayment rates can be expressed entirely as functions of factors that we can hedge.
  - If the idiosyncratic risk is negligible, the remaining risk might be modeled as driven by things like interest rates and other macroeconomic variables.

- ▶ For example, aggregate house-price risk could be hedged with baskets of building company stock or real-estate holding companies.
- ▶ Credit-card pools might be hedgeable with stocks of consumer finance companies.

- Then – if the pools cashflows only do depend on spanned factors – we could proceed to pricing them via the familiar steps:

  1. Express the pool cash-flows as (determinisitic) functions of the economic state variables.

  2. Fit stochastic models for the (true) evolution of the state variables.

  3. Risk-neutralize these using estimates of the market price of risk of each.

  4. Value the tranches via simulating the risk-neutralized model and discounting the expected cash-flows.

- Thus, large diversified pools may be another class of derivatives to which no-arbitrage pricing applies.

- If we had a pool of 10000 automobile loans from all over the U.S., for example, we might think that the defaults can be modelled by a continuous decay-factor, δ_t.
  - This would be like the spoilage rate for a commodity, with the pool's principal balance, Π_t, decaying like $d\Pi/\Pi = -\delta_t \, dt$
  - Perhaps δ_t can be modelled as a function of interest rates, and the stock market, and the credit spread on risky corporate bonds.
  - Then no-arbitrage pricing would allow us to compute the price of tranches of the pool using the risk-neutralized decay rate.

III. Unhedgeable risk

- Some ABS are created from underlying assets that are definitely not large diversified pools.

- An interesting example is **revenue-backed bonds**.
  - Companies sometimes sell bonds whose cash-flow is backed by revenue streams from licenses or patent payments.
  - Artists and athletes sell the rights to their own revenues.
  - Public sector entities may issue debt tied to revenue from specific taxes or fees.

- As with other ABS, the motivation here is to transfer the risk that it is inefficient for the issuer to bear.

- Notice, by the way, that these examples do not involve default risk.
  - However, they certainly DO involve risk.
  - The amount of cash generated by the assets may be highly idiosyncratic.

- Likewise, small loan pools are exposed to the idiosyncratic default risk of the individual borrowers.

- It would not be realistic to assume such risks were spanned by traded assets.

- When we move away from risks whose exposures we can hedge with existing markets, we can no longer say exactly what it will cost to replicate the pool cashflows.
  - Thus we have no basis for asserting that that the price must be equal to anything in particular.
  - Different people may have different subjective risk-prices for the unhedgeable exposure.
- This is the key limitation of our models that we have to keep in mind.
  - *The price for an unspanned risk can be whatever the market wants to pay for it.*
- In a couple of weeks we will think about using our modeling framework to compute *subjective* valuations for such cash-flows.
- Even when we cannot price ABS by no-arbitrage methods, however, we can still use stochastic modeling techniques to help us understand and quantify the risks in the asset pool.
- To illustrate, consider the largets ABS market in the world.

IV. Guaranteed Mortgage-Backed Securities

- Almost all of *housing finance* is backed by mortgages. In the U.S., almost all standard-quality residential mortgage loans are packaged into pools, whose repayment is guaranteed by a government sponsored agency.
  - ▶ These are not tranched securities. There is only one class of bonds, which receives all the cash-flows minus some fees.
  - ▶ The "agency" might be GNMA, FHMC, GNMA, or FHA. They were created specifically to encourage securitization so that originators would not face capital constraints.
    - ∗ In 2017, GNMA alone guaranteed issuance of over $470 billion of new MBS.
    - ∗ Total outstanding principal is 1.8 *trillion*.
- For loans to be eligible for such pooling, they must be "conforming", which means they must be smaller than a certain size (i.e., not for luxury mansions) and the borrowers must have met some credit quality threshhold.
  - ▶ To make life simpler, the issuer will typically group loans into pools based on certain common features of the loan.
  - ▶ For example, all the loans might have 6.5% fixed interest, 25 year life, and have been created in the first quarter of 2010.
- Agency-backed bonds are centrally cleared through DTCC. And liquid repo markets for these bonds enable short-selling.

- Now because the government repays the principal on any mortgage that goes into foreclosure, there is virtually no default risk *or* recovery risk in these bonds.

- Instead, what makes these securities interesting is that there is *timing risk*.

(A) A homeowner may choose to repay his/her loan at any time (for example if the house gets sold or the loan is refinanced at a lower rate) with minimal penalty.

(B) Also, if the homeowner does default, the principal repayment by the insuring agency is immediate. But the timing of such events is uncertain.

So either one affects the present value of the ultimate cash-flows.

- Let's think about modelling the aggregated cash-flows to the bondholders.

- Our first step will be to specify a model of prepayment rates. I will let Z_t denote the percentage of the principal that is repaid at time t.
  - ▶ For now, we won't distinguish between the default and non-default (refinancing) components of Z.
  - ▶ If we make a transformation $\pi = \log(Z/(1-Z))$ (so $Z = e^{\pi}/(1+e^{\pi})$) then π summarizes the same information, and it is not restricted to be between 0 and 1.

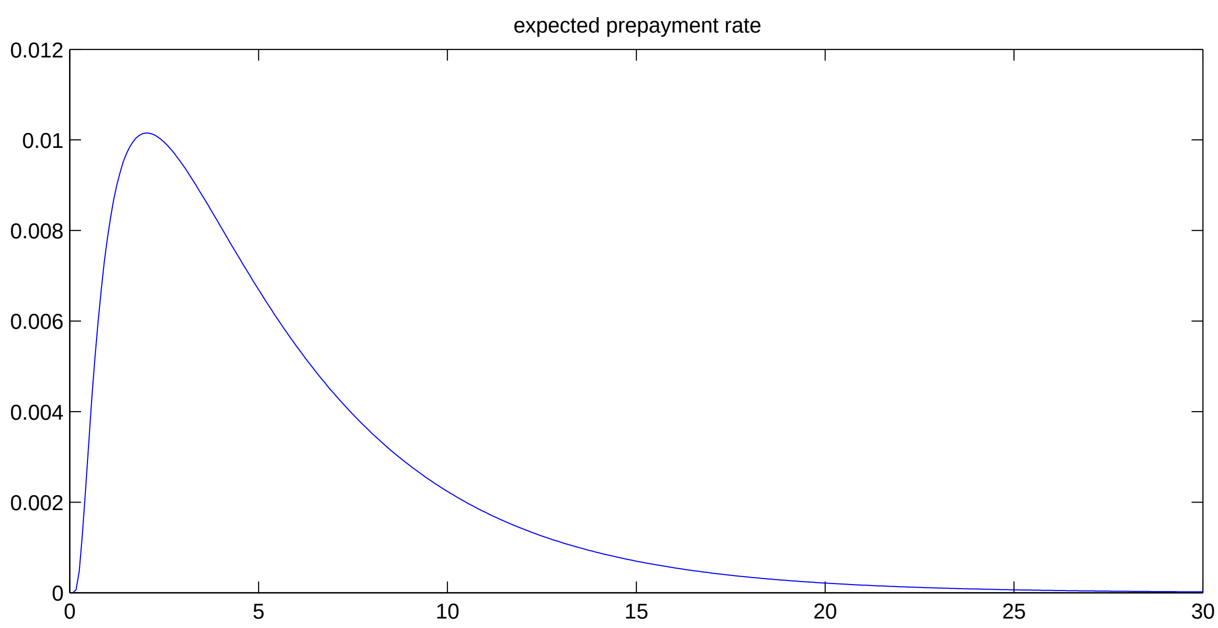
* If O_t represents the fraction of the original loans in the pool that have not repaid by t then its law of motion is simply

$$O_{t+1} = O_t\ (1 - Z_t).$$

- The transformed variable might obey a model of the form:

$$\pi_t = \bar{\pi}(t, T) + b\ (r_{t-1} - c) + \epsilon_t$$

- Here $\bar{\pi}$ is the unconditional mean per period. Most repayment occurs between years 2 and 5; there is little after year 15. So it might look like this (transforming back to Z units):



- In practice, one can buy detailed data sets on prepayment histories and – given a particular pool – construct the expected prepayment profile as a function of pool characteristics including: average age and term of mortgages; borrower demographics (age, income, locations); loan features (adjustable, fixed, balloon, etc).

- There are also predictable seasonalities in $\bar{\pi}()$. Fewer mortgages are prepaid in the winter, for example.

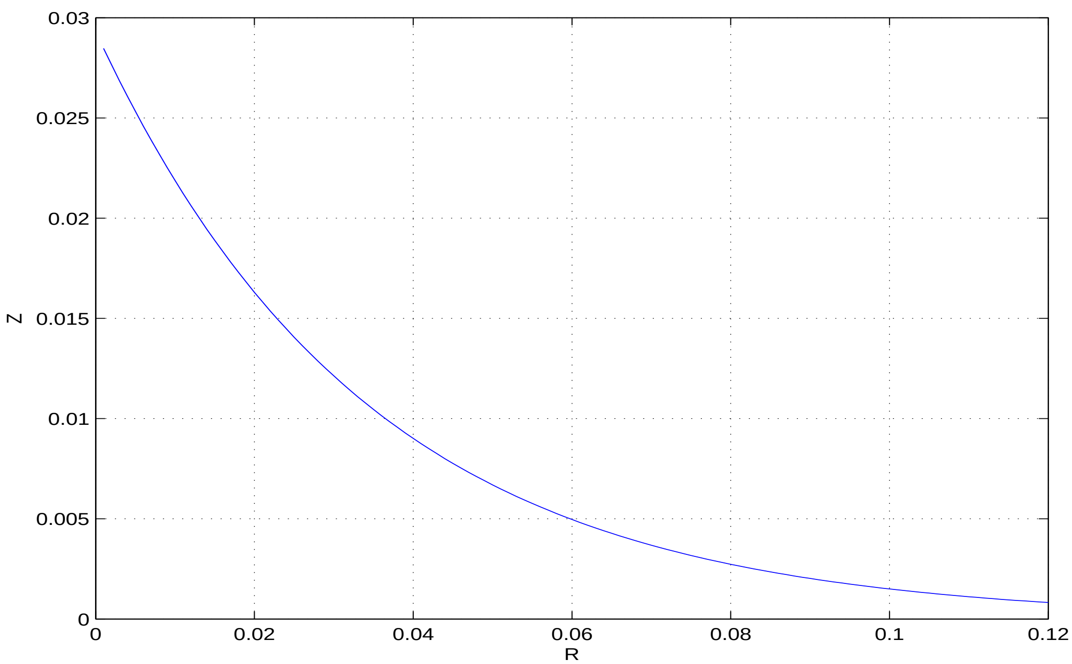
- The second term in my π_t model captures the interest-rate sensitivity of prepayment. The dominant influence on prepayment rates comes through the homeowner's incentive to refinance.

  - So r_{t-1} could be the current new mortgage interest rate.

    - We might model it directly, or else view it as a function of the long-term Treasury rate in an embedded term-structure model.

  - And c could represent the average coupon rate on the mortgages in the pool.

* If π has a linear dependence on r, this implies that Z is a very concave function, which captures the homeowners' optionality of prepayment.



- Of course, this too can be improved with real data.

  * One interesting feature of real-world behavior is that the rate sensitivity declines with the fraction of loans remaining. So we might have $b = b_0 + b_1 O_t$.

  * This effect, called *burnout*, reflects the fact that homeowners who do not take advantage of early refinancing opportunities probably won't do so later either (perhaps due to behavioral factors).

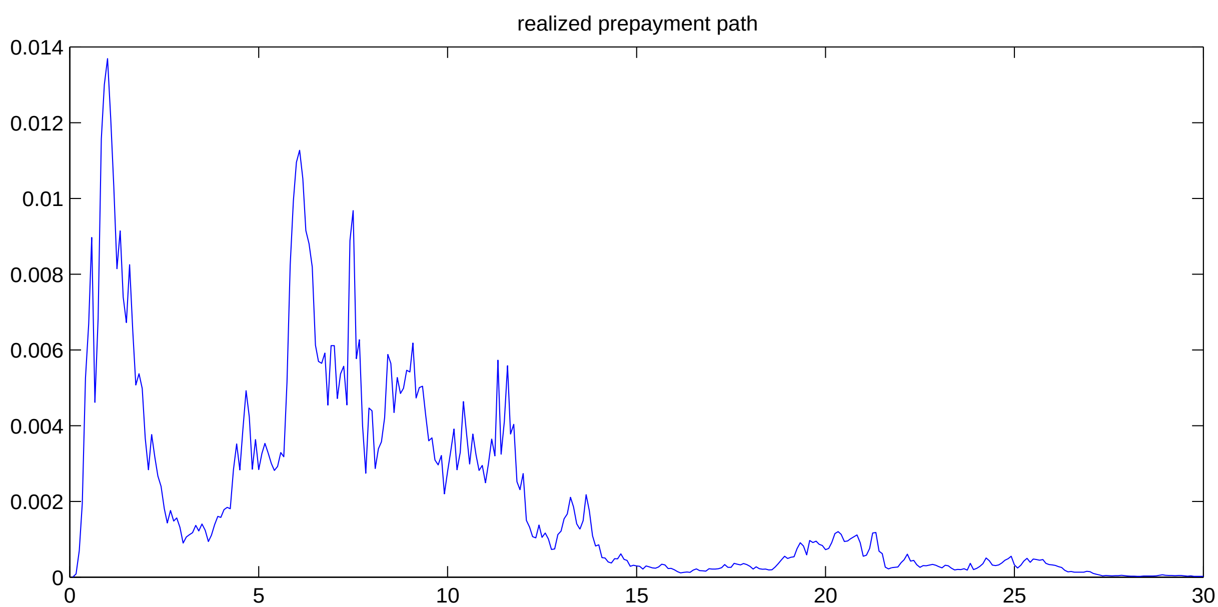
▶ Finally, the third term in my π specification captures all other shocks, due to the local economy, weather, etc that we cannot predict.

* Even state-of-the-art prepayment models only achieve R^2s of around 90%.

* These residual shocks will have some persistence, rather than being $i.i.d.$

- To use the model, we would need to quantify the stochastic parameters for ϵ_t and r_t.
  - ▶ Most importantly, we need to estimate (a) the variance and (b) the persistence of each type of shock.

- An actual repayment history might look like this.



- Ok, that's a model of the early payment. To fully describe the cash flows of our mortgage pool, we need to also describe the scheduled payments.
  - ▶ We expressed the pre-payments as a fraction of remaining *loans* outstanding, O.
    - $*$ The loan amortization schedule determines how how much principal remains in each loan.
  - ▶ For standard fixed-rate mortgages, the principal balance $p(n)$ at the start of month $n+1$ is $(1+c)p(n-1) - A$ where A is the scheduled payment (principal plus interest) and the loan interest rate is c (per month).
    - $*$ Then by iteration

$$p(n) = p(0)(1+c)^n - A\sum_{k=0}^{n-1}(1+c)^k = p(0)(1+c)^n - A\frac{(1+c)^n - 1}{c}.$$

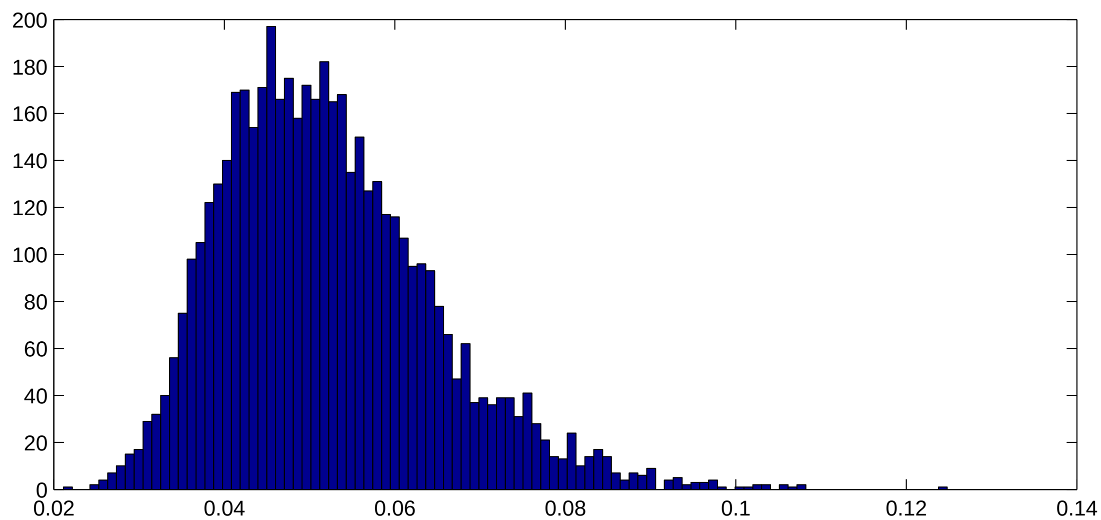
    - $*$ One can then solve for the A amount such that the full principal is repaid by any given T. If $p(360) = 0$ and $p(0) = 1$, for example, then

$$A = \frac{c}{1 - \frac{1}{(1+c)^{360}}}.$$

      (Here c is the interest rate *per period*, not annualized.)
  - ▶ Plugging in the solution for A gives the full schedule $p(n)$.
  - ▶ Then the total cashflow at month n is

$$A\ O(n) + p(n)Z(n)O(n).$$

- Now, given some estimated parameters for the r and ϵ processes, we have a full description of what the pool cash-flows will be along any realized outcome.
  - ▶ So it is a simple matter to simulate outcomes and compute, e.g., the present value of all the payments.
- Here's the realized annual return distribution (assuming riskless reinvestment of cash-flows) from one simulation run of the above model, using some plausible parameters.



- Having the full distribution allows us to say, for example, what the probability is of experiencing a return less than 4 percent.
- Note that there are no really scary outcomes from this asset because of the default protection.

- Models just like this are actually used by investors to analyze MBS pools.

- By further simulation, it would be straightforward to compute the exposure to r by seeing how much the terminal cash changes for a change in the starting value r_0.
  - ▶ This could tell us how to hedge the interest rate risk both today and through the life of the bond.
  - ▶ To see how much risk is left once we do that, we can compute the distribution that would result if we shut down the variation in the riskless rate.

  This information might detemine the amount of capital we want to reserve against this security for risk management.

- If you think about the nature of the risk here, the concern is that holders of the pool recieve their money back sooner precisely when they do not want to: when rates go down.
  - ▶ Conversely, when rates go up, they are stuck with long-duration low coupon bonds.

- Hence prices do not rise very much as rates go down, and fall relatively fast as they rise.

- The type of model developed above would be very useful for hedging and risk evaluation.

- But notice I did not suggest that the model tells us the *value* of the security.
  - ▶ This is because timing – or prepayment – risk may not be hedgeable.
  - ▶ Remember that an R^2 of 0.90 means that 10 percent of the variance of prepayments is unpredictable and is thus not associated with economy-wide factors that might be spanned by asset markets.

- We thus cannot assert that the risk-neutral discounted value of the cash-flows must be the no-arbitrage price of the pool.

V. CDOs as derivatives.

- Just like other loans, corporate bonds can be packaged into pools and sold off as separate tranches.
  - ▶ These are called collateralized debt obligations (CDOs).
- This is a unique type of ABS in the sense that the underlying assets are themselves traded securities.
- This raises the possibility that we can directly replicate (or perfectly hedge) the cash-flows to the CDO tranches by trading in those underlying bonds.
  - ▶ Hence no-arbitrage pricing should apply here.
- In an idealized case, the underlying assets are all bonds or loans maturing at the termination date of the CDO. The CDO is then totally passive.
- Some CDOs aren't like this. Like CLOs,
  - ▶ The assets are not separately traded (or are very illiquid).
  - ▶ The assets may have differing lives.
  - ▶ The CDO manager may have the right to change the assets by trading in the market.
  - ▶ Some of the tranches may be callable.
  - ▶ There may be additional guarantees of repayment by third parties.

- Such complex CDOs are not pure derivatives. We should not expect no-arbitrage models to apply to them.

- But the idealized CDOs do exist. So let's think about modeling them.

- Actually we can distinguish between two types of such securities.

  Cash. These are what we just described. They hold tradeable corporate bonds maturing at T. The tranches are defined by their upper and lower attachment points (and their coupon interest rates). When a bond defaults, the principal amount of the lowest tranche is reduced by the amount of the loss, $(1 - R)$. The amount R is paid to the highest tranche (and its remaining principal is lowered by that amount.)

  Synthetic. These own riskless bonds maturing at T and *short positions* in CDSs (to date T) on a collection of risky names. The fees they receive plus the riskless interest makes up the interest payments to the tranches.

- In our idealized case, the two structures are economically identical. The cashflows are a function only of the history of default losses.

- A further sub-case of a synthetic CDO is **unfunded**.
  - Here there are no riskless bonds at all, so the only cash flows to tranche holders come from the short CDS positions.

- ▶ When an investor goes "long" a tranche, he pays nothing. He receives a share of the CDS fees, and nothing at maturity.

- ▶ When a default occurs, holders of the lowest tranche must pay $(1 - R)$ to settle the CDS – until its notional principal is exhausted. The top tranche's principal is reduced by R, but it receives no cash.

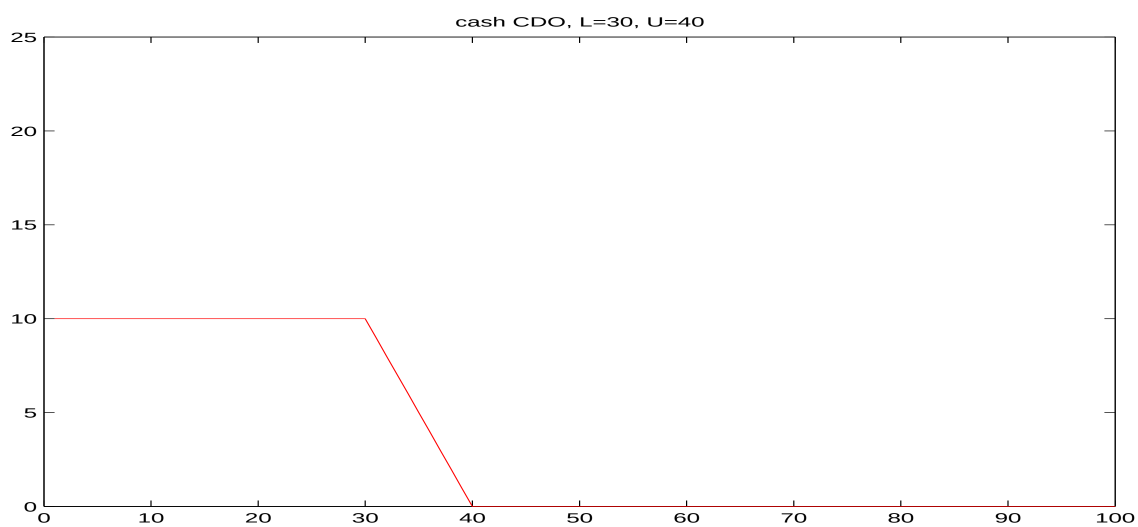
- We could go further and construct a purely theoretical unfunded synthetic CDO today by selecting a set of names and *imagining* that we sell protection on them and then tracking their collective cashflows until T.

- In fact, the market does this. There are several standard indexes of CDS portfolios.
  - ▶ For example, the **CDX, NA, IG** index tracks the performance of a portfolio of 125 equally-weighted North-American, investment-grade, cash-settled, 5-year CDSs. A new version is created every six months.
  - ▶ We can then define a hypothetical CDO tranche by specifying upper and lower attachment points. We can then track the hypothetical cash-flows of any such tranche over time.
  - ▶ Also, people can then trade these purely theoretical index tranches by doing what amount to **return swaps**: one side paying a fee (as a percentage of remaining principal), and the other paying the default losses for which the tranche of the portfolio is responsible.

▶ We then have market-determined prices (fees) for each tranche over time.

Notice that no one actually ever has to create this CDO as a legal entity and there can still be trade in the synthetic tranches. And there is no constraint on their size.

- If we have a tranche with upper and lower attachment points U and L, we can plot the total payouts to the protection selling leg as function of the total default losses of the original pool.



- Next time we will take up the issue of applying no-arbitrage valuation to such CDO tranches.

VI. Summary

- Securitizing cashflows is a hugely important financial engineering tool.
  - ▶ It transfers risks from entities who are averse to bearing them (or are constrained by regulation) to those who are less so.
- The keys to accurate modelling of asset backed securities are reliable models of the mechanisms that trigger default and prepayment.
- When pools are very large, the drivers of these risks may be hedgeable macroeconomic statistics, in which case no-arbitrage valuation tool can be used to price them.
  - ▶ This is often not the case. Asset-backed structures can still achieve their financial engineering objectives (low cost funding) even for pools with few borrowers and large idiosyncratic risk.
- In these cases, our models cannot tell us a no-arbitrage valuation.
- When the pools are literally traded assets, no-arbitrage valuation may apply if all the risks can be hedged.