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Lecture Note 9.3: Asset-backed Finance

Introduction:

Last time we analyzed the pricing and risk characteristics of CDOs composed of tradeable corporate bonds. We never discussed *why* such strange things exist.

CDOs are a special case of a much broader class of instruments: *asset-backed securities.* This note describes the general features of this class. We will consider the financial engineer problem it is designed to address, and see how our tools can be used to price and hedge the products.

Unlike CDOs, often these products <u>cannot</u> be considered credit derivatives. However, under some conditions, they may be considered as derivatives of non-traded risk factors. On the other hand, we have to be especially aware of the limitations of no-arbitrage pricing models in this context.

Outline:

I. The Problem; The Solution

II. Example: Guaranteed Mortgage-Backed Securities

III. The Role of the Models

IV. Default Risk in Pools

V. 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 risks are particular to individual borrowers and cannot be hedged.

- At the same time, 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.

- On the other hand, these loans are <u>not</u> made by diversified investors. They are made by individual banks. (They are obviously too small to be sold as bonds to the public market.)

- Banks themselves might not care about idiosyncratic risks either. IF they themselves have access to competitive finance from perfect markets, then their own cost of capital will not depend on the idiosyncratic risks they bear. So they, in turn, should be able to provide competitive rates on the financing they offer customers.

- In practice, though, banks DO face limits on the idiosyncratic risk they can hold in their loan portolios.
  - ▶ Their competitive advantage comes from deposit pools that the government guarantees. These are not easily expandable. And governments regulate the ratio of loans to deposits.

- ▶ Another constraint on financing for banks comes from *asymmetric information* problems.
  - ∗ They 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 behave as if they are *averse to idiosyncratic risk*.

- In a competitive market, any bank that can overcome this problem will be able to provide cheaper loans and enhanced profitability.

- 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 the event of 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. In fact, this is one reason to introduce *tranching:* if the originator holds the most exposed piece of credit risk, that is a strong incentive to enforce a minimum quality level.

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

- Let's look at a very important example of pooling.

II. Guaranteed Mortgage-Backed Securities

- One of the largest components of the asset-backed securities market is for pools of standard-quality residential mortgage loans, whose repayment is guaranteed by a government-sponsored agency.
  - ▶ This is not a tranched security. 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.
  - ▶ Despite the proliferation of more complicated products, this continues to be the way that most mortgages in the U.S. are ultimately financed.
    - ∗ In 2012, U.S. agency-backed of $2 *trillion* of new bonds.
    - ∗ Total outstanding principal was $5.9 trillion at the end of 2013.
- For loans to be eligible for such pooling, they must be "conforming", which means they must be no bigger than a certain size and the borrowers must have met some credit quality threshhold.
  - ▶ To make life simpler, the issuer will also 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) Typically, 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 has to be specifying 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.

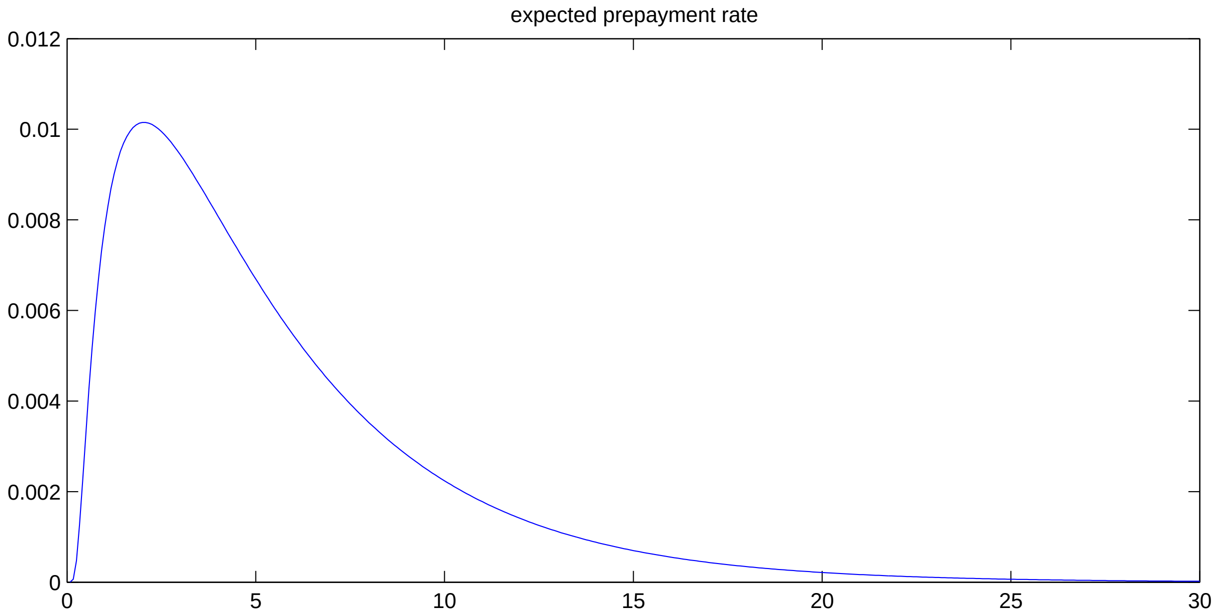
  * If O_t represents the fraction of the original loans in the pool that have not repaid by t then its law of motion is simply

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

- 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):



- I just made that function up. In real life, 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.

- 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.

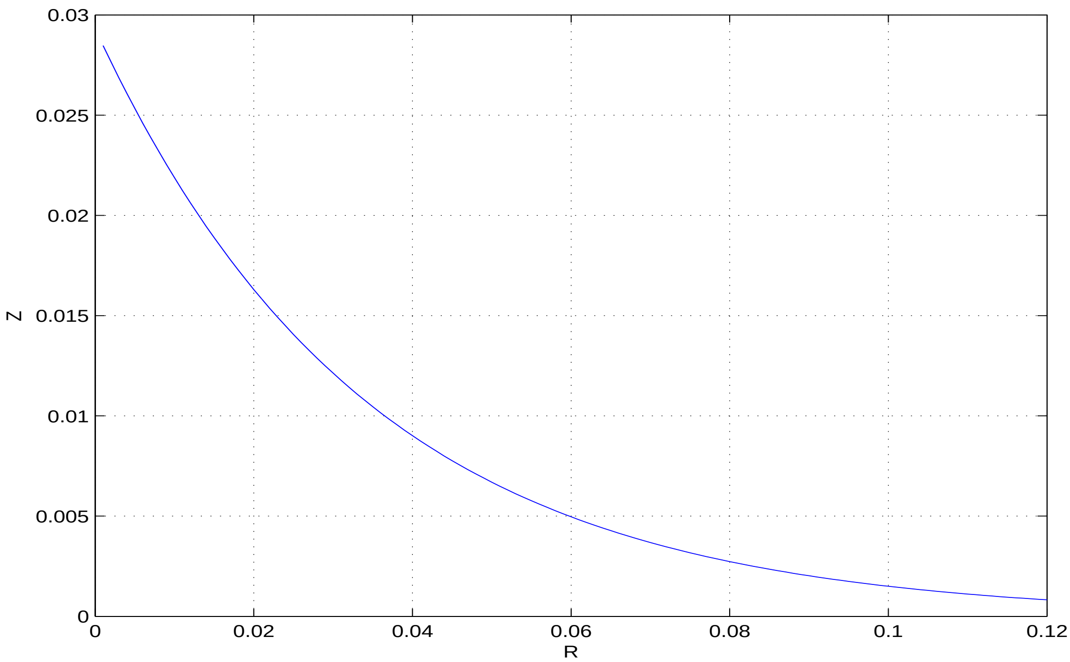
- So in my specification above r_{t-1} might be the current new mortgage interest rate.

  * Most prepayment models include just this single state variable.

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

- The variable c might be the weighted average coupon rate (WAC) on the mortgages in the pool.

* I'm using a linear form, but in terms of Z, it is a very concave function of $r - c$, as one might want in order to capture the homeowners' option in reduced form.



- Of course, there is no reason why one should be content with a simple linear form. This too can be improved with real data.

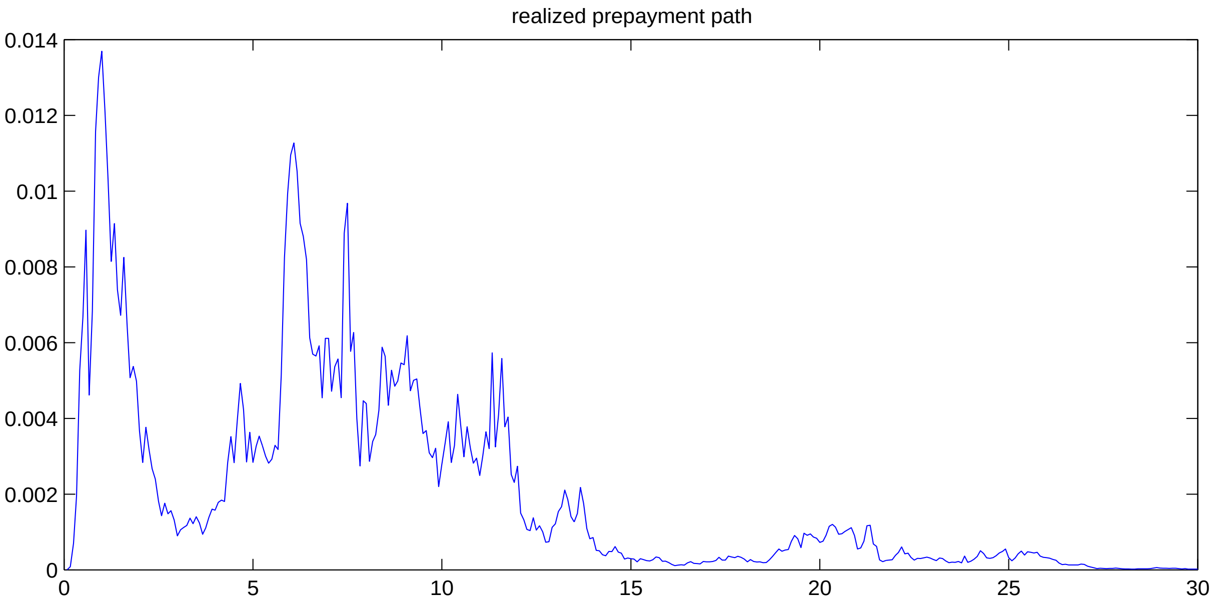
  * An interesting feature of real-world behavior is that the rate sensitivity declines with the fraction of loans remaining. So we might have $b = b_0 + b_1 O_t$.

  * This feature, 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 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.
  - ▶ I'm going to assume we've got some relevant historical data, and fit first-order autoregressive processes for each.

- An actual repayment history might look like this.



- Ok, that's a model of the early payment. To fully describe the cash flows, we need to also write down the algorithm for the scheduled payments.
  - ▶ We expressed the pre-payments as a fraction of remaining *loans* outstanding, O.
    - $*$ We need to know how much principal was left in these loans. Then we have to compute the scheduled ammortization.
  - ▶ 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

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

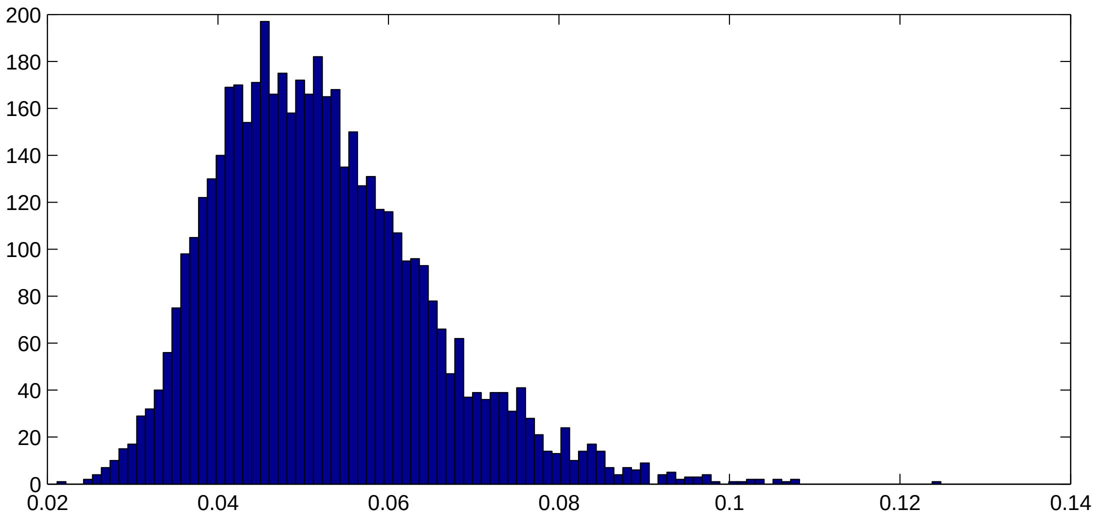
    - $*$ One can then solve for the A amount such that the full principal is repaid by any given T. If $p(360) = 0$ and $p(0) = 1$, for example, then

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

  - ▶ 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.
  - ▶ Since the interest rate is the key state variable, the exercise has to take into account the variability of the discount factor along each path, of course.
- Here's the realized annual return distribution (assuming riskless reinvestment of cash-flows) from one simulation run of the above model, given some plausible parameters.



- The expected return was 5.31 percent and the NPV was 101.89.

- We can summarize the risk by the standard deviation of annualized returns. But we can actually do much more.
  - Having the full distribution allows us to say, for example, what the probability is of experiencing a return less than 2 percent.
  - Note that there are no really scary outcomes from this asset because of the default protection.
- With this model it would also 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.

III. The Role of Derivatives Models.

- The discussion above shows that it is not that hard to build a simple discrete-time model of MBS cash-flows based on a stochastic prepayment specification.

- I argued that this would be very useful for hedging and risk evaluation.

- But notice what I did not do:
  - I did not suggest that the model tells us the *value* of the security. Why?

  - Because I did not assert that timing – or prepayment – risk is hedgeable.

  - Remember that an R^2 of 0.90 means that around 10 percent of the variance of prepayments is unpredictable and unhedgeable.

- 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 <u>replicate</u> the pool cashflows.
  - Thus we have no basis for asserting that that <u>the</u> 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 that we have to keep in mind.

- ▶ It is often *tempting* to conclude that the expected payoff or NPV should tell us what the price should be.

- ▶ But that is beyond the purview of no-arbitrage pricing.

  The price for an unspanned risk can be whatever the market wants to pay for it.

- Having said all of that, if a pool of assets is very large, then it may be that the risks it retains are only functions of economy-wide state variables – for which there are hedging instruments available.

- For example, a pool could contain 2000 mortgages. At this level, the law of large numbers means that the cash-flows may become predictable functions of a few statistics, perhaps: (a) interest rates; (b) the unemployment rate.
  - ▶ These may be hedgeable.

- To continue the example above, we might extend our model for the (transformed) prepayment rate by

$$\pi_t = \bar{\pi}(t, T) + b_1(r_t - c) + b_2\ e_t$$

  where e_t is unemployment rate. (Of course there is still no reason to think a linear specification is correct. This is just for illustration.)

- In other words, the unhedgeable "epsilon" term may be gone.

- ▶ Before believing such a model's valuation, one would need to be convinced that the specification really did have an extremely high R^2.
- ▶ Obviously some serious econometric work would have to go into fitting the model.

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

  i. Fit stochastic models for the true evolution of dr_t, and de_t (and their correlation).

  ii. Risk-neutralize these using some estimate of the market price of risk of each.

  iii. Value the security via discounting the expected cash-flows under the adjusted model.

- Thus, under some assumptions, large diversified pools may be another class of derivatives to which our theories apply.

IV. Pools with Default Risk.

- A large segment of the asset-backed finance market deals with pools of loans whose principal payments are not guaranteed by anybody. Examples include
  - Machinery lease (such as aircraft);
  - Other small-business loans;
  - Credit-card debts;
  - Automobile loans;
  - Student loans.

  As of the end of 2013, there were about \$ 1 trillion of such bonds outstanding.

- And, of course, there is an enormous amount of property lending that is not guaranteed, including:
  - Commercial property mortgages;
  - "Non-conforming" residential mortgages (including subprime).

- The presence of default risk makes the pool much riskier, and motivates <u>tranching</u> as a mechanism to isolates those risks.
  - A typical *collaterlized loan obligation* (CLO) might have 10 tranches.
  - It would not be unusual for the top 80% or more of the principal to get rated AA or AAA.

- Indeed, this is the primary reason why CDOs were invented: to increase the supply of high-quality bonds starting from low-quality ingredients.

- While tranched pools of other loans look just like CDOs, there are important differences from the idealized ones we studied previously.
  - 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.

- Most important, of course, there is another risk to be quantified.

- In some cases, the pools may really be large enough to model the credit risk as functions of hedgeable factors and then price them by no-arbitrage.

- If we had a pool of 10000 automobile loans, 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 itself evolves over time like a CIR square-root diffusion.
  - Perhaps δ_t is spanned by the level of interest rates and the stock market.
  - Then no-arbitrage pricing would allow us to compute the price of tranches of Π using the risk-neutralized decay rate.
- Or, return to our discrete-time example of MBS.

- If, as above, we write Z_t for the percentage of the principal that is prepaid at time t and $\pi^p = \log(Z/(1-Z))$ with

$$\pi_t^p = \bar{\pi}^p(t,T) + b(r_t, e_t)$$

then we could likewise let W_t be the percentage of the pool principal that <u>defaults</u> at time t, and define $\pi^d = \log(W/(1-W))$ and choose a second function

$$\pi_t^d = \bar{\pi}^d(t,T) + c(r_1, h_t, e_t)$$

where h_t is an index of house prices.

  - ▶ We could also model the recoveries upon default as, e.g, $R(r_1, h_t, e_t)$.

- Then, in our cash-flow modelling, at each step we would reduce the outstanding principal (after any scheduled amortization) of the pool by the factor $(1-W_t)\,(1-Z_t)$.

  - ▶ As usual, that amount gets subtracted from the principal amount of the most junior tranche still alive.

  - ▶ And the most senior tranche is paid $(1-W_t)\,(1-Z_t)\,R_t$.

- We will have more to say about one sub-case of such structures – those based on subprime mortgage pools – next time.

V. Summary

- Asset-backed securities will continue to represent a large segment of financing activity.

- They exist to solve a some basic funding constraints for the provision of small loans.

  Pooling reduces idiosyncratic eposures and creates securites large enough to justify issuance costs.

  Tranching Is used to segment risks. When originators retain the lowest tranches this can help solve asymmetric information problems.

- In most cases, the residual repayment risk is not hedgeable, and models cannot tell us a no-arbitrage valuation.

- However, models of the true distribution of the payoff – built using the same stochastic tools – can provide valuable information about the expected return and loss distribution.

  ▶ These models may also give a good representation of the market's pricing of the securities, which can tell us how to hedge them.