Chapter 8: BASICS OF RESIDENTIAL MORTGAGE BACKED SECURITIES

8.1 SECURITIZATION

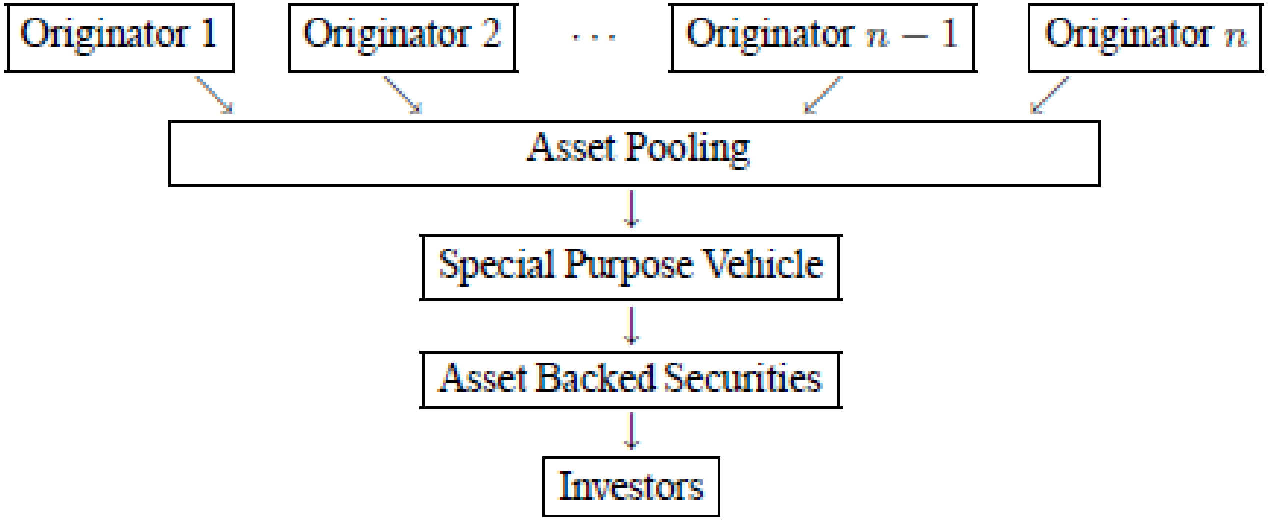
- **8.1.1 The Main Players in the RMBS Market**
- **8.1.2 Private Labels and the 2007 – 2009 Credit Crisis**
- **8.1.3 Default Risk and Prepayment in Agency RMBSs**

8.1 SECURITIZATION

- Some institutions hold in their assets securities that are too risky for them, and would like to sell them to some other investors who are better suited to bear the risk
  - This could be because the assets are not well diversified
- A solutions is to have several institutions pool similar assets together to make them more appealing to outside investors
- To do so a Specific Purpose Vehicle (SPV) is created which formally buys the assets and raises the necessary capital from the investors

8.1 SECURITIZATION (cont.)

Figure 8.1 The Securitization Process



8.1.1 The Main Players in the RMBS Market

- The main players in the Residential Mortgage Backed Securities market are:
  - Ginnie Mae: Government National Mortgage Association (GNMA). A wholly-owned government corporation, whose main function is to guarantee the timely payments of RMBS backed by loans made through different government programs
  - Fannie Mae: Federal National Mortgage Association (FNMA). Until the 2007 – 09 crisis it was a shareholder-owned corporation, now it is under government conservatorship. Fannie Mae provides credit guarantees on mortgage loans that are securitized through Fannie Mae and also maintains a large mortgage portfolio and issues debt to finance its portfolio
  - Freddie Mac: Federal Home Loan Mortgage Corporation (FHLMC). Also a stockholder-owned institution until the credit crisis of 2007 – 2008, it follows the same business model as Fannie Mae.

8.1.2 Private Labels and the 2007 – 2009 Credit Crisis

- In addition to the three government institutions, residential mortgage backed securities are also issued by other institutions
  - Their share has increased over time up to 2007
- Part of the reason for this increase is that government-sponsored agencies can only securitize 'conventional' mortgages:
  - Principal amount below a given cutoff ($417,000 in 2008)
  - Loan-to-value ratio of at most 80%
- The private label market filled the gap, assuming some risks, as the value of the collateral was providing a lower cushion against the probability of default
- The 2007 – 2009 financial crisis hit this sector specially hard
  - Many investors were unwilling to purchase securities not completely backed by the U.S. government
- Non-agency MBS numbers have down significantly since

8.1.2 Private Labels and the 2007 – 2009 Credit Crisis (cont.)

Table 8.2 Mortgage Related Issuance

Year	Agency	Nonagency	Total	Agency Share	Nonagency Share
1996	440.7	51.9	492.6	89.46%	10.54%
1997	535.0	69.4	604.4	88.52%	11.48%
1998	952.0	191.9	1,143.9	83.22%	16.78%
1999	884.9	140.5	1,025.4	86.30%	13.70%
2000	582.3	101.7	684.0	85.13%	14.87%
2001	1,454.8	218.8	1,673.6	86.92%	13.08%
2002	1,985.3	288.5	2,273.8	87.31%	12.69%
2003	2,725.8	440.6	3,166.4	86.09%	13.91%
2004	1,375.2	532.7	1,907.9	72.08%	27.92%
2005	1,321.0	901.2	2,222.2	59.45%	40.55%
2006	1,214.7	917.4	2,132.1	56.97%	43.03%
2007	1,372.2	773.9	2,146.1	63.94%	36.06%
2008	1,299.2	40.5	1,339.7	96.98%	3.02%

Notes: Agency issuance includes GNMA, FNMA, and FHLMC mortgage backed securities and CMOs. Nonagency issuance includes both private-label MBS and CMOs. Quantities are $ billions.

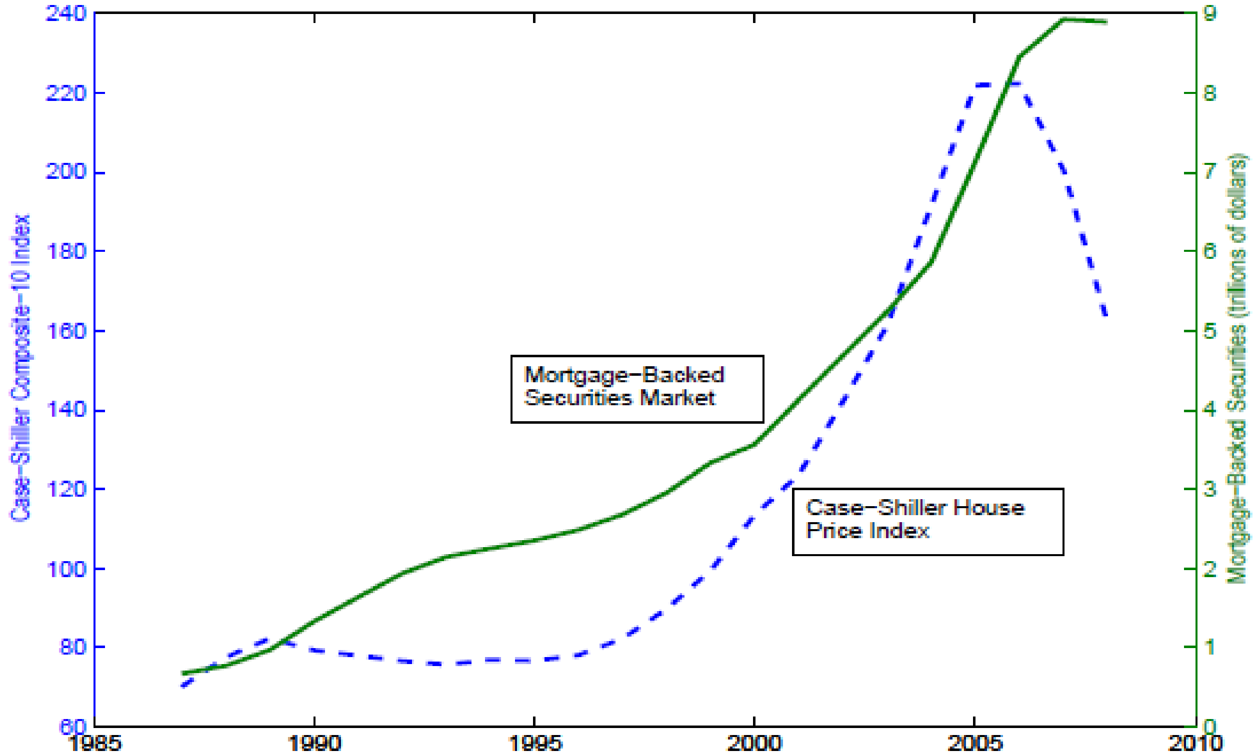
Souce: SIFMA. Government-Sponsored Enterprises, Thomson Financial, Bloomberg

8.1.3 Default Risk and Prepayment in Agency RMBSs

- It is important to distinguish between types of risk:
  - Default risk refers to the probability that an unusually large number of homeowners' defaults on their mortgage payments, i.e. stop paying the monthly coupons
    - Agency RMBS is not exposed directly to the credit risk of the mortgages in the RMBS pool
    - Agencies insure investors against the default of individual mortgages
  - Prepayment risk refers to the probability of receiving cash flows too early compared to the expected life of the mortgage
    - This is more common to RMBS, and it has important implications for these securities valuation

8.1.3 Default Risk and Prepayment in Agency RMBSs (cont.)

Figure 8.2 House Prices and the Mortgage Backed Securities Market



Source: SIFMA and Standard & Poor / Case-Shiller.

8.2 MORTGAGES AND THE PREPAYMENT OPTION

- **8.2.1 The Risk in the Prepayment Option**

- **8.2.2 Mortgage Prepayment**

8.2 MORTGAGES AND THE PREPAYMENT OPTION

- Consider the following example, illustrating a mortgage's mechanics:
- Consider a 30-year fixed rate mortgage with rate $\bar{r}_{12}^m$
- L is the amount of the mortgage lent to the homeowner:

$$L = \sum_{i=1}^{30\times 12} \frac{C}{\left(1+\frac{\bar{r}_{12}^m}{12}\right)^i}$$

where C refers to the coupon being paid monthly

- It is convenient to define the following constant:
- $A = (1 + \bar{r}_{12}^m)^{-1}$
- So we can rewrite $L = \sum_{i=1} C \times A_i$ and get the following:

$$C = \frac{L}{\sum_{i=1}^{30\times 12} A^i}$$

8.2 MORTGAGES AND THE PREPAYMENT OPTION (cont.)

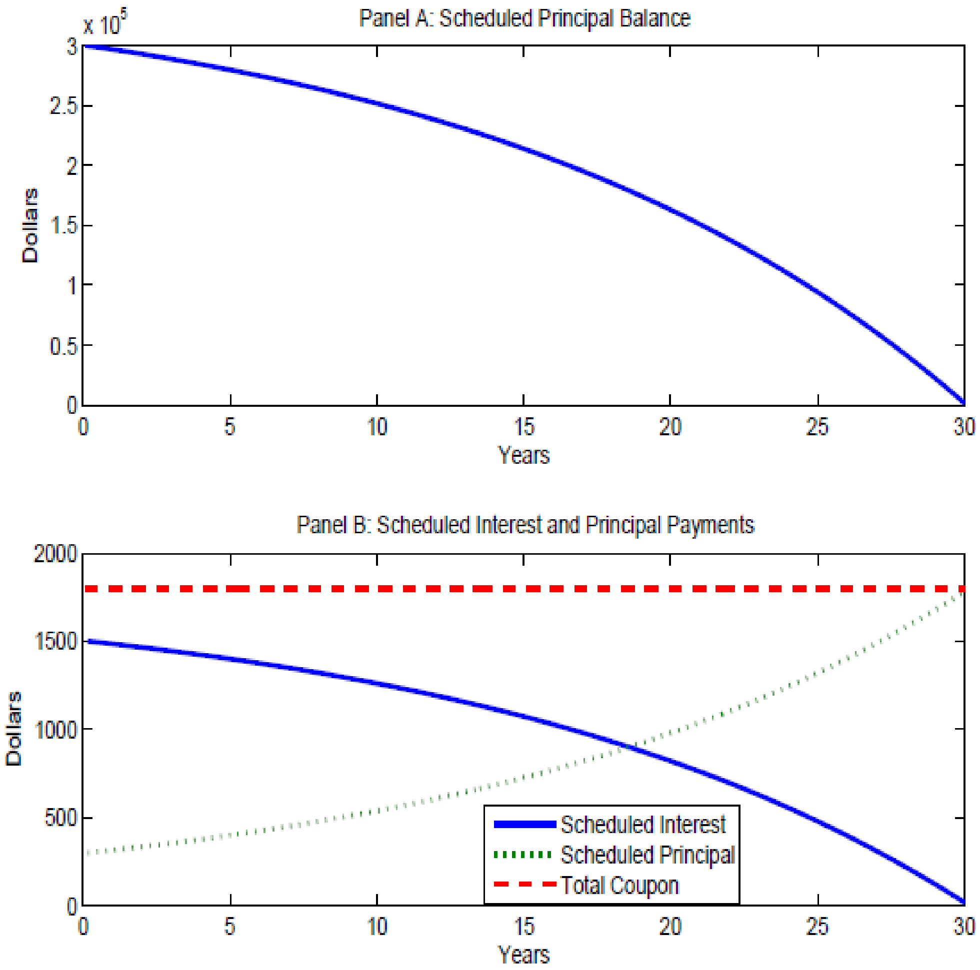
- Note that the coupon C includes both interest payments and principal repayment
  - The fraction of C that is related to each varies over time
- Interest paid at $t = I_t = \bar{r}_{12}^m \times L_t$
- Principal paid at $t = L_t^{paid} = C - I_t$
- So: $L_{t+1} = L_t - L_t^{paid}$
- Given the above and let n be the number of payments at t

$$L_t = \sum_{i=1}^{n} \frac{C}{\left(1 + \frac{\bar{r}_{12}^m}{12}\right)^i} = C \times A \times \frac{1 - A^n}{1 - A}$$

- So the value of a mortgage is:

$$P(t) = \sum_{i=1}^{n} \frac{C}{\left(1 + r_{12}^m(t, T_i)/12\right)^i}$$

8.2 MORTGAGES AND THE PREPAYMENT OPTION (cont.)

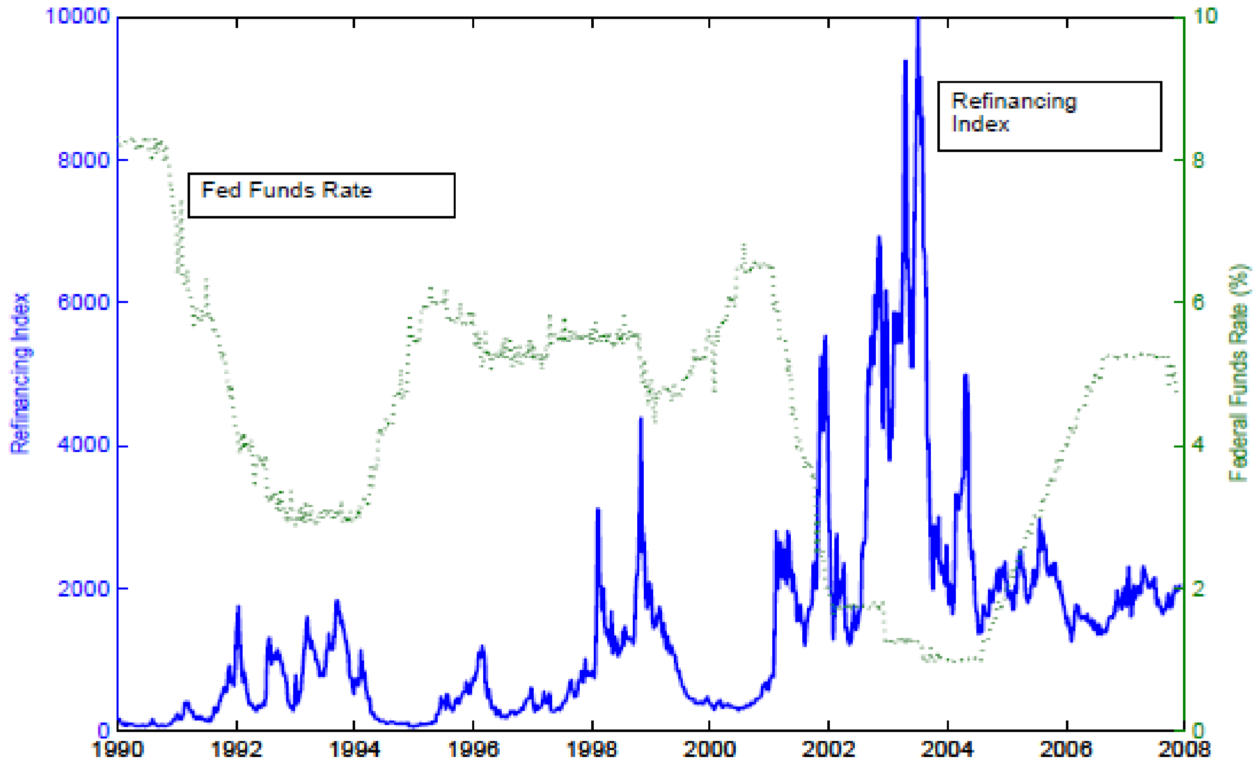


8.2 MORTGAGES AND THE PREPAYMENT OPTION (cont.)

- An example:
  - The years 2001 to 2003 saw record refinancing levels: When the Federal Reserve acted to prevent a recession by lowering the Federal funds rate from 6% to less than 1%, it set in motion a chain reaction in which banks were able to lower mortgage rates as well, as their own funding cost decreased substantially
  - The fixed 30-year mortgage rate decreased during this period from 8.6% to 5.83%. The one-year adjustable rate dropped even more, from about 7% in 2000 to 3.76% in 2003
  - Homeowners had then the choice between keeping the old higher mortgage rate or refinancing at lower rates
  - The lower level of mortgage rates generated a large wave of refinancing, as shown in Figure 8.4
  - This figure reports the Mortgage Bankers' Association (MBA) refinancing index from early 1990 to late 2007
  - The MBA refinancing index is based on the number of applications for refinancing, and it is computed from a weekly survey
  - The large spike in 2002 - 2003 clarifies the relation between the level of interest rates (low) and the decision of homeowners to refinance their mortgages

8.2 MORTGAGES AND THE PREPAYMENT OPTION (cont.)

Figure 8.4 Refinancing and the Federal Funds Rate



Source: Federal Reserve and Bloomberg.

8.2.1 The Risk in the Prepayment Option

- Why are prepayments a risk?
- Prepayments bring down the rate of return for a bank
  - When prepayment is exercised by the mortgage owner, banks loose the stream of high interest payments and instead receive lower interest on the same cash, since it now invests in a low interest environment
- There is no default in prepayment, these are different concepts

8.2.2 Mortgage Prepayment

- The general level of interest rates is an important reason of prepayment, but it is not the only one
- Other factors include:
  - Seasonality: Summers are characterized by large prepayments, as this is the period in which people move from one place to another for various reasons
  - Age of the mortgage pool: Young mortgages are characterized by large interest rate payments and low principal, by paying early homeowners can save the interest payments
  - Family circumstances: Default, disasters, or sale of the house
  - Housing prices: If the property value of a house declines, it is more difficult to refinance, and thus prepayments tend to decline
  - Burnout effect: Mortgage pools heavily refinanced in the past then to be insensitive to interest rates

8.3 MORTGAGE BACKED SECURITIES

- **8.3.1 Measures of Prepayment Speed**
- **8.3.2 Pass-Through Securities**
- **8.3.3 The Effective Duration of Pass-Through Securities**
- **8.3.4 The Negative Effective Convexity of Pass-Through Securities**
- **8.3.5 The TBA Market**

8.3 MORTGAGE BACKED SECURITIES

- Three quantities are important in determining the value of a MBS:
  - Weighted Average Maturity (WAM): obtained from the pool of mortgages
  - Weighted Average Coupon (WAC): obtained from the pool of mortgages
  - Prepayment speed: Measured relative to set benchmarks (see next section), it can be also used as a quoting tool for MBS prices

8.3.1 Measures of Prepayment Speed

- The most common measures are:
  - **Constant Maturity Mortality**: It assumes a constant probability that the mortgage will be prepaid after next coupon, so on a monthly basis:

    $\Pr(\text{Prepayment at } t = 1) = p$

    $\Pr(\text{Prepayment at } t = 2) = (1 - p)p$

    $\Pr(\text{Prepayment at } t = 3) = (1 - p)^2 p$

    •On an annualized bases called Conditional Prepayment Rate (CPR):

    $\Pr(\text{Survival up to } t = 12) = (1 - p)^{12} = (1 - CPR)$

    •CPR can be computed from p: $CPR = 1 - (1 - p)^{12}$
  - **PSA Experience**: An industry benchmark is the one established by the Public Securities Association, which makes the following assumptions:

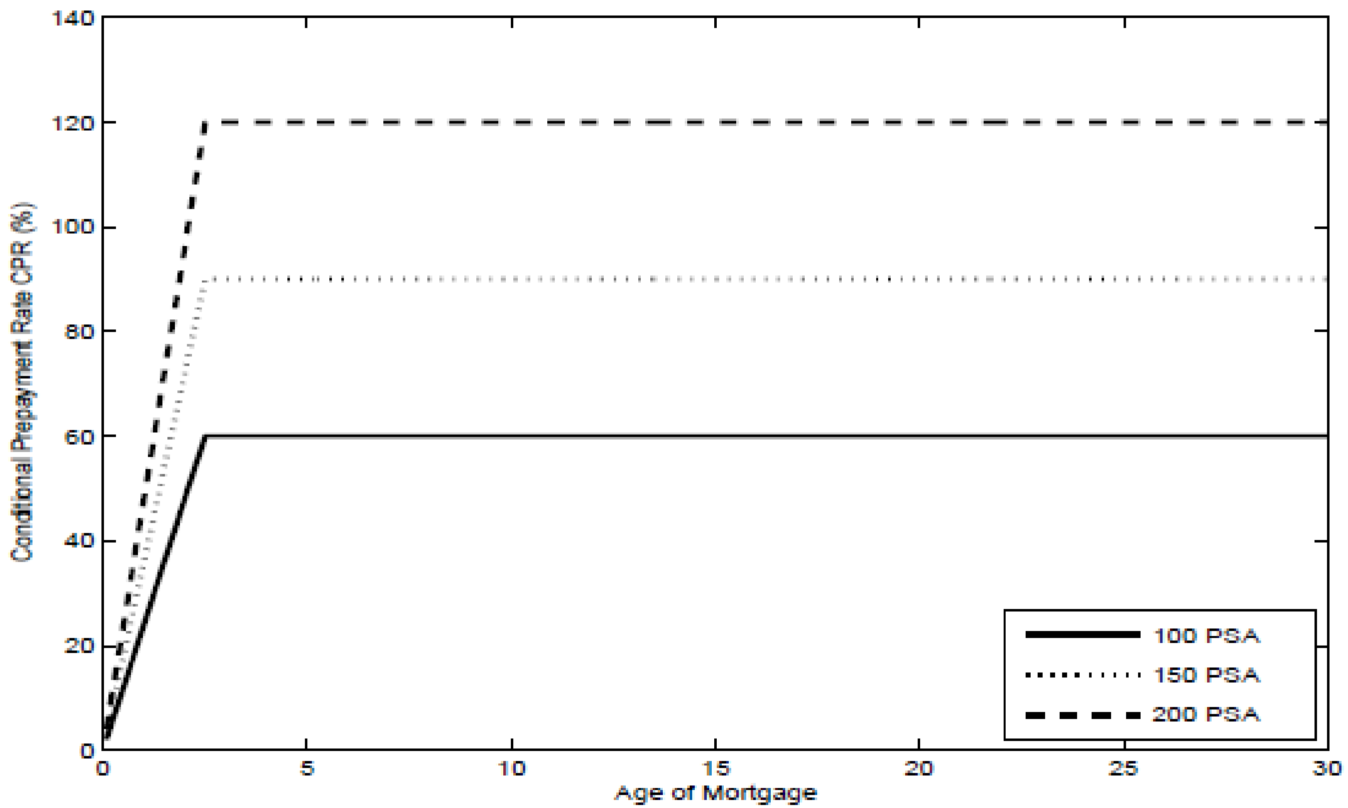
    •CPR = 0.2% of the principal is paid in the first month;

    •CPR increases by 0.2% in each of the following 30 months;

    •CPR levels off at 6% thereafter until maturity
  - Speed is measured as a percentage of this scenario (e.g. 150%PSA)

8.3.1 Measures of Prepayment Speed (cont.)

Figure 8.5 PSA Prepayment Convention



8.3.2 Pass-Through Securities

- A Pass-Through security is the simplest MBS
- It represents a claim on a fraction of the total cash flow going from the home owners to the pool of mortgages
  - Note that the mortgage pool pays WAC, but the holder of the pass-through security gets the pass-through rate r_{12}^{PT}, which is lower than WAC
  - The difference is the profit for whomever sets up the security

8.3.2 Pass-Through Securities

- An example:
  - Consider a MBS pass through with principal $600 million, the original mortgage pool has a WAM = 360 months, and WAC = 6.5%, and the pass-through security pays a coupon equal to $r^{PT}_{12} = 6\%$, lower that the average coupon rate of the mortgage pool, both to ensure there is enough cash available for coupon payments, and also to provide a compensation for the MBS issuer (e.g., Fannie Mae or Freddie Mac)
  - How do we compute the value of the pass through? We can use the PSA level to determine the speed of prepayment, and therefore the timing and size of future cash flows
  - In particular, given a PSA level, for instance 200% PSA, we obtain the CPR_t for each month t and thus the corresponding monthly prepayment rate: $p_t = 1 – (1 – CPR_t)^{1/12}$
  - Given that the PSA level determines exactly the amount of principal that is paid back, we can compute the value of the pass-through security by first computing the sequence of cash flows, and then, treating these as certain cash flows from a highly rated company, we discount them to today using the appropriate discount rate
  - Note that Agency MBS are essentially default risk free, implying that the coupons will be paid to the investors

8.3.2 Pass-Through Securities

- An example (cont'd):
  - To compute the sequence of cash flows, consider a given time t during the life of the mortgage pool in which L_t is the outstanding principal at the beginning of the period
  - From this value, we can compute the following quantities for time t:

Mortgage interest payment: $I_t = L_t \times r^m{}_{12} / 12$

Scheduled principal: $Pay^{sch}{}_t = C_t - I_t$

Principal payment: $Pay^{prp}{}_t = p_t \times L_t$

  - Given the scheduled principal payments and prepayments, we can finally update both the outstanding principal and the total coupon flow at the beginning of the following month t +1:

Outstanding principal: $L_{t+1} = L_t - Pay^{sch}{}_t - Pay^{prp}{}_t$

Update of scheduled coupon: $C_{t+1} = (1 - p_t) \times C_t$

  - In particular, the new total flow from the pool coupons equals the previous month coupon flow adjusted for the fraction of prepaid mortgages:
    - For instance, if 100% of homeowners prepay their mortgages at time t, then $p_t = 1$, and the coupon at time t+1 is zero, as we would expect
    - Conversely, if nobody repays the mortgages, then $p_t = 0$, and $C_{t+1} = C_t$, that is, the total coupon flow is constant

8.3.2 Pass-Through Securities

- An example (cont'd)
  - These calculations are shown in Table 8.3 for the first 36 months
    - Column 1 reports the month and
    - Column 2 shows the constant prepayment rate (CPR) implied by a 200% PSA
    - Column 3 displays the monthly prepayment rate
    - Column 4 computes the coupon C_t, except for its first entry (first row), which instead uses the coupon implied by the weighted average coupon (WAC), the weighted average maturity (WAM) and the initial principal balance
    - Column 5 reports the mortgage interest payment
    - The principal scheduled and the principal prepaid are computed next
    - The total cash flow of the pass-through security does not depend though on the mortgage interest rate, but on the pass-through interest rate r^{PT}, thus Column 8 reports the pass-through interest payment, computed as: $I^{PT}_t = L_t \times r^{PT}_{12} / 12$
    - Column 9 provides the total cash flow
      - The pass-through interest rate, scheduled mortgage principal, and mortgage prepayment sum up to form the total cash flow of the pass-through: $CF_t = I_t + Pay^{sch}_t + Pay^{prp}_t$
    - Column 10 updates the new amount of principal remaining

8.3.2 Pass-Through Securities

- An example (cont'd)
  - The value of the pass-through security is then obtained by treating the cash flows in Column 9 as known amounts of dollars in the future, without any uncertainty; thus, they are simply discounted by using a discount function appropriate for this credit rating
  - Some of these pass-through securities are default free: For instance, Ginnie Mae originated pass-through securities are guaranteed against default by the full faith of the U.S. Government, and thus investors in these securities are not subject to default
  - Similarly, over the years market participants believed also that the securities issued by Fannie Mae and Freddie Mac had small default risk, as it was believed that the U.S. government would bail these agencies out in case of financial troubles
  - If we think of these securities having zero or small default risk, then we can use the Treasury discount curve to discount these cash flows
  - Assume for instance a flat term structure with constant (c.c.) 5% yield
  - The corresponding discount $Z(0,T)$ is reported in the last column
  - For this exercise, the value of the pass-through security is \$635 million, above its par value of \$600 million

Table 8.3 Computations: Cash Flows of Pass-Through Security

Month i (1)	CPR (2)	p (3)	Coupon (4)	Mortgage Interest (5)	Principal Scheduled (6)	Principal Prepaid (7)	Pass-Through Interest (8)	Total Cash Flow (9)	Principal L_t (10)	Discount $Z(0,T)$ (11)
1	0.20%	0.03%	3.79	3.25	0.54	0.20	3.00	3.74	599.26	0.9979
2	0.40%	0.07%	3.79	3.25	0.55	0.40	3.00	3.94	598.31	0.9958
3	0.60%	0.10%	3.79	3.24	0.55	0.60	2.99	4.14	597.16	0.9938
4	0.80%	0.13%	3.78	3.23	0.55	0.80	2.99	4.34	595.81	0.9917
5	1.00%	0.17%	3.78	3.23	0.55	1.00	2.98	4.53	594.25	0.9896
6	1.20%	0.20%	3.77	3.22	0.55	1.20	2.97	4.73	592.50	0.9876
7	1.40%	0.24%	3.77	3.21	0.56	1.40	2.96	4.92	590.54	0.9855
8	1.60%	0.27%	3.76	3.20	0.56	1.60	2.95	5.11	588.39	0.9835
9	1.80%	0.31%	3.75	3.19	0.56	1.79	2.94	5.30	586.03	0.9814
10	2.00%	0.34%	3.74	3.17	0.56	1.99	2.93	5.48	583.48	0.9794
11	2.20%	0.37%	3.72	3.16	0.56	2.18	2.92	5.66	580.73	0.9773
12	2.40%	0.41%	3.71	3.15	0.56	2.38	2.90	5.84	577.80	0.9753
13	2.60%	0.44%	3.69	3.13	0.56	2.57	2.89	6.02	574.67	0.9733
14	2.80%	0.48%	3.68	3.11	0.56	2.75	2.87	6.19	571.35	0.9713
15	3.00%	0.51%	3.66	3.09	0.56	2.94	2.86	6.36	567.85	0.9692
16	3.20%	0.55%	3.64	3.08	0.56	3.12	2.84	6.53	564.16	0.9672
17	3.40%	0.59%	3.62	3.06	0.56	3.30	2.82	6.69	560.29	0.9652
18	3.60%	0.62%	3.60	3.03	0.56	3.48	2.80	6.84	556.25	0.9632
19	3.80%	0.66%	3.58	3.01	0.56	3.65	2.78	7.00	552.04	0.9612
20	4.00%	0.69%	3.55	2.99	0.56	3.82	2.76	7.15	547.65	0.9592
21	4.20%	0.73%	3.53	2.97	0.56	3.99	2.74	7.29	543.10	0.9572
22	4.40%	0.76%	3.50	2.94	0.56	4.15	2.72	7.43	538.38	0.9552
23	4.60%	0.80%	3.48	2.92	0.56	4.31	2.69	7.56	533.51	0.9532
24	4.80%	0.84%	3.45	2.89	0.56	4.47	2.67	7.69	528.48	0.9512
25	5.00%	0.87%	3.42	2.86	0.56	4.62	2.64	7.82	523.31	0.9492
26	5.20%	0.91%	3.39	2.83	0.56	4.77	2.62	7.94	517.98	0.9473
27	5.40%	0.95%	3.36	2.81	0.55	4.91	2.59	8.05	512.52	0.9453
28	5.60%	0.98%	3.33	2.78	0.55	5.05	2.56	8.16	506.92	0.9433
29	5.80%	1.02%	3.29	2.75	0.55	5.18	2.53	8.27	501.19	0.9414
30	6.00%	1.06%	3.26	2.71	0.55	5.31	2.51	8.36	495.33	0.9394
31	6.00%	1.06%	3.23	2.68	0.54	5.25	2.48	8.27	489.54	0.9375
32	6.00%	1.06%	3.19	2.65	0.54	5.19	2.45	8.18	483.81	0.9355
33	6.00%	1.06%	3.16	2.62	0.54	5.13	2.42	8.08	478.15	0.9336
34	6.00%	1.06%	3.12	2.59	0.53	5.07	2.39	7.99	472.55	0.9316
35	6.00%	1.06%	3.09	2.56	0.53	5.01	2.36	7.90	467.01	0.9297
36	6.00%	1.06%	3.06	2.53	0.53	4.95	2.34	7.81	461.53	0.9277

8.3.3 The Effective Duration of Pass-Through Securities

- The effective duration of a mortgage backed security is given by the formula:

$$D \approx \frac{1}{P}\frac{P(+x\_bps) - P(-x\_bps)}{2 \times x\_bps}$$

- where P is the current price of the MBS, and $P(+x\_bps)$ and $P(-x\_bps)$ are the prices of the same security after we shift upward or downward the yield curve by x basis points, respectively.
- In this computation, the price of the MBS takes into account the variation in the prepayment speed induced by the variation in interest rates.

8.3.3 The Effective Duration of Pass-Through Securities

- An example:
  - Consider the pass-through MBS discussed, we assume that the current PSA level is PSA = 200%
  - Consider now the calculation of its duration assuming first that the PSA level is unaffected by the change in interest rate; in this case, because the pass-through MBS has a constant coupon, we can compute its duration and obtain a duration value of $D = 5.83$
  - Consider now the case in which if the interest rate moves down from 5% to 4.50%, the PSA increases from 200% to 250%, while if the interest rate moves up from 5% to 5.50%, the PSA decreases from 200% to 150%
  - How can we compute the duration of the pass-through security in this case? We can apply the definition of duration, namely:

$$D = -\frac{1}{P}\frac{dP}{dr}$$

  - Given this definition, we can approximate the duration of the pass-through security while taking into account the impact of interest rate changes on PSA levels as follows:

$$D = -\frac{1}{P}\frac{P(+50bps) - P(-50bps)}{2 \times 50bps}$$

  - where P = \$634.76 is the current value of the pass-through security and $P(+50bps)$ and $P(-50bps)$ are the values of the same pass-through security when we increase and decrease the interest rate by 50 basis points, respectively, and the PSA levels accordingly

8.3.3 The Effective Duration of Pass-Through Securities

- An example (cont'd):
  - By carrying out exactly the same computations as before but for the two cases in which the interest rate is either 5.5% or 4.5%, and the PSA level is 150% or 250%, respectively, we find P(+50bps) = $619.13 and P(-50bps) = $647.45; substituting these values we have:

$$D \approx -\frac{1}{\$634.76}\frac{\$619.13-\$647.45}{2\times 50bps} = 4.46$$

  - This duration is much smaller than the duration that we obtained when we neglected the impact on the change in PSA due to changes in interest rates, which was 5.83
  - Missing the impact of interest rate variation on the speed of prepayment may grossly overstate the sensitivity of the pass-through security to changes in interest rates, and thus the performance of any duration-based hedging activity

8.3.4 The Negative Effective Convexity of Pass-Through Securities

- An important characteristic of MBS is negative convexity
  - Fixed income securities have their prices increase substantially when interest rates fall
  - Negative convexity, instead, states that if interest rate decline makes the rate of prepayment increase, then the price of the security does not increase as much

8.3.4 The Negative Effective Convexity of Pass-Through Securities (cont.)

- The effective convexity of a mortgage backed security is given by the formula:

$$C \approx \frac{1}{P}\frac{P(+x\_bps)+P(-x\_bps)-2\times P}{(x\_bps)^2}$$

- where P is the current price of the MBS, and $P(+x\ bps)$ and $P(-x\ bps)$ are the prices of the same security after we shift upward or downward the yield curve by x basis points, respectively.
- In this computation, the price of the MBS takes into account the variation in the prepayment speed induced by the variation in interest rates

8.3.4 The Negative Effective Convexity of Pass-Through Securities (cont.)

- An example:
  - Consider Table 8.4:
    - The first two columns show the impact of interest rates on the price of the pass through, when the speed of prepayment is kept constant at 200% PSA
    - The next three columns show the case in which as the interest rate declines from 6% to 2%, the PSA increases from 100% to 500%
  - Suppose that as the interest rate declines, the PSA increases, while if the interest rate increases, the PSA declines
  - A higher prepayment rate moves the price of the pass-through closer to its principal value ($600 million): if everybody prepayed at the same time, the value of the pass through would be exactly $600 million; in reality, even with dramatic decreases in interest rates, many households do not prepay their mortgages
  - Still, even if the PSA increases only to 500%, the value of the pass-through security goes up only to $688 million, compared to $765 million in the case of constant PSA
  - Figure 8.6 plots the value of the pass-through security with respect to the interest rate for the cases in which the PSA is constant at 200% (the dotted line) and the case in which the PSA increases as interest rates decline (the solid line)
  - The pass-through security with changes in PSA is less sensitive to interest rate variation when interest rates are low, while it is more sensitive when interest rates are high; in other words, the pass-through security displays negative convexity

8.3.4 The Negative Effective Convexity of Pass-Through Securities (cont.)

- Another example:
  - We want to compute the convexity of the pass-through security when the current interest rate is $r = 5\%$
  - Referring to Table 8.4, we can apply the formula with $x = 50$
  - In this case, we have:

$$C \approx \frac{1}{P}\frac{P(+50bps)+P(-50bps)-2\times P}{(50bps)^2} = \frac{1}{634.76}\frac{619.13+647.45-2\times 634.76}{(50bps)^2} = -184.89$$

  - As expected from Figure 8.6 and the previous discussion, the effective convexity of the MBS is negative

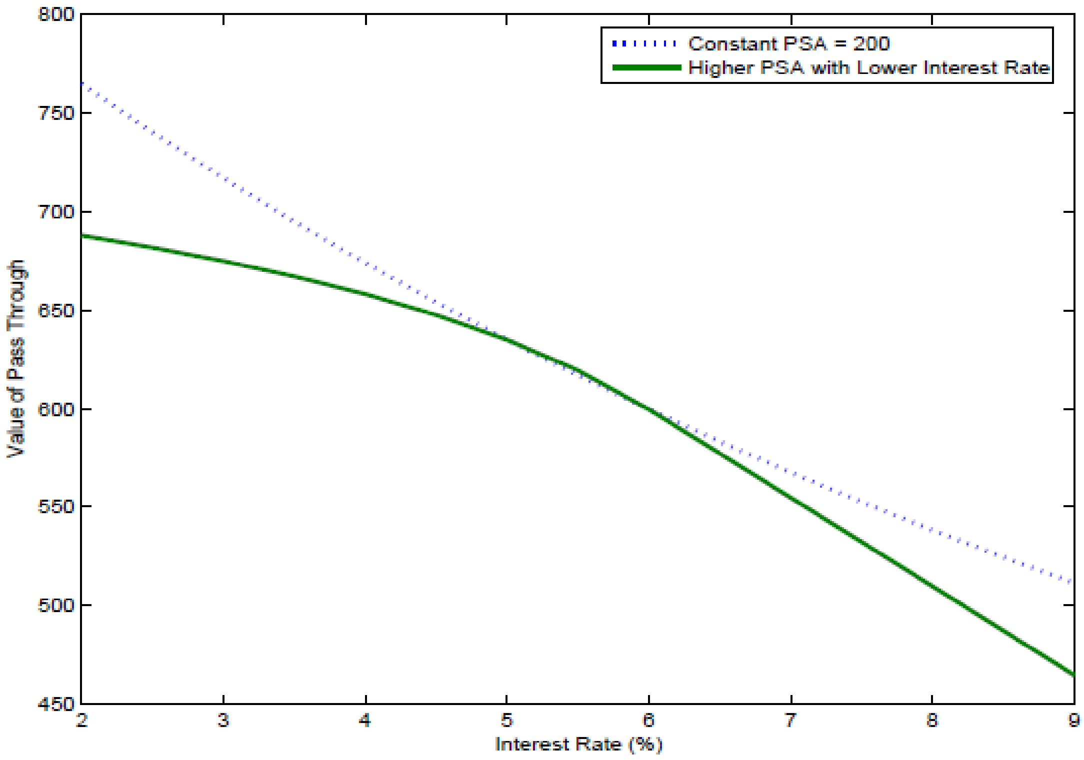
8.3.4 The Negative Effective Convexity of Pass-Through Securities (cont.)

Table 8.4 Pass-Through Security Value versus Interest Rate and PSA

Constant PSA = 200%		Increasing PSA with Lower Interest Rate		
Interest Rate	Value	Interest Rate	PSA	Value
2.00%	764.57	2.00%	500	687.80
2.50%	740.00	2.50%	450	681.64
3.00%	716.72	3.00%	400	674.76
3.50%	694.63	3.50%	350	666.97
4.00%	673.66	4.00%	300	658.00
4.50%	653.73	4.50%	250	647.45
5.00%	634.76	5.00%	200	634.76
5.50%	616.71	5.50%	150	619.13
6.00%	599.50	6.00%	100	599.33
6.50%	583.08	6.50%	90	576.96
7.00%	567.41	7.00%	80	554.53
7.50%	552.44	7.50%	70	532.06
8.00%	538.12	8.00%	60	509.54
8.50%	524.42	8.50%	50	487.01
9.00%	511.30	9.00%	40	464.45

8.3.4 The Negative Effective Convexity of Pass-Through Securities (cont.)

Figure 8.6 The Value of a Pass-Through MBS with Respect to the Interest Rate



8.3.4 The Negative Effective Convexity of Pass-Through Securities (cont.)

Table 8.5 A Sample of Par Value Ginnie Mae Pass-Through Prices and Treasury Yields

	Ginnie Mae Pass-Through					Treasury Constant Maturity Rates		
Date	Bid	Ask	Coupon	WAC	WAM	10-Year	20-Year	30-Year
09/26/1997	100.0313	100.0000	7.0	7.5	315	6.08	6.43	6.37
06/12/1998	100.0313	100.0000	6.5	7.0	324	5.43	5.75	5.66
08/07/1998	100.0000	99.96875	6.5	7.0	327	5.40	5.72	5.63
05/05/2006	100.1250	100.0938	6.0	6.5	315	5.12	5.35	5.20
07/28/2006	99.96875	99.9375	6.0	6.5	318	5.00	5.17	5.07
08/17/2007	100.0938	100.0625	6.0	6.5	320	4.68	5.06	5.00

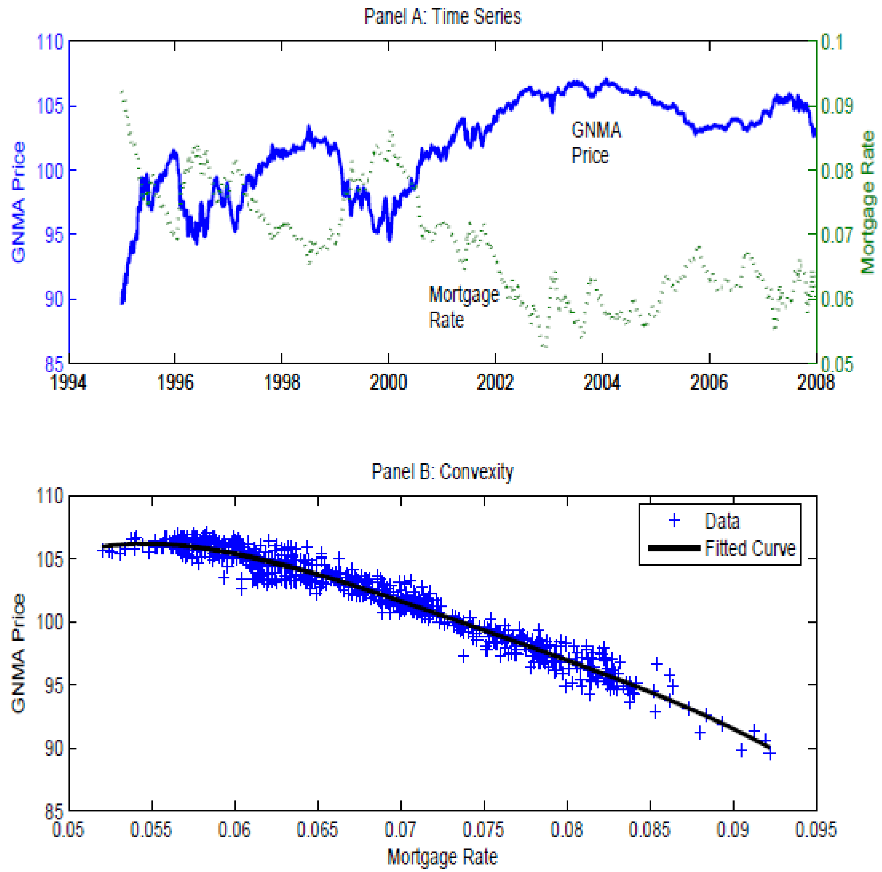
Source: Bloomberg and Federal Reserve Board.

8.3.5 The TBA Market

- Secondary market for Pass Through securities is very active
- Most of the MBS trading are on a “To-Be-Announced” (TBA) basis, which means that the traders don’t know the exact composition of the mortgage pool when they start trading
  - However the mortgage pools tend to be quite homogenous
- The TBA market functions like a forward market of MBS

8.3.5 The TBA Market (cont.)

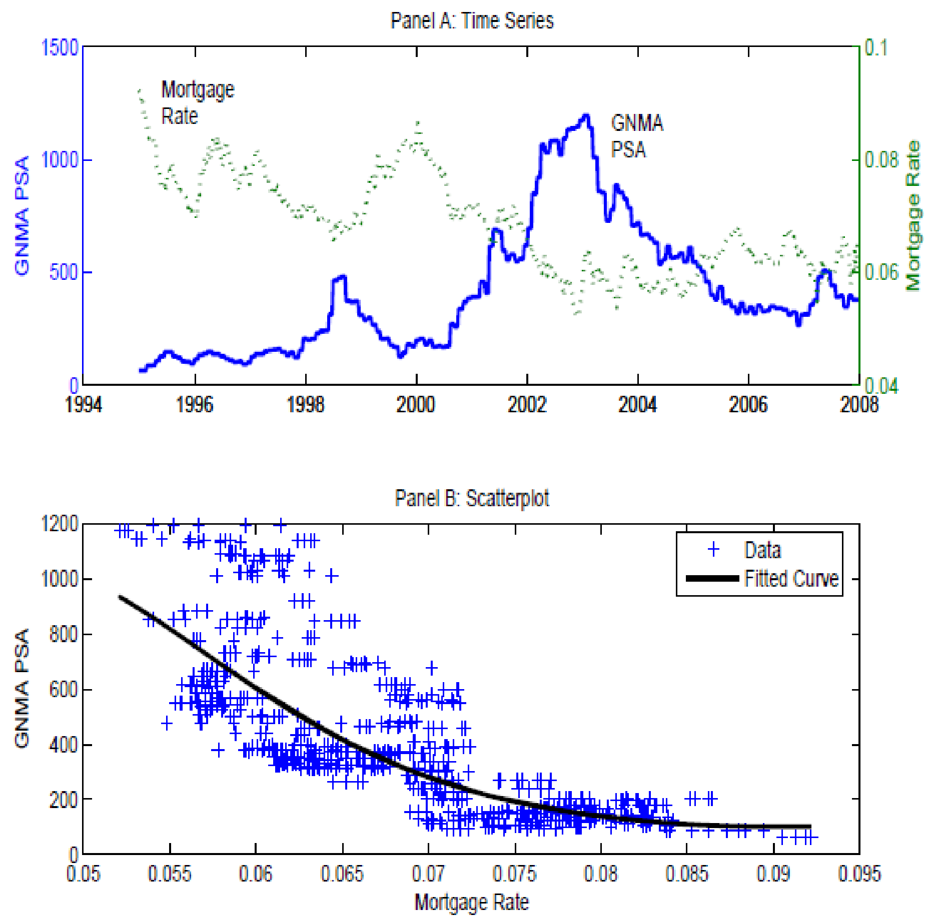
Figure 8.7 GNMA 7 Prices and Mortgage Rates



Data source: Bloomberg and Federal Reserve Board.

8.3.5 The TBA Market (cont.)

Figure 8.8 GNMA 7 PSA and Mortgage Rates



Data source: Bloomberg and Federal Reserve Board.

8.4 COLLATERALIZED MORTGAGE OBLIGATIONS (CMO)

- **8.4.1 CMO Sequential Structure**

- **8.4.2 CMO Planned Amortization Class (PAC)**

- **8.4.3 Interest Only and Principal Only Strips**

8.4 COLLATERALIZED MORTGAGE OBLIGATIONS (CMO)

- CMO are securities with more complex structures than pass through securities
- This is a security that offers different levels of prepayment risk
- The advantage of structuring CMOs with different risk return characteristics is to appeal to different investors' clienteles, which may increase the liquidity of these securities

8.4.1 CMO Sequential Structure

- The basic idea of a sequential structure is to divide the total principal into smaller groups called "Tranche A", "Tranche B", "Tranche C", and so on
- Each tranche receives:
  - A fixed coupon rate payment, in percentage of the tranche principal
  - Sequentially all the principal payments, scheduled or prepaid, up to the point at which the whole principal of the tranche is paid out
- Sometimes a "Tranche Z" is added, which receives no cash flows (like a zero coupon), but the coupon is accrued over time to its principal
  - Once all other classes have been retired, the principal payments go to Tranche Z

8.4.1 CMO Sequential Structure

- An example:
  - Consider the same pass-through from pervious examples, but this time we subdivide all of the cash flows generated by the pass-through security into smaller cash flows into four classes, A, B, C, and D
    - Tranche A has $250m principal, Tranche B $150m, Tranche C $125m and Tranche D $75m
    - Let each tranche have a coupon of 6%, as the original pass through does
  - Table 8.6 illustrates the procedure: the first column is the month, the second column is the total cash flow of the pass-through security; this cash flow is now divided across the four tranches
  - Initially, tranche A receives both principal payments and interest
    - The interest component is computed as the coupon rate (6%) times the remaining balance in Column 3
    - The principal payment is given by the total of scheduled and prepaid principal from the original pool
    - For instance, the first principal payment is $0.74 = $0.54 + $0.20, where $0.54 is the scheduled principal, and $0.20 is the prepaid principal
  - Similarly, in month 2, Tranche A investors receives a total of principal equal to $0.95 = $0.55 + $0.40, where $0.55 and $0.40 are the scheduled and prepaid principal
  - And so on…

8.4.1 CMO Sequential Structure

- An example (cont'd):
  - Tranche B to D in these first months are paid the interest only, but no principal at all
    - For instance, Tranche B receives an interest of \$0.75 = 150 × 6% / 12
  - Tranche B begins receiving principal payments when all the principal of Tranche A (\$250 million) has being paid back to investors (month 60)
  - The procedure to define principal payments to Tranche B is the same as the one we discussed for Tranche A
    - For instance, in month 61 Tranche B receives \$4.14 of principal, of which \$0.46 is a scheduled payment and \$3.68 is a prepayment
  - In this illustration, Tranche B is paid back in month 105, and thus principal payments are made to Tranche C
  - This latter tranche is paid back in month 180, and principal payments begin to be made to Tranche D
  - We can then value of each tranche by using the standard present value formula
  - We obtain that Tranche A is valued at \$256.42 million, Tranche B at \$158.42 million, Tranche C at \$135.71 million, and Tranche D at \$84.21 million
  - Of course the sum of the values of tranches is the same as the value of the pass-through MBS, that is, \$634.76 million

8.4.1 CMO Sequential Structure

- An example (cont'd):
  - It is important to note that the different allocation of principal payments drastically changes the sensitivity of the MBS to interest rate movements
  - For instance, the effective duration of Tranche A is 1.96, the duration of Tranche B is 3.99, of Tranche C is 6.27 and the duration of Tranche D is 10.04
  - Since the pass-through security is a portfolio of tranches, the duration of the pass through equals the weighted average of durations, that is, 4.46, as discussed earlier
  - The speed of prepayments affects the time at which the various tranches are paid back
  - The illustration in Table 8.6 assumes 200% PSA
  - If for instance we considered 100% PSA, then Tranche A is retired in month 96 (instead of 60), Tranche B in month 171 (instead of 105), Tranche C in month 267 (instead of 180)
  - The duration of individual tranches changes accordingly, in this case, to 3.70 for Tranche A, 8.15 for Tranche B, 11.39 for Tranche C, and 13.96 for Tranche D

Table 8.6 Collateralized Mortgage Obligation – Sequential Structure

	Total	Tranche A				Tranche B				Tranche C				Tranche D			
Month	CF	Balance	Pri.	Int.	CF	Balance	Pri.	Int.	CF	Balance	Pri.	Int.	CF	Balance	Pri.	Int.	CF
1	3.74	250.00	0.74	1.25	1.99	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
2	3.94	249.26	0.95	1.25	2.19	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
3	4.14	248.31	1.15	1.24	2.39	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
4	4.34	247.16	1.35	1.24	2.59	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
5	4.53	245.81	1.55	1.23	2.78	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
6	4.73	244.25	1.76	1.22	2.98	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
7	4.92	242.50	1.96	1.21	3.17	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
8	5.11	240.54	2.16	1.20	3.36	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
9	5.30	238.39	2.35	1.19	3.55	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
10	5.48	236.03	2.55	1.18	3.73	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
11	5.66	233.48	2.75	1.17	3.91	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
12	5.84	230.73	2.94	1.15	4.09	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
55	6.29	22.72	4.43	0.11	4.54	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
56	6.22	18.29	4.38	0.09	4.47	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
57	6.15	13.91	4.33	0.07	4.40	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
58	6.08	9.58	4.28	0.05	4.33	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
59	6.01	5.30	4.23	0.03	4.26	150.00		0.75	0.75	125.00		0.63	0.63	75.00		0.38	0.38
60	5.94	1.06	1.06	0.01	1.07	150.00	3.13	0.75	3.88	125.00		0.63	0.63	75.00		0.38	0.38
61	5.87					146.87	4.14	0.73	4.87	125.00		0.63	0.63	75.00		0.38	0.38
62	5.81					142.73	4.09	0.71	4.81	125.00		0.63	0.63	75.00		0.38	0.38
63	5.74					138.64	4.05	0.69	4.74	125.00		0.63	0.63	75.00		0.38	0.38
64	5.68					134.59	4.00	0.67	4.68	125.00		0.63	0.63	75.00		0.38	0.38
65	5.61					130.59	3.96	0.65	4.61	125.00		0.63	0.63	75.00		0.38	0.38
66	5.55					126.63	3.91	0.63	4.55	125.00		0.63	0.63	75.00		0.38	0.38
67	5.48					122.72	3.87	0.61	4.48	125.00		0.63	0.63	75.00		0.38	0.38
100	3.74					15.51	2.66	0.08	2.74	125.00		0.63	0.63	75.00		0.38	0.38
101	3.70					12.85	2.63	0.06	2.70	125.00		0.63	0.63	75.00		0.38	0.38
102	3.65					10.22	2.60	0.05	2.65	125.00		0.63	0.63	75.00		0.38	0.38
103	3.61					7.61	2.57	0.04	2.61	125.00		0.63	0.63	75.00		0.38	0.38
104	3.57					5.04	2.54	0.03	2.57	125.00		0.63	0.63	75.00		0.38	0.38
105	3.53					2.50	2.50	0.01	2.51	125.00	0.02	0.63	0.65	75.00		0.38	0.38
106	3.49									124.98	2.49	0.62	3.11	75.00		0.38	0.38
107	3.45									122.49	2.46	0.61	3.07	75.00		0.38	0.38
108	3.41									120.03	2.43	0.60	3.03	75.00		0.38	0.38
109	3.37									117.60	2.40	0.59	2.99	75.00		0.38	0.38
110	3.33									115.20	2.38	0.58	2.95	75.00		0.38	0.38
111	3.29									112.82	2.35	0.56	2.91	75.00		0.38	0.38
112	3.25									110.48	2.32	0.55	2.87	75.00		0.38	0.38
175	1.52									5.99	1.12	0.03	1.15	75.00		0.38	0.38
176	1.50									4.87	1.10	0.02	1.13	75.00		0.38	0.38
177	1.48									3.77	1.09	0.02	1.11	75.00		0.38	0.38
178	1.46									2.68	1.08	0.01	1.09	75.00		0.38	0.38
179	1.45									1.61	1.06	0.01	1.07	75.00		0.38	0.38
180	1.43									0.54	0.54	0.00	0.55	75.00	0.51	0.38	0.88
181	1.41													74.49	1.04	0.37	1.41
182	1.39													73.45	1.03	0.37	1.39
183	1.38													72.43	1.01	0.36	1.38
184	1.36													71.41	1.00	0.36	1.36
185	1.34													70.41	0.99	0.35	1.34
186	1.33													69.42	0.98	0.35	1.33
187	1.31													68.44	0.97	0.34	1.31

8.4.2 CMO Planned Amortization Class (PAC)

- PAC securities are also in tranches, e.g. A, B, C and Companion
- Tranches A, B, C and so on receive prepayments according to a pre-specified schedule, which is related to PSA levels chosen ex ante by the MBS issuer
- Differences in the prepayment speed are absorbed by the Companion tranche

8.4.2 CMO Planned Amortization Class (PAC)

- An example:
  - Once more, we divide all of the cash flows generated by the pass through into two smaller cash flows, going to Tranche A and its Companion Tranche; let's assume that the PSA range is PSA^{hi} = 300% and PSA^{lo} = 80%
  - The calculations imply that the PAC Tranche has principal $356.69 million, and the Companion Tranche has principal $243.31 million
  - Figure 8.9 shows the two cash flow profiles, with the high PSA spiking up initially, and then declining below to the cash flow profile of the low PSA; the PAC scheduled cash flow, then, is computed as the minimum between these two cash flows
  - The scheduled cash flow is determined by using the issuer's best guess of what future real prepayments will be; however, in reality, prepayments depend on market conditions, interest rates, housing prices and so on (these other factors will have an impact on the speed of prepayment)
  - Figure 8.10 shows four panels with the cash flow to the PAC Tranche and the Companion Tranche, under four different assumptions about the realized (true) PSA
    - For instance, suppose that the true PSA is 100%: Panel A of Figure 8.10 shows the profile of the PAC Tranche cash flow, which equals in fact the one in Figure 8.9; the Companion Tranche has to absorb any difference between the true cash flow from the pass through (the solid line) and the one promised to the PAC Tranche holders (the dashed line).

8.4.2 CMO Planned Amortization Class (PAC)

- An example:
  - Consider now the case in which prepayments accelerate, perhaps because the Federal Reserve decreased the Fed funds rate and mortgage rates declined
  - Panel B shows the cash flow profile when the PSA goes up to 200%: this change makes the total cash flow from the pass through (the solid line) increase substantially; however, this increase in prepayments does not affect the PAC Tranche, as its profile (the dashed line) does not change at all
  - The impact is instead on the Companion Tranche, whose cash flow increases substantially
  - Panel C displays the same plot but under a realized 300% PSA: in this case for a while the Companion Tranche can absorb the difference in prepayment between the promised cash flows and the true cash flows; however, as the Companion Tranche receives principal prepayments, its principal declines and at some point it is fully retired
  - As soon as the capital of the Companion Tranche is depleted, the cash flow of the PAC Tranche equals the one of the pass through; so effectively the PAC Tranche reverts back to the original pass through, with same prepayment risk

8.4.2 CMO Planned Amortization Class (PAC)

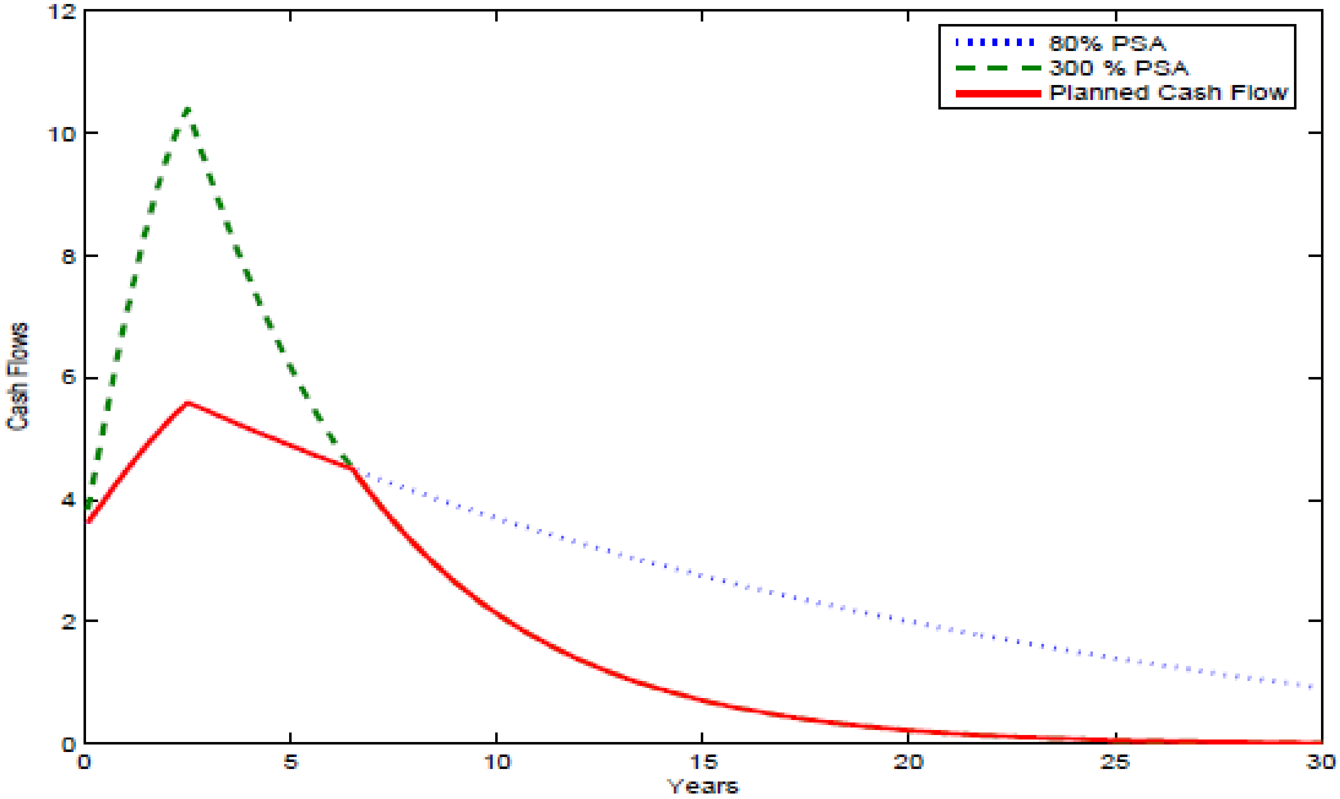
- An example:
  - What happens if the realized (true) PSA is actually above the highest forecasted PSA? As shown in Panel D of Figure 8.10, in this case, the Companion Tranche's principal is repaid very quickly, and thus the cash flow of the PAC Tranche has to jump suddenly to the one of the pass through
  - In this case, the PAC Tranche cash flows revert back to the ones of a standard pass-through security, with the (prepayment) risk
  - What is the price impact of changes in PSA to the PAC Tranche and Companion Tranche? By construction, so long as the PSA level is within the boundaries and the Companion Tranche is not retired, the PAC Tranche cash flow is given by its scheduled cash flow; as such, the price does not change at all
    - The price of the PAC Tranche corresponding to Panels A, B, and C in Figure 8.10 is $377.16 million
  - That is, moving the PSA between 100% and 300% does not change the value at all
  - In this sense, this tranche is not subject to prepayment risk
  - Since the pass through security is affected by changes in PSA, it must be the case that the Companion Tranche value changes substantially with PSA
    - The value of the Companion Tranche in the three panels is $269.77, $257.62, and $250.54 million

8.4.2 CMO Planned Amortization Class (PAC)

- An example:
  - This variation induces a strong negative convexity effect (Figure 8.11)
    - Figure 8.11 reports the result of the same exercise as the interest rate declines and the PSA is increased accordingly to capture the increase in prepayment that lower interest rates would trigger
  - The PAC Tranche displays essentially a linear relation with interest rates, except for low interest rates
  - From Table 8.4 we assume that PSA reaches all the way to 500%, which is much larger than the upper PSA amount of 300%
  - We know that in this case, the PAC reverts back to a pass through, and hence the negative convexity
  - The Companion Tranche displays a much stronger negative convexity than the original Pass Through, with its valuation becoming almost constant as interest rates decline

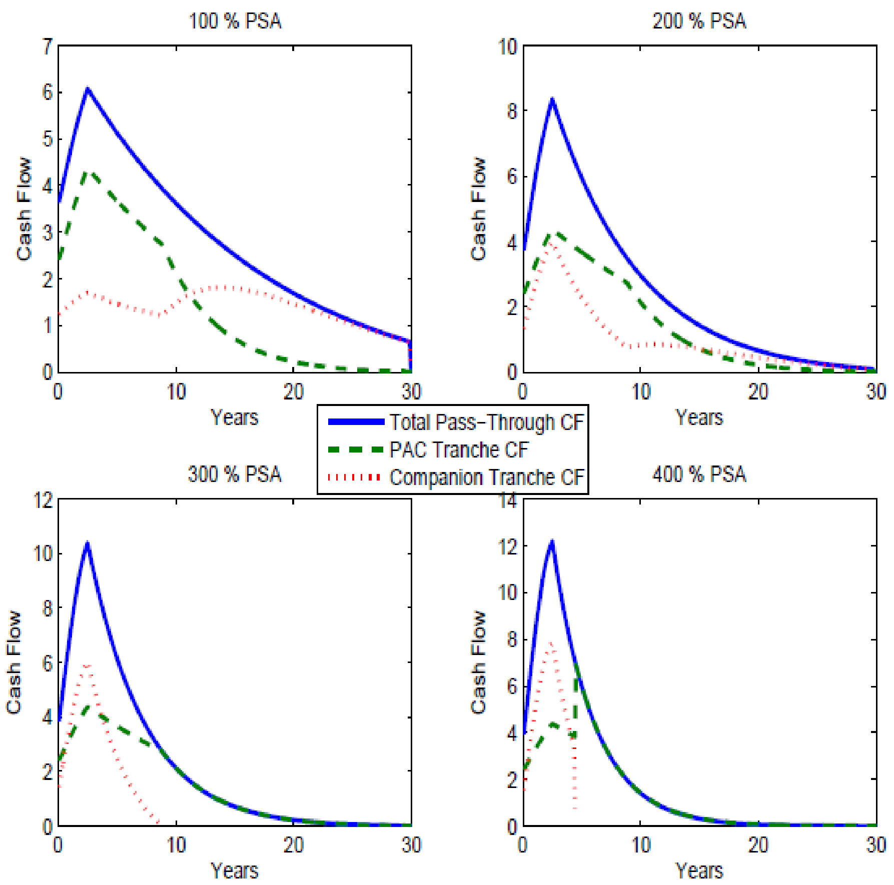
8.4.2 CMO Planned Amortization Class (PAC) (cont.)

Figure 8.9 PAC Scheduled Cash Flow



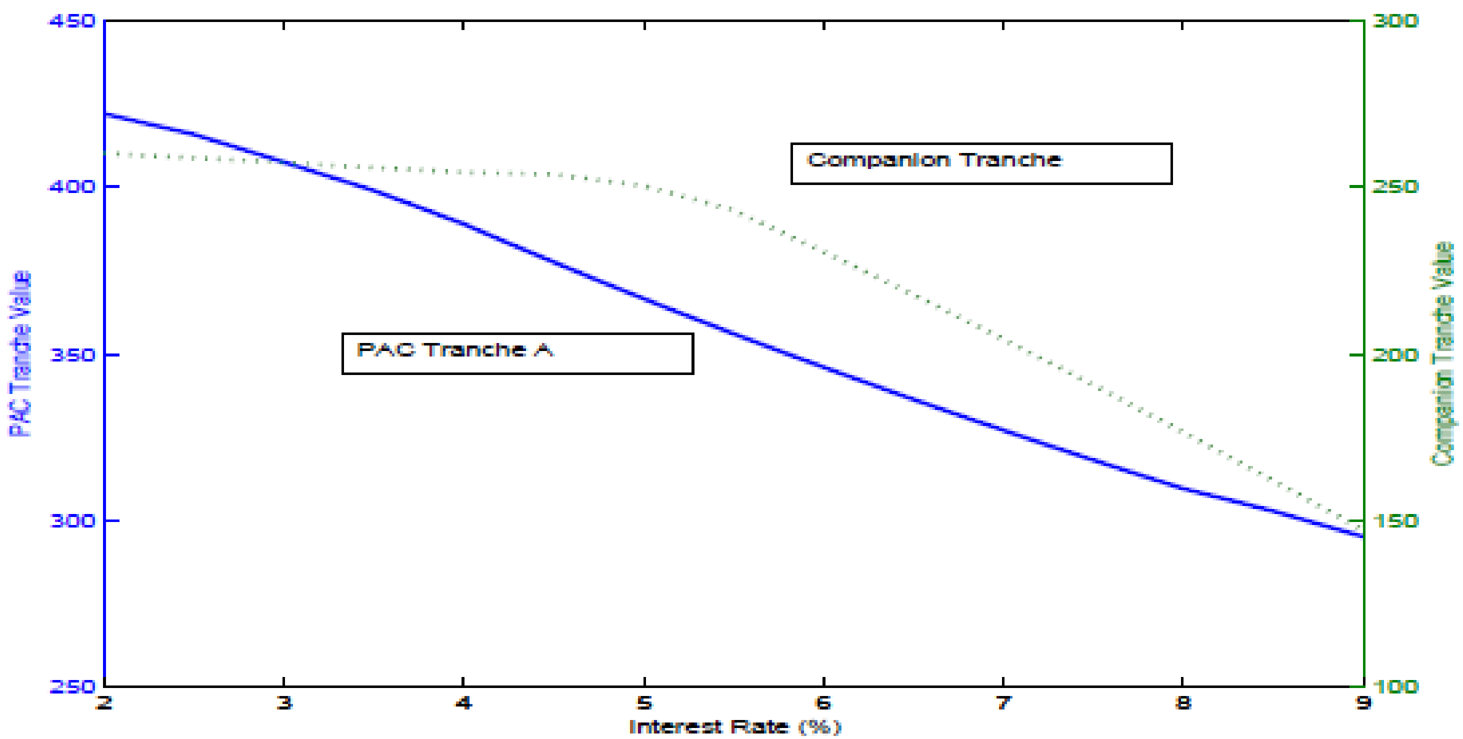
8.4.2 CMO Planned Amortization Class (PAC) (cont.)

Figure 8.10 PAC Scheduled Cash Flow and True PSA



8.4.2 CMO Planned Amortization Class (PAC) (cont.)

Figure 8.11 PAC and Companion Tranche Value



8.4.3 Interest Only and Principal Only Strips

- Interest Only (IO) strips receive all interest payments from the underlying collateral and none from the principal
  - If interest rates decline and prepayment increases, lower interest payments will occur in the future as now less principal is available to compute the interest, as a consequence the IO looses value
- Principal Only (PO) strips receive all the principal payments, scheduled and unscheduled, and no interest
  - If interest rates decline and prepayments increase, all cash flow will go to the PO strips, receiving cash flows in the immediate future, increasing the value of the PO strips

8.4.3 Interest Only and Principal Only Strips

- An example:
  - Now consider that the payments to the IO strip simply correspond to the interest payments for the pass through, contained in Column 8 of Table 8.3
  - The payments to the PO strip correspond to the sum of Columns 6 and 7 of the same table
  - The interesting part about IOs and POs is their behavior as the speed of prepayment changes
  - Table 8.7 shows the impact that lower interest rates and higher PSA have on the value of the strips
    - The most interesting effect is the fact that IO value decreases substantially as interest rates decline and PSA increases
    - In contrast, to counterbalance, the PO strip must increase dramatically to ensure a higher total value, as shown earlier in Table 8.3 for the pass-through security
  - This behavior greatly affects the effective duration of IO and PO strips

8.4.3 Interest Only and Principal Only Strips

- An example:
  - Now consider that the payments to the IO strip simply correspond to the interest Indeed, consider again the case in which the current rate is r = 5%, and PSA = 200%; we can compute the effective duration of IO and PO strips as follows

$$D^{IO} \approx -\frac{1}{P^{IO}} \frac{P^{IO}(+50bps) - P^{IO}(-50bps)}{2 \times (50bps)} = -\frac{1}{210.78} \frac{235.52 - 190.86}{2 \times (50bps)} = -21.19$$

$$D^{PO} \approx -\frac{1}{P^{PO}} \frac{P^{PO}(+50bps) - P^{PO}(-50bps)}{2 \times (50bps)} = -\frac{1}{423.98} \frac{383.61 - 456.89}{2 \times (50bps)} = 17.21$$

  - The effective duration of the IO strips is negative, and substantial, consistently with the previous discussion
  - In contrast, the effective duration of the PO strips is strongly positive
  - This is not surprising, as the weighted average of the effective durations of the IO and PO strips must add up to the effective duration of the original pass-through
  - security, which we found to be 4.46
  - Thus, if the IO strips have a large negative duration, it must be the case that PO strips have a large positive duration

Table 8.7 Value and Duration of IO and PO Strips

Interest Rate	PSA	IO Value	PO Value
2.00%	500	131.75	556.05
2.50%	450	140.05	541.58
3.00%	400	149.71	525.05
3.50%	350	161.06	505.91
4.00%	300	174.57	483.42
4.50%	250	190.86	456.59
5.00%	200	210.78	423.98
5.50%	150	235.52	383.61
6.00%	100	266.75	332.58
6.50%	90	267.07	309.89
7.00%	80	267.35	287.18
7.50%	70	267.59	264.47
8.00%	60	267.79	241.76
8.50%	50	267.95	219.06
9.00%	40	268.07	196.38