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Making Markets for Structured Mortgage Derivatives

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Most of the ideas presented here were developed when I was Managing Director of Quantitative Finance at PaineWebber, Inc. The reviewer, Cliff Smith, gave pointed and useful comments that substantially improved the paper in every part. Any remaining errors are mine alone.

Abstract

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This paper distinguishes between securitization, in which simple pass-through instruments are created, and structuring, in which mortgages derivative claims are created. The point is to explain how structuring a transaction brings value to a deal's underwriter. Briefly, an underwriter must defeat arbitrage between pass-throughs and derivatives. The potential for price discrimination and market segmentation by the underwriter is used to analyze the structuring process. In the course of the analysis, the legal rules for trusts, the algebraic rules for structuring, and the limits on permissible price discrimination are discussed. Results for an actual transaction illustrate the important features of the analysis.

1. Introduction

A structured finance transaction transforms a pool of more or less similar loans into a set of derivative instruments collateralized by the pool. An underwriter who structures a transaction has a simple purpose: to sell the set of derivatives for more money than a direct sale of the pool or a pass-through instrument alone would fetch. The underwriter accomplishes a transaction by establishing an independent entity, usually a trust, which becomes the mechanism for structuring the derivatives. This entity represents a passive financial intermediary. Then the underwriter buys the collateral and sells it to the trust, after which the collateral becomes a trust asset. Simultaneously, the trust issues a set of derivative instruments to finance its collateral purchase. The underwriter buys these derivatives from the trust and sells them to investors. If the underwriter has accurate information about investors' particular demands, the proceeds from selling derivative instruments exceed the underwriter's costs of buying the collateral, structuring the trust's claims, and selling the derivative instruments. At the same time, the set of derivative claims establishes the entity's capital structure.

Securitizing loans and structuring loan derivatives have developed into major forms of financial intermediation. In 1997, the Government National Mortgage Association (GNMA or Ginnie Mae), Federal National Mortgage Association (FNMA or Fannie Mae), and Federal Home Loan Mortgage Corporation (FHLMC or Freddie Mac) together securitized $368 billion in mortgages. About $457 billion of mortgages went into private mortgage conduits, as well (see Board of Governors of the Federal Reserve System, 1997). In the agency issues, about $167 billion of the securitized mortgages were further structured into mortgage derivative instruments. Most of the private pools also received further structuring. In addition to the mortgage activity, in 1997 about $185.1 billion in other types of loans were securitized. These asset-backed transactions comprise home equity and revolving credit loans, business loans, automobile loans, receivables, and other kinds of paper, such as time-share loans. The Bond Markets Association (1998) contains breakdowns of these data. Much of this asset-backed issuance was also structured, albeit quite simply. For comparison, the volume of conventional corporate bond issuance totaled $687.3 billion in 1997 (The Bond Markets Association, 1998).

To outline the structuring business, one can distinguish among four possible dispositions for collateral such as mortgages. First, the originator holds the collateral, does the servicing, and bears all the interest rate and credit risks. This procedure is the traditional way that thrifts operated through the 1970's. Second, the originator sells the collateral to an investor who then bears the risk of ownership. This disposition is termed a whole loan transaction. Third, the originator sells the whole loans to a passive entity like a trust, which then issues proportional claims on the collateral. This method is called securitization. Investors in the securitized claims bear the collateral risk. To mitigate collateral credit risk, the trust may secure insurance of some sort at this stage. Finally, a passive entity can buy either the collateral from the originator or the securitized claims from the initial securitizing entity and then issue a variety of instruments that divide the collateral cash flows into different classes. This method represents a structured and securitized transaction.

Securitizing loans and structuring trades are related but different activities (see Hess and Smith, 1988). Securitization is a more basic process. The originator passes the loans into an entity and it issues one class of simple pass-through instruments rather than a set of derivative claims. A structured finance transaction also involves securitization. In effect, the entity that buys the collateral creates a virtual pass-through that represents a potential financing vehicle before its cash flows are divided into different derivatives. When structuring is accomplished, the virtual pass-through disappears without being issued. The derivative claims are issued instead. The sum of the cash flows over all the derivatives in each time period equals the cash flows of the pass-through that disappears into the derivatives. In fact, in most mortgage-based transactions, pass-through instruments that represent securitized mortgages, are structured through a second entity to create mortgage derivative instruments called collateralized mortgage obligations, or CMO's. The mystery in the structuring process centers on how value is created by replacing a simple pass-through instrument with a set of derivative claims.

This paper's purpose is to analyze how a structured finance transaction creates value for the underwriter who sets up the trade by buying simple collateral and structuring mortgage derivatives. The mechanics of structuring are explained in the next two sections. Both the legal requirements and algebraic requirements for a conforming transaction are explained. The limits on structuring are detailed in the fourth section. Briefly, arbitrage between pass-throughs and derivatives should eliminate an underwriter's profits. The institutions and transactions to accomplish the arbitrage are detailed along with the potential source of arbitrage failure. In the fifth section, arbitrage failure is analyzed. Market segmentation and third-degree price discrimination are used to identify the source of profits in structured finance trades. While pass-throughs are commodity products that trade in relatively liquid markets, derivative claims are tailored instruments designed for specific sorts of investors. The last section of the paper is a summary.

2. Structuring transactions

Securitization is a direct process that creates value by segmenting credit creation functions. It capitalizes on specialization in the credit creation process by separating loan origination, servicing, and intermediation (see Hess and Smith, 1988). An originator delivers a pool of loans to an entity that independently finances the collateral and removes the pool of loans from the originator's balance sheet. The originator may service the loans or sell a servicing contract to a specialized loan servicer.

Servicing is an important aspect of mortgage securitization. The servicer collects interest and principal from mortgagors, pursues delinquent payments, and initiates foreclosures for the owner of a whole loan mortgage pool. A mortgage pass-through pays its owner a proportional share of the pool's principal and interest collected, less the servicing fee and any guarantee fee paid to the securitization's sponsor or a third-party guarantor. For example, investors in FNMA guaranteed pass-throughs receive the principal paid by a pool, plus the total interest paid, less 25-75 basis points of the interest paid to a servicer and 15 basis points paid to FNMA to guarantee timely payment of principal and interest to pass-through owners. Thus, the value of a whole loan pool equals the value of pass-throughs issued against the pool, plus the value of servicing, less the net value of insurance.

From a tax standpoint, it is crucial to set up the securitization to avoid taxation at the entity level. Otherwise, the collateral's interest earnings could be taxed twice, first at the entity level where the loans are securitized, and again at the investor level. As a result, the securitizing entity must avoid displaying the characteristics of a taxable corporation, such as employing associates, having a centralized management, having an objective to carry on business and divide the gains among associates, continuing life, free transferability of interest, and a structure that supports the ongoing existence of the entity (see Lore, 1986). To avoid taxes, the entity cannot conduct business through active management, and must be formed simply to facilitate ownership of its assets, the loan collateral.

Greenbaum and Thakor (1987) provide a discussion of the motives for securitization. Securitization transforms a bulky pool of whole loans into divisible and tradable pass-through instruments. The loans in the pool have roughly similar characteristics and servicing requirements. Pass-through instruments are usually created with a simple fixed investment trust established under state law. The securitizing entity contracts with competitive vendors for servicing and bond administration (see Oldfield, 1997). Pass-through investors get proportional, or pro rata, claims on the cash flows produced by the collateral of the trust, after deducting servicing costs and expenses, based on the proportion of the pool they own through the instruments they buy. In addition, the entity that issues the pass-through instruments almost always arranges for some type of credit enhancement to insulate pass-through investors from collateral default risk. A pass-through is defined here as a pro rata claim on the interest and principal paid by the pool into the securitizing trust. A derivative is a claim that pays a unique amount of interest and principal under specific situations. Credit enhancement can be arranged in two different ways. First, a guarantor for the loans in the pool can be engaged by the trust. This action creates a second asset in the trust, along with the collateral, but does not create a derivative claim issued by the trust. Second, a structured form of credit enhancement can be arranged. The trust can issue both senior and subordinated classes of claims, for which the subordinated class absorbs all collateral defaults until the principal claim of that class is extinguished. These two classes are structured derivatives because the collateral default risk is separated in the trust's financing instruments.

Given that securitization alone creates economic value for the originator, the issue analyzed here concerns the next step: further structuring a transaction into a set of derivative claims. The analysis shows how structuring creates additional value for an informed underwriter who can segment the markets for a variety of different instruments based upon uniform collateral.

Collateralized mortgage obligations, or CMO's, are structured to rearrange the cash flows from the underlying mortgage collateral, consisting of either agency pass-throughs or whole loans, to suit the needs of different types of potential investors. Thus pass-throughs and CMO's have different purposes. Pass-throughs are, to the extent possible, standard instruments designed to be liquid and tradable in secondary markets. Collateralized mortgage obligations are tailored for specific investment sectors and, once issued, trade infrequently. In essence, a primary CMO transaction entails the establishment of an entity, whether trust, corporation, or partnership, to buy mortgage collateral and simultaneously issue a variety of collateralized mortgage obligations to finance the collateral purchase. The entity's assets consist of the mortgage collateral pledged to a bond trustee to back its bonds. The entity's liabilities are the collateralized mortgage obligations.

The purpose of a CMO transaction is to break the collateral cash flows into separate classes of claims to satisfy investors with different preferences. In 1984, U.S. Treasury amendments to fixed investment trust tax regulations largely prevented tax-free trusts from issuing multiple classes of structured mortgage derivative instruments.[1] The Treasury amendments allow two exceptions. First, simple strips of interest and principal are permissible in a tax-free fixed investment trust (see below). Second, senior and subordinated interests are allowed in which both classes have identical claims on cash flows, but the senior class has payment priority in case of default. The real estate mortgage investment conduit (REMIC) rules in the 1986 tax code now make other types of trusts and corporate structures attractive types of entities to accommodate tax-free collateralized mortgage obligation transactions. REMIC status is a tax election for a standard entity, like a business trust, established under state law. If REMIC status is selected, the entity used for structuring must issue an equity claim called a residual interest. In summary, simple deal structures can use a standard investment trust under the 1984 rules to avoid entity taxation. More complex structures require a REMIC as defined in 1986. The transactions discussed in this paper all concern tax exempt structuring entities.

Stripped mortgages, or stripped pass-throughs, are common types of private-issue mortgage derivatives. Stripped mortgage-backed securities are permissible in a standard tax-free fixed investment trust without a REMIC election. If REMIC status is elected, a strip can comprise two tranches in a structure that also has other CMO bonds. However, real estate mortgage investment conduit status for a deal that is wholly composed of strips requires the presence of a residual interest. In a strip, the collateral principal and interest flows are unbundled

[1] This is called the Sears problem after a structured transaction done for Sears Mortgage Securities by Dean Witter Reynolds Securities. See Lore (1986) for a discussion of this issue.

at the entity level and sold separately. A strip is a horizontal slice through the collateral payment stream. Principal and interest are paid out monthly as they flow into the trust. A strip can be partial or complete. For example, GNMA pass-through instruments with a 9% coupon can be split to give a variety of products. A complete strip assigns the interest to one bond class, called an interest-only or IO piece, and the principal to a second class, called a principal-only or PO piece. Alternatively, the mortgage-backed collateral can be split into a class that receives half the principal and one-third of the interest, and another class that receives half the principal and two-thirds of the interest. In effect, the first class is a discount, fast-speed pass-through, with an effective coupon at 6% on 9% pools. The second class is a premium slow-pay pass-through, with an effective coupon at 12% on 9% pools. Virtually any other combination of principal and interest is possible for a strip structure.

A trust issuing mortgage derivatives has an analytic structure based on the rules governing its cash flows. The structure for this type of trust can be represented with two tables, T_p for principal and T_I for interest. A separate T_p and T_I must be used because principal and interest streams cannot be mixed. For example, for 30-year mortgage collateral, each table has 360 columns, one for each month of the trust's life. Each table also has $N+2$ rows, where $N+2$ represents the number of different regular tranches or bond classes that are contemplated, plus a row for the residual interest and a row for trust expenses. The j^{th} row and t^{th} column in T_p and T_I each use a function to compute the principal and interest due for the j^{th} tranche in month t. Rules governing the construction of T_p and T_I derive from trust and REMIC restrictions. Summing down each column in T_p, the total principal paid on a date, according to T_p's allocations, must equal the total principal received from the collateral on that date. An identical rule holds for the columns of T_I with respect to interest. Again for T_p, summing across a row must give the total stated principal due that tranche, allowing for prepayments and defaults. Note that principal and interest are not immediately paid out. Once the principal and interest collected by the REMIC's servicer are wired to the bond administrator, some time elapses while the payment is processed and paid out to bondholders in accordance with the REMIC's structure. In general, the time lag is made as short as possible. In addition, the rules disallow negative payments of interest or principal. Finally, the rule in each j^{th}, t^{th} cell of each table must be a function. For any principal and interest payment into the trust, one and only one possible principal and interest payment can be made to a tranche.

Once T_p and T_I are specified, the arrays reflect the payment structure established by the terms of the deal. For example, suppose a trust issues IO and PO strips. Then T_I directs all interest to the interest-only class, less trust expenses, while T_p directs all principal to the principal-only class. Eq. (1) depicts the type of 3×360 arrays for T_p and T_I that arise for the case in which agency collateral is retained for the trust, and no REMIC election is made, so that there is no need for a subordinated class, or residual interest.

$$T_p = \begin{bmatrix} 1 & 1 & 1 & \cdots & 1 \\ 0 & 0 & 0 & \cdots & 0 \\ 0 & 0 & 0 & \cdots & 0 \end{bmatrix}; \quad T_I = \begin{bmatrix} 0 & 0 & \cdots & 0 \\ (1\text{-}e/i_1) & (1\text{-}e/i_2) & \cdots & (1-e/i_{360}) \\ (e/i_1) & (e/i_2) & \cdots & (e/i_{360}) \end{bmatrix} \qquad (1)$$

In table T_I, the amount of interest used for trust expenses is labeled e. In this structure, T_p and T_I have 3 rows and 360 columns if the collateral is 30 year mortgages or pass-throughs. Since no REMIC election is necessary for this trust, no residual claim is created. The collateral interest payment in period t is i_t. All expenses are paid from interest. The first row of T_p directs all principal to the first or principal-only claim. The second and third rows of T_p direct zero principal to either the interest-only piece or the expense liability. In T_I, the first row directs zero interest to the PO piece. The second row directs all interest, net of expenses, to the IO piece, while the third row directs interest to pay trust expenses.

Strips are curious instruments. Each piece is riskier, in an offsetting manner, than the underlying collateral. An IO owner or an investor holding a mostly interest bond wants the collateral to prepay slowly. His preferences are similar to CMO residual owners or holders of an excess servicing contract. A PO owner or an investor holding a mostly principal piece wants the collateral to prepay fast. Thus, stripping mortgage collateral allows an arbitrageur to buy one instrument, usually an agency pass-through, split the underlying instrument into two parts through a trust, and sell the two parts to different investors with divergent hedging demands or expectations. Strips provide a way for an investor to take a position that magnifies exposure to collateral prepayment speed. If the different classes of investors pay a slight premium to get the exposure they want, the separate strip bonds command a premium over the collateral.

Collateral that has been stripped into interest-only and principal-only bonds allows an investor to create any partial strip based on the same collateral. For example, IO strips and PO strips based on Ginnie Mae 9's can be combined to partial strips with effective rates of 6% and 12% by combining proper proportions of the two complete strips. An investor purchases PO's on \$1,000,000 underlying, or notional, principal and purchases IO's on \$670,000 notional principal, creating a 6% artificial fast-pay pass-through instrument based on the same Ginnie Mae 9's. If the prices per \$100 notional principal are \$51 for the principal-only piece and \$46 for the interest-only piece, then the 6% combined IO-PO package costs \$81 2/3 per \$100 notional principal claim. The package price is calculated as (51 + (0.67) (46)), or 81 2/3. This price eliminates arbitrage opportunities. The price for a partial strip with a 12% effective rate based on Ginnie Mae 9's must be 112 1/3 to prevent simple secondary-market arbitrage.

The principal table T_p contains the basic set of structuring rules. With the amount of principal allocated to each tranche, T_I computes the interest due. The principal table can be visualized as nested sets of matched rows. For example, T_p's first division is for senior and subordinated subsets of tranches. If the first $j = 1 \dots h$ rows are senior tranches with the same priority, then rows $h+1 \dots N+1$ are subordinated tranches that will be the first to absorb any upcoming principal shortages. With a simple senior and subordinate structure, the functions in T_p are calculated as follows. Total principal received equals scheduled principal plus prepayments, less missed payments, plus collections. The trust's servicer identifies the quantity of each type of principal to the trust's administrator. The principal paid to both senior and subordinated classes is the scheduled principal plus prepayments, based on the proportion of principal due each class. However, all missed payments and collections are applied to the amount paid to the subordinated class. This process continues each month until the subordinated class is extinguished or the REMIC is terminated. Interest is divided the same way.

Because all the trust assets back the senior classes, the senior classes are credit enhanced, and are considered to be over collateralized. The rows in the senior class can represent different types of tranches, like IO's and PO's. Similarly, the subordinated subset of tranches can be lumped together, such that $h+1 \dots N+1$, specified above, could represent one tranche or a subordinate subset that has been further subdivided. One subdivision creates a paired subordinate structure. For example, two subsets of subordinated tranches can be constructed, one senior-subordinated and the other super-subordinated. Of course, if agency pass-through collateral is used for the trust's assets, no subordinated subset of tranches is constructed.

If senior and subordinated classes are further subdivided, each subdivision, or cut, creates pairs of tranches. For example, the senior class can be split into fast-pay and Z-bonds, where Z represents zero coupon. The stated principal due to each class need not be equal. The fast-pay tranche receives all principal and interest until the stated principal amount is paid. After that point is reached, the Z tranche receives all future principal and interest. Another way to structure tranches is to provide prepayment protection for one tranche, within specified ranges of prepayments, and to shift the prepayment risk on a companion class. This method creates so-called preferred amortization class bonds and preferred class companion, or support, bonds. A preferred amortization class and its supports can be further subdivided, as well.

3. Rules for REMIC structures

Mortgage structuring is the focus of the analysis in this paper because mortgage-backed instruments can be divided into a multitude of different derivatives. For example, in 1993 Merrill Lynch executed a transaction based upon $2.5 billion of Fannie Mae guaranteed mortgage-backed securities in which a single trust issued 103 different classes of collateralized mortgage obligations. The REMIC's collateral, guaranteed by Fannie Mae, was mortgages that were already securitized into pass-throughs. Traditionally, most asset-backed transactions, other than mortgage-backed securities, emphasized securitization with structuring opportunities limited to credit enhancement. In the 1996 small business tax bill, Congress created a new structuring vehicle called a Financial Asset Securitization Investment Trust, or FASIT. A FASIT allows flexibility in structuring asset-backed transactions using commercial loans, auto loans, and other types of financial assets for collateral. The analysis developed here for mortgage structuring also applies to structures set up through FASITs. The new legislation allows for a wide variety of structured deals based on many types of loan collateral. As a result, the volume of asset-backed securites based on FASITs will likely increase in the near future.

A FASIT is somewhat similar to a REMIC in that a FASIT can be a trust, partnership, or corporation established under state law that elects FASIT status for tax purposes. A FASIT is dedicated to financing debt instruments like consumer loans and revolving credit. It can issue multiple regular interests and one type of residual interest. Unlike a REMIC, a FASIT can also own hedging instruments like Treasury bond futures contracts. In addition, while a REMIC must purchase all of its assets and issue all of its claims on its first day of existence, a FASIT can buy new assets and issue new claims at any time, as long as the FASIT is not used as an asset trading vehicle. For this reason, FASITs face restrictions on their asset sales. The U.S. Treasury and I.R.S. have not yet issued final regulations on FASITs. Further application of this technique will remain limited until these final regulations are issued.

The REMIC provisions of the 1986 tax code are designed to facilitate the creation of privately issued mortgage-backed securities. In effect, the REMIC provisions circumvent the restrictive provisions of the fixed income trust amendments established in April 1984. The 1986 tax code, with additional U.S. Treasury interpretations, establishes a formal structure for qualifying mortgage derivative instruments. A real estate mortgage investment conduit is a tax-free pass-through entity with two types of claims, regular interests and residual interests. A variety of regular interests, consisting of multiple bond classes or tranches, can be issued by one REMIC, but it can issue only one class of residual interest. Regular interests entitle their owners to receive a specified amount of principal. The timing, but not the total amount, of principal payments can vary with the prepayment speed of the collateral. Thus, permissible regular interests include standard slow-pay and fast-pay tranches, Z-bonds, preferred amortization tranches, and senior or subordinated tranches. All residual owners must receive equal shares of excess entity cash flows, apportioned according to their ownership stakes. The REMIC entity can be structured as a tax-free corporation, partnership, or business trust. Trusts are usually elected because they have lower organization costs, and their passive nature assures investors that the collateral will not change after the derivative issue.

Most CMO transactions with complex claim structures are set up as a business trust. A business trust is a standard for-profit business in which title to the collateral assets passes to the bond trustee. A business trust is taxed as a corporation or partnership, whichever it most closely resembles in operation. Entities issuing CMOs are usually taxed as corporations, unless REMIC status is elected. In a corporation, the title to the asset remains with the entity. Both corporations and business trusts establish two types of claims: debt, issued as CMO bonds, and equity, issued as CMO residuals. For either business trust or corporation, it is essential to establish that the entity owns the collateral. Otherwise, the transaction is construed as a sale of collateral to the CMO certificate holders. To establish that the entity owns the collateral, the residual or equity interest in the collateral must bear risks and capture gains that normally accrue to ownership. For example, residual owners in a whole-loan collateralized REMIC bear the first default risk, but capture the benefits of slow-paying collateral. In addition, to assure that a collateralized mortgage obligation transaction is not simply a direct sale of collateral to CMO trust investors, the payments made by the CMO to regular interests cannot simply mirror the inflows from the collateral. The residual interest must comprise at least some small fraction, not more than two percent, of the collateral principal.

Trusts that qualify as real estate mortgage investment conduits are not subject to federal taxes. For derivatives issuing trusts that do not qualify for REMIC status, the smallest possible residual interest is created to minimize federal taxation of the entity. That is, interest earned is taxable while interest paid on collateralized mortgage obligations is tax deductible at the entity level. Principal flows through the entity without being taxed. Thus, if virtually all the interest earned on the collateral is paid out to CMO bondholders, minimal taxable profits are earned by the entity. This arrangement reduces the impact of taxation in the structuring of non-qualifying collateralized mortgage obligation transactions. Securitization with simple structures, like senior-subordinated classes or strips of interest-only and principal-only claims, are frequently done with a standard fixed investment trust without REMIC status because investment trusts with these structures are tax exempt and do not require a residual interest.

In a basic collateralized mortgage obligation transaction, the several classes of bonds repay their obligations according to separate schedules. Various classes, called tranches, have different principal priorities and pay down as a function of the speed of the underlying collateral. A CMO structure can be viewed as vertical or temporal slices through the collateral cash flows. For example, consider a very simple hypothetical trust structure, with three regular tranches plus a residual interest, whose principal asset consists of $270 million principal value of 30-year Freddie Mac pools, with a 9% pass-through rate based on 9.5% coupon residential mortgages. For this example, ignore any transactions or underwriting costs. Trust administration expense amounts to a few basis points of interest per year. The first tranche has a coupon rate of 9% and receives $150 million of principal. The second tranche has a coupon rate of 9% and receives its $59 million principal after the initial $150 million principal flows to the first tranche. The third tranche has a coupon rate of 8.5% and receives its $59 million principal after the first and second tranches are completely paid down. Thus, each tranche pays principal in sequence. Interest is paid simultaneously to all tranches until a tranche pays its full principal value. Monthly principal and interest payments from the pass-through collateral are collected by the real estate mortgage investment conduit and paid out to bondholders monthly. The residual owners receive excess interest during the lives of the three regular tranches and the final two million dollars of principal. Slicing the flows in this manner makes the first tranche a short-term premium instrument, the second tranche a medium-term instrument worth about par value, and the third tranche a long-term discount instrument. Each tranche is priced initially against the active-issue Treasury note or bond with the nearest average life. Yield markups range between 25 and 150 basis points. The longer tranches have some measure of prepayment protection since the initial prepayments go to the earliest tranche. Thus, if prepayments rise temporarily, principal does not flow through to the longer tranches too early. However, cash flows for all tranches have more temporal uncertainty for both principal and interest than the Treasury securities against which they are priced.

The simple three-tranche plus residual interest example has more complex T_p and T_I arrays than the IO - PO strip structure shown in Eq. (1). Payment arrays for principal and interest are given in Table 1 and Table 2. All regular tranches and the residual interest receive both principal and interest. While principal payments are sequential, interest payments to all tranches are paid simultaneously but cease to a tranche once its principal is paid fully. The 8.5% coupon on tranche C assures that the interest payments to the residual class are quite generous relative to its principal amount. The actual accounting for trust expenses is a bit more complicated than depicted in Table 2. Early in the trust’s life, some excess interest is accumulated in reserve accounts owned by the trust. Later, when collateral interest payments decline, these accounts are used to pay trust expenses. Because the trust's sponsor or underwriter remains liable for expenses if the trust cannot pay them, trust dissolution is set to ensure that no liability falls on the sponsor. Even at a zero prepayment speed the REMIC will not exist for 360 months. Times denoted in Table 1 and Table 2 as *r*, *s*, and *t* are variable, and depend upon prepayments of collateral principal.

Suppose all the mortgages in the underlying FHLMC collateral pool are instruments that were newly originated in the most recent month. In addition, assume that each mortgagor makes an accurate and timely payment in the first month. This scenario implies that the underlying collateral, new conventional 30-year mortgages with 9.5% coupon rates, generates a total payment of $2,139,792.57 to the servicer. Given a yearly servicing fee of 37.5 basis points and an FHLMC insurance and processing fee of 12.5 basis points, the servicer retains $84,375 of the interest and FHLMC gets $28,125 of the interest. The pass-through rate is 9% so the balance, $2,292.57 principal and $2,025,000 interest, passes through the FHLMC pool to the REMIC. These quantities are used with T_p and T_I in Tables 1 and 2. Given trust expenses of $10,000 per month, $2,292.57 principal and $2,015,000 interest are available for tranche owners. In month 1, all of the principal goes to the A tranche owners. The interest in month 1 is divided as follows: $1,125,000 goes to the A tranche, $442,500 goes to the BB tranche, $417,916.67 goes to the C tranche, and $29,583.33 goes the residual interest holders. This division accounts for the total principal and interest received by the REMIC according to the structuring rules in Tables 1 and 2. Of course, monthly collateral payments are often more irregular, given prepayments, nonpayments, heterogeneous coupon rates, and variance in the actual origination month. All of these factors must be tracked by the trust's administrator to account accurately for payments and claims against FHLMC.

Many other types of bonds have appeared in derivative mortgage structures. A floating-rate tranche can be created with fixed-rate collateral by either pairing it with an inverse floating-rate tranche or having higher floating rates take interest payments from residual owners. The rates for floaters and inverse floaters are usually keyed to the London interbank offered rate known as LIBOR. Floaters and inverse floaters pay in tandem and must have caps and floors on interest payments that preserve the collateral pass-through rate. For example, consider a floater with $100 million principal value based on 10% coupon pass-through collateral that pays 6 month LIBOR plus 100 basis points capped at 20%. Its companion might be an inverse floating rate tranche with $100 million principal value that pays a 20% return minus the payment on the floating rate tranche. The floor for this tranche is zero. Many other types of structures are also possible. The only constraint is that total cash flows due from collateral must equal flows due bondholders, residual owners, and trust expenses. In addition, interest and principal payments cannot be mixed. All principal paid into the REMIC must be paid out as principal, and all interest paid into the REMIC must be paid out as interest, less expenses. Finally, if REMIC status is not elected, the residual interest must be small enough, and the resulting bonds large enough, to minimize the taxation of the entity's income.

With allocation rules for tranches defined in T_p and T_I, such as those shown in Tables 1 and 2, these arrays specify the fraction of principal and interest due each tranche, given the collateral's principal and interest payment paths. To show how allocation rules work, define k_t as the amount of principal paid into the trust in the current payment period t, and K_t as the vector of current and all previous principal payments into the trust. The fraction of principal paid out of the trust to tranche i in period t is defined as $x_{it}(K_t)$. Thus, the fraction of principal paid to tranche j in period t can depend on both the current and past principal payments into the trust. If only the current principal inflow from the collateral determines the fraction due to tranche j, then the fraction is written $x_{it}(k_t)$. For a trust overall with N regular tranches plus a residual,

$$\sum_{j=1}^{N+1} x_{jt}(K_t) \cdot k_t = k_t \,. \qquad (2)$$

In words, the total principal received by the trust in period t must be paid out to tranches in period t. With this conservation requirement, if the principal payment for any tranche in period t depends upon past principal receipts by the trust, one or more other tranches must also receive principal payments based upon past inflows, such that the total principal received at time t by the trust is also paid out at time t.

Interest payments for tranches of a structured transaction are also based on specified sets of rules. Let i_t be the interest paid in period t from the collateral owned by the trust that is available for REMIC claimants. Also, define W_t to be a vector of variables, such as an index level at time t, a timing indicator to specify when a zero-coupon tranche starts interest payments, or the principal value of collateral at t that can affect interest payments to a tranche. Then $y_{jt}(i_t, W_t)$ is the function that determines tranche j's interest payment at time t. To account fully for interest payments at time t, one must also allow for trust administrative expenses, e_t, incurred by the structuring trust. Expenses are paid as a fraction of interest due to the trust from the collateral. Interest is the only trust income available for expense payments. Principal inflows are considered a return of principal to trust claimants, and cannot be used to pay trust expenses. With this structure for the trust,

$$(\sum_{j=1}^{N+1} y_{jt}(i_t, W_t) + (e_t / i_t))i_t = i_t . \quad (3)$$

At any time t, the total interest due to the trust from the collateral equals the amount paid out for interest payments to tranches and trust expenses. Thus interest, like principal, must be conserved.

Collateral servicing can be an important feature of structured transactions (see Oldfield, 1997). Insurance against collateral default risk can be important also. With agency mortgage-backed collateral, servicing and insurance are handled in the primary securitization of the underlying mortgages. As a result, the structuring trust can function without a servicing contract or insurance policy. However, if the trust uses whole loan collateral, it must contract for mortgage servicing. The servicing claim makes an $(N+3)^{\text{rd}}$ row in T_p and T_I. An insurance premium makes an $(N+4)^{th}$ row. Given the focus here on CMOs that are based on agency collateral, servicing contracts and insurance policies are omitted from this analysis. Trust administration expenses are a very small and standard part of the interest received each month. To ensure that expenses can be met, most structured transactions feature a “clean up call” on tranches, such that all bonds are redeemed by the trust when the collateral level gets so small that expenses become a predominant drain on interest.

The functions x_{jt} and y_{jt} are the entries in tables T_p and T_I. Given an arbitrary payment speed for the collateral, the allocation functions x_{jt} and y_{jt} compute the principal and interest fraction paid each tranche at each time period. Thus, tables T_p and T_I become allocation matrices keyed to the particular payment speed specified. For example, the principal-only and interest-only strip rules given in Eq. (1) satisfy this structure. For an IO-PO strip transaction, the fractions x_{jt} and y_{jt} are independent of collateral payment speed or any other argument. A more complicated example with three regular tranches and a residual, as outlined in Table 1 and Table 2, also shows how these rules work when tranche payouts depend upon prepayments.

From the conservation Eqs. (2) and (3), the total principal and interest due to the structuring trust in each time period equals the total principal and interest due to the bondholders and other claimants at the same time. To establish a nominal value for each tranche, an underwriter selects a projected payment path for the future principal and interest payments the collateral is predicted to generate. Then the yield to maturity for the collateral at the chosen projected payment speed, or pricing speed, is calculated, setting the present value of projected collateral cash flows equal to the nominal principal value of the collateral. This nominal or par value of the collateral is labeled Q_p, representing the present value of promised payments. The underwriter must usually try a few combinations of speeds and yields to find a reasonable projection of principal and interest payments paired with a yield. Finally, the projected pricing speed for principal and interest payments due from the collateral are passed through the structuring tables T_p and T_I to project principal payments and interest payments assigned to each tranche. Expenses are projected too. These projected flows are discounted at the collateral coupon yield to give a nominal value for each tranche, labeled Q_j, and expenses, termed E. Then, given the conservation relations from Eqs. (2) and (3),

$$\sum_{j=1}^{N+1} Q_j + E = Q_p . \tag{4}$$

On the left side of Eq. (4) is the sum of nominal present values for the $N+1$ tranches plus expenses of the trust. On the right side is the collateral's par value at the given pricing speed. In fact, the structuring underwriter can choose different yields for different tranches to adjust the par value and yield for one tranche relative to another tranche. However, Eq. (4) must always be satisfied for any structure and prepayment speed at each payment date.

The underwriter's problem in structuring a deal is to achieve a profit from the exercise. This constraint requires the underwriter to design a structure such that:

$$p_p Q_p - \sum_{j=1}^{N+1} p_j Q_j + E < 0\,, \tag{5}$$

in which p_p is the collateral price when sold as a pass-through and p_j is the j^{th} tranche's price. In words, the aggregate value of tranches sold must exceed the value of a pass-through based on the same collateral plus the value lost from structuring trust expenses. In addition, the constraint presented in Eq. (4) must be satisfied.

An example from a simple REMIC shows how an actual transaction was structured. This transaction took place during the first years that REMIC elections were possible, and offered five regular classes of bonds plus a residual interest. Table 3 gives the primary market information for this actual structured transaction based on new production 30-year FNMA 10's. This transaction was done by an underwriter to capture profits by structuring pass-throughs into mortgage derivatives. The collateral was purchased directly from Fannie Mae. The CMO trust series B is a Delaware business trust established solely to own mortgage collateral and sell collateralized mortgage obligations. All bonds offer monthly payments and stated yields are based on corporate calendar conventions. The trust elected real estate mortgage investment conduit status for tax purposes. There are six tranches: a large floating rate bond keyed to one month LIBOR (tranche B-1); three short- to intermediate-term tranches priced to give increasing yield pickup over the

Treasury yield curve (tranches B-2 to B-4); and a long-term Z-bond with a yield premium of 200 basic points over the 20-year Treasury bond (tranche B-5). The Z-bond tranche is sequential to tranches B-1 through B-4, and pays no interest before its principal payments commence. The final tranche, B-6, is the residual interest. The residual interest tranche is not listed on the sheet because it was wholly placed before the other tranches were offered. The syndicate fees per each $1,000 bond are also given, $1.75 to $0.75 per bond for the manager; $1.75 to $0.75 per bond for the underwriters, and $3.00 to $5.00 per bond for the selling group firms. The reallowance is the amount of sales commission given up for a sale by one selling agent to another. This example shows how an underwriter sets up a structure to sell different tranches to different customers. To sell the mortgage derivatives at a profit, the underwriter must find an opportunity to buy collateral, set up an entity, create the derivatives that appeal to investors, and sell them at a markup over costs. The limits to this sort of trading are detailed in the next section.

4. Arbitrage limits to structured finance

The neutrality of structuring in a securitized transaction requires efficient arbitrage among markets for collateral pass-throughs and markets for derivative claims. Shleifer and Vishny (1997) provide a discussion of the limits to arbitrage. Efficient arbitrage prevails in liquid markets with low transaction costs for creating and trading structured products among investors with common information. If such conditions exist, financial structuring, using credit enhancement, tranche creation, or default and prepayment risk divisions among various REMIC or more commonplace investment trust claims, has no effect on overall REMIC value (see Modigliani and Miller, 1958; and Jaffe, 1991). In fact, structuring reduces the value of derivative collateralized claims in arbitrage-efficient markets due to the fees and commissions required to create the claims. Trading pass-throughs is much easier than selling derivatives if markets are liquid, well informed, and easily accessed by potential pass-through and derivative investors.

To show the limits of value enhancement in liquid markets with standard collateral and claims, visualize an idealized world without trading costs, trust expenses, or frictions in information flow among investors. Within this universe, an arbitrageur can eliminate potential value differences between trusts holding identical collateral but maintaining different claims. Specifically, suppose two whole loan packages, with identical measurable characteristics, are available. One loan package is purchased by an unstructured REMIC labeled U. REMIC U issues one class of pure pass-through instruments, called P. The other loan package is bought by a structured REMIC, labeled S. REMIC S issues two classes of derivatives, an A piece and a B piece. Both REMICs arrange for outside servicing on the same basis. Thus, each trust owns a whole loan package serviced by an outside contractor under the same terms, conditions, and servicing fee. Each REMIC has an equal expected amount of principal and interest available each month to pay its bondholders. In this idealized world, the value of REMIC U's pass-through instruments equals REMIC S's aggregate value of A and B class claims. Given the equivalence, structuring the pass-through into A and B pieces conveys no additional value. Without this equivalence, an arbitrageur can make an immediate profit in this idealized world.

In this demonstration, two points are important. First, details about subordination, and carve-outs of principal and interest claims for REMIC S issues can be omitted. The A piece and B piece of REMIC S issues can be senior and subordinate claims, principal-only and interest-only claims, or any other type of tranched structure. Second, the demonstration holds as a one-period proof. That is, it works for any arbitrary month in the lives of REMIC U and REMIC S issues, and therefore it works in general. In effect, imagine demonstrating the proof in the last cash flow period for each trust, then work backwards to the present. By induction, the proof is true in each period.

The key player that forces structuring neutrality is a tax-free arbitrageur who competes with the underwriter. A real estate investment trust (REIT), another type of specialized real estate trust, is a perfect vehicle for this type of arbitrage. Unlike a REMIC trust, which cannot change its structure once established, a real estate investment trust can be actively managed and still avoid taxes as long as it pays out ninety percent of its earnings. A REIT can buy, sell, and finance investments in REMIC securities. This feature shows that the real estate investment trust can buy and sell pass-through instruments issued by an unstructured REMIC, or A piece and B piece claims issued by a structured REMIC. Moreover, the REIT can buy pass-throughs from an unstructured REMIC and subsequently issue its own A or B piece claims whose cash flows are exactly matched to those issued by a structured REMIC. When the cost of doing these transactions is very low, and potential investors in the instruments are freely known to the REIT's manager, then no structuring advantage can persist for underwriters of REMIC trusts of type S.

For example, suppose the market value of the A and B pieces issued by REMIC S exceeds the market value of the pass-through investment issued by REMIC U. The REIT can buy pass-through instruments issued by REMIC U and issue its own A-type and B-type claims using the pass-through instruments issued by REMIC U as collateral. Because the cash flows from pass-through P are precisely those used to pay A and B pieces issued by REMIC S, the transaction is possible. This "buy cheap and sell rich" trade structure captures an arbitrage profit for the REIT's shareholders. Similarly, if either or both A-type and B-type claims are cheap relative to P, then the real estate investment trust can buy A and B pieces and issue its own pass-through instrument that resembles P. Once again, the cash flows support this arrangement, since the cash flows arising from A, plus the cash flows arising from B, are identical to the cash flows arising from P. The arbitrage process outlined here works very quickly in markets for real estate mortgage investment conduit claims secured by standard sorts of collateral. For example, the preponderance of REMICs use standard agency mortgage-backed securities for collateral, and then issue collateralized mortgage obligations. This exercise is profitable only when the aggregate CMO value across all issued tranches exceeds the collateral price. To prevent arbitrageurs from driving profits to zero, a structuring underwriter must create idiosyncratic tranches tailored for specific investors who do not share information and trade directly with one another. Thus Merrill did 103 tranches in the example cited above.

For an arbitrageur to eliminate a structuring underwriter's profits, it is important that transaction costs are low, plenty of buyers and sellers for the different types of collaterized instruments are known to the arbitrageur, and new claims can be issued quickly or sold short to willing buyers. Otherwise, the arbitrageur cannot perform arbitrage trades, and price differences for different claims relative to the collateral can persist. Also, if the arbitrageur is unable to find two very similar packages of collateral, the arbitrageur will have difficulty duplicating the products that must be arbitraged. Thus, loans against mobile homes, time share loans, and low quality consumer loans are all candidates for securitization with very simple or no structuring (see Oldfield, 1997). These unusual and unconventional types of collateral are characterized by unique bundles of financial assets of uncommon sorts that trade sporadically in whole loan markets. The structuring underwriter's main advantages in these trades are a customer list of potential purchasers for tailored claims, and an ability to do complex transactions cheaply and quickly. The benefits of structuring are different from the substantial economies in specialization generated by securitization. Instead, structuring can create rents for the underwriter through price discrimination. If no rents are available, an underwriter simply securitizes the loans, or structures a trade without price discrimination. In this case, profits come from securitization, not structuring.

5. Price discrimination and structured finance

In a structured transaction, the underwriter must calculate the best way to divide the cash flows emanating form the collateral. The structuring analysis performed by the underwriter is similar to the unbundling strategy undertaken by the seller to boost the sales proceeds in an auction (see Palfrey, 1983). To begin, suppose the demand functions for various derivative products are linear and imperfectly price elastic. This assumption serves to simplify the analysis. In addition, suppose a constraint holds such that, at some set of prices, the sum of demands for derivative claims equals the demand for an unstructured pass-through instrument. Put another way, the demand for the whole bundle of cash flows must equal the sum of demands for its pieces given some set of prices for the bundle and its pieces. This condition is necessary because each buyer of a derivative claim would take an entire pass-through instead of a piece of it if the pass-through itself was priced cheaply. With perfectly elastic demands, this summing up condition eliminates the profit potential in a deal. However, with imperfect elasticities, the types of arbitrage trades outlined in Section 4 are hampered, and structuring profits can result from price discrimination. A successful underwriter must possess some advantage, based on either customer information, access to collateral, or structuring analytics. Otherwise, competitors can freely replicate and execute transactions that force monopoly rents to unattractive levels.

The derivative design and sales process in a structured transaction works like a multistage auction. To obtain demand information while creating a transaction, an underwriter discusses alternative structures and products with potential investors. Given customers' preferences for derivative claims, the underwriter designs a tentative deal size and structure. When the transaction is nearly complete, a summary sheet, containing tranche information, is sent to the underwriter's sales people. The sales staff then explain the derivatives to customers and solicit orders. Customers respond with price and quantity bids that the underwriter uses for final pricing. If the underwriter expects to profit on the transaction based upon the customer demand information, then the collateral is purchased, public offer prices are set, the entity is established, and bonds are underwritten and sold to investors. The demand functions that the underwriter constructs are like those assembled by a market maker (see O'Hara and Oldfield, 1986). Indeed, the whole process works much like standard bond underwriting. Once public offer prices are fixed for tranches, all customers pay the same price for bonds in the same tranche. The resulting bond sales process is nondiscriminatory. The price discrimination works by unbundling and selling different tranches for different prices, not by charging different prices for the same bonds.

An underwriter seeks private information about investor demands to structure derivatives, segment the market, and set prices intended to discriminate among different sets of customers. Since an infinite variety of alternative structures are available to an underwriter, the entire set of feasible derivatives cannot be tested with potential investors. Investors do not respond with practical bids for multitudes of hypothetical bonds. Instead, an underwriter tries to find a few reliable customers who voice special needs for specific cash flows. The underwriter endeavors to design a structure that creates specific tranches for these and similar customers, along with a combination of more or less generic CMO tranches that can be readily sold. The whole structure is tested with potential investors, negotiated and adjusted to reflect additional information, then sized, priced and sold.

The underwriter's structuring problem can be set up in an optimization framework. Suppose the demand for pass-through instruments based upon specific collateral can be written as a linear function of price, such that

$$Q_p = u_p - v_p p_p . \tag{6}$$

Here, as before, Q_p is the total par value of pass-throughs and p_p is the pass-through price per dollar of par value. Demand parameters are u_p and v_p, where u_p and v_p are positive. Given a potential structure proposed to investors based on the same specific collateral, let the demand for the j^{th} tranche be written as

$$Q_j = u_j - v_j p_j , \tag{7}$$

in which Q_j is the j^{th} tranche's par value at pricing speed, p_j is the tranche price per dollar of par value, and u_j and v_j are positive demand parameters. The unbundling condition means that, for some set of tranche prices $p_1^0 \ldots p_{n+1}^0$, and some pass-through price p_p^0, the sum of tranche demands equals the demand for pass-through instruments, less the value of the expense fraction labeled a, or

$$\sum_{j=1}^{N+1} (u_j - v_j p_j^0)(1-a) = p_p^0 Q_p . \tag{8}$$

In addition, the cash flow constraint set out in Eq. (4) requires that the sum of tranche par values plus the present value of expenses E equals the par value of pass-throughs. In other words, Eqs. (4) and (8) together imply that the quantities of derivatives supplied must equal the collateral used, and that the quantities of claims demanded must add up to the whole bundle, including trust expenses.

To insure that the demand for individual tranches sums to equal pass-through demand, a specific set of demand functions can be used in which the parameterization is simplified, such as

$$\sum_{j=1}^{N+1} u_j = u_p(1-a), \tag{9}$$

and

$$\sum_{j=1}^{N+1} v_j = v_p(1-a). \tag{10}$$

With these restrictions on parameters, Eq. (8) is easily satisfied with feasible prices. For example, inspection shows that, if all tranche prices and the pass-through price equal unity, the unbundling condition is satisfied. While these prices satisfy the unbundling condition, they do so at zero profit for the structuring underwriter. The underwriter must find other prices in order for the deal to be profitable.

The underwriter's strategy is to maximize a structure's premium over pass-throughs by choosing tranche quantities that also satisfy the trust's cash flow constraint.

$$Max \sum_{j=1}^{N+1} p_j Q_j - p_p Q_p - w(Q_p(1-a) - \sum_{j=1}^{N+1} Q_j), \quad w.r.t. \quad Q_j\text{'s}, \ Q_p, \text{and } w. \tag{11}$$

In Eq. (11), w is the Lagrange multiplier for the cash flow constraint. Solve Eqs. (6) and (7) for prices, and substitute the result for prices p_j and p_p in Eq. (11). The first-order conditions are:

$$\begin{aligned} &(u_j / v_j) - 2(Q_j / v_j) + w = 0; \\ &-(u_p / v_p) + 2(Q_p / v_p) - w = 0; \\ &-(Q_p(1-a) + \sum_{j=1}^{N+1} Q_j) = 0. \end{aligned} \tag{12}$$

In the expression given in Eq. (12), there are $N+1$ tranche equations of the first type, as well as the equation for pass-through par value Q_p and the equation for the Lagrange multiplier w. This setting yields $N+3$ equations to solve for the $N+1$ different Q_j's, plus Q_p and w. The solution is simplified for the specific demand functions used here, because w = 0. This relation occurs because the specific demand equations used here naturally force the constraint to be satisfied. Solutions for tranche quantities plus the par value of the virtual pass-through give:

$$Q_j = u_j / 2 , \tag{13}$$

and

$$Q_p = u_p / 2 . \tag{14}$$

The corresponding prices are:

$$p_j = u_j / 2v_j , \tag{15}$$

and

$$p_p = u_p / 2v_p . \tag{16}$$

These results are the standard quantities and prices that arise from linear demand functions. Each derivative claim comes to market with a different par value and price because each (u_j, v_j) pair is unique. If the profit from structuring is large enough, the transaction is structured and sold.

An example shows how creating a tranched offer can create profits from structuring. In Section 3, a transaction was introduced and its structure is outlined in Tables 1 and 2. Let the demand for pass-through instruments against a specific pool of collateral with standard servicing be written as $Q_p = 540 - 270 p_p$. The units of measure for parameters u_p and v_p are set to yield Q_p as denominated in million dollars of par value and p_p in price per dollar of par value.

Suppose first that a structure is given in which the first tranche is labeled A and the second tranche is labeled B. This supposition indicates that tranche B is the combination of tranches BB and C in the example given in Section 3. The demands for these classes are summarized in the functions, $Q_A = 300 - 137.50 p_A$ and $Q_B = 236 - 130.50 p_B$, in which parameter values are measured like u_p and v_p. Trust expenses are ignored here to concentrate on the tranching solutions. The expense item is quite small and makes little difference in the results. The residual class demand function used here is $Q_R = 4 - 2 p_R$. This demand function means that the residual commands no price discriminating rents relative to a pass-through. It is adopted to focus the analysis on tranching regular interests. In fact, if it can be sold, the residual class is frequently a source of significant profits. Note that when the prices of the first two tranches, the residual, and the pass-through are equal to one, or $p_A = p_B = p_R = p_p = 1.00$, then the quantities demanded of each tranche sum to the quantity demanded of the whole asset, or $Q_A + Q_B + Q_R = Q_p$. The optimizing quantities and prices are $Q_p = 270{,}000{,}000$, $Q_A = 150{,}000{,}000$, $Q_B = 118{,}000{,}000$, and $Q_R = 2{,}000{,}000$, with $p_p = 1.00$, $p_A = 1.09091$, $p_B = 0.904215$, and $p_R = 1.00$. From the example, the A class is a premium price short-term tranche and the B piece is a discount price long-term tranche. The total proceeds from selling the pass-through would be \$270,000,000. Tranching instead gives total proceeds of \$270,333,689 for the regular tranches plus \$2,000,000 for the residual. Hence, the virtual unstructured pass-through disappears into the tranches. By unbundling the cash flows, structuring derivatives, and segmenting the market, the underwriter earns \$2,333,689 in the transaction.

Suppose the underwriter divides the tranches into standard-size bonds with \$100,000 par value so that an A class bond costs \$109,090.91 and a B class bond costs \$90,421.50. To match the cash flow of one equivalent pass-through instrument, an arbitrageur must buy 150/270th of an A class bond and 118/270th of a B class bond, plus 2/270th of a $100,000 residual share. The total outlay for this investment is $100,864.34. Thus, a proportional investment in an A bond, a B bond, and a residual share together costs more than an equivalent pass-through instrument priced at $100,000. This difference means that arbitrage trading at the margin cannot spoil the deal. Of course, if a competing arbitrageur can locate the same customers that the underwriter uses, buy pass-throughs or collateral identical to the underwriter's, and structure the same transaction, then the arbitrageur can compete for profits. The underwriter's advantages are customer knowledge and rapid execution ability.

To show how further unbundling can lead to additional profits, suppose the B class is subdivided into a medium-term tranche labeled BB and a long-term tranche labeled C. This structure accords with the example in Table 1 and Table 2. Let the tranche demand functions be $Q_{BB} = 118 - 60\,p_{BB}$ and $Q_c = 118 - 70.50\,p_c$. Parameter units are given as before. The optimal prices and quantities for the two new tranches are $p_{BB} = 0.983333$ and $Q_{BB} = 59{,}000{,}000$ for the BB tranche, and $p_c = 0.836879$ and $Q_c = 59{,}000{,}000$ for the C tranche. These prices and quantities reflect the original structure given in the example in Section 3. The total proceeds from selling these tranches is $107,392,553, which exceeds the proceeds from the undivided B class sale by $695,235. Clearly, given the demand function types used here, more tranching leads to greater profits. To discriminate perfectly, an underwriter could attempt to create a unique bond for each customer.

The total potential proceeds from pure price discrimination in the pass-through market, selling pass-throughs for prices ranging between $p_p = 200$ to $p_p = 100$ to different customers, is $405,000,000 in this example. Dividing the virtual pass-through into a few tranches enables the underwriter to capture only a modest amount of the total surplus available. Since pure price discrimination in the pass-through market is not a feasible strategy in a public offering of pass-throughs, tranching is the mechanism used to capture at least some of the surplus in the marketplace. An underwriter cannot charge different customers different prices for the same class bonds in a public offering, but different classes can have different prices.

The six-tranche CMO transaction summarized in Table 3 illustrates the kind of structure indicated by the optimization results given in Eqs. (13) through (16). The transaction was based upon $150 million notional value FNMA pass-throughs. The structure was driven by two of the underwriter's customers. One customer wanted the exact type of residual created in Trust B, while the other wanted a product based on a FNMA guaranteed 10% pass-through pool with a floating interest rate tied to LIBOR. The first customer bought the whole residual and the second customer bought all of tranche B-1. The other tranches accommodate the floater and the residual. Each tranche has a different par value and price. The FNMA 10% coupon collateral price was about $100 29/32's per $100 par value, so that the actual asset value of the REMIC trust was about $151,360,000. On the trust's liability side, the weighted average tranche price was about $96.104 per $100 par value for tranches B-1 through B-5. The total trust proceeds on these regular interests, less $975,000 of spread revenue to the underwriter, was $143,085,000. Note that the longer maturity tranches were harder to sell but easier to hedge. Thus, underwriting these tranches earned a smaller fraction of spread revenue and selling these tranches earned a larger fraction. The residual interest, tranche B-6, was based on an inverse LIBOR floating interest rate with a principal value of only $100,000, an amount well under two percent of total principal. As an almost pure interest-only strip, it claimed all the initial excess interest from the 10 percent coupon collateral not paid to tranches B-1 through B-5 or used for expenses. When tranches B-1 through B-4 are fully paid, the Z-bond tranche B-5 receives virtually all of the remaining interest, and the interest flow to the residual drops to nearly zero. Once B-5's principal is paid, B-6 gets the remaining $100,000, plus any excess reserves. Given the potential interest flow, the residual brought a private placement price of about $10,000,000.[2] Of this total, about $8,275,000 went to the REMIC for collateral purchase while the balance was retained by the underwriter. Thus, the underwriter gained about $2,700,000 on the transaction. After sales commissions for both regular interests and the residual, the net profit was about $2,000,000. An exact value for the principal's profit is tedious to reconstruct because of the obscure details of trade settlement. These details include delayed delivery, collateral delivery variances, cost of carry, and trading results of bond swaps. The $2,000,000 profit compared very favorably with a 1/16th spread, which equals $93,750 before commissions, on the simple purchase and sale of the collateral as a Fannie Mae pass-through. Origination, underwriting, and sales of the trust series B REMIC interests were all accomplished by the sole underwriter of the deal. Thus the indicated payments for management, underwriting, and sales reflect allocation within the REMIC sponsor's firm. They were standard amounts for syndicated deals of this type.

6. Conclusion

By structuring the claims of an entity used to securitize a pool of loans or to purchase a simple pass-through, an underwriter establishes a passive financial intermediary's capital structure. This paper's purpose is to analyze why an underwriter undertakes this activity. In

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[2] The residual's price for this transaction is known by the author who was involved with the deal.

markets in which arbitrageurs can easily replicate or undo an underwriter's structuring effort, and where expenses are insignificant, the value of a set of derivative claims should equal the value of a simple pass-through instrument based on the same collateral. Since structuring is widespread, apparently arbitrage between pass-throughs and derivatives is somehow defeated by a structuring underwriter. The proposal offered here is that, like a market maker, a structuring underwriter exploits imperfectly elastic demands for derivative claims. The structuring activity is designed to segment customers and create price discrimination by selling different tranches for different prices. Price discrimination creates profits for the underwriter.

Most approaches to financial valuation assume infinitely elastic demand functions and perfect arbitrage. These assumptions are compelling, but they result in transactions without profits for an underwriter. Rationally, underwriters actively seek opportunities in markets where arbitrage is difficult. Mortgage transactions provide an opportunity for profits because different investors can view the same collateral and have different expectations about prepayments and defaults. In addition, for bundles of whole loans, pools can have unique characteristics that make arbitrage extremely difficult. However, the structuring underwriter need not capture all of the available profit. If collateral is sold competitively, some of the gains from structuring flow to the collateral's seller. The bidder with the best unbundling strategy can bid the highest amount. This setting passes some structuring rents to the informed originator.

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Table 1

Principal Distribution: Three Regular Tranches Plus Residual

This table represents the T_p or principal division array for a sequential payment structure based on 30 year mortgage pass-throughs. All monthly collateral principal payments go to tranche A until its full amount of principal is payed in month $r-1$. All principal payments then switch to tranche BB until its full principal amount is payed in month $s-1$, then all principal payments go to tranche C. When tranche C is fully payed in month $t-1$, all remaining principal is payed to the residual interest. When the collateral principal value falls below some nominal amount such as $500,000, the residual is called, the trust is dissolved, and collateral and any cash reserves held by the trust are delivered to the residual owner. Thus, the trust will generally not exist for 360 months. All expenses are paid from interest so the last column is zeroes.

	Tranche				
Month	A	BB	C	Residual	Expenses
1	1	0	0	0	0
2	1	0	0	0	0
⋮	⋮	⋮	⋮	⋮	⋮
r	0	1	0	0	0
⋮	⋮	⋮	⋮	⋮	⋮
s	0	0	1	0	0
⋮	⋮	⋮	⋮	⋮	⋮
t	0	0	0	1	0
⋮	⋮	⋮	⋮	⋮	⋮

Table 2

Interest Distribution: Three Regular Tranches Plus Residual

This table represents the T_I or interest distribution array for a sequential pay structure based upon 30 years mortgage pass-through collateral. Each tranche receives interest until its principal value is payed in full. The amounts A_t, B_t, and C_t are the quantities of principal payed to tranches A, BB and C up to and including time t. Similarly, K_t is the total collateral principal payment made into the REMIC up to and including time t. The residual dividend d_t equals the fraction of interest available after regular tranche interest payments and expenses are made. It equals one minus all the other row entries for regular tranches at time t. The total interest from collateral in time t is i_t, and the trust expense is e. The residual cannot receive a negative dividend so the trust is dissolved when i_t becomes small enough relative to trust expenses to make $(1-(e_t/i_t))$ very small.

	Tranche				
Month	A	BB	C	Residual	Expenses
1	(150/270)	(59/270)	$(59/270)(8.5/9)$	d_1	(e/i_1)
2	$(150-A_1)/(270-K_1)$	$59/(270-K_1)$	$(59/(270-K_1))(8.5/9)$	d_2	(e/i_2)
⋮	⋮	⋮	⋮	⋮	⋮
r	0	$(59-B_{r-1})/(270-K_{r-1})$	$(59/(270-K_{r-1}))(8.5/9)$	d_r	(e/i_r)
⋮	⋮	⋮	⋮	⋮	⋮
s	0	0	$(59-C_{s-1})/(270-K_{s-1})(8.5/9)$	d_s	(e/i_s)
⋮	⋮	⋮	⋮	⋮	⋮
t	0	0	0	$1-(e/i_t)$	(e/i_t)
⋮	⋮	⋮	⋮	⋮	⋮

Table 3

Primary Market Information for Paine Webber 1987 Trust Series B REMIC

The table displays a pricing sheet for a six-tranche REMIC structure with five regular interests based upon new production FNMA 10% pass-throughs. The residual interest's characteristics are not listed in the table because it was privately placed before the five regular interests were offered to investors. Principal amount is the tranche size and coupon denotes the interest passed through to the tranche. LIBOR denotes the London interbank offer rate, which is the index used for tranche B1. The floating rate has a 12% cap and 0% floor. Offer price is the price per $100 principal amount for a tranche's bond. Stated maturity is the tranche maximum life, average life and duration are based upon the prepayment speed used for pricing. Yield is the internal rate of return computed at pricing speed. The gross spread is the difference between the offer price to the public and the price paid to the REMIC. This gross spread is subdivided into the amounts kept by the syndicate manager, underwriters, and sales group. Reallowance refers to bonds allocated for sale to one selling firm but sold by another. The offer date was August 14, 1987, delivery date September 30, 1987, and interest accrual date September 1, 1987. The REMIC pays interest on the first of each month beginning on November 1, 1987.

Tranche characteristics	1987 Trust Series B tranches				
	B1	B2	B3	B4	B5
Principal amount	$69,710,000	$48,375,000	$ 7,875,000	$17,040,000	$ 6,900,000
Coupon	1 Month LIBOR plus 70 basic points	8 percent	8 percent	8 percent	9.95 percent
Offer price	$100	$96 15/32	$89 23/32	$86 2/32	87 21/32
Stated maturity	04/01/12	11/01/08	02/01/10	04/01/12	10/01/17
Average life	5.59 years	3.37 years	7.84 years	10.84 years	18.51 years
Duration	4.25 years	2.82 years	5.72 years	6.95 years	16.80 years
Yield	7.565 percent	9.2 percent	9.96 percent	10.23 percent	10.93 percent
Gross spread	$0.65	$0.65	$0.65	$0.65	$0.65
Manager	$0.175	$0.175	$0.125	$0.10	$0.075
Underwriters	$0.175	$0.175	$0.125	$0.10	$0.075
Selling group	$0.30	$0.30	$0.40	$0.45	$0.50
Reallowance	$0.125	$0.125	$0.25	$0.25	$0.25