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I am submitting a dissertation written by Yatin Narayan Bhagwat entitled "U.S. Treasury Strippable and Non-strippable Bonds: Investigation of Relative Pricing Differences". I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Business Administration.

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U.S. Treasury Strippable and Non-Strippable Bonds: An
Investigation of Relative Pricing Differences

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Degree

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ABSTRACT

The United States Treasury initiated the Separate Trading of Registered Interest Payments and Principal of Securities (STRIPS) program in February 1985. All Treasury notes and bonds with ten year or greater initial maturities are eligible for stripping.

Four major questions are addressed in this dissertation.

1. Does the pricing relationship between STRIPS and the original bonds imply that the STRIPS are priced by a zero tax clientele?
2. Do taxes create differences in values between a bond and a replicating portfolio of STRIPS on an after-tax basis?
3. What is the impact of tax option effect on the relative pricing of a non-strippable bond and a replicating portfolio of STRIPS?
4. Does the eligibility to strip and reconstitute add value to a bond relative to an otherwise identical non-strippable bond?

The dissertation shows that:

1. The term structure estimated by STRIPS is a pre-tax term structure.
2. An investor in most situations for a non-flat term structure may prefer to choose between a bond and a portfolio of STRIPS.
3. The pricing differences between strippable and non-strippable bonds arise due to a tax option effect, an eligibility effect, and the effect of frictions.

4. Price of a non-strippable bond is less than an otherwise identical strippable bond, which implies that stripping and reconstitution is valued by investors.

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Chapter I

Introduction

A. The Issues

The United States Treasury initiated the Separate Trading of Registered Interest Payments and Principal of Securities (STRIPS) program in February 1985. All Treasury notes and bonds with ten year, twenty year and thirty year initial maturities that are issued after February 1985 are eligible for stripping. Bonds issued before February 1985 remain non-strippable. Stripping is the process of separating each coupon payment and principal of the eligible bond and selling them separately as zero coupon bonds. The resulting securities are called STRIPS.

As an illustration, if a 20-year bond with 40 semi-annual coupons is stripped, the underlying bond is resold as 41 zero coupon bonds, each of which trades separately in the secondary market. Each coupon and principal STRIP is assigned a different (CUSIP)¹ identification number. Coupon STRIPS originating from different underlying bonds and maturing on the same date have identical CUSIP numbers. However, coupon STRIPS and principal STRIPS with the same maturity have different CUSIP numbers.

¹CUSIP represents Committee on Uniform Security Identification Procedures

In 1987, the Treasury allowed strips to be rebundled into the original underlying securities. The process of rebundling the stripped coupons and principal is referred to as reconstitution. Reconstitution of a bond can be achieved by combining coupon STRIPS originating from any underlying bond and a principal STRIP originating from the original bond being reconstituted. Strippable bonds are reconstitutable into original bonds.

Approximately 24% of par value of the Treasury issues eligible for stripping has been stripped and 1.54% of par value has been reconstituted as of May 1992².

Four major questions are addressed as a part of the dissertation.

1. Does the pricing relationship between STRIPS and the original bonds imply that STRIPS are priced by a zero tax bracket clientele? What does this imply about clienteles?
2. Do taxes create differences in values between a bond and a replicating portfolio of STRIPS on an after-tax basis? Would taxable investors prefer one or the other? What does this imply about clienteles?
3. What is the impact of the tax option effect (explained in Chapter III) on the relative pricing of a non-strippable bond and a replicating portfolio of STRIPS?
4. Does the eligibility to strip and reconstitute add value to a bond relative to an otherwise identical non-strippable

²Source: U.S Treasury Monthly Statement of Public Debt.

bond?

Following is a more detailed discussion of the issues.

A.1 Term Structure Estimation and Tax Clientele Effects

The term 'clientele effect' implies that agents belonging to different groups behave in qualitatively different manners. These clienteles form because of asymmetry. The asymmetry may be due to differences in individual preferences and beliefs, rational business practices by institutional market participants, state legal constraints, and the provisions in the income tax code.

Individual preferences can create clienteles. For example, anticipation of rising interest rates may induce some investors to commit funds in bonds with relatively shorter maturities. Other investors may anticipate falling interest rates and may desire to invest in bonds with relatively longer maturities. These clienteles are formed on the basis of maturity preferences arising out of investors' beliefs. This is an example of an intra-security clientele, since there is segmentation within a single type of security.

Investors may also choose between different kinds of instruments. An investor's preference for a government bond is an example of inter-security clientele. In this case an investor's risk preference creates a spectrum of risk oriented clienteles.

The nature of their businesses affects the investment

practices of many institutions. For example, the liabilities of banks possess relatively short maturities. Hence, these types of institutions prefer to hold assets with relatively short maturities. Life insurance companies and pension funds, in general, prefer to invest in bonds with longer maturities.

Federal statutes influence the investment behavior of many financial institutions. For example, banks are not permitted to invest in stocks. Another example is the Employee Retirement and Investment Security Act (ERISA) (1974), which provides asset allocation guidelines to pension funds. Defined Benefit Plans are required to maintain minimum funding standards for being guaranteed by the Pension Benefit Guarantee Corporation. A fund manager of a Defined Contribution Plan is required by law to make "prudent" investments precluding investments in extremely risky securities.

Exemption of taxes on income from specific securities also affects investor behavior which can lead to the creation of clienteles. Individuals in high tax brackets may choose to hold municipal bonds which are tax free. Pension funds must meet federal fiduciary standards to qualify for favorable tax treatment and hence do not typically invest in otherwise tax free investments.

Other asymmetries are created by tax statutes that differentiate between capital gains and ordinary income

based on income realization. Although capital gains and ordinary income are taxed at the same rate, asymmetries may be created due to flexibility provided by law in recognition of capital gains. The current U.S. tax code creates asymmetries which induce investors to realize losses and postpone realization of gains.

It is possible that tax clientele effects exist in the U.S. Treasury bond market. These tax clienteles may be formed on the basis of the tax rate of the investors and the after tax cash flows of bonds. Individuals belonging to the same tax clientele value some specific bonds more than others. Investors belonging to high tax brackets prefer to buy low coupon bonds.

Tax clientele effects in the U. S. Treasury bond markets have been studied by Ronn (1987). Using a linear programming (LP) technique, the results support existence of tax clienteles. Litzenberger and Rolfo (1984) (L&R) study the tax effects on triplets of premium and discount Government bonds with the same maturity dates. L&R (1984) conduct parametric and non-parametric tests and do not find any support for tax clienteles in the U. S. Treasury bond market. As these studies indicate, the existence of tax clienteles in the market for U. S. Treasury bonds is an unresolved issue.

Tax clienteles make estimation of a pre-tax term structure ambiguous. For example, a single term structure

is typically estimated for a set of bonds on the assumption that the set of bonds are held long by investors.

Estimation of term structure on the basis of bond prices and before-tax coupons may result in a weighted average of the correct term structure for each tax bracket if some bonds are priced by different tax clientele. It may also erroneously include bonds which are not rationally held by investors in specific tax brackets.

As shown in this dissertation, STRIPS must be priced by a zero-tax term structure. Therefore, STRIPS enable an unambiguous estimation of a pre-tax term structure.

A.2 After-tax Valuation of STRIPS vis-a-vis Underlying Bonds

Another issue is the rational choice between STRIPS and coupon bonds for investors liable to taxes. An investor who decides to invest in U. S. Treasury Bonds may select between a coupon bond or a portfolio of STRIPS replicating the normal bond. The investor's objective is to maximize after expected after-tax cash flows.

The coupon income from a bond is treated as ordinary income and difference between sale price and purchase price of a bond is treated as capital gain (loss). Premium paid at the time of purchase of a premium bond may be amortized on a specified basis. The amount of discount for a discount bond is treated as capital gain payable at maturity or at the time of sale of the bond.

In the case of STRIPS, the difference between imputed

prices (based on yields to maturity on the date of purchase) at the end and beginning of a year is treated as ordinary income. Changes in term structure may affect the magnitudes of capital gains differently for STRIPS and the underlying bonds if the bonds are sold prior to maturity. The asymmetry created by the tax statute is exacerbated by changes in the term structure of interest rates, assuming all other relevant variables remain constant.

A simulation study in this dissertation identifies the asymmetry created by taxes and its influence on investors' asset allocation policy in the Treasury bond market. The results of the simulation study indicate that for upward and downward sloping term structures, the investor will invariably prefer to hold either a bond or portfolio of STRIPS.

A.3 Tax Option Effect and Effect of Frictions

The tax-option effect has been demonstrated by Constantinides and Ingersoll (1984). The tax option effect arises due to the ability of the investors to optimize post-tax cash inflows due to the option to realize capital losses and to postpone capital gains.

Consider a portfolio of STRIPS that replicates the contractual pre-tax cash flows of a bond. The after-tax cash flows of a portfolio of STRIPS can be optimized separately by the exercise of the tax-timing options embedded in each STRIP. As Merton (1973) has shown, a

portfolio of options should be at least as valuable as a single option on the same asset. Therefore, if tax options have value, the replicating portfolio should be worth more than the bond.

A.4 Eligibility to Strip and Reconstitute

The timing of the laws concerning stripping and reconstitution provides a laboratory to investigate separately the effects of stripping and reconstitution on prices of bonds. Do the options to bundle and rebundle relatively long term U. S. Treasury bonds *per se* create any price differences? If yes, what are the magnitudes of these price differences? These are some of the unanswered questions that are addressed in this dissertation.

Market frictions exist in the form of bid-ask spread and transactions costs. These frictions should reduce the ability of investors to arbitrage between bonds and STRIPS. The effect of frictions is incorporated in the empirical studies conducted in this dissertation.

The findings will provide empirical evidence to formulate stripping and reconstitution policies for the long term and short term Treasury issues. The results may provide motivation to other agencies such as state, city and county administrations, and corporations to consider stripping and reconstitution of their debt issues.

B. Methodology and Results

The methodology is explained in detail in Chapter V and

Chapter VI. Following is a brief description.

The term structure of interest rates is estimated from U. S. Treasury STRIP prices. The estimated term structure is used to value the strippable bonds (SR), and the non-strippable (NS) bonds³. This is equivalent to forming a replicating portfolio of STRIPS.

Three methods are used. In the first, average values of bid-ask quotes are used and transactions costs are not included. In the last two, the bid and ask prices, and transactions costs are used appropriately for the stripping and reconstitution methods. As an illustration, stripping involves the addition of brokerage charges to the ask price of the original bond and deduction of brokerage charges from the bid price of STRIPS.

The values of the bonds estimated on the basis of STRIP term structure are then compared with the market price of the bond to determine profit opportunities underlying each method.

The dissertation shows that:

(1) The term structure estimated by STRIPS is a pre-tax term structure.

(2) An investor in most situations when the term structure is upward or downward sloping would choose between a bond and a portfolio of STRIPS.

³The prices of a strippable bond and a non-strippable bond are denoted as P_{SR} and P_{NS} respectively.

(3) The pricing differences arise due to a tax option effect, an eligibility effect, and the effect of frictions.

(4) $P_{NS} < P_{SR}$, which implies that stripping and reconstitution eligibility is valued by investors.

Chapter II

Institutional Features of STRIPS

The trading of U. S. Treasury STRIPS is a recent phenomenon. Section A of this chapter describes institutional features of the U. S. Treasury STRIPS. In Section B the prior research related to STRIPS is presented.

A. STRIP Bonds

All notes and bonds with ten or more years of original maturity issued by the U. S. Treasury since February 1985 are maintained in the Federal Reserve's book-entry system in a manner that permits separate trading and ownership of interest and principal components.⁴

For record keeping and transfer purposes, each marketable Treasury security has a unique identification (CUSIP) number. STRIPS derived from coupons with the same maturity date are assigned the same CUSIP number irrespective of their source. However, STRIPS derived from a principal payment are assigned different CUSIP numbers than STRIPS derived from a coupon payment with the same maturity.

In order for a book-entry security to be separated into its component parts, the par value must be an amount which,

⁴ "STRIPS - an exciting new market for zero coupons" by P.S Nagan and K. A. Kaufman, ABA Bank Journal, March 1985, pp.12-13.

based on the stated coupon rate, will produce a semi-annual interest payment of \$1,000, or a multiple of \$1,000. For example, a security with a 12% interest requires a minimum amount of \$50,000 (at par) of the original bond to produce interest components in even \$1000 amounts. A holder of \$50,000 par value of this strippable Treasury securities could convert them at a Federal Reserve Bank into separate STRIPS, with \$3,000 (or any multiple of \$1000) face value at maturity.

After an auction, financial institutions that have been awarded securities may request that, as of the issue date, some or all of their allotment be held as STRIPS. In addition, an institution may convert its holdings to STRIPS subsequent to the issue date.

In aggregate, STRIPS are traded in a range of 120 maturities, with separate instruments maturing every three months, covering a period from one day to thirty years. The face value of all STRIPS are in multiples of \$1000. Although STRIPS can only be created through from the Federal Reserve by such financial institutions as banks, savings banks, credit unions, savings and loan associations and bond dealers, other investors may purchase them in a secondary market. Investors receive only a safekeeping receipt issued by the financial institution from which they were purchased.

The bid and ask prices of U.S. Treasury Bonds and STRIPS in the secondary market are published in the Wall

Street Journal for each trading day. The publishers obtain the market data from market agencies. This study includes data obtained from Bear, Sterns and Company via Street Software Technology Inc. The fractional part of a bond or a STRIP is quoted as parts per thirty-two ($1/32$).

Reconstitution is "reverse-stripping". Reconstitution is a process whereby investors assemble coupon STRIPS and the principal STRIP into a bond. The maturity dates of each coupon STRIP coincides with the coupon payment of the reconstituted bond. Under present market conditions, only the principal STRIP from the original bond can be used in reconstitution because only one strippable bond matures on any day. The availability of 20-year and 30-year strippable bonds and 10-year notes with the same date of maturity will create substitutable principal STRIPS.

B. Prior Research related to STRIPS

Stripping of U.S. Treasury bonds with maturities of ten years and exceeding ten years was initiated by the U. S. Treasury in 1985 and reconstitution of strippable securities was permitted in 1987. Data on the daily prices have been available since 1989 in the Wall Street Journal. Thus, stripping is a recent phenomenon and has lately attracted attention of researchers in finance. Hence, prior research related to STRIPS is scant relative to research done on fixed income securities.

Livingston and Gregory (henceforth L&G) (1991) have

studied pricing of U. S. Treasury STRIPS. They suggest that the option to strip and reconstitute should be valued by the market. They examine the relationship between the value of strips and underlying bonds by considering two cases: (1) The underlying bonds can be stripped but the STRIPS cannot be rebundled (termed as reconstitution in this dissertation and other researchers). This case is applicable to strippable bonds traded and issued from 1985 to 1987. (2) The underlying bonds can be stripped and the STRIPS can be rebundled.

They make the following propositions with respect to reconstitutable and non-reconstitutable bonds:

1. The market value of a strippable bond must equal the market value of the reconstitutable strips.
2. The price of a bond which can be stripped into rebundlable strips is at least as great as the price of a bond which can be stripped into non-reconstitutable strips.

Hence, strippable bonds should bear a premium over non-reconstitutable bonds and non-reconstitutable bonds should bear a premium over non-strippable bonds, *ceteris parabus*.

L&G (1991) compare the value of stripped securities versus the value of the underlying bond for four tax treatments by simulation: capital gains (losses) only, ordinary income tax on gains and losses without capital gains (losses), linear amortization of the premium paid at the time of purchase of a bond, and the constant yield

method whereby income is taxed at ordinary income tax rate. They ignore transactions costs. In general, they conclude that the total value of the STRIPS does not equal the value of the underlying bond.

L&G (1991) also compare the prices of bonds and replicated bonds for upward and downward sloping term structures. They find that profitability of stripping and reconstitution depends on bond maturity, the term structure of interest rates and tax rates.

L&G (1991) show in a simulation study that for rising term structures, the relative value of strips increases with maturity. In a two-period framework, they compare the value of a portfolio of STRIPS and the par value of the underlying bond at a 50% tax rate. The total value of the portfolio of STRIPS is greater than the par value of the bond. The rising term structure causes the portfolio of STRIPS to have higher total after-tax and higher after tax cash flows in time 1 due to higher amortization available for the two-year STRIP.

L&G (1991) also show that the relative value of STRIPS increases as tax rates increase for upward sloping term structures. As the tax rate increases, the after tax cash flows from the STRIPS decrease. The amortization is higher in the case of the coupon received in the second time period. The higher amortization results in a larger tax shield resulting in a higher after-tax cash flow.

The cash flows for a STRIP derived from a principal payment are identical to the cash flows of a STRIP derived from a coupon payment with identical maturity. However, Daves and Ehrhardt (henceforth D&E) (1992) discover a significant pricing difference between the two instruments. Principal STRIPS are consistently priced higher than coupon STRIPS, *ceteris paribus*. They suggest this may be due to different degrees of liquidity and different reconstitution features. Citing evidence from equity markets and markets for Treasury bills, D&E (1992) also suggest that liquidity differences may cause price differences.

Reconstitution of a bond is achieved by the assembling of coupon STRIPS with maturities coinciding with the coupon payment of the bond, and the principal STRIP. Only one principal STRIP is currently available for reconstitution of any strippable bond. Principal STRIPS are not substitutes.

As the U.S. Treasury issues additional strippable bonds each quarter, the number of substitutable coupon STRIPS for a given date of maturity for which STRIPS are currently available increases. Additional supply of principal STRIPS is created for new maturity dates. Consider the hypothetical issuance of \$1,000,000 worth of 30-year bonds in May of 1991; each bond has a face value of \$1,000 and a coupon rate of 10%, payable semi-annually. This issue creates the potential for 1,000 principal STRIPS maturing in May 2021, each with a face value of \$1,000. It also creates

the potential for 50 coupon STRIPS maturing in May 2021.

Suppose that \$1,000,000 worth of 30-year bonds are issued in November 1991. The potential total volume in for coupon STRIPS maturing in May 2021 doubles but the volume for principal STRIPS maturing in May 2021 remains unchanged.

D&E (1992) define the liquidity of STRIPS in three ways: size of the market measured by the total number of coupon and principal STRIPS in existence at a given moment, total potential volume of STRIPS, and bid ask spread.

An Ordinary Least Squares Regression done on the log-linearized form of the equation:

$$P_{it} = P_{0t} L_{it} R_{it}$$

where P_{0t} denotes the price of a generic coupon instrument with no liquidity and no reconstitution effect, L_{it} denotes the liquidity effect, and R_{it} denotes the reconstitution effect.

The OLS regression is done for the entire sample period spread between August 25, 1989 to May 28, 1991. Eight samples of trading day data are collected; four samples are prior to June 30 1990 and four samples are after June 30 1990. Although the strippable bonds are issued on the 15th of the auction month, the 25th day of each auction month has been chosen to allow reasonable time for the bonds to be traded in the form of STRIPS. The regression is highly significant for the full sample with an F statistic of 33.18, and the adjusted R^2 equal to 0.48. The results

indicate high explanatory power of the model and are stronger in comparison to Silber's (1991) study to explain liquidity effects in restricted stock offering which has an R^2 equal to 0.29.

The intercept is negative and significant for the entire sample which implies that a coupon STRIP is more valuable than a principal STRIP. The estimated coefficient for the dummy variable for whether a principal STRIP is permitted to be used in reconstitution, is positive and significant for each sub-period; it is positive but not significant for the entire sample.

The conclusion is that reconstitution is valued by the market. The number of issues for which a security may be used in reconstitution is not significantly different from zero.

The coefficients for the incremental volume created by stripping are significant and possesses the predicted sign, indicating that increases in this dimension of liquidity result in increase in value. The coefficients for another dimension of liquidity, the total potential volume, are not significant. The coefficients on the bid-ask spreads are significant with the wrong sign.

Chapter III

Literature Survey

This dissertation examines the relative pricing of U.S. Treasury bonds and STRIPS. The pricing differences between strippable and non-strippable bonds may arise due to tax effects, resulting in the formation of tax clienteles and/or the creation of tax-options. The pricing differences may also be attributed to the eligibility of stripping and reconstitution possessed by the strippable bonds, known as the "reconstitution" effect. This chapter presents a review of related research.

We first introduce the general literature related to formation of clienteles and then discuss the literature with specific references to default-free fixed income securities issued by governments. The studies related to clientele effects have been conducted over more than three decades. In contrast, stripping and reconstitution of Treasury securities is a recent phenomenon. Hence, a major portion of the literature review is related to a discussion of various types of clienteles.

There are many types of clientele effects. Inter-security clienteles are formed, for example, when investors prefer bonds over stocks. These clienteles may be formed due to tax considerations and risk preferences of individual

investors. A broad classification of clientele types is done in Section A.

Corporations may prefer to issue debt on account of deductibility of interest against the income allowed by the tax statute. Section B and Section C examine simplified environments with corporate taxes, and both personal and corporate taxes, respectively. These scenarios are included in the literature review to explain the evolution of clientele formation as the complexity of tax laws increases.

Dividend clienteles, explained in Section D, are formed by the preference of individuals for current income. Dividend clienteles may be caused by taxes because capital gains are not taxed until realization. Since taxation appears to be one of the motivating factors, the inclusion of research related to the formation of dividend clienteles seems logical. Similarly, debt clienteles may be caused by taxes, as individuals in high tax brackets prefer to borrow on personal account. Debt clienteles are discussed in Section E.

The literature review then shifts the focus to default-free fixed income government securities. The theoretical aspects of the literature are reviewed in Section F; the empirical evidence supporting existence of tax clienteles in the British 'gilts' market in Section G.

The tax option effect is discussed in Section H and Section I, because the existence of the tax option effect

implies the existence of tax clienteles. The empirical evidence related to tax clientele effects in the U. S. Treasury bond market is summarized in Section J. The empirical evidence on relevance of taxes in term structure estimation is provided in Section K.

A. Classification of Clientele Effects

A broad classification of clienteles is made in this section. In subsequent sections, each type of clientele is discussed in greater detail with an emphasis on tax related formation of clienteles.

A.1 Broad Classification

Clienteles that are formed on the basis of risk preferences may be of either an "inter-security class" or an "intra-security class" type. An investor's preference for U.S. Treasury bonds instead of corporate bonds is an example of the former type of clientele.

An investor's preference for a specific bond within the entire set of corporate bonds is an example of an "intra-security class" clientele. Clienteles formed on the basis of maturity preferences are generally of the "intra-security class" type.

Risk preference and maturity preference of investors result from the individual utility functions of investors. They may exist in a world with or without taxes. In a world with taxes, asymmetries are created by the differential taxation of ordinary income and capital gains, which results

in clienteles in the equity and bond markets.

Taxable and tax-exempt types of fixed income securities create inter-security "tax clienteles", as shown by Miller (1977). Different tax rates on ordinary income and capital gains and opportunities to defer realization of capital gains create "tax clienteles" in the bond and equity markets. Farrar and Selwyn (henceforth F&S) (1967) and Brennan (1970) have studied tax clienteles in the equity markets and their effects on capital structure. Section C of this chapter discusses their study in greater detail.

Opportunities to defer realization of capital gains, preference for liquidity, and the need for current consumption create "dividend clienteles". Lewellen et. al. (1978) have examined the dividend clientele phenomenon for investors belonging to different demographic groups and different tax rates. They support "life cycle" clientele effects and suggest that corporations do not follow a "tax tailored policy".

B. Corporate Taxes Only and Clienteles

This section is directly related to the formation of inter-security clienteles. It is assumed that corporations alone are taxed on their income and individuals are not liable to pay taxes. Thus, corporate debt is subsidised and corporations prefer debt over equity, if the associated bankruptcy is costless. This section of the literature review has been included as it provides a gradual transition

to a more complicated tax environment, enabling a more lucid understanding of the phenomenon of clientele formation.

B. 1 Modigliani and Miller (1958)

Many theories in finance have assumed the absence of taxes. Modigliani and Miller (1958) (henceforth M&M) proposed that in a world with no taxes, the market value of any firm is independent of its capital structure.

The intuition behind the M&M (1958) proposition is that two firms, which are identical in terms of the assets that they hold, should conform to the law of one price. The fundamental identity between two firms is unaffected by the way the securities financing the assets are packaged in perfect capital markets.

Divestment of equity from a levered firm, accompanied by borrowing on personal account and investment of the joint proceeds in a non-levered firm does not offer any profit opportunities. "Homemade leverage" is created in such a situation and the level of risk remains unchanged. Hence, the market values of the levered and unlevered firms, which have same perpetual cash flows, are identical.

M&M (1963) further discuss the effects of the method of corporate taxation on the valuation of firms. The distribution of returns after taxes of two firms with different degrees of leverage are not identical. The arbitrage process cannot force the firms' values to be proportional to their after tax returns. This means that

tax advantages of debt financing do exist.

B. 2 Barnea Haugen and Senbet (1985)

Barnea, Haugen and Senbet (1985) (henceforth BH&S) extend the M&M (1958, 1963) argument to show that corporate taxes may affect the capital structure of firms. BH&S (1985) state that the power of the M&M theorem is in dispelling the traditional illusion that in an environment where packaging financial claims is costless, identical products sold in different packages can be priced differentially.

C. Personal Taxes, Corporate Taxes and Clienteles

Taxes are levied on income to holders of financial instruments. Individual investors and corporations are taxed differently. An important step towards recognizing the effects of personal tax structure on corporate financial policy was taken by F&S (1967), who consider different sets of corporate and personal financial strategies.

C. 1 Farrar and Selwyn (1967)

They first consider a single investor subject to specific tax rates. The investor owns a share in a corporation and has a desired total (corporate and personal) debt per share. F&S (1967) evaluate alternative corporate financial policies in terms of the after tax income received by the investor.

If the criterion of maximizing the net income per share received by investors is accepted, F&S (1967) show that it

will be optimal for a firm to use any residual earnings for share repurchase than for dividend payments, so long as the investor's marginal tax rate on dividends exceeds his marginal tax rate on capital gains⁵.

Corporate debt is advantageous for all investors in dividend-paying corporations, although the value of corporate debt to different investors depends directly upon the marginal tax rate.

For a non-dividend paying corporation, different financial policies may be optimal for different investor groups, depending on their marginal tax rates. High marginal tax rate investors prefer the corporation to pursue a zero debt strategy to maximize the amount of debt the investors may issue on their personal account, consistent with their desired total debt per share. Low marginal tax rate investors, in contrast, would prefer the corporation to pursue a maximum debt strategy.

This possibility of conflict between different groups of investors within the same corporation is resolved by F&S (1967). They state that investors in a single corporation may be relatively homogenous with respect to marginal tax rates, if different tax clienteles of investors are attracted by distinct characteristics of operating income streams.

Thus, F&S (1967) assume that tax clienteles exist and

⁵ This assumes that such repurchases are allowed by the IRS.

that income and wealth distribution policies differ with respect to the marginal tax rate of the investors. F&S (1967) also assume that the investor's objective is to maximize after-tax income. The validity of this objective relies on an assumption that the investor is locked into his existing holdings.

C. 2 Brennan (1970)

Brennan (1970) modifies the basic Capital Asset Pricing Model of Sharpe (1964), Mossin (1966) and Lintner (1965) to accomodate the imperfections created by taxes. The effects of taxes on income from dividends and capital gains are incorporated in the model. Investor utility functions are defined on the mean and variance of after tax returns. The return on each security has two components, a terminal dividend, which is known, and an uncertain terminal price.

Each investor enters the market with an initial endowment and by trading with other investors achieves an equilibrium asset position. Each investor has marginal tax rates on dividend and capital gains income which are constant and independent of his portfolio choice. Under uncertainty and when different investors have different marginal tax rates, Brennan (1970) asserts that the expected or required risk premium on a security is a function of its covariance with the return on market portfolio, and its dividend yield.

The intuitive interpretation of Brennan's result is

that for a given level of risk, the higher is a security's prospective dividend yield, the higher is the total return required by the investor. This is due to the higher rate of tax levied on dividends than on capital gains.

Brennan (1970) shows that individuals in different tax brackets hold portfolios with different dividend yields, and that the CAPM holds on an after tax basis, with a single weighted average tax rate applying to all securities. In a world with corporate and personal taxes, dividend clienteles form.

C. 3 Long (1977)

Long (1977) shows that individuals in different tax brackets hold the same portfolios only if there exists an exact cross-sectional linear relationship between expected return and dividend yield.

F&S (1967), Brennan (1970), and Long (1977) all assume that there exist investors with individual tax rates different from zero.

D. Capital Gains, Ordinary Income, and Dividend Clienteles

Dividend clienteles are intra-security clienteles and are formed when investors in high tax bracket prefer stocks with capital gains over stocks with current income received in cash. Investors in low brackets prefer the opposite.

D. 1 Miller and Modigliani (1961)

The dividend clientele effect was originally suggested by M&M (1961). They state: "The exact correspondence of the

frequency distribution of corporate payout ratios with the distribution of investor preferences for payout ratios leads to a situation whose implications are in no fundamental respect different from the perfect market case".

M&M (1961) proposed the irrelevance of dividend policy by matching the investor's needs with the dividend payout of firms. Thus, they indirectly suggested the formation of dividend clienteles.

D. 2 Miller and Scholes (1978)

Miller and Scholes (1978) argue that stockholders can completely protect dividends from taxes by borrowing and investing in tax sheltered investments such as pensions. They present sufficient conditions for taxable investors to be indifferent to dividends despite tax differentials in favor of capital gains. They make the following assumptions.

1. Accumulators (risk takers) and widows and orphans (non risk takers) are two types of individual investors.
2. The tax rates on ordinary income and capital gains are different.
3. A tax haven exists, perhaps in the form of life insurance and pension funds.

They propose that given the above assumptions and the firm's investment decision, the firm's dividend decision has no effect on the wealth or economic welfare of its

shareholders. Investors value dividends using a marginal tax rate of zero. Miller and Scholes (1978) argue against formation of tax-induced dividend clienteles because of availability of tax exempt investments.

Empirical evidence on the above competing theories is presented below. In reality, the tax statute sets a limit on the amount of tax shelter. In addition, the evidence has been related to equity instruments and not bonds.

D. 3 Elton and Gruber (1970)

Elton and Gruber (E&G) (1970) attempt to measure clientele effects by observing the average price decline when a stock goes ex-dividend. They demonstrate that the ratio of the decline in stock price to the dividend paid becomes a means of estimating the marginal tax rate of the average investor.

E&G (1970) assume that the capital gains tax rate is half the ordinary income tax rate and that no arbitrage profits can be earned. They find that the lower a firm's dividend yield, the smaller the percentage of the investor's return received in the form of dividends. Based on this finding, E&G (1970) conclude that investors who hold stocks which have high dividend yields should be in low tax brackets relative to shareholders who hold stocks with low dividend yield.

D. 4 Kalay (1982)

Kalay (1982), has argued that arbitrage may be carried

out by traders who short sell a stock. These traders then would have to pay ordinary income taxes on short term gains. He shows that to prevent arbitrage profits the price decline must equal the amount of dividend payout. This is completely different from the conclusion reached by Elton and Gruber (1970).

Eades, Hess and Kim (EH&S) (1984) replicate the work done by E&G (1970) for the time interval May 1, 1975 to December 31, 1980 and suggest that, given lower transactions costs, it was easier for short term traders to arbitrage, as argued by Kalay (1982). Hence, the empirical evidence by EH&S (1984) does not support existence of any dividend clientele effects.

E. Corporate Debt, Personal Debt and Debt Clienteles

Debt clienteles are a type of inter-security clientele, with the tax status of individuals determining either the investment in equity of a firm or investment in the debt of a levered firm. The tax statute determines the investors' policies. Hence, this section has been introduced in the literature review.

According to the debt clientele hypothesis, personal debt is preferred to corporate debt by individuals where marginal personal tax rates are higher than the corporate tax rate, since they are able to deduct interest payments at a higher rate.

Low tax bracket investors prefer to invest in firms

with high leverage. Kim, Lewellen and McConnell (1979) tested for leverage-related clientele effects by studying 1140 companies whose stock was owned by at least three investors from among a group of 887. The results do not support the debt clientele hypothesis.

E. 1 Harris, Roenfeldt and Cooley (1983)

Harris, Roenfeldt and Cooley (1983) estimated investor-implied tax rates by using the procedure suggested by Elton and Gruber (1970). They find that implied tax rates are strongly negatively correlated with corporate financial leverage. Thus, investors in high tax brackets prefer to invest in the stock of firms with low leverage and prefer to borrow on personal account. Their finding supports the debt clientele hypothesis.

E. 2 Miller (1977)

Miller (1977) suggests that in the absence of taxes on equity income, the equilibrium marginal personal tax rate on bond income, known as the "effective" tax rate, is equal to the marginal corporate tax rate.

The Miller (1977) world recognizes the existence of corporate and personal income taxes on bonds. Miller (1977) believes that these taxes create clienteles, but each clientele is as good as any other with respect to its effect on firm value. Even though interest payments on borrowed funds are deductible from the income of a levered corporation, the prices of taxable corporate bonds gross up

the tax advantage of debt financing. The apparent gain from leverage disappears and hence each clientele is as good as the other.

These interest payments, according to Miller (1977), are already grossed up, since the recipients of interest income are subject to income tax. The advantage of tax deductibility at the borrower's end serves to offset the disadvantages of tax liability at the lender's end. Thus, market equilibrium is restored due to changes in the yields on stocks and bonds and through changes in ownership patterns. This results in an equilibrium level of aggregate debt and an aggregate debt equity ratio.

The result is that the value of a firm is independent of its capital structure. The existence of taxes and the tax provisions related to interest payments do create clienteles, but the after tax returns for each clientele are equal.

F. Formation of Clienteles: A Theoretical Framework

F. 1 Dybvig and Ross (1986)

Studies on tax clientele effects usually assume that each individual's income is taxed at a known effective rate. Based on this assumption, Dybvig and Ross (D&R) (1986) interpret the meaning of tax clienteles in quantities, as well as prices and quantities.

They assume three kinds of assets: a riskless coupon bond, a discount bond and a municipal bond. The coupon bond

is taxed at the ordinary income tax rate, the discount bond is taxed at capital gains tax rate, and the municipal bond is not taxed.

Assuming that investors have Von Neumann-Morgenstern utility functions, D&R (1986) describe cases when clientele effects exist in quantities only. They also define clienteles in prices and quantities both. Given the pre-tax cash flow and taxable income, they obtain a relationship between the price of an asset and the value of one more unit of the asset measured in terms of after tax cash flow.

F.1.1 No clientele effects (marginalist case)

If no clientele effects exist then the price of an asset and the after-tax cash flow of any other asset are equal. Thus, each asset has the same return because all agents have the same marginal tax rate. Individuals are indifferent between holding specific kinds of assets.

F.1.2 Clientele effect in quantities but not in prices

In this case, not all agents face equality between the price of an asset and the after tax cash flows from any other asset. The inequality results in interior solutions for some assets. This situation is akin to the Miller (1977) world.

In this situation the price of an asset may be equal to the after tax net present value of any other asset for individuals whose particular tax bracket equals the average market tax bracket (known as 'effective tax' rate in

Miller's world). Thus, some investors receive equal after tax returns from all assets and may hold positive amounts of each asset.

Assume r_m and r_c as the coupon rate on the municipal and corporate bonds respectively and τ_c as the tax rate on interest income from corporate bonds. In the Miller (1977) world equilibrium is reached when,

$$r_m = r_c (1 - \tau_c).$$

The after tax return at the *effective* tax rate on corporate bonds is equal to the return on municipals. The supply and demand quantities for corporate bonds are in equilibrium.

F.1.3 Clientele effect in quantities and prices

In this case, the price of an asset and the after tax cash flow of any other asset are unequal for every agent. No agent is marginal on all assets. High income investors prefer municipal bonds, low income investors prefer coupon bonds. This is the situation described by F&S (1967) and Brennan (1970). The tax clientele effects investigated by Schaefer (1982) and Ronn (1987), discussed in Section F.2 and Section J.3 respectively, are in quantities and prices both. Schaefer (1982) states that the absence of an *effective* tax (in Miller's framework) bracket implies the existence of a clientele effect.

F.2 Schaefer (1982)

F.2.1 Frictions

Schaefer (1982) has analyzed theoretically the equilibrium in fixed income security markets with the existence of taxes. Three conditions are necessary for equilibrium.

1. There are no frictions other than taxes.
2. There are investors in at least two tax brackets.
3. There is spanning for some subset of securities.

When a security is spanned, it implies that the cash flow from the security can be replicated by portfolios of existing securities. Spanning implies completeness of market. Any new security that cannot be created from existing securities will result in a non-unique price for the security under consideration. Spanning ensures a unique price for each security.

F.2.2 Frictions: Asymmetric Taxation

Arbitrage opportunities would be absent for two investors, one of them being tax exempt, only if (1) the two bonds had the same coupon rate or (2) the ratio $(1-t_c)/(1-t_g)$, where t_c is the tax rate on ordinary income and t_g is the tax rate on capital gains in a market with two riskless bonds, is the same for both investors.

If one of the investors is tax exempt, this implies

that tax arbitrage opportunities will be absent only if income and capital gains are taxed at the same rate. Any two investors face the same price in a security market. For a no arbitrage situation, the ratio of prices of two securities must be equal to the ratio of after tax cash flows received by each individual.

In the example provided by Schaefer (1982), taxation produces a difference in the ratio of after-tax payments, making it impossible for two investors in different tax brackets to agree on the relative values of the bonds. The distinction between "income" and "capital gains" is crucial in most practical cases. If taxes are not neutral and if there are no frictions of any form, then arbitrage may be possible so long as investors have different tax positions.

F.2.3 Frictions: Asymmetric Holding Positions

Schaefer (1982) then examines another case with frictions. A form of friction suggested is asymmetry between long and short positions. A ban on short sales is an extreme asymmetry. Long and short positions are asymmetric if, for example, the after tax cash flow in period j from one unit of bond i held long is a_{ij} and the after tax cash flow from one unit held short is $-q_{ij}$, where, generally, $q_{ij} > a_{ij}$. The asymmetry in cash flow might result from differences in the tax treatment of long and short positions, from transaction costs, or institutional features associated with short sales.

If the asymmetries are sufficiently pronounced to eliminate arbitrage opportunities, the only motivation for individuals to take short positions is to construct a profile of portfolio cashflows which is not feasible with entirely nonnegative portfolio weights. However, when there is a large number of securities, and asymmetries preclude arbitrage opportunities, individuals will have little motivation to take short positions.

Consequently, prices may be equal to those which would result if short sales were explicitly disallowed.

F.2.4 Frictions: Asymmetric Taxation and Asymmetric Positions

Schaefer (1982) also explores pricing with short sales restrictions in a three-asset, two-date world for seven cases and concludes that prices reach an equilibrium with frictions.

In a frictionless world, unless taxes are neutral, equilibrium requires that each individual has the same marginal tax rate. This is identical to the single tax rate in the mean variance model of Brennan (1970).

With restrictions on short sales, the implicit tax rate has been shown to be independent of the after tax payments to an investor and hence is not a weighted average or any other function of the individual tax rates. With frictions the implicit tax rate suggested by Brennan (1970) is only bounded and not determined by the tax rates of individuals.

Schaefer (1982) has also suggested that frictions lead to an equilibrium with clientele effects. Miller's model (1977) belongs to this category insofar as it implies that municipal bonds are held by investors with tax rates equal to or higher than the corporate tax rate, and that taxable bonds are held only by investors with tax rates equal or lower than the corporate rate.

The friction which brings about this equilibrium is an assumed inability of investors with tax rates different from corporate tax rate to arbitrage between taxable bonds on one hand and municipal bonds on the other.

G. Empirical Evidence on Existence of Tax Clienteles in 'British Gilts' Market

G. 1 Schaefer (1982) Revisited

Schaefer (1982) presents empirical evidence to suggest that tax induced clienteles exist in the market for British government securities (gilts). A bond is *not* rationally held by investors in a certain tax bracket if a portfolio of bonds dominates that bond. A portfolio of bonds dominates a bond held by an investor in a particular tax bracket if:

- (i) the cash flows from the former are at least as great, and
- (ii) the price is lower.

A clientele effect exists if a security is rationally held by investors in only particular tax brackets. The set of tax brackets for which the security is rationally held is

called its tax clientele. A clientele effect is said to exist if there are investors in a tax bracket who hold a bond and that the same bond is dominated for other tax brackets.

Schaefer (1982) believes that the market is 'incomplete' with respect to the maturity dimension, and that conditions of no arbitrage alone are insufficient to assign a unique value to a bond. Under a minimal set of assumptions, an upper bound on the value of the bond is calculated. Tax clienteles are said to exist for a bond when the upper bound is less than the market price of the bond. The structure of security prices is used in determining the existence of tax clientele effects.

G. 2 Methodology employed by Schaefer (1982)

Two complementary methods are developed to compute an upper bound. The first method assumes that the discount function is weakly monotonic and that short sales are restricted. The second method assumes the discount function is smooth and is represented by a linear combination of smooth component functions.

Dominating portfolios are computed using linear programming (L.P.). The basic model for computing least cost dominating portfolios is given by Hodges and Schaefer (1977). A least cost portfolio is obtained such that the after tax cash flows from the portfolio are at least as great as the after tax cash flow from a bond. The net

present value (**NPV**) of a bond h is the difference between the price of the least cost portfolio and the price of bond h . **NPV** can never be positive because bond h is itself included in the portfolio. A bond with a negative **NPV** provides arbitrage profits. Restrictions on short sales preclude an investor from earning arbitrage profits. The definition of **NPV** here is equivalent to an *opportunity cost*.

G. 3 Major Assumptions made by Schaefer

1. Short sale positions are not allowed and hence may not eliminate tax arbitrage opportunities.
2. The market is incomplete with respect to maturity dimension because cash flows from a given bond may not be "replicated" by cash flows from a portfolio of other bonds.
3. Transactions costs are ignored.
4. Callable bonds are excluded from the sample.

G. 4 Data employed by Schaefer (1982)

The data for this study consist of month end prices of all gilts from January 1955 to 1978. The issues addressed by Schaefer are:

1. Do clientele effects exist in the gilt market?
2. Is there a relationship between the tax clientele for a bond and the fraction of a total return which is derived in the form of capital gains?
3. Are tax clienteles stable for particular bonds

over time?

G. 5 Results

Out of the thirty six bonds included in the sample, two are dominated for all tax brackets. With these exceptions, every other bond is undominated for individuals in at least one tax bracket ranging from 10% to 100%. It is also found that for each tax bracket there exists at least one undominated bond. If all the bonds in a tax bracket are undominated, it would be termed as the "effective" tax rate as stated by Miller (1977).

A clientele effect is not ruled out by an effective tax rate because there may be investors with tax rates different from the effective tax rate who still regard some bonds as dominated. In the spirit of Miller (1977), the effective tax rate is the marginal tax rate of all investors. In this situation a clientele effect cannot exist because no investor's choice of securities is actually influenced by his tax rate. Absence of an effective tax rate is a sufficient, though not a necessary, condition for the existence of a clientele effect.

For each month over the ten-year period from January 1968 to December 1977 the number of dominated bonds for each tax bracket is noted. The minimum number of dominated bonds ranges from 1 to 5 for all the observations. As the minimum number of dominated bonds taken over tax brackets, is never zero, an effective tax rate does not exist. The results are

inconsistent with the type of equilibrium hypothesized by Miller (1977).

Schaefer (1982) provides conclusive evidence that clientele effects exist in the British Consols market, with high coupon bonds being held primarily by investors with low tax rates and vice versa for investors with high tax rates.

G.6 Tax clienteles and Characteristics of Bonds

Schaefer (1982) also explained the relationship between tax clienteles by ranking the bonds on the basis of ratio of capital gains to current yield. The rationale behind using this measure is that the capital gain to income ratio decreases with maturity for a given coupon level.

Bonds with the lowest capital gain to current yield ratio have high coupons and low tax bracket clienteles, bonds with the highest rankings have low coupons and high tax bracket clienteles. It appears that there is indeed a strong and persistent relationship between a bond's tax clientele and the fraction of its return which comes in the form of capital gain.

The tax clientele for a bond depends on :

- (i) coupon level, maturity and number of shares issued of the bond, and
- (ii) the distribution of investor wealth over tax brackets.

Assuming that these factors may be constant over time, a simple test conducted by Schaefer (1982) shows that the

clientele effects are persistent, not transitory, phenomena.

H. Capital Gains, Ordinary Income and the Tax Option Effect

This section introduces the concept of a tax option effect. Section I provides a discussion of simulation studies conducted to measure the tax option effect. The influence of taxes on the relative pricing of government securities has been studied, for example by L&R (1984b) in the context of a static equilibrium in which the prices of bonds reflect the tax status of marginal purchasers who hold bonds to maturity.

C&I (1984) recognize the existence of differential tax treatments for ordinary income and capital gains. An optimal trading policy may be the postponement of realization of capital gains and the immediate realization of capital losses; they define the difference in value between a buy-and-hold strategy and the optimal trading strategy as the tax option effect. They assume existence of a single effective tax rate. By this it is implied that there is one clientele for which every bond remains undominated.

I. Tax Option Effect and Simulation Studies

In estimating the yield curve for zero coupon bonds, two problems have been enunciated by C&I (1984), tax clienteles and the buy-and-hold assumption. For a given investor, some bonds of particular maturities and coupon rates may be dominated by combinations of other bonds. In

that case the tax clienteles defined by Schaefer (1982) arise. This problem is ignored by C&I (1984).

I. 1 Constantinides and Ingersoll (1984)

Instead, they focus their attention on the investment horizon. Prior to C&I (1984), estimation procedures assumed either that the bond was held until maturity, without any intermediate realization of capital gains and/or losses (this is also known as the buy-and-hold policy), or that capital gains and losses are realized every period as they occur.

A dynamic strategy gives an investor the option of realizing losses and gains prior to maturity. A taxable investor would find it optimal to exercise these tax options for some but not all bonds of a given maturity.

C&I (1984) define a bondholder's optimal trading policy which implies realization of capital losses (short term if possible), deferment of realization of capital gains (especially if they are short term), and change of holding period status from long term to short term by sale and repurchase of the bond.

The change of holding period enables realization of losses in the short term. The transaction may result in increase in the the basis through sale of the bond and repurchase as the amortized premium is added to the purchase price to establish the basis.

They attempt to find the price of a default free

coupon bond and the value of the timing option regarding the optimal trading policy. They assume an **effective tax** rate for an investor. The investor is assumed to continue in the same tax bracket until the bond matures. The investor purchases the coupon bond and follows the desired optimal trading policy as opposed to a continuous realization or a buy-and-hold policy.

Through their simulation, C&I (1984) conclude that the bond price is increasing (decreasing) in the ordinary income tax rate, if capital gains (losses) are expected. They also conclude the potential effect of tax trading on bond prices cannot be safely ignored in practice.

I. 2 Constantinides and Ingersoll (1984) and Schaefer (1982): A Reconciliation

Both Schaefer's (1982) tax clientele model of a segmented bond market and the tax option model of C&I (1984) predict that the prices of coupon bonds would be convex in their coupons. This implies that the two bond portfolios offering the identical pre-tax return if held to maturity will not sell for the same price.

C&I (1984) attribute the convexity to the tax timing option defined as the difference between the bond prices under the optimal trading policy and buy-and-hold policy. The basic intuition for this convexity is Merton's (1973) study of stock purchase options. The right to realize capital gains and losses optimally and the right to amortize

convey a valuable option to the bondholder. A portfolio of bonds must be at least as valuable as a single bond since the portfolio's options can be exercised individually.

In absence of restrictions on short sales and in absence of transaction costs, this would imply an arbitrage opportunity for tax exempt investors.

Since C&I (1984) formally consider only a single class of investors, the problem of consistency of their tax option effect with a no-arbitrage condition does not arise. In the Schaefer (1982) model, restrictions on short sales are used to prevent arbitrage by tax exempt investors.

A major conclusion of their paper is that the tax timing option is an important fraction of the bond price. C&I (1984) note that the tax option effect can cause the existence of tax clienteles, such as those found by Schaefer (1982).

J. Empirical Studies Related to Tax Clientele and Option Effects in U.S. Treasury Bond Market

J. 1 Litzenberger and Rolfo (1984a)

L&R (1984a) discuss equilibrium in a bond market where there is a complete set of three dated nominal claims on tax exempt income, ordinary income, and capital gains income.

They note that under progressive taxation, unrestricted short selling would result in the existence of tax arbitrage until an allocation of the three classes of dated nominal claims is reached, at which point all investors are in the

same tax bracket.

They explain that equilibrium is feasible under divergent marginal tax rates when there are restrictions on negative net holdings of taxable and tax exempt dated nominal claims. They argue that such regulations are effectively embodied in the tax laws.

L&R (1984a) argue that a short selling restriction on coupon bonds is not a necessary condition for equilibrium in a complete bond market. Schaefer (1982) also considers the condition without frictions and with neutral tax laws for equilibrium to be reached in a complete bond market.

Schaefer (1982) requires equality between ordinary income tax and capital gains tax rate. However, the primary contribution of the L&R (1984) study is a discussion of equilibrium in a semicomplete bond market where the available securities consist of two or more coupon bonds for every date. The prices of bonds of a given maturity are a linear function of their coupons.

Hence, the vectors of payoffs of the three classes of time-dated claims from holding a given coupon bond can be replicated by a portfolio two other bonds of the same maturity. The three classes of dated nominal claims are not spanned by coupon bonds, because for each maturity date there are a maximum of two linearly independent coupon bonds.

Under these conditions, an equilibrium with investors in

diverse tax brackets holding positive amounts of all bonds is feasible, and there is a locus of ordinary income and capital gains tax rates that is consistent with the relative prices of coupon bonds.

L&R (1984a) show that in Germany, Japan, the United Kingdom, and the United States this locus includes the interest income and capital gains tax rates of major taxable holders of government securities.

For example, in the United States, where commercial banks hold 31.5 percent of privately held government securities, the estimated interest income tax rate conditional on their capital gains tax rate is not significantly different from the statutory rates of 46 percent and 48 percent over the sample period.

J. 2 Litzenberger and Rolfo (1984b)

L&R (1984b) study the tax effects on Government bonds with the same maturity dates for domestic and international markets. They study triplets of bonds with the same maturity date, with all three members of the triplet selling at either a premium or discount.

Convexity in triplets implies that the price of the bond with the middle coupon is lower than the price of a portfolio of the other two bonds included in the triplet, assuming that the coupons from the single bond and the portfolio are identical.

They conduct parametric and non-parametric tests for

samples obtained from Data Resources Inc. (DRI) and Center for Research in Security Prices (CRSP) samples. Their results find convexity to exist which is attributed to the existence of the tax option effect, but do not support the segmentation of bond holdings implied by tax clienteles.

J.3 Jordan and Jordan (1991)

Jordan and Jordan (J&J) (1991) replicate the study conducted by L&R (1984). They find that the isolation of the tax-option effect by L&R (1984) has been a misstatement. For tax purposes, the appropriate criterion for determining whether a bond is selling at a premium or discount is the flat price. L&R (1984) incorrectly classify bonds based on the price plus accrued interest. The number of discount bonds is thus understated in the L&R (1984) study.

J&J (1991) do not find the convexity to be large enough to provide arbitrage opportunities for taxable investors. The degree of convexity is obscured by bid-ask spreads and restriction on short sales. According to J&J (1991), there is little evidence of significant arbitrage opportunities. They also conclude that tax clientele effects do not exist.

J. 3 Ronn (1987)

Ronn (1987) proposes a linear programming approach to analyze U.S. Government bonds that explicitly allows for transaction costs involved in bid-ask spread. Unlike Schaefer's (1982) approach, the methodology requires only one linear program per tax bracket and allows for limited

short sales.

The problem is to maximize current cash flow subject to non-negative cash flows in each subsequent time period; he also constrains the number of bonds that can be purchased or sold short. He finds that for the tax exempt investor class, the "underpriced" portfolio contains high coupon bonds, with the "overpriced" portfolio dominated by low coupon bonds.

This is evidence of a clientele effect in the pricing of U.S. Government instruments, with tax exempt investors gravitating towards high coupon bonds. However, pricing is affected by market segmentation caused by preferences for maturity and tax timing option.

An analysis by Ehrhardt (1989) of the dual problem described by Ronn (1987) lends additional support in favor of the tax clientele hypothesis.

The optimal values of Ronn's (1987) dual problem are non-zero. Ehrhardt (1989) argues that this means not all bonds are priced within the bid-ask spread. This is a clear rejection of any equilibrium model based upon a single class of marginal investors, including the "representative tax bracket" hypothesis suggested by Jordan (1984), and L&R (1984).

J. 5 Ehrhardt, Jordan and Prisman (1990)

Ehrhardt, Jordan and Prisman (1990) (henceforth EJ&P) explain that in Schaefer's model each security has different

replicating portfolios across varying tax brackets. L&R's (1984) model is based on an invariant portfolio, so it is a very weak test of clienteles.

EJ&P (1990) have suggested a regression methodology based on an extension of the methodology of Prisman (1990) to include tax option and tax clientele effects. These are two different effects and not necessarily mutually exclusive.

Using linear splines to represent unknown the functional form, EJ&P (1990) find strong support for a joint tax clientele and tax option effect. The tax clientele effect is evidenced by the finding that low coupon bonds are not held by the zero tax bracket investors. The tax option effect is more valuable for premium bonds as any increase in price creates a greater tax shield due to amortization of the premium. This may not be witnessed in the case of discount bonds if the prices do not exceed par value.

K. Estimation of Term Structure: Empirical Evidence on Relevance of Taxes

K. 1 McCulloch (1975)

McCulloch (1975) employed the regression approach and estimated the term structure of prices that minimized the standard error of regression. He argues that a major source of error in estimation of the term structure based on pre-tax cash flows is caused by difference in taxation of premium and discount bonds. A Tax-adjusted term structure

eliminates this source of error. McCulloch (1975) estimated a tax adjusted term structure for ordinary income tax rate at 19% and a capital gains tax rate at 9.5%. Schaefer (1982), as stated earlier, used the LP approach.

K. 2 Jordan (1984)

An empirical weakness of the LP methodology, noted by Jordan (1984), is that by design no negative "residuals" are permitted. The result is a tendency to overstate the clientele effect and to bias downward the estimated discount function.

Also if on a purely random basis a bond is overpriced, it will not appear in the primal solution. The discount function is estimated on the lower priced bond and thus biased downward. The tendency of the approach to fit to extremes of the data is noted by Schaefer (1981).

Jordan (1984) collected forty samples of cross-sectional observations for U.S. Treasury bills, bonds and notes for the last day of first trading month of each quarter.

A regresssion of the price of the coupon after adjustment for accrued interest and division by bid-ask spread (to adjust for heteroscedasticity) on the coupons of bonds was conducted. According to an intuitive argument, ommission of taxes overstates the regressors and results in overestimated prices or negative residuals, which would increase with coupon and price.

In the residual-coupon regression, Jordan (1984) found a greater number of significant coefficients than would be expected if the residuals were unbiased but the sign of the coefficients exhibited no pattern.

Omission of taxes results in statistically significant but ambiguously signed bias in the residual-coupon and residual-price regression. An explanation by Jordan (1984) is that when Ordinary Least Squared Regression (OLS) is applied to the non-tax adjusted regression, the expected value of the residual is different from zero.

Jordan (1984) finds that tax effects exist and attempts to identify the ordinary income tax rate (T) and capital gains tax rate (CGT) by using an iterative OLS search. Higher correlation between T and CGT that minimize the standard error of regression are characterized by higher mean yields, more negatively sloping yield curves, poorer fits of non-tax adjusted OLS regression of price on coupons, and greater proportion of discount bonds in the sample.

Clientele effects may be responsible for the results.

The asymmetries created by the Internal Revenue Code in the form of different tax rates on ordinary income and capital gains creates tax timing options.

K. 3. Heuson and Lasser (1990)

Heuson and Lasser (H&L) (1990) examine after-tax yield differences between U. S. Treasury iso-maturity premium and discount bonds for various tax brackets. The tax bracket

that minimizes the yield difference lies between 20 per cent and 25 per cent for the entire sample which is lower than the corporate tax rate of 46 per cent.

The tax timing option increases the premium bond prices more than the discount bond prices. This biases the premium bonds' before tax yields downward relative to discount bond yields, lowering the tax bracket that equates after tax yields. H&L (1990) do not attempt to explain the source of price differences.

J&J (1991) state that convexity results from two effects: the premium amortization effect and the tax option effect. The premium amortization effect exists due to the preferential tax treatment accorded to premium bonds, whereby investors can linearly amortize the premium and reduce tax outflows. The premium amortization effect is responsible for the yield differences observed by H&L (1990).

L. Conclusion

This chapter has examined the issue of clientele formation in general and the issue of tax clienteles in particular. Evidence from the literature finds support for tax clientele and tax option effects. Both these effects arise due to the asymmetries created by tax statutes.

The tax option effect potentially has a great importance in the pricing of STRIPS because each STRIP security has an attached "tax timing option". The tax

timing option allows investors to realize gains and losses in an optimal fashion. The ability to strip and reconstitute permits the creation of portfolio of options, with the underlying bond having an option on a portfolio in the context of Merton's (1973) observation. Therefore, STRIPS provide a unique laboratory for testing tax option effects.

The after tax term structure has been estimated by McCulloch (1975) for a pair of ordinary income tax rate and capital gains tax rate. Tax clienteles arising due to investors being taxed at differing rates may result in a non-unique after-tax term structure. However, the availability of prices of strippable/reconstitutable bonds enable elimination of arbitrage as shown earlier. Chapter IV examines the usefulness of STRIPS in estimation of a pre-tax term structure.

The eligibility to strip and reconstitute may create price differences between strippable and non-strippable bonds as investors may value the stripping/reconstitution option. In Chapter V three scenarios are developed to highlight the causes of price differences between strippable and non-strippable bonds.

CHAPTER IV

STRIP Bonds and Term Structure Estimation

Section A describes methods to estimate the term structure of interest rates on a pre-tax basis. The term structure estimation with frictions in the form of commissions and bid-ask spreads is described in Section B. The arbitrage possibilities arising due to taxes and changes in term structure are discussed in Section C.

A. Estimating the Term Structure: No Taxes, No Commissions, and No Frictions due to Bid-Ask Spread

In this section, methods to estimate the term structure in a world without taxes, without commissions, and without bid-ask spreads are discussed. A theorem stating that STRIPS enable estimation of a pre-tax term structure is proved. The estimation of the pre-tax term structure by an alternative method, linear programming, is also discussed and contrasted in Section A.

A.1 The Term Structure using STRIPS

Let $\mathbf{X}$ define an $N \times T$ matrix of pre-tax cash flows, with X_{jt} denoting the cash flow of security j ($j = 1, \dots, N$) on date t , $t \in \{1, T\}$. Let $\mathbf{P}$ denote an $N \times 1$ vector of prices, with P_{st} ($s = 1, \dots, N$) denoting the price of bond s with maturity t ; each bond is assumed to have a face value of \$100. Let $\mathbf{d}$ denote a $T \times 1$ vector of discount rates.

A term structure is defined as a vector d such that $\mathbf{x}d = P$.

Theorem: In a market with no frictions or transactions costs, STRIP bonds define a pre-tax term structure of interest rates.

Proof: Consider a sample of N default-free bonds that are eligible for stripping and reconstituting. Assuming \$100 of principal for each bond:

$$X_{jt} = C_{jt} \quad \text{for } t = 1, 2, \dots, T-1 \text{ and}$$

$$X_{jt} = 100 + C_{jt} \quad \text{for } t = T$$

where C_{jt} is the coupon paid each period and T is the number of payment periods until maturity.

A bondholder is entitled to receive periodic payments in the form of coupons and principal. Replication of a bond's coupon and principal payments can be achieved by the purchase of coupon STRIPS and a principal STRIP with maturity dates coinciding with the dates of cash flows from the underlying bond. The portfolio of coupon STRIPS and principal STRIP with cash flows identical to the cash flows of the underlying bond is defined as a replicating portfolio. The price of a STRIP is quoted for a par value of \$100. The discount rate d_t for time t is estimated as $100/P_{\text{STRIP},t}$, where $P_{\text{STRIP},t}$ is defined as price of STRIP maturing in time t .

CASE I. Price of Bond s at time t is $P_{st} < \sum X_{jt}d_t$

For strippable bonds, an opportunity to receive

arbitrage profits exists if $P_{st} < \sum X_{jt} d_t$. In this case an investor buys the non-stripped bond and sells the STRIPS obtained from the bond. An increase in quantity demanded of the bond raises its price and an increase in quantity supplied of STRIPS lowers their price. The difference between the price of the bond and sum of the prices of STRIPS approaches zero. At equilibrium, $P_{st} \geq \sum X_{jt} d_t$ for all strippable bonds.

Case II. $P_{st} > \sum X_{jt} d_t$

For reconstitutable bonds, an investor buys the STRIPS and sells the reconstituted bond to receive arbitrage profits. An increase in demand for STRIPS raises their price and increase in supply of bonds lowers their price. At equilibrium, $P_{st} \leq \sum X_{jt} d_t$.

As the bond is both strippable and reconstitutable, the magnitude of P_{st} must equal to the $\sum X_{jt} d_t$ for $s = 1, \dots, N$. Therefore, $\mathbf{X}\mathbf{d} = \mathbf{P}$ where each matrix $\mathbf{X}$ and vectors $\mathbf{d}$ and $\mathbf{P}$ are as defined earlier. Since the cash flows included in matrix $\mathbf{X}$ are on pre-tax basis the STRIP bonds define a pre-tax term structure. Although $\mathbf{X}\mathbf{d} = \mathbf{P}$ is defined on a pre-tax basis, another vector $\mathbf{d}'$ and $\mathbf{X}$ may exist such that $\mathbf{X}\mathbf{d}' = \mathbf{P}$. Q.E.D.

As discussed later in this section, the result of this theorem holds without requiring the existence of short sales. This is in contrast to some other models of term structure estimation that are suggested in the literature.

A.2 Linear Programming Estimation of the Term Structure

Schaefer (1981) proposed a linear programming approach for estimating the term structure. Let W_j be the number of bonds held in the portfolio. Long positions are denoted by a positive sign preceding W_j and short positions are denoted by a negative sign preceding W_j . The objective function for the primal is given by,

$$\begin{aligned} \text{Min } \sum P_{st} W_j \\ \text{s.t. } \sum X_{jt} W_t &> 0 \quad \text{for each } t. \\ -\infty &< W_j < \infty \end{aligned}$$

If W_j is negative, the bond is sold short. This is a cash inflow at time of sale, but a cash outflow on each coupon payment date. If W_j is positive, the bond is held long and this results in a negative cash flow when the bond is bought, but a positive cash flow at each payment date. Given all positive X_{jt} , the solution to this LP must be either zero or infinity. Since infinite profits are assumed to not exist, the solution must be zero.

Because the solution is not infinity, there exists a feasible solution to the dual. The dual is given by,

$$\begin{aligned} \text{Max } \sum 0d_t \\ \text{s.t. } \sum X_{jt} d_t &= P_j \text{ for each bond.} \end{aligned}$$

So d_t defines a pre-tax term structure.

This is the same result as the theorem in Section A.1, except Schaefer's (1981) derivation requires no restriction on short sales. The results of the theorem are valid for

only strippable/ reconstitutable bonds⁶.

Schaefer (1981) incorporates a ban on short sales by adding a constraint: $W_j \geq 0$. As shown by Schaefer (1981) the dual is no longer $\mathbf{Xd} = \mathbf{P}$, but is $\mathbf{X_T d^*} \leq \mathbf{P}$ where $\mathbf{X_T}$ is a $N \times T$ matrix of cash flows and $\mathbf{d^*}$ is a $T \times 1$ vector of discount rates.

In contrast, with a sample of STRIPS

$$\sum X_{jt} d_t = P_j,$$

else an investor can strip or reconstitute a bond. So there exists a set of d_t (defined by STRIP prices, which are observable) that "prices" this set of bonds. By way of comparisons Schaefer's (1981) d_* does not price each bond; instead, $X_{jt} d^* \leq P_j$.

B. Term Structure Estimation with Frictions Due to Commissions and Bid-Ask Spreads

This section introduces frictions due to bid-ask spreads and commissions in bond and coupon purchases and sales. With the aforesaid frictions, bounds on the value of the replicated portfolio are set by the price of the underlying bond, the bid-ask spreads and the commissions on the bond and STRIPS. A linear programming approach, with the inclusion of transactions costs and bid-ask spreads, suggested by Ronn (1987) and Ehrhardt (1989) is compared with the approach using prices of STRIPS also with inclusion of associated transactions cost and bid-ask spreads.

⁶Schaefer's (1981) result is applicable to all bonds.

B.1 Use of STRIPS in Estimation of Term Structure

The following variables are defined as:

$d_{t,A}$ = ask price of a STRIP maturing on payment date t ;

$d_{t,B}$ = bid price of STRIP maturing on payment date t ;

$P_{j,A}$ = ask price of bond j ;

$P_{j,B}$ = bid price of bond j ;

$F_{s,t}$ = commission for STRIP maturing on payment date t ;

and

$F_{j,p}$ = commission for bond j ; and

$X_{j,t}$ = coupon payment (including principal at maturity) for bond j on payment date t ;

$t = 1, \dots, T$ payment dates;

$j = 1, \dots, N$ bonds;

The stripping method is defined as the purchase of a bond at the ask price and the sale of the resulting STRIPS at their bid price. The profit (arbitrage) on stripping a bond is defined as:

$$\text{Profit} = \sum X_{jt} d_{t,B} - \sum F_{s,t} - F_{j,p} - P_{j,A} \leq 0$$

The summation is over the set of payment dates $t = 1, \dots, T$.

The Reconstitution method is defined as the purchase of a replicating portfolio of coupon and principal STRIPS at their ask price and the sale of the reconstituted bond at its bid price. The profit (arbitrage) on reconstitution is defined as:

$$\text{Profit} = P_{j,B} - \sum X_{jt} d_{t,A} - \sum F_{s,t} - F_{j,p} \leq 0$$

Let $S_{s,t}$ be defined as the spread on STRIP t , $S_{s,t} =$

$d_{t,A} - d_{t,B}$. Let $S_{j,p}$ be defined as spread on bond j , $S_{j,p} = P_{j,A} - P_{j,B}$. Let d_s be defined as the average of the spread, $d_s = d_{t,B} + 0.5S_{s,t} = d_{t,A} - 0.5S_{s,t}$. Let P_j be defined as the average of bid and ask quotes, $P_j = P_{j,B} + 0.5S_{j,p} = P_{j,A} - 0.5S_{j,p}$.

Using the average of the bid and ask levels, the profit on stripping and reconstitution, respectively, are defined as:

$$\sum X_{jt} [d_t - 0.5S_{s,t}] - \sum F_{s,t} - F_{j,p} - [P_j + 0.5S_{j,p}] \leq 0$$

and $0 \geq -\sum X_{jt} [d_t + 0.5S_{s,t}] - \sum F_p - F_{s,t} + [P_j - 0.5S_{j,p}]$.

Let $Z_t = \sum F_{s,t} + F_{s,p} + 0.5\sum X_{j,t}S_{s,t} + 0.5S_{j,p}$. Then:

$$P_j - Z_t \leq \sum X_{jt} d_t \leq P_j + Z_t$$

Thus, the introduction of frictions puts bounds on the value of $\sum X_{jt} d_t$. This is in contrast to the case of no frictions in which the value of the replicated portfolio, $\sum X_{j,t}$, must exactly equal P_j .

B.2 Using LP Approach as Suggested by Ronn (1987) and Ehrhardt (1989)

Ronn (1987) tests an LP approach to bond portfolio management by a model that purchases "underpriced" bonds (for a given tax bracket) at their ask prices, while simultaneously selling at "overpriced" bonds at the bid price. The objective is to maximize the current cash flow while having a non-zero cash flow in the future. Although Ronn (1987) states the dual problem, he uses the primal as the basis for his empirical work. Ehrhardt (1989) corrects

minor errors in Ronn's (1987) dual problem and provides a more intuitive explanation of the dual.

The objective of the dual problem is to minimize the slack variable subject to:

$$\sum X_{jt}d_t + y_j \geq P_{j,B} \quad j=1, \dots, N$$

$$\sum X_{jt}d_t - y_{N+j} \leq P_{j,A} \quad t=1, \dots, T-1$$

$$d_t - (1+\rho)d_{t+1} \geq 0 \quad (\text{to ensure non-negative interest rates}),$$

$$d_t, y_j \geq 0,$$

where $P_{j,B}$ and $P_{j,A}$ are bid and ask prices for bond j , t is a payment date from 1 to T , d_t are discount factors that define the term structure. The value of d_t is a function of the choice of the tax rate used in defining X_{jt} . For this section the tax rate is assumed to be zero. d_t is the present value of \$1 at time t . y_j represents a slack variable.

The bounds on the value of $\sum X_{jt}d_t$ are shown in the following steps.

$$\sum X_{jt}d_t \geq P_{j,B} - y_j$$

$$\sum X_{jt}d_t \leq P_{j,A} + y_{N+j}$$

$$\therefore P_{j,B} - y_j \leq \sum X_{jt}d_t \leq P_{j,A} + y_{N+j}$$

Using the notation from Section B.1:

P_j is defined as average of bid and ask prices of bond j

$$S_{j,P} = P_{j,A} - P_{j,B}$$

The values of $P_{j,A}$ and $P_{j,B}$ are expressed in terms of P_j :

$$P_j = P_{j,B} + 0.5S_{j,P} = P_{j,A} - 0.5S_{j,P}.$$

$$\therefore P_j - 0.5S_{j,p} - y_j \leq \sum x_{jt}d_t \leq P_{j,A} + 0.5S_{j,p} + y_{N+j}.$$

The bounds on the value of $\sum x_{jt}d_t$ arise due to frictions. The terms $0.5S_{j,p} + y_j$ are analogous to the term Z_t defined in section B.1 on page 64.

Ehrhardt (1989) interprets the dual as an effort to find a term structure that is monotonic decreasing and that prices the bond within the constraint of bid-ask prices. If y_j is zero for all j , then all bonds are priced within their bid-ask prices. An analogous situation is observed in the estimation of the term structure using STRIPS at their bid-ask quotes prices the bonds within boundaries set by the frictions.

C. Taxes and the Term Structure of Interest Rates, and STRIP bonds

This Section explains the valuation differences between a bond and the replicating portfolio of STRIPS when taxes are considered. In general, taxes due on cash flows received from STRIPS are different from the taxes due on the cash flows received in the form of coupons. A simulation study demonstrates this tax effect and provides guidance for investors.

C.1 Clientele Effects Due to Taxation

Consider an investor who must select between a coupon paying bond or a portfolio of STRIPS with identical after-tax cash flows. The investor would prefer the minimum cost alternative. As demonstrated below, taxes create

differences in after-tax cash flows received from a bond and a portfolio of its STRIPS. Thus, clienteles are created in which certain brackets prefer the bond and other brackets prefer the constituent STRIPS.

Assume that the hypothesized investor is subject to a tax rate τ on all income (including capital gains) and that the investor holds the bond until maturity. All bonds pay \$1000 at maturity. For clarity of exposition, assume that the bond matures in two time periods. The market price of the bond is P . The market prices of the STRIPS maturing in periods 1 and 2 are P_1 and P_2 respectively. Let R_1 and R_2 denote the pre-tax spot rates for period 1 and 2 respectively. R_1 and R_2 are defined by the two STRIPS prices; e.g., $R_1 = (1000)/P_1 - 1$ and $R_2 = (1000/P_2)^{0.5} - 1$.

To compare the two alternatives the investor must first replicate the after tax cash flows of the bond. This can be achieved by the purchase of X_1 units of the stripped coupon (STRIP1) to be received in time period 1 and X_2 units of stripped coupon (STRIP2) to be received in time period 2 (the computations of X_1 and X_2 are shown later). The portfolio of STRIPS is constructed such that the after tax cash flows from the STRIPS and the underlying bond are equal in each time period.

Holders of STRIPS receive the face value of the STRIP at maturity. Although no cash inflow is paid to STRIP holders until maturity, investors are required to pay income

taxes on the imputed ordinary income for the interim fiscal periods. The imputed income is determined by the imputed change in the market price of the STRIP during a fiscal period, based on the yield to maturity as computed at the time of purchase⁷. If a STRIP is sold prior to maturity, the difference between the sale price and this imputed value of the STRIP is treated as capital gain or loss.

The after tax cash flows of two STRIPS with different times to maturity are not identical. This difference arises due to two factors:

1. The price of a zero coupon bond approaches its face value at a non linear rate with respect to time to maturity for any given term structure of interest rates.

2. For a non-flat term structure of interest rates the spot rate used in the computation of imputed income varies for STRIPS of different maturities.

Following are the assumptions used in this analysis:

- (1) C is the coupon paid each period by the coupon bonds;
- (2) the coupon bond matures in two time periods;
- (3) P is the market price of the coupon bond;
- (4) τ is the tax rate on all income;
- (5) R_1 and R_2 are the spot rates (which are the yields)

⁷The difference between the purchase price and the imputed value of the STRIP is treated as capital gain or loss.

for year 1 and 2 respectively of the two STRIPS.

(6) P_1 and P_2 are the prices of STRIP 1 and STRIP 2 maturing in period 1 and period 2 respectively.

C.2 After-tax Cash Flow of STRIPS

In the case of STRIP1, the imputed income is based on the spot rate R_1 . For STRIP2, the imputed income is based on the spot rate R_2 .

After-tax Cash Flows of STRIPS

	Period 1	Period 2
STRIP 1	$1000 - [1000 - 1000/(1+R_1)]\tau =$ $ATCF_{1,1}$	
STRIP 2	$-[1000/(1+R_2) - 1000/(1+R_2)^2]\tau =$ $ATCF_{2,1}$	$1000 - [1000 - 1000/(1+R_2)]\tau =$ $ATCF_{2,2}$

$ATCF_{i,t}$ = After-tax cash flow from STRIP i in period t.

Case I. After-tax cash flows of a Discount Bond.

During each period the investor is liable to pay taxes on the coupon income. During the second period the investor is also liable to pay capital gains taxes on the difference between face value of the bond and purchase price in addition to taxes on coupon income. Following are the after-tax cash flows of discount coupon bond.

	Period 1	Period 2
Discount Bond	$C(1-\tau)$ $= ATCF_{b,1}$	$C(1-\tau) - (1000-P)\tau + 1000$ $= ATCF_{b,2}$

$ATCF_{b,t}$ = After-tax cash flow from bond b at time t.

Case II. After-tax Cash Flow of a Premium Bond

The premium on the bond is amortized on a straight line basis and pre-tax coupon income is lowered by the amount amortized. This reduces the tax liability in each period. Following are the cash flows.

	Period 1	Period 2
Premium Bond	$C(1-\tau) + \{(P-1000)/2\}\tau$ $= ATCF_{b,1}$	$C(1-\tau) + (P-1000)/2\}\tau$ $+ 1000 = ATCF_{b,2}$

C.3 Finding the Replicating Portfolios

The following derivation shows how to find a portfolio of STRIPS that replicates the coupon bond. Let $ATCF_{i,t}$ be the after-tax cash flow from STRIP i in time period t. Let $ATCF_{b,t}$ be the after tax cash flow from the coupon bond in time t. The time to maturity of the coupon bond is 2 years; i.e. i ranges from 1 to 2. Let X_1 and X_2 be the number of units of STRIP1 and STRIP2 respectively that compose the portfolio. This implies the following system of equations:

$$X_1 (ATCF_{1,1}) + X_2 (ATCF_{2,1}) = ATCF_{b,1}$$

$$X_2 (ATCF_{2,2}) = ATCF_{b,2}$$

Since $ATCF_{i,t}$ and $ATCF_{b,t}$ are known, the two equations can be solved to obtain the values of X_1 and X_2 .

The cost of the replicating portfolio of STRIPS is $P_1X_1 + P_2X_2$. The price of the bond is P_b . The investor's rational behavior is:

1. If $P_1X_1 + P_2X_2 > P_b$, then buy the bond;
2. If $P_1X_1 + P_2X_2 < P_b$, then buy the portfolio of STRIPS;
3. If $P_1X_1 + P_2X_2 = P_b$, then buy either or neither.

This section is based on the assumption that $Ad=P_b$ on a pre-tax basis; i.e. d is a pre-tax term structure. A is a NXT matrix of cash flows, where N is the number of bonds and T is the number of time periods over which cash flows are received. This implies that the zero-tax bracket investors are pricing the STRIPS and the coupon bond. The question is: given d^* and A_T , the matrix of cash flows on an after tax basis at tax rate τ such that $A_T d^* = P$, is the price of the the replicated portfolio (on an after tax basis at tax rate = τ) equal to P_b ? In other words, are the STRIPS and the coupon bond also priced by tax bracket τ ?

If the STRIPS and the coupon bond are priced by tax bracket τ , then the following set of three equations must be true:

$$X_1 (ATCF_{1,1}) + X_2 (ATCF_{2,1}) = ATCF_{b,1} \quad (I)$$

$$X_2 (ATCF_{2,2}) = ATCF_{b,2} \quad (II)$$

$$P_1X_1 + P_2X_2 = P_b \quad (III)$$

X_1 and X_2 are the unknown variables. The number of unknown variables is less than the number of equations. In general, there will not be a unique solution to this system of equations. From equation II,

$$\therefore X_2 = ATCF_{b,2}/ATCF_{2,2} \equiv A.$$

The value A is substituted in equations I and II

$$\begin{aligned} \text{So, } X_1 (ATCF_{1,1}) + A(ATCF_{2,1}) &= ATCF_{b,1} \\ X_1P_1 + AP_2 &= P_b \end{aligned}$$

The value of X_1 is obtained from the above two equations in terms of the known quantities.

$$X_1 = [ATCF_{b,1} - A(ATCF_{2,1})]/ATCF_{1,1}$$

$$X_1 = (P_b - AP_2)/P_1$$

As the left hand sides are the same variable, the following equation is described:

$$[ATCF_{b,1} - A(ATCF_{2,1})]/ATCF_{1,1} = (P_b - AP_2)/P_1.$$

Rearranging the terms,

$$ATCF_{b,1} [P_2 ATCF_{1,1} - P_1 ATCF_{2,1}] = ATCF_{2,2} [P_b ATCF_{1,1} - P_1 ATCF_{b,1}]$$

Let $d_1 \equiv 1/(1+R_1)$ and $d_2 \equiv 1/(1+R_2)$. Since $Ad = P$, then, $P_1 = 1000d_1$, $P_2 = 1000d_2^2$ and $P_b = Cd_1 + (1000+C)d_2^2$. The maximum order of d_2 is four; the maximum order of d_1 is 2; and the maximum order of τ is 2. The polynomial has several solutions.

For example, if τ and d_1 are fixed then four solutions may be possible. If τ and d_2 are fixed then two solutions

may be possible.

With the following constraints:

$$0 \leq d_1 \leq 1$$

$$0 \leq d_2 \leq 1$$

$$0 \leq \tau \leq 1$$

there may or may not be any solution.

C.4 Simulation

Based on the equations I, II, and III stated on page 69, a simulation is conducted for a bond with two time periods to maturity and the constituent STRIPS. The simulation is conducted for an upward sloping and a downward sloping term structures. The spot rates are 10% and 11% for period 1 and period 2 respectively for the upward sloping term structure. The spot rates are 10% and 9% for period 1 and period 2 respectively for the downward sloping term structure. Five different tax rates are used: 20%, 30%, 40%, 50%, and 60%. The coupon rate varied between 6% to 18% with increments of 1%.

Figures I and II show the plots of the differences between prices of replicating portfolio of STRIPS and the prices of the coupon bonds against prices of the bonds, for upward and downward sloping term structures, respectively.

For an upward sloping term structure, as shown in Figure I, the price of the portfolio of STRIPS is less than the price of the bond for lower price bonds (lower coupon rates) for all tax rates included in the simulation. This

implies that investors in these tax brackets prefer to hold the portfolio of STRIPS and do not hold the bond in unstripped form. Thus clienteles, driven by the tax statute, are observed because investors rationally may choose the optimal path.

For a downward sloping term structure shown in Figure II, the price of the portfolio is always greater than the price of the bond for the spectrum of bond prices (coupon rates) and tax rates.

This implies that the decision of an investor to choose between a bond or its replicating portfolio of STRIPS depends upon the term structure of interest rates and the tax rate of the investor. This is conclusive evidence that asymmetry created by taxes can lead to clientele effects with respect to the asset allocation policy between coupon bonds and STRIPS.

Chapter V

Pricing Phenomena: Tax Clienteles, Eligibility to Strip/ Reconstitute, and Tax Option Effects

This chapter discusses three potential phenomena that may affect bond pricing. Short discussions of tax clienteles, the stripping/reconstitution effect, and the tax-option effect are provided in Sections A, B, and C, respectively, with an emphasis on the effect each would have on relative pricing of replicating portfolios and the underlying bond. Section D integrates the effects and describes testable hypotheses.

A. Tax Clientele Effect

As stated in an earlier section $\mathbf{Ad} = \mathbf{P}$ where the cash flows in $N \times T$ matrix $\mathbf{A}$ are on a pre-tax basis. Let matrix $\mathbf{A}_\tau$ define an $N \times T$ matrix of after-tax cash flows, with $A_{\tau jt}$ denoting the after-tax cash flow of security j ($j = 1, \dots, N$) on date t , $t \in \{1, T\}$ based on a tax rate τ . Let $\mathbf{P}$ denote an $N \times 1$ vector of prices, with P_j ($j = 1, \dots, N$) denoting the price of bond j . Let $\mathbf{d}_\tau$ denote a $T \times 1$ vector representing discount rates. Under asymmetric treatment of ordinary and capital income, $\mathbf{A}_\tau$ is not a linear transformation of $\mathbf{A}$, and $\mathbf{d}_\tau$ is not a linear transformation of $\mathbf{d}$.

Suppose $\mathbf{Ad} = \mathbf{P}$ for a set of bonds. There does not generally exist a non-zero tax rate τ such that $\mathbf{A}_\tau \mathbf{d}_\tau = \mathbf{P}$, as

shown in Chapter IV. Therefore, this set of bonds is priced by the zero tax bracket clientele.

Consider a second set of bonds such that $Ad \neq P$. If these bonds are priced by tax clientele τ , then $A_\tau d_\tau = P$. A bond is held if $A_\tau d_\tau = P$ and is not held if $A_\tau d_\tau < P$.

Assume that investors have either a zero tax rate or a tax rate of τ . Consider the following:

1. Strippable and Reconstitutable Bond (S) with market price = P_S ;
2. Non-strippable Bond (NS) with market price = P_{NS} .

In the absence of frictions, Chapter IV demonstrates that the relationship $Ad = P_S$ should hold for a strippable bond, indicating that the bond is priced by investors in the zero tax bracket. If $Ad = P_{NS}$, then these bonds are also priced by the zero tax clientele. Suppose $Ad \neq P_{NS}$. It is possible that investors in tax bracket τ set the price the non-strippable bond at P_{NS} ; i.e. there exists a τ such that $A_\tau d_\tau = P_{NS}$. This would be consistent with the existence of tax clientele effects.

B. The Eligibility to Strip and Reconstitute

Any pricing differences between strippable and non-strippable bonds may be due to the stripping eligibility itself. The simulation study in Chapter IV shows that an investor may prefer to choose to hold a bond in unstripped form or may prefer to hold the portfolio of STRIPS constituting the bond. The investor's choice is ruled by

the shape of the term structure. The eligibility to strip and reconstitute provides an investor, an opportunity to match the desired maturity profile of the investment. The eligibility to strip/reconstitute has the potential to add value to an investor's existing investment in the U.S. Treasury strippable bond market.

The following section develops two potential hypotheses to explain the causes of price differences between the two types of bonds.

The following hypotheses are developed:

Hypothesis 1: There is no difference in relative prices of strippable and non-strippable bonds.

Both types of bonds are priced according to the STRIP term structure i.e. $(Ad - P_{SR}) = (Ad - P_{NS}) = 0$. This would imply that eligibility to strip and reconstitute is not valued by investors. It would also imply that the two types of bonds are priced by the same term structure on a pre-tax basis.

C. Tax Option Effect and Flexibility/Marketability Effect

If the tax option effect exists as described in Chapter III, then Constantinides & Ingersoll (1984) show that the prices of coupon bonds would be convex in their coupons. In other words, a bond and a portfolio of bonds offering the identical pre-tax return, if held to maturity, may not sell for the same price. The pricing differences are attributed to tax timing options arising due to Merton's (1973) observation that a portfolio of individual options on

individual securities is at least as valuable as a single option on the same portfolio of securities.

In the absence of the bonds being eligible for stripping/reconstitution, the tax option might exist for a single security. The eligibility to strip/ reconstitute enables investors to realize the capital gains and losses on a larger number of securities on stripping.

In the absence of any other effects, and in the presence of asymmetric taxation in the form of differential treatment of capital gains and ordinary income, the tax option effect holds. The tax option effect predicts that $Ad > P$, irrespective of whether finite effects of frictions and eligibility to strip exist.

When an investment in U.S. Treasury bonds is held in the form of STRIPS, it provides an investor with added flexibility to optimize the cash flows on an after tax basis. The flexibility is in two forms: the timing of the cash flows described as the tax timing option, and the flexibility in the form of selective marketability whereby an investor can choose not to realize gains/losses on STRIPS with specific maturities.

Tax timing option is the ability of the investor to optimize cash flows available to any type of security held in isolation or in a portfolio. Selective marketability is the ability of the investor to optimize cash flows of selected securities held in a portfolio. For example, when

a bond is held in the form of STRIPS, an investor can realize the capital losses on a subset of the portfolio. The investor may take this action in response to different shifts in term structure of interest rates for bonds with long-term and short-term maturities.

D. Integration of the Hypotheses in the Presence of Market Frictions

In this section the eligibility effect and the effect of frictions are explained, followed by a discussion which integrates the hypotheses.

D.1 Eligibility Effect and Frictions in the Form of Bid-Ask Spreads and Commissions

The eligibility effect may create pricing differences between strippable and non-strippable bonds. The eligibility to strip/reconstitute provides an investor a choice of timing the action of stripping/reconstitution. Hence, the strippable bonds should be valued higher than the non-strippable bonds. The pricing differences should be positively correlated with maturity, because holders of long maturity securities have a longer time to exercise the eligibility to strip. The effect of frictions on the price of securities is also positively correlated with maturity, unless the cost of frictions is either zero or infinity.

D.2 Testable Hypotheses Based on Joint Effects

The tax option effect is larger in the case of a portfolio of STRIPS. The number of STRIPS in a portfolio

obtained by stripping a bond increases with maturity. Hence, the price of STRIPS obtained from a strippable bond with relatively larger maturity will be affected positively to a greater extent. The tax option effect increases the value of $Ad - P$.

The eligibility to strip and reconstitute affect the price P of a strippable/reconstitutable bond positively, assuming investors value stripping. Thus, the tax option effect increases the value of $Ad - P$ and the eligibility effect lowers the value of $Ad - P$.

The effect of frictions increases with maturity. Frictions erode the eligibility effect in strippable bonds as maturity increases. Frictions have an effect of increasing the magnitude of $Ad - P$. Frictions have an effect complementary to the tax option effect.

The following testable hypotheses are stated with respect to the effects described earlier in this chapter.

Hypothesis 2: $P_{SR} > P_{NS}$

The price of strippable/reconstitutable bonds is greater than the price of non-strippable bonds due to the eligibility effect. Also the non-strippable bonds are priced lower than the strippable bonds because the tax option effect exists in the pricing of the former type of bonds.

Hypothesis 3: $P_{LSR} - Ad = P_{SSR} - Ad$

P_{LSR} and P_{SSR} are defined as the price of a long term

strippable bond (maturity between 2015 and 2021) and a short term strippable bond (maturity between 1995 and 2001), respectively.

The values of P_{LSR} and P_{SSR} are dependent on the maturity of the bond because the bond with a longer maturity provides the investor with greater opportunity to optimize actions. The eligibility effect increases with maturity. Hence in absence of frictions P_{LSR} should be greater than P_{SSR} . The effect of frictions is opposite and is also correlated with maturity.

Chapter VI

Empirical Tests, Results and Discussion

The empirical tests are discussed in this Chapter. Descriptions of the data and methodology are provided in Section A. The results of mean pricing differences are described in Section B; potential explanations for these results are discussed in Section C. In Section D, the tax option effect, the eligibility to strip and reconstitute (known as the "eligibility effect"), and the effect of frictions on pricing are discussed. The impact of maturity on each of these effects is also addressed in Section D. The valuation differences between reconstitutable, non-reconstitutable and non-strippable bonds are explained in this Section on the basis of the theoretical framework developed in earlier Sections. The findings are summarised in Section E.

A. Data and Methodology for Pricing Replicating Portfolios

A.1 DATA

Daily market prices of U. S. Treasury bonds, notes, and STRIPS are obtained from the Wall Street Journal (WSJ). The data are provided to WSJ by Bear Sterns & Co. The data include date of maturity, bid and ask prices, and coupon rates for bonds and notes. The bid and ask prices are closing quotes from a sample of dealers. The quotes in the

WSJ are based on face values of \$100 for bonds and STRIPS. The data used for empirical tests for one trading day of each month from August 1990 to November 1991. Data are also gathered for all trading days in March 1991.

The sample contains two types of bonds:

1. Strippable Bonds (for a total of 1384 observations);
2. Non-Strippable Bonds (for a total of 1871 observations).

The STRIPS and strippable securities mature on the 15th day of the month in either February, May, August or November. All coupon payments for these bonds also occur on these dates. The spot rates for these payment dates are computed from the prices of STRIPS maturing on these dates. Let P_{st} denote the price of a STRIP maturing on payment date t ; let R_t denote the spot rate for time payment date t . Let T_t denote the time of payment date t measured in years. The spot rate is computed as $R_t = (100/P_{st})^{1/T_t} - 1$ for payment date t .

The coupon payment dates of non-strippable bonds do not always coincide with the payment dates for STRIPS. Hence, it is not possible to use the same procedure to compute spot rates for payment dates of these bonds. The spot rates corresponding to the payment dates of non strippable bonds are priced by spot rates computed by linear interpolation. The approximation is directly proportional to the time in days between the interest payment date of a non-strippable

bond and the nearest interest payment date of the two surrounding strippable bonds. The following example demonstrates the linear interpolation.

Assume a non-strippable bond matures on 05/31/1998. This means that spot rates will be needed for every May 31 and November 30 for each year between the current date and 5/31/1998. The following procedure shows how to estimate the spot rate for 5/31/1998, which is denoted as R_1 . A similar procedure can be used to estimate the other required spot rates.

Let STRIP 1 mature on date 05/15/1998 and STRIP 2 mature on date 08/15/1998. Let P_1 and P_2 be the price of STRIP 1 and STRIP 2, respectively, as observed on 5/31/1990. The spot interest rate computed for 05/15/1998 is $R_1 = (100/P_1)^{(1/8)} - 1$ (as the number of years to maturity of STRIP 1 is equal to 8), and spot interest rate computed for 08/15/1998 is $R_2 = (100/P_2)^{(1/8.25)} - 1$. STRIP 2 matures in 8.25 years. Let $F_{1,2}$ denote the forward interest rate between 05/15/1998 and 08/15/1998. Then the following relationship is defined:

$$(1+R_2)^{8.25} = (1+R_1)^{8.0} (1+F_{1,2})^{0.25}$$

$$\therefore (1+F_{1,2})^{0.25} = \left((1+R_2)^{8.25} / (1+R_1)^{8.0} \right)$$

Substituting for the values of R_1 and R_2 in terms of P_1 and P_2 respectively leads to:

$$\therefore (1+F_{1,2}) = \left[(100/P_2) / (100/P_1) \right]^4 = [P_1/P_2]^4$$

R_T is the spot rate for the payment on 05/31/1998 i.e. for a period of 8 years and 16 days. R_1 is the spot rate for 8 years. R_T is computed using linear interpolation as:

$$(1+R_T)^{8.0+16/365} = (1+R_1)^{8.0} (1+F_{1,2})^{16/365}.$$

For each payment date, the time to the smallest maturity of adjacent STRIP is measured. For this example the time is equal to $0.5 - \text{Absolute}[0.5 - 16/365]$, where the number of days between the maturity date of the non-strippable bond and the maturity date of STRIP 1 is equal to 16.

A.2 Methods for Replicating Portfolios

The coupons and the principal payment from a bond are discounted using the spot rates obtained from the U.S. Treasury STRIPS. This is equivalent to forming a portfolio of STRIPS that replicates the cash flow of the bond.

The principal for each bond is \$100. Let C_{jt} denote the coupon paid for bond j in period t . Let X_{jt} denote the cash flow from bond j in time period t . t is the payment date. Let T_t be the number of years until payment date t .

$$\begin{aligned} X_{jt} &= C_{jt} && \text{for } t = 1, 2, \dots, M_j - 1 \text{ and} \\ X_{jt} &= 100 + C_{jt} && \text{for } t = M_j \text{ where } M_j \text{ is the payment} \\ &&& \text{at maturity} \end{aligned}$$

$$d_t = 1/(1+R_t)^{T_t} \text{ is the discount rate.}$$

The value of the replicating portfolio is defined by the term $\sum X_{jt}d_t$.

Three methods have been adopted to study the pricing

differences between bonds and STRIPS. The three methods are explained below. A discussion of the results follows the explanation. Although non-strippable bonds cannot be stripped or reconstituted, all three methods are applied to non-strippable bonds for purposes of comparison.

A.2.1 Average Pricing Differences

The term structure of spot rates is estimated from the "average" of bid and ask prices of STRIPS and all transactions costs are ignored. The underlying bond is replicated by discounting its coupons and principal payment at the corresponding average spot rates. The underlying bond price is defined as the average value of its bid-ask quotes, and is adjusted for accrued interest.

The difference between the bond price and the value of the replicating portfolio, $P - \sum x_{jt}d_t$, is measured for each bond for each day that the bond is in the sample. Table I⁸ presents the means for each type of bond included in the sample by the Average method; this is an "Overall Mean Difference" (OMD) for this method. All discussion will be deferred until Section B.

A "Daily Mean Difference" is computed for each sample date (DMD) (this contains all bonds in the sample for that date). The DMD values for all strippable bonds, as measured by the average method, are presented in Table II. The DMD values for non-strippable bonds are presented in Table III.

⁸All Tables are presented in Appendix

The mean difference for each bond is also computed; this is a "Bond Mean Difference" (BMD). The BMD values for strippable bonds, as measured by the average method, are displayed in Table IV. Table V presents the BMD values for non-strippable bonds, as measured by the average method.

A.2.2 Stripping Pricing Differences

The process of stripping involves the purchase of a coupon bond and the subsequent sale of each coupon payment and principal payment of the bond. The spot rates for the replicating portfolio are estimated from the bid prices of STRIPS. The price of the coupon bond is set at its ask price, since it must be bought if stripping is to occur. According to Daves and Ehrhardt (1992) the brokerage costs at the rate of $\$(1/256)$ per dollar of the security price are added to the ask price.

The mean of pricing differences for all observations for each type of bond is denoted as OMD. Table VI presents the OMD for by the stripping method. The DMD values for all strippable bonds are presented in Table VII, as measured by the stripping method. The DMD values for non-strippable bonds are presented in Table VIII as measured by the stripping method.

In Table IX the BMD values for strippable bonds as measured by the stripping method are presented. Table X presents BMD values for non-strippable bonds as measured by stripping.

A.2.3 Reconstitution Pricing Differences

The process of reconstitution is the purchase of the appropriate STRIPS required to replicate an underlying bond and sale of the reconstituted bond. The term structure used to price the replicating portfolio is estimated from the ask price of STRIPS since the STRIPS must be bought. The underlying bond's price is set at its bid price, since it is sold after reconstitution. The brokerage costs at $\$(1/256)$ per dollar of the security price are included.

Table XI presents the OMD results as measured by this method. The DMD values for strippable bonds, as measured by the reconstitution method, are presented in Table XII. The DMD values for non-strippable bonds are presented in Table XIII, as measured by the reconstitution method.

In Table XIV the BMD values for strippable bonds are shown. Table XV presents results for non-strippable bonds.

B. Discussion of Mean Pricing Differences

In this section the Mean Pricing Differences for all bonds by the three methods are described. Also, a preliminary interpretation is provided to facilitate further analysis of the results in the next section. The discussion is classified into two sections: Strippable Bonds and Non-Strippable Bonds.

B.1 Strippable Bonds

The average method examines if any pricing differences exist between the STRIPS and the underlying bond without

market frictions in the form of bid-ask spreads and brokerage costs. The pricing differences by stripping method will indicate if stripping offers profit opportunities.

B.1.1 Average Method

The OMD values are positive and significant as measured by the average method. Table I includes the OMD values for each type of bond. The results imply that reconstitution of the strippable bonds is profitable without inclusion of bid-ask spreads and transactions costs. The statistics related to the DMD values by the average method for all strippable bonds are shown in Table II. A positive DMD value indicates that the market price of the bond is greater than the value of the replicated bond obtained using the pre-tax term structure.

Thus, a positive DMD value indicates that reconstitution is a profitable strategy. The DMD values are positive for 30 observations and 26 of the positive DMD values are significant at 5% level of significance. This indicates that if the market imperfections created by transactions costs are ignored, the strippable bonds are priced higher than the constituent STRIPS.

B.1.2 Stripping Method

The DMD values for all strippable bonds by the stripping method are negative. The statistics related to DMD values for strippable bonds are presented in Table VII.

The BMD values for strippable bonds, as measured by stripping method, are shown in Table IX. The BMD values are negative for all except one strippable bond which is significant at 5% level of significance. It appears that stripping is not a profitable strategy for strippable bonds which confirms the results obtained by the average method. Yet, dealers strip Treasury bonds due to non zero transactions costs.

B.1.3 Reconstitution Method

The DMD value for 15 observations are negative for all strippable bonds, as measured by the reconstitution method, and are presented in Table XII. The DMD values are positive and significant for 4 observations. The BMD values for strippable bonds, are shown in Table XIV.

B.1.4 Mean of Price Differences for the Entire Sample of Strippable Bonds

The OMD values for each category of bond are presented in Table I, as measured by the average method. The OMD values for all strippable bonds are positive and significant by the average method. The OMD values, as measured by the stripping method are negative for strippable bonds. These are presented in Table VI.

The OMD values are negative for strippable bonds, as measured by the reconstitution method. The OMD values, as measured by the reconstitution method, are displayed in Table XI.

B. 2 Non-Strippable Bonds

All the tests described in Section B.1 are conducted for the non-strippable Treasury securities. These are either securities issued before February 1987 or issued after February 1985 with maturities less than ten years. The securities issued after February 1985 mature in months other than February, May, August and November. The dates of maturity of non-strippable bonds usually do not coincide with the dates of maturity of STRIPS. The spot rates for non-strippable bonds are computed by interpolation. The spot rates are used to replicate the non-strippable bonds by three methods.

B.2.1 Average Method

Two DMD values are positive out of 34 DMD values in the case of non-strippable bonds, as measured by the average method and none of the positive values are significant at a confidence level of 5%. The results are displayed in Table III.

The BMD values for non-strippable bonds by the average method are documented in Table V. The BMD values for 10 bonds are positive and 8 of these are significant at a confidence level of 5%.

B.2.2 Stripping Method

The DMD values are positive for 15 values, and positive and significant for non-strippable bonds for 5 values, as measured by the stripping method. These DMD values are

presented in Table VIII.

The BMD values, as measured by the stripping method are presented in Table X. Thirty-three BMD values are positive and 25 of these are significantly different from zero at 5% level of significance.

B.2.3 Reconstitution Method

All the DMD values, presented in Table XV, are negative for the non-strippable bonds, as measured by the reconstitution method. The BMD values, as measured by the reconstitution method, are negative for most bonds. Only 5 of the BMD values are positive and significantly different from zero at 5% level of significance.

B.2.4 Overall Mean of Price Differences for the Entire Sample of Non-Strippable Bonds

The OMD values for all non-strippable bonds are negative and significantly different from zero at 5% level of significance as measured by the average and reconstitution method. The OMD values for non-strippable bonds as measured by the average and reconstitution methods are presented in Table I and Table XI respectively.

The OMD values for all non-strippable bonds by stripping are negative and not significantly different from zero at 5% level of significance. These values are presented in Table VI.

C. Discussion

C.1 Average Method

The DMD values are positive and significantly different from zero for most observations. The BMD values are negative for non-strippable bonds (Table IX). The OMD value is positive and significant for strippable bonds (Table I). The OMD value is negative for non-strippable bonds (Table I). The findings by the average method support the view that strippable bonds are priced higher than the non-strippable bonds.

Also, the strippable bonds are valued greater than the price estimated by the STRIPS' term structure. In contrast, the non-strippable bonds are priced below the level estimated by the STRIPS' term structure.

In Table XVII, the frequency distribution of arbitrage opportunities as measured by stripping and reconstitution are shown. The DMD values included in Table XVII are, however, measured by the average method. Approximately 34% of the observations either show profit opportunities by stripping or do not show profit by either method and the remaining show profit opportunities by reconstitution. In other words, about one-third of the bonds fall into each of the three categories. However, the distribution differs markedly for different bond types.

A substantial number of observations do not show profit opportunities either by stripping or reconstitution. Out of

the 43 strippable bonds included in the sample, 24 strippable bonds do not show positive BMD values by stripping or reconstitution. Out of 54 non-strippable bonds included in the sample, 14 bonds do not show positive BMD values by either method. Thus, more than one-third of all the bonds included in the sample are priced such that $Ad \approx P$. For these bonds the hypothesis that zero-tax clientele price the bond cannot be rejected.

In Table XVIII the statistics related to the distribution of DMD values across each category of bond are included. More than 50% of the strippable bonds do not show profit opportunities by either stripping or reconstitution (Table XVIII-A). More than 50% of the non-strippable bonds show profit opportunities by stripping (Table XVIII-B). Approximately 25% of the non-strippable bonds do not show profit opportunities by either method.

C.2 Stripping Method

The DMD values, as measured by the stripping method, are negative for strippable bonds (Table VII). Also the BMD values for strippable bonds of either type are negative (Table IX). Approximately 50% of BMD values for non-strippable bonds are positive.

The OMD values are negative by the stripping method for strippable and non strippable bonds (Table VI).

The stripping method does not consistently offer profitable opportunities for all strippable bonds. The non-

strippable bonds, however show a greater proportion of profit opportunities by stripping. The relative pricing differences are discussed later in this section.

C.3 Reconstitution

A majority of DMD values for strippable bonds are positive (Table XII). However, approximately 40% of the bonds show positive BMD values (Table XIV). The DMD and BMD values are negative for most non-strippable bonds, as measured by the reconstitution method (Tables XIII and XV).

The empirical evidence suggests that reconstitution would not be a profitable strategy for non-strippable bonds, if they were eligible for stripping/reconstitution. It is also found that strippable bonds are priced higher relative to the price set by the pre-tax term structure based on STRIPS' prices.

The results are discussed below within the context of the pricing hypotheses developed in Chapter IV.

D. Explanation of Pricing Differences

The OMD values for all the three types of bonds are presented in Table I, as measured by the average method. Let P define an $N \times 1$ vector of prices, with P_j ($j=1,2,\dots,N$) denoting the price of bond j . Let A define an $N \times T$ matrix of cash flows, with A_{jt} denoting the cash flow of security j , on date t , $t \in \{1,T\}$. Let d denote a $T \times 1$ vector of discount rates.

The OMD value, as measured by the average method is defined as $P - Ad$. The average method ignores bid-ask spreads and transactions costs. The OMD value is the largest for reconstitutable bonds, and the OMD value is the smallest for non-strippable bonds. Let δ be defined as $Ad - P$.

Even with the inclusion of frictions in the form of bid-ask spreads and transactions costs, the OMD values are positive and significantly different from zero in the case of reconstitutable bonds, as measured by the reconstitution method (Table XIX). This implies that $P_{SR} > Ad$ where P_{SR} denotes the price of strippable/reconstitutable bonds. The relative pricing relationship appears to be: $P_{SR} > P_{NS}$, where P_{NS} denote the prices of non-strippable bonds.

The following sections discuss the effects on the value of δ under different hypotheses.

D.1 Tax Option Effect and Flexibility Penalty

Based on the tax option effect studied by C&I (1984) and Merton's (1973) theory of a portfolio of options, $Ad \geq P$ for all types of bonds. This is because each of the STRIPS provide flexibility to investors to realize capital gains and losses in the pursuit of an optimal trading policy. The value of such a tax option increases with maturity, since there will be more opportunities to take advantage of this option for longer maturity bonds.

When an investment in U.S. Treasury bonds is held in the form of STRIPS, it provides the investor with added

flexibility to optimize the cash flows on an after tax basis. The flexibility is in the form of selective marketability of the STRIPS for non-uniform shifts in term structure in an attempt to optimize the value of the investment. The flexibility of tax timing and selective marketability is not available for non-strippable bonds. In the absence of any other effects, the value of δ is positive and is positively related to maturity.

D.2 Eligibility effect: No Frictions

The eligibility to strip and reconstitute may create pricing differences. The non-strippable bonds do not possess eligibility to strip or reconstitute and the non-reconstitutible bonds do not possess the eligibility to reconstitute. This suggests that the price of a strippable bond (P_{SR}) is greater than the price of a non-strippable bond (P_{NR}), assuming other factors are constant. Since Ad is an equivalent pricing operator for all three types of bonds, it is expected that $\delta_{NS} < \delta_{SR}$ because $P_{SR} > P_{NS}$. No particular sign is predicted for δ .

The eligibility effect should be positively related to maturity, since there is a longer period during which an investor might take advantage of stripping/reconstitution. Therefore, the price of a strippable bond increases with respect to maturity, assuming all other factors constant. Therefore, δ_{SR} should be related to maturity; there is no predicted relationship for δ_{NS} .

D.3 Eligibility Effect: Frictions

The previous discussion was for the case of no frictions. Frictions increase with maturity. Thus, the value of δ with frictions is greater than the value of δ without frictions. Frictions also affect the price of strippable bonds with differing maturities differently because the cost of stripping and reconstitution increases with maturity. Thus, frictions have an effect opposite to the eligibility effect on the price of the strippable bonds. Frictions have a negative effect on the price of a strippable bond and the effect of frictions increases with maturity of the bond. Frictions tend to reduce the value of the realizable profit on stripping or reconstitution.

D.4 U.S. Treasury Bonds and Maturity Characteristics

The timing of the U.S. Treasury's introduction of stripping and reconstitution results in three distinct regions with respect to maturity and bond characteristics.

- (1) Maturity upto 1997 - Non-strippable bonds
- (2) 1995-2006 - Strippable bonds
- (4) 2015-2021 - Strippable bonds.

The non-strippable bonds included in the sample have the shortest maturities, with none maturing later than 1997. Stripping, but not reconstitution, of securities was initiated in 1985. Reconstitution was initiated in May 1987. Non-reconstitutable bonds issued between February 1985 and February 1987 have been classified reconstitutable

since May 1987.

Approximately 50% of the observations for strippable bonds show profit opportunities by reconstitution. The strippable bonds with maturity up to year 2001 typically show positive BMD values, as measured by the reconstitution method (Table XIV). The strippable bonds maturing after 2018 typically do not show positive BMD values.

In the case of strippable bonds with relatively shorter maturities $P > Ad$ (δ value < 0) and the strippable bonds with relatively longer maturities show $P < Ad$. The next sub-section discusses the joint effects of tax-option, eligibility, and frictions on the pricing of strippable and non-strippable bonds.

D.4.1 Price of a bond and seasoning effect

The price of a bond is also affected by the length of time a bond is outstanding. For example, a bond outstanding for five years is more seasoned than a bond outstanding for two years. As seasoning increases, the liquidity of a bond is expected to fall and hence the price of the bond. In other words, a bond issued in the year 1985 is more seasoned than a similar bond issued in the year 1989. The bond issued in the year 1989 has greater P relative to the bond issued in the year 1985, if seasoning effect alone exists. The more recently issued bond has greater liquidity and larger volume. The eligibility effect increases the price P of a bond and is positively related to maturity. The more

seasoned a bond is, the lower is its price due to lower liquidity. Although seasoning effect is expected for a short duration from the time of issuance of a bond, the results suggest possibility of seasoning for relatively longer duration.

D.5 Integrating the tax option effect, eligibility effect, seasoning effect and the effect of frictions

The mean OMD values for strippable bonds with relatively shorter maturities, as measured by the average method are greater than the corresponding mean OMD values for strippable bonds with relatively longer maturities.

This implies that the difference between P and Ad is larger for bonds with relatively shorter maturities. The value of P of strippable bonds is positively affected by the eligibility effect and negatively affected by frictions. The tax option effect on P is lower in magnitude than the combined tax options on the replicating portfolio.

In the case of strippable bonds with relatively shorter maturities, the tax option effect and the effect due to frictions is not as pronounced as in the case of strippable bonds with relatively longer maturities. In other words, the eligibility and the seasoning effects dominate the tax option effect and the effect of frictions for the strippable bonds with maturities prior to 2001.

The OMD values, as measured by the average method, are plotted against year of maturity in Figure III for

strippable bonds with maturity upto year 2001. The OMD values increase progressively for bonds with maturity upto year 2001. The value of P increases because eligibility effect is positively related to maturity. Also the strippable bond with maturity in year 2001 is less seasoned than the bond maturing in 1995. Hence, the price of the bond with maturity in 2001 is expected to be higher than the price of the bond maturing in 1995. Although a formal test is not conducted, figure III shows that price of a bond maturing in year 2001 is greater than the price of a bond maturing in year 1995.

The OMD values, as measured by the average method, for strippable bonds maturing between year 2015 and year 2021 are plotted against year of maturity in Figure IV. The OMD values are mostly negative. The OMD values increase with the maturity of the bonds. As the maturity increases, the value of P increases due to eligibility and seasoning effects. Although a formal test is not conducted, figure IV shows support for this observation.

In the case of strippable bonds with relatively longer maturities, the tax option effect and the effect of frictions dominate the eligibility effect. This may explain the value of Ad observed to be greater than P.

The non-strippable bonds do not possess the eligibility to strip. The tax option effect is smaller for the single bond than for the replicating portfolio, hence Ad

is greater than P . The tax option effect is positively related to maturity. This effect is small in magnitude because the non-strippable bonds have the shortest maturities among the three types of bonds.

E. Summary

This study of pricing of U. S. Treasury bonds shows significant price differences between the Strippable and Non-strippable bonds. Following are the major conclusions:

(1) Approximately 50% of the strippable bonds and 27% of the non-strippable bonds are priced such that $Ad = P$. This finding for a large set of bonds implies that the hypothesis that d is a pre-tax term structure cannot be rejected. This result is important because the stripping and reconstitution phenomena are able to drive away arbitrage possibilities. Stripping/ reconstitution enable estimation of a pre-tax term structure in a simple way.

(2) Despite the fact that no arbitrage is possible for 27% of the non-strippable bonds, the results show that the non-strippable bonds are priced on average such that $Ad \geq P$. This finding support the existence of tax option effects and "liquidity/ divisibility" penalty effects⁹.

(3) The pricing of strippable bonds is affected by the eligibility to strip/reconstitute and the costs introduced by frictions.

⁹ The result is not inconsistent with tax clienteles. However, the methodology cannot establish the relationship $A_{\tau}d_{\tau} = P$, so no conclusions with respect to clienteles can be drawn.

Chapter VII

Summary and Conclusions

This study of pricing of U. S. Treasury bonds shows significant price differences between the Strippable and Non-strippable bonds. Following are the major conclusions:

(1) Approximately 50% of the strippable bonds and 27% of the non-strippable bonds are priced such that $Ad = P$. This finding for a large set of bonds implies that the hypothesis that d is a pre-tax term structure cannot be rejected. This result is important because the stripping and reconstitution phenomena are able to drive away arbitrage possibilities. Stripping/ reconstitution enable estimation of a pre-tax term structure in a simple way.

(2) Despite the fact that no arbitrage is possible for 27% of the non-strippable bonds, the results show that the non-strippable bonds are priced on average such that $Ad \geq P$. This finding support the existence of tax option effects and "liquidity/ divisibility" penalty effects¹⁰.

(3) The pricing of strippable bonds is affected by the eligibility to strip/reconstitute and the costs introduced by frictions. The eligibility to strip increases the value of the strippable bonds.

¹⁰ The result is not inconsistent with tax clienteles. However, the methodology cannot establish the relationship $A_t d_t = P$, so no conclusions with respect to clienteles can be drawn.

The tax option effect and the effect of frictions increase the value of the cash flows Ad . Both the tax option effect and the effect of frictions increase with the maturity of the bond. Hence, $P-Ad$ is larger for strippable bonds with relatively shorter maturities. In the case of strippable bonds with relatively shorter maturities, the eligibility effect dominates the tax option effect and the reconstitution effect. Hence, $P \geq Ad$.

The results also show that $P_{NS} < P_{SR}$ because $(P-Ad)_{NS} < (P-Ad)_{SR}$. This is evidence in support of the eligibility effect. The eligibility to strip and reconstitute is valued in the market. The results also show that frictions erode much of the eligibility effect because the strippable bonds with shorter maturities have greater $P-Ad$ values relative to strippable bonds with longer maturities.

The strippable bonds are priced higher relative to prices set by the pre-tax term structure. This finding has policy implications for the U.S. Treasury. Stripping and reconstitution of bonds result in higher cash inflows at the time of issuance. If investors exercise the stripping and reconstitution eligibilities to maximize after-tax cash flows, the U.S. government may receive lower tax payments. If investors do not exercise the stripping and reconstitution eligibilities, the U.S. government receives the eligibility premium in the form of higher issue price of strippable securities.

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APPENDIX

Table I

Overall Mean Pricing Difference (OMD): Price of Underlying Bond - Replicating Portfolio of Strips by Average Method

Sample	No. of obser- vations	No. of Mean Diff- erences>0	Mean Diff- erence	Variance	T- Value	Probability
Strippable	1384	907	0.1679	0.1274	17.50	0.0001
Non-Strippable	1871	647	-0.0767	0.0851	-11.36	0.0001

Table II

Daily Mean Difference (DMD): Price of Underlying Bond - Replicating
Portfolio of Strips of Strippable Bonds by Average Method

Date of Sample	No.of obser- vations	No.of Mean Diff- erences>0	Mean Diff- erence	Variance	T- Value	Probability
1990/08/07	36	31	0.2512	0.0635	5.97	0.0001
1990/09/04	38	22	0.1997	0.1306	3.40	0.0016
1990/10/10	38	20	0.0646	0.0734	1.47	0.1499
1990/11/07	38	22	0.0844	0.0489	2.35	0.0241
1990/12/06	38	19	0.0248	0.0619	0.61	0.5429
1991/01/10	38	20	0.0774	0.1307	1.31	0.1952
1991/02/25	41	36	0.3235	0.1068	6.33	0.0001
1991/03/01	41	32	0.2092	0.1073	4.08	0.0002
1991/03/04	41	33	0.2721	0.1023	5.44	0.0001
1991/03/05	41	32	0.2628	0.1320	4.63	0.0001
1991/03/06	41	27	0.2016	0.1228	3.68	0.0007
1991/03/07	41	13	-0.1743	0.1613	-2.78	0.0083
1991/03/11	41	34	0.2916	0.1289	5.21	0.0001
1991/03/12	41	37	0.2962	0.1331	5.20	0.0001
1991/03/13	41	33	0.3376	0.1347	5.89	0.0001
1991/03/14	41	34	0.2746	0.1222	5.03	0.0001
1991/03/15	41	25	0.2106	0.1344	3.68	0.0007
1991/03/18	41	34	0.2701	0.1191	5.01	0.0001
1991/03/19	41	37	0.3309	0.1107	6.36	0.0001
1991/03/20	41	34	0.3027	0.1385	5.21	0.0001
1991/03/21	41	33	0.2681	0.1290	4.78	0.0001
1991/03/22	41	31	0.2934	0.1606	4.69	0.0001
1991/03/25	41	28	0.2437	0.1369	4.22	0.0001

Table II: (cont.)

Type of Bonds:Strippable Method:Average						
Date of Sample	No.of obser- vations	No.of Mean Diff- erences>0	Mean Diff- erence	Variance	T- Value	Probability
1991/03/26	41	34	0.2537	0.1249	4.60	0.0001
1991/03/27	41	22	0.1483	0.1520	2.44	0.0194
1991/03/28	41	19	0.0814	0.1333	1.43	0.1609
1991/04/08	41	28	0.1593	0.1040	3.16	0.0030
1991/05/20	42	26	0.1368	0.0859	3.02	0.0043
1991/06/20	42	20	0.0732	0.1006	1.49	0.1425
1991/07/05	42	24	0.1071	0.0828	2.41	0.0204
1991/08/22	42	14	-0.0477	0.0862	-1.05	0.2977
1991/09/23	43	25	0.1142	0.1021	2.34	0.0239
1991/10/23	43	15	-0.0047	0.1091	-0.09	0.9261
1991/11/12	43	13	-0.0272	0.0646	-0.70	0.4865

Table III

Daily Mean Difference (DMD): Price of Underlying Bond - Replicating Portfolio of Strips
of Non-Strippable Bonds by Average Method

Date of Sample	No. of obser- vations	No. of Mean Diff- erences > 0	Mean Diff- erence	Variance	T- Value	Probability
1990/08/07	55	25	0.0425	0.0270	1.92	0.0605
1990/09/04	55	24	-0.0659	0.2318	-1.01	0.3148
1990/10/10	55	25	-0.0655	0.2237	-1.03	0.3086
1990/11/07	55	26	0.0308	0.0157	1.82	0.0742
1990/12/06	55	17	-0.0498	0.0148	-3.04	0.0037
1991/01/10	55	14	-0.0503	0.0305	-2.14	0.0370
1991/02/25	57	21	-0.1087	0.1875	-1.89	0.0633
1991/03/01	57	17	-0.1399	0.0936	-3.45	0.0011
1991/03/04	57	24	-0.0465	0.1226	-1.00	0.3205
1991/03/05	57	25	-0.0538	0.1032	-1.27	0.2111
1991/03/06	57	26	-0.0477	0.0957	-1.16	0.2494
1991/03/07	57	20	-0.0943	0.0915	-2.35	0.0221
1991/03/11	57	23	-0.0476	0.0840	-1.24	0.2202
1991/03/12	57	26	-0.0258	0.0809	-0.68	0.4968
1991/03/13	57	25	-0.0208	0.0866	-0.53	0.5957
1991/03/14	57	35	-0.0389	0.1013	-0.93	0.3606
1991/03/15	57	20	-0.0568	0.0965	-1.38	0.1730
1991/03/18	57	25	-0.0401	0.0812	-1.06	0.2929
1991/03/19	57	19	-0.0246	0.0749	-0.68	0.5002
1991/03/20	57	19	-0.0771	0.0710	-2.18	0.0331

Table III: (cont.)

Type of Bonds:Non-Strippable Method:Average						
Date of Sample	No. of obser- vations	No. of Mean Diff- erences>0	Mean Diff- rence	Variance	T- Value	Probability
1991/03/21	57	17	-0.1120	0.0696	-3.21	0.0022
1991/03/22	57	18	-0.0970	0.0690	-2.79	0.0072
1991/03/25	57	19	-0.0672	0.0640	-2.01	0.0490
1991/03/26	57	18	-0.0729	0.0593	-2.26	0.0277
1991/03/27	57	15	-0.1401	0.0487	-4.79	0.0001
1991/03/28	57	8	-0.2055	0.0375	-8.00	0.0001
1991/04/08	55	9	-0.1694	0.0298	-7.28	0.0001
1991/05/20	53	15	-0.1023	0.0964	-2.39	0.0201
1991/06/20	53	17	-0.1076	0.1786	-1.85	0.0695
1991/07/05	52	12	-0.1469	0.0612	-4.28	0.0001
1991/08/22	48	11	-0.2177	0.1048	-4.66	0.0001
1991/09/23	48	9	-0.1436	0.0364	-5.21	0.0001
1991/10/23	46	8	-0.0929	0.0159	-4.99	0.0001
1991/11/12	46	12	-0.0621	0.0132	-3.66	0.0007

Table IV

Bond Mean Difference (BMD): Price of Underlying Bond - Replicating Portfolio of Strips of Strippable Bonds by Average Method

Month and Year of Maturity	Coupon (%)	No. of Obs- vations	No. of Mean Diff- erences > 0	Mean Diff- erence	Variance	T- Value	Probability
May95	10.500	34	9	-0.1245	0.0089	-7.69	0.0001
Aug95	10.500	34	9	-0.0728	0.0131	-3.71	0.0008
Nov95	9.500	34	4	-0.2519	0.0236	-9.57	0.0001
Feb96	8.875	34	28	0.1746	0.0238	6.59	0.0001
May96	7.375	34	28	0.1478	0.0184	6.34	0.0001
Nov96	7.250	34	18	0.0052	0.0256	0.19	0.8518
May97	8.500	34	29	0.1847	0.0221	7.23	0.0001
Aug97	8.625	34	32	0.2662	0.0248	9.85	0.0001
Nov97	8.875	34	23	0.0596	0.0389	1.76	0.0873
Feb98	8.125	34	34	0.4289	0.0239	16.16	0.0001
May98	9.000	34	30	0.1932	0.0246	7.76	0.0001
Aug98	9.250	34	5	0.2187	0.0309	7.26	0.0001
Nov98	8.875	34	22	0.0490	0.0306	1.63	0.1121
Feb99	8.875	34	34	0.3699	0.0187	15.74	0.0001
May99	9.125	34	32	0.2429	0.0181	10.52	0.0001
Aug99	8.000	34	34	0.5952	0.0306	19.84	0.0001
Nov99	7.875	34	34	0.4508	0.0360	13.85	0.0001
Feb00	8.500	34	33	0.5296	0.0502	13.78	0.0001
May00	8.500	34	32	0.3651	0.0417	10.43	0.0001
Aug00	8.750	33	31	0.4941	0.0569	11.90	0.0001

Table IV: (cont.)

Type of Bonds: Strippable
Method: Average

Month and Year of Maturity	Coupon (%)	No. of Obs- vations	No. of Mean Diff- erences > 0	Mean Diff- erence	Variance	T- Value	Probability
Nov00	8.500	28	26	0.4477	0.0702	8.94	0.0001
Feb01	7.750	28	28	1.1038	0.0919	19.26	0.0001
May05	12.000	34	6	-0.1681	0.0426	-4.75	0.0001
Aug05	10.750	34	17	-0.0648	0.0470	-1.74	0.0909
Feb06	9.375	34	34	0.9371	0.0376	28.19	0.0001
Feb15	11.250	34	3	-0.1540	0.0274	-5.42	0.0001
Aug15	10.625	34	5	-0.0908	0.0449	-2.49	0.0176
Nov15	9.875	34	1	-0.2199	0.0305	-7.34	0.0001
Aug16	9.250	34	13	-0.0540	0.0169	-2.42	0.0211
May16	7.250	34	2	0.1968	0.0202	8.08	0.0001
Nov16	7.500	34	23	0.0530	0.0196	2.21	0.0344
May17	8.750	34	16	-0.0347	0.0224	-1.35	0.1858
Aug17	8.875	34	19	0.0175	0.0206	0.71	0.4799
May18	8.000	34	14	-0.0451	0.0296	-1.53	0.1360
Nov18	9.000	34	17	0.0241	0.0590	0.58	0.5660
Feb19	8.875	34	17	-0.0035	0.0237	-0.13	0.8969
Aug19	8.125	34	14	-0.0029	0.0198	-0.10	0.9247
Feb20	8.500	34	18	-0.0039	0.0264	-0.14	0.8910
May20	8.750	34	19	0.0167	0.0424	0.48	0.6394
Aug20	8.750	33	14	-0.0317	0.0332	-1.00	0.3247
Feb21	7.785	28	28	1.0628	0.0304	32.21	0.0001
May21	8.125	7	2	-0.0494	0.0293	-0.76	0.4740

Table IV: (cont.)

Type of Bonds: Strippable Method: Average						
Month and Year of Maturity	Coupon (%)	No. of Obser- vations	No. of Mean Diff- erences > 0	Mean Diff- erence	Variance	T- Value Probability
Aug21	8.125	3	1	0.0680	0.3263	0.20 0.8558

Table V

Bond Mean Difference (BMD): Price of Underlying Bond - Replicating Portfolio of Strips of Non-Strippable Bonds by Average Method

Month and Year of Maturity	Coupon (%)	No. of observ- ations	No. of Mean Diff- erences > 0	Mean Diff- erence	Variance	T- Value	Probability
Mar91	9.750	26	0	-0.2520	0.0368	-6.69	0.0001
Mar91	6.750	26	1	-0.1941	0.0291	-5.80	0.0001
Apr91	9.250	27	1	-0.5141	0.1323	-7.34	0.0001
Apr91	12.375	27	1	-0.4582	0.1689	-5.68	0.0001
May91	8.750	27	2	-0.0613	0.0095	-3.26	0.0031
May91	14.500	27	2	-0.8569	0.6228	-5.64	0.0001
May91	8.125	27	1	-0.6496	0.2344	-6.97	0.0001
Jun91	8.250	29	2	-0.0874	0.0117	-4.34	0.0002
Jul91	13.750	30	2	-0.1944	0.1498	-2.75	0.0101
Aug91	7.500	30	9	-0.1114	0.0612	-2.53	0.0173
Aug91	8.750	30	4	-0.1382	0.0603	-3.08	0.0045
Aug91	14.875	30	14	-0.0776	0.0858	-1.45	0.1575
Sep91	9.125	32	1	-0.1331	0.0087	-8.05	0.0001
Oct91	12.250	32	1	-0.1966	0.0181	-8.25	0.0001
Nov91	6.500	34	1	-0.2302	0.0385	-6.84	0.0001
Nov91	8.500	34	1	-0.2090	0.0387	-6.20	0.0001
Nov91	14.250	34	1	-0.2100	0.0642	-4.83	0.0001
Dec91	8.250	34	3	-0.0661	0.0033	-6.75	0.0001
Jan92	11.625	34	4	-0.0789	0.0042	-7.07	0.0001
Feb92	6.625	34	4	-0.0636	0.0039	-5.93	0.0001
Mar92	7.875	34	4	0.0083	0.1097	0.15	0.8841
Apr92	11.750	34	1	-0.1782	0.0103	-10.47	0.0001
May92	6.625	34	0	-0.1332	0.0081	-8.60	0.0001

Table V: (cont.)

Type of Bonds: Non-Strippable Method: Average							
Month and Year of Maturity	Coupon (%)	No. of observ- ations	No. of Mean Diff- erences > 0	Mean Diff- erence	Variance	T- Value	Probability
May92	13.750	34	1	-0.2698	0.0222	-10.57	0.0001
Jun92	8.250	34	5	-0.0813	0.0078	-5.37	0.0001
Jul92	10.375	34	1	-0.1369	0.0056	-10.71	0.0001
Aug92	7.250	34	26	0.0846	0.0145	4.09	0.0003
Sep92	8.750	34	7	-0.0715	0.0075	-4.82	0.0001
Oct92	9.750	34	3	-0.1972	0.0179	-8.57	0.0001
Nov92	8.375	34	2	-0.2459	0.0226	-9.53	0.0001
Nov92	10.500	34	1	-0.2824	0.0262	-10.17	0.0001
Dec92	9.125	34	5	-0.1121	0.0097	-6.65	0.0001
Jan93	8.750	34	4	-0.0934	0.0070	-6.54	0.0001
Feb93	8.250	34	13	-0.0407	0.0048	-3.42	0.0017
Feb93	10.875	34	9	-0.0604	0.0069	-4.24	0.0002
Mar93	9.625	34	7	-0.0884	0.0109	-4.94	0.0001
Apr93	7.375	34	21	-0.0059	0.0089	-0.36	0.7206
Jul93	7.250	34	23	-0.0552	0.0149	-2.63	0.0219
Aug93	8.750	34	15	-0.0172	0.0121	-0.91	0.3692
Oct93	7.125	34	7	-0.0618	0.0096	-3.68	0.0008
Nov93	9.000	34	3	-0.2282	0.0270	-8.09	0.0001
Jan94	7.000	34	24	-0.0769	0.0127	-3.98	0.0004
Feb94	8.875	34	27	0.1232	0.0192	5.17	0.0001

Table V: (cont.)

Type of Bonds:Non-Strippable Method:Average							
Month and Year of Maturity	Coupon (%)	No. of observ- ations	No. of Mean Diff- erences>0	Mean Diff- erence	Variance	T- Value	Probability
Apr94	7.000	34	28	0.2025	0.0215	8.04	0.0001
Jul94	8.000	34	29	0.1512	0.2145	1.90	0.0657
Oct94	9.500	34	6	-0.1181	0.0202	-4.85	0.0001
Jan95	8.625	34	27	0.0413	0.0555	1.02	0.3136
Apr95	8.375	34	26	0.0868	0.0509	2.24	0.0318
Jul95	8.875	34	25	0.0868	0.0509	2.24	0.0318
Oct95	8.625	34	6	-0.0635	0.0476	-1.70	0.0992
Jul96	7.875	34	32	0.2011	0.0218	7.94	0.0001
Oct96	8.000	34	9	-0.0914	0.0365	-2.79	0.0087
Jan97	8.000	34	31	0.2241	0.0486	5.93	0.0001
Apr97	8.500	34	31	0.2072	0.0284	7.16	0.0001
Jul97	8.500	34	33	0.2165	0.0272	7.65	0.0001

Table VI

Overall Mean Pricing Difference (OMD): Price of Underlying Bond - Replicating Portfolio of Strips by Stripping Method

Sample	No. of obser- vations	No. of Mean Diff- erence>0	Mean Diff- erence	Variance	T- Value	Probability
Strippable	1384	152	-0.3550	0.1208	-37.99	0.0001
Non-Strippable	1871	985	-0.0005	0.0960	-0.07	0.9464

Table VII

Daily Mean Difference (DMD): Price of Underlying Bond - Replicating Portfolio of Strips of Strippable Bonds by Stripping

Date of Sample	No. of observations	No. of Mean Diff-erences > 0	Mean Diff-erence	Variance	T-Value	Probability
1990/08/07	36	1	-0.4328	0.0530	-11.21	0.0001
1990/09/04	38	4	-0.3832	0.1115	-7.07	0.0001
1990/10/10	38	8	-0.2401	0.0600	-6.04	0.0001
1990/11/07	38	3	-0.2693	0.0378	-8.53	0.0001
1990/12/06	38	6	-0.2136	0.0502	-5.87	0.0001
1991/01/10	38	7	-0.2645	0.1152	-4.80	0.0001
1991/02/25	41	1	-0.5140	0.1020	-10.30	0.0001
1991/03/01	41	3	-0.3957	0.1041	-7.85	0.0001
1991/03/04	41	1	-0.4581	0.0966	-9.44	0.0001
1991/03/05	41	2	-0.4472	0.1205	-8.25	0.0001
1991/03/06	41	1	-0.3763	0.1159	-7.08	0.0001
1991/03/07	41	23	-0.0050	0.1430	-0.08	0.9324
1991/03/11	41	1	-0.4745	0.1199	-8.77	0.0001
1991/03/12	41	1	-0.5082	0.1220	-9.31	0.0001
1991/03/13	41	1	-0.5204	0.1244	-9.44	0.0001
1991/03/14	41	1	-0.4614	0.1134	-8.77	0.0001
1991/03/15	41	5	-0.3605	0.1351	-6.28	0.0001
1991/03/18	41	1	-0.4569	0.1103	-8.81	0.0001
1991/03/19	41	1	-0.5190	0.1058	-10.21	0.0001
1991/03/20	41	2	-0.4863	0.1315	-8.58	0.0001
1991/03/21	41	2	-0.4633	0.1214	-8.52	0.0001
1991/03/22	41	1	-0.4761	0.1337	-8.34	0.0001
1991/03/25	41	1	-0.4259	0.1260	-7.68	0.0001
1991/03/26	41	1	-0.4374	0.1175	-8.17	0.0001

Table VII: (cont.)

Type of Bonds:Strippable Method:Stripping						
Date of Sample	No. of obser- vations	No. of Mean Diff erences>0	Mean Diff- erence	Variance	T- Value	Probability
1991/03/27	41	4	-0.3518	0.1773	-5.35	0.0001
1991/03/28	41	7	-0.2582	0.1250	-4.68	0.0001
1991/04/08	41	3	-0.3501	0.1018	-7.02	0.0001
1991/05/20	42	4	-0.2922	0.0860	-6.45	0.0001
1991/06/20	42	9	-0.2262	0.0969	-4.70	0.0001
1991/07/05	42	4	-0.2615	0.0848	-5.82	0.0001
1991/08/22	42	10	-0.1518	0.0817	-3.44	0.0013
1991/09/23	43	7	-0.2817	0.1123	-5.51	0.0001
1991/10/23	43	15	-0.1821	0.1089	-3.62	0.0008
1991/11/12	43	11	-0.1385	0.0700	-3.43	0.0014

Table VIII

Daily Mean Difference (DMD): Price of Underlying Bond - Replicating Portfolio of Strips of Non-Strippable Bonds by Stripping Method

Date of Sample	No. of observations	No. of Mean Differences > 0	Mean Difference	Variance	T-Value	Probability
1990/08/07	55	12	-0.1311	0.0338	-5.28	0.0001
1990/09/04	55	20	-0.0223	0.2551	-0.33	0.7444
1990/10/10	55	22	-0.0256	0.2367	-0.39	0.6983
1990/11/07	55	18	-0.1149	0.0236	-5.54	0.0001
1990/12/06	55	31	-0.0344	0.0216	-1.74	0.0880
1991/01/10	55	32	-0.0255	0.0396	-0.95	0.3455
1991/02/25	57	32	0.0319	0.2067	0.53	0.5982
1991/03/01	57	34	0.0662	0.1038	1.55	0.1266
1991/03/04	57	28	-0.0320	0.1371	-0.65	0.5157
1991/03/05	57	26	-0.0330	0.1155	-0.73	0.4660
1991/03/06	57	25	-0.0292	0.1068	-0.67	0.5033
1991/03/07	57	32	0.0137	0.1013	0.33	0.7461
1991/03/11	57	26	-0.0272	0.0963	-0.66	0.5116
1991/03/12	57	21	-0.0515	0.0935	-1.27	0.2089
1991/03/13	57	22	-0.0533	0.0998	-1.28	0.2072
1991/03/14	57	26	-0.0195	0.0937	-0.48	0.6324
1991/03/15	57	30	-0.0239	0.1359	-0.49	0.6266
1991/03/18	57	26	-0.0396	0.0943	-0.97	0.3343
1991/03/19	57	22	-0.0760	0.0926	-1.88	0.0647
1991/03/20	57	31	0.0000	0.0826	0.00	0.9995

Table VIII:(cont.)

Type of Bonds:Non-Strippable Method:Stripping						
Date of Sample	No. of obser- vations	No. of Mean Diff- erences>0	Mean Diff- rence	Variance	T- Value	Probability
1991/03/21	57	38	0.0362	0.0823	0.95	0.3452
1991/03/22	57	35	0.0187	0.0818	0.49	0.6229
1991/03/25	57	32	-0.0076	0.0758	-0.21	0.8365
1991/03/26	57	32	-0.0019	0.0705	-0.06	0.9563
1991/03/27	57	38	0.0647	0.0575	2.03	0.0462
1991/03/28	57	41	0.1302	0.0439	4.69	0.0001
1991/04/08	55	31	0.0122	0.0469	0.42	0.6784
1991/05/20	53	30	0.0347	0.1060	0.78	0.4413
1991/06/20	53	32	0.0384	0.1868	0.65	0.5203
1991/07/05	52	33	0.0744	0.0688	2.05	0.0460
1991/08/22	48	35	0.1485	0.1140	3.05	0.0038
1991/09/23	48	36	0.0764	0.0413	2.60	0.0123
1991/10/23	46	30	0.0232	0.0194	1.12	0.2648
1991/11/12	46	26	0.0035	0.0096	0.24	0.8080

Table IX

Bond Mean Difference (BMD): Price of Underlying Bond - Replicating Portfolio of Strips of Strippable Bonds by Stripping Method

Month and Year of Maturity	Coupon (%)	No. of Observations	No. of Mean Differences > 0	Mean Difference	Variance	T- Value	Probability
May95	11.250	34	12	-0.0031	0.0100	-0.18	0.8590
Aug95	10.500	34	11	-0.5231	0.0139	-2.58	0.5947
Nov95	9.500	34	29	0.1225	0.0234	4.67	0.0001
Feb96	8.875	34	2	-0.3012	0.0267	-10.76	0.0001
May96	7.375	34	2	-0.2798	0.0199	-11.56	0.0001
Nov96	7.250	34	8	-0.1489	0.0291	-5.09	0.0001
May97	8.500	34	0	-0.3247	0.0231	-12.46	0.0001
Aug97	8.625	34	0	-0.4108	0.0254	-15.02	0.0001
Nov97	8.875	34	7	-0.2085	0.0392	-6.14	0.0001
Feb98	8.125	34	0	-0.5771	0.0238	-21.81	0.0001
May98	9.000	34	1	-0.3488	0.0258	-12.67	0.0001
Aug98	9.250	34	2	-0.3753	0.0315	-12.33	0.0001
Nov98	8.875	34	5	-0.2061	0.0317	-6.75	0.0001
Feb99	8.875	34	0	-0.5269	0.0184	-22.62	0.0001
May99	9.125	34	0	-0.4065	0.0178	-17.77	0.0001
Aug99	8.000	34	0	-0.7390	0.0178	-32.28	0.0001
Nov99	7.875	34	0	-0.5905	0.0574	-14.37	0.0001
Feb00	8.500	34	0	-0.7083	0.0753	-15.05	0.0001
May00	8.500	34	0	-0.5304	0.0418	-15.12	0.0001
Aug00	8.750	33	0	-0.6381	0.0537	-15.81	0.0001

Table IX: (cont.)

Type of Bonds:Strippable Method:Stripping							
Month and Year of Maturity	Coupon (%)	No. of Obser- vations	No. of Mean Diff- erences>0	Mean Diff- erence	Variance	T- Value	Probability
Nov00	8.500	28	1	-0.5926	0.0669	-12.13	0.0001
Feb01	7.750	28	0	-1.2464	0.0894	-22.06	0.0001
May05	12.000	34	14	-0.0605	0.0401	-1.76	0.0875
Aug05	10.750	34	5	-0.1553	0.0476	-4.14	0.0002
Feb06	9.375	34	0	-1.1481	0.0376	-34.53	0.0001
Feb15	11.250	34	9	-0.1116	0.0277	-3.91	0.0004
Aug15	10.625	34	6	-0.1720	0.6185	-4.03	0.0003
Nov15	9.875	34	6	-0.0415	0.0226	-1.61	0.1167
Aug16	9.250	34	2	-0.1899	0.0167	-8.56	0.0001
May16	7.250	34	1	-0.4118	0.0234	-15.70	0.0001
Nov16	7.500	34	1	-0.2721	0.0235	-10.36	0.0001
May17	8.750	34	3	-0.1991	0.0250	-7.34	0.0001
Aug17	8.875	34	2	-0.2505	0.0223	-9.78	0.0001
May18	8.000	34	1	-0.1947	0.0303	-6.52	0.0001
Nov18	9.000	34	1	-0.2641	0.0549	-6.57	0.0001
Feb19	8.875	34	1	-0.2357	0.0241	-8.86	0.0001
Aug19	8.125	34	1	-0.2272	0.0204	-9.28	0.0001
Feb20	8.500	34	1	-0.2311	0.0269	-8.21	0.0002
May20	8.750	34	3	-0.2557	0.0434	-7.16	0.0069
Aug20	8.750	33	4	-0.1860	0.0349	-5.72	0.0001
Feb21	7.785	28	0	-1.2669	0.0271	-40.72	0.0001

Table IX: (cont.)

Type of Bonds: Strippable Method: Stripping							
Month and Year of Maturity	Coupon (%)	No. of Obser- vations	No. of Mean Diff- erences > 0	Mean Diff- erence	Variance	T- Value	Probability
May21	8.125	7	1	-0.1498	0.0303	-2.27	0.0631
Aug21	8.125	3	2	-0.2866	0.3233	-0.87	0.4746

Table X

Bond Mean Difference (BMD): Price of Underlying Bond - Replicating Portfolio of Strips of Non-Strippable Bonds by Stripping Method

Month and Year of Maturity	Coupon (%)	No. of obser- vations	No. of Mean Diff- erences>0	Mean Diff- erence	Variance	T- Value	Probability
Mar91	9.750	26	26	0.2518	0.0498	5.75	0.0001
Mar91	6.750	26	26	0.5219	0.0768	9.79	0.0001
Apr91	9.250	27	26	0.5219	0.0769	9.79	0.0001
Apr91	12.375	27	27	0.4421	0.1293	6.39	0.0001
May91	8.750	27	22	0.0040	0.0298	0.12	0.9047
May91	14.500	27	27	0.8458	0.4991	6.22	0.0001
May91	8.125	27	25	0.6701	0.1428	9.22	0.0001
Jun91	8.250	29	3	0.0368	0.0187	1.45	0.1581
Jul91	13.750	30	26	0.1474	0.1542	2.06	0.0490
Aug91	7.500	30	16	0.0675	0.0623	1.48	0.1496
Aug91	8.750	30	12	0.0916	0.0618	2.02	0.0529
Aug91	14.875	30	26	0.0027	0.0926	0.05	0.9615
Sep91	9.125	32	31	0.0919	0.0069	6.25	0.0001
Oct91	12.250	32	31	0.1604	0.0133	7.86	0.0001
Nov91	6.500	34	33	0.1722	0.0342	5.43	0.0001
Nov91	8.500	34	33	0.1958	0.0329	6.30	0.0001
Nov91	14.250	34	29	0.1670	0.0489	4.41	0.0001
Dec91	8.250	34	21	0.0351	0.0094	2.11	0.0424
Jan92	11.625	34	24	0.0294	0.0036	2.86	0.0074
Feb92	6.625	34	22	0.0143	0.0035	1.40	0.1696
Mar92	7.875	34	23	-0.0608	0.1111	-1.06	0.2958

Table X: (cont.)

Type of Bonds:Non-Strippable Method:Stripping							
Month and Year of Maturity	Coupon (%)	No. of obser- vations	No. of Mean Diff- erences>0	Mean Diff- erence	Variance	T- Value	Probability
Apr92	11.750	34	31	0.1334	0.0056	10.40	0.0001
May92	6.625	34	30	0.0861	0.0051	7.02	0.0001
May92	13.750	34	33	0.2301	0.0109	12.87	0.0001
Jun92	8.250	34	22	0.0140	0.0087	0.87	0.3889
Jul92	10.375	34	32	0.0840	0.0031	8.77	0.0001
Aug92	7.250	34	2	-0.1890	0.0126	-9.80	0.0001
Sep92	8.750	34	21	0.0087	0.0082	0.56	0.5813
Oct92	9.750	34	30	0.1443	0.0143	7.04	0.0001
Nov92	8.375	34	30	0.1945	0.0173	8.63	0.0001
Nov92	10.500	34	33	0.2353	0.0168	10.60	0.0001
Dec92	9.125	34	6	0.0515	0.0095	3.09	0.0041
Jan93	8.750	34	25	0.0303	0.0068	2.14	0.0401
Feb93	8.250	34	22	-0.0252	0.0048	-2.12	0.0413
Feb93	10.875	34	10	-0.0331	0.0082	-2.13	0.0405
Mar93	9.625	34	12	-0.0038	0.0110	-0.21	0.8326
Apr93	7.375	34	8	-0.0952	0.0102	-5.51	0.0001
Jul93	7.250	34	3	-0.1790	0.0121	-9.48	0.0001
Aug93	8.750	34	9	-0.0639	0.0128	-3.29	0.0024
Oct93	7.125	34	10	-0.0371	0.0098	-2.18	0.0368
Nov93	9.000	34	30	0.1558	0.0239	5.87	0.0001
Jan94	7.000	34	3	-0.1891	0.0131	-9.61	0.0001
Feb94	8.875	34	3	-0.2414	0.0186	-10.32	0.0001

Table X: (cont.)

Type of Bonds:Non-Strippable Method:Stripping							
Month and Year of Maturity	Coupon (%)	No. of obser- vations	No. of Mean Diff- erences>0	Mean Diff- erence	Variance	T- Value	Probability
Apr94	7.000	34	1	-0.3283	0.0160	-15.13	0.0001
Jul94	8.000	34	4	-0.2972	0.2451	-3.50	0.0014
Oct94	9.500	34	17	0.0099	0.0209	0.40	0.6914
Jan95	8.625	34	2	-0.1652	0.0591	-3.96	0.0004
Apr95	8.375	34	2	-0.2421	0.0116	-13.07	0.0001
Jul95	8.875	16	5	-0.1878	0.0138	-9.33	0.0001
Oct95	8.625	34	11	-0.0592	0.0488	-1.56	0.1276
Oct96	8.000	34	30	-0.2258	0.0389	-6.68	0.0104
Jan97	8.000	34	34	-0.3825	0.0390	-11.29	0.0001
Apr97	8.500	34	34	-0.3570	0.0200	-14.92	0.0001
Jul97	8.500	34	34	-0.3546	0.0171	-15.59	0.0001

Table XI

Overall Mean Pricing Difference (OMD): Price of Underlying Bond - Replicating Portfolio of Strips by Reconstitution Method

Sample	No. of observ- ations	No. of Mean Diff- erences > 0	Mean Diff- erence	Variance	T- Value	Probability
Strippable	1384	588	-0.0041	0.1363	-0.41	0.6770
Non-Strippable	1871	427	-0.1477	0.0788	22.75	0.0001

Table XII

Daily Mean Difference (DMD): Price of Underlying Bond - Replicating Portfolio of Strips of Strippable Bonds by Reconstitution Method

Date of Sample	No. of observations	No. of Mean Differences > 0	Mean Difference	Variance	T-Value	Probability
1990/08/07	36	18	0.0696	0.0765	1.51	0.1399
1990/09/04	38	18	0.0162	0.1524	0.25	0.7991
1990/10/10	38	18	-0.1108	0.0894	-2.28	0.0282
1990/11/07	38	15	-0.0972	0.0609	-2.42	0.0201
1990/12/06	38	11	-0.1630	0.0779	-3.62	0.0009
1991/01/10	41	18	-0.1097	0.1510	-1.74	0.0899
1991/02/25	41	27	0.1331	0.1157	2.50	0.0164
1991/03/01	41	16	0.0228	0.1158	0.42	0.6701
1991/03/04	41	22	0.0862	0.1119	1.65	0.1070
1991/03/05	41	18	0.0785	0.1481	1.31	0.1988
1991/03/06	41	19	0.0268	0.1324	0.47	0.6397
1991/03/07	41	8	-0.3536	0.1825	-5.29	0.0001
1991/03/11	41	21	0.1087	0.1415	1.85	0.0715
1991/03/12	41	21	0.0843	0.1810	1.27	0.2104
1991/03/13	41	22	0.1549	0.1489	2.57	0.0140
1991/03/14	41	19	0.8776	0.1349	1.53	0.1339
1991/03/15	41	19	0.0607	0.1591	0.97	0.3355
1991/03/18	41	19	0.0833	0.1326	1.46	0.1507
1991/03/19	41	23	0.1429	0.1192	2.64	0.0115
1991/03/20	41	21	0.1191	0.1496	1.97	0.0556
1991/03/21	41	21	0.0730	0.1433	1.23	0.2240
1991/03/22	41	19	0.1106	0.2082	1.55	0.1284
1991/03/25	41	19	0.0617	0.1518	1.01	0.3166

Table XII: (cont.)

Type of Bonds:Strippable Method:Reconstitution						
Date of Sample	No. of obser- vations	No. of Mean Diff- erences>0	Mean Diff- erence	Variance	T- Value	Probability
1991/03/26	41	19	0.0701	0.1362	1.22	0.2307
1991/03/27	41	12	-0.0552	0.1439	-0.93	0.3574
1991/03/28	41	11	-0.0953	0.1448	-1.60	0.1164
1991/04/08	41	14	-0.0310	0.1113	-0.60	0.5470
1991/05/20	42	15	-0.0270	0.0907	-0.59	0.5565
1991/06/20	42	14	-0.0880	0.1091	-1.73	0.0894
1991/07/05	42	12	-0.0560	0.0859	-1.24	0.2205
1991/08/22	42	10	-0.1740	0.0943	-3.67	0.0007
1991/09/23	43	13	-0.0530	0.0979	-1.11	0.2704
1991/10/23	43	11	-0.1180	0.1119	-2.32	0.0247
1991/11/12	43	6	-0.1920	0.0649	-4.9630	0.0001

Table XIII

Daily Mean Difference (DMD): Price of Underlying Bond - Replicating Portfolio of Strips of Non-Strippable Bonds by Reconstitution Method

Date of Sample	No. of observations	No. of Mean Differences > 0	Mean Difference	Variance	T-Value	Probability
1990/08/07	55	15	-0.0539	0.0220	-2.70	0.0093
1990/09/04	55	26	-0.0709	0.2425	-1.07	0.2904
1990/10/10	55	18	-0.1488	0.2125	-2.39	0.0202
1990/11/07	55	12	-0.0534	0.0098	-4.01	0.0002
1990/12/06	55	6	-0.1341	0.0099	-9.98	0.0001
1991/01/10	55	9	-0.1263	0.2384	-6.07	0.0001
1991/02/25	57	16	-0.1775	0.1706	-3.25	0.0020
1991/03/01	57	12	-0.2217	0.0810	-5.88	0.0001
1991/03/04	57	17	-0.1173	0.1104	-2.67	0.0100
1991/03/05	57	16	-0.1329	0.1029	-3.13	0.0028
1991/03/06	57	15	-0.1167	0.0871	-2.99	0.0042
1991/03/07	57	20	-0.1241	0.0857	-3.20	0.0022
1991/03/11	57	16	-0.1145	0.0737	-3.18	0.0024
1991/03/12	57	18	-0.0952	0.0703	-2.70	0.0089
1991/03/13	57	19	-0.0950	0.7587	-2.60	0.0118
1991/03/14	57	18	-0.0972	0.1381	-1.97	0.0533
1991/03/15	57	18	-0.1217	0.0791	-3.27	0.0019
1991/03/18	57	18	-0.1120	0.0701	-3.19	0.0023
1991/03/19	57	15	-0.1251	0.0662	-3.67	0.0005
1991/03/20	57	13	-0.1542	0.0613	-4.70	0.0001

Table XIII: (cont.)

Type of Bonds:Non-Strippable Method:Reconstitution						
Date of Sample	No. of obser- vations	No. of Mean Diff- erences>0	Mean Diff- rence	Variance	T- Value	Probability
1991/03/21	57	13	-0.1800	0.0590	-5.59	0.0001
1991/03/22	57	13	-0.1754	0.0584	-5.48	0.0001
1991/03/25	57	13	-0.1420	0.0543	-4.60	0.0001
1991/03/26	57	6	-0.1477	0.0503	-4.97	0.0001
1991/03/27	57	1	-0.2076	0.0418	-7.66	0.0001
1991/03/28	57	1	-0.2807	0.0332	-11.62	0.0001
1991/04/08	55	9	-0.1773	0.0297	-7.62	0.0001
1991/05/20	53	13	-0.1698	0.0878	-4.17	0.0001
1991/06/20	53	11	-0.1767	0.1711	-3.11	0.0026
1991/07/05	52	5	-0.2194	0.0550	-6.74	0.0001
1991/08/22	48	5	-0.2868	0.0967	-6.39	0.0001
1991/09/23	48	3	-0.2108	0.0327	-8.08	0.0001
1991/10/23	46	4	-0.1625	0.0137	-9.42	0.0001
1991/11/12	46	1	-0.1206	0.0303	-4.70	0.0001

Table XIV

Bond Mean Difference (BMD): Price of Underlying Bond - Replicating Portfolio of Strips of Strippable Bonds by Reconstitution Method

Month and Year of Maturity	Coupon (%)	No. of Obs- vations	No. of Mean Diff- erences > 0	Mean Diff- erence	Variance	T- Value	Probability
May95	10.500	34	4	-0.2413	0.0064	-17.48	0.0001
Aug95	10.500	34	1	-0.1892	0.0102	-10.92	0.0001
Nov95	9.500	34	2	-0.3724	0.0204	-15.20	0.0001
Feb96	8.875	34	22	0.0568	0.0177	2.48	0.0181
May96	7.375	34	12	0.0273	0.0136	1.36	0.1816
Nov96	7.250	34	6	-0.1182	0.0208	-4.78	0.0001
May97	8.500	34	21	0.0561	0.0186	2.40	0.0221
Aug97	8.625	34	28	0.1326	0.0207	5.37	0.0001
Nov97	8.875	34	11	-0.0768	0.0321	-2.49	0.0177
Feb98	8.125	34	32	0.2928	0.0211	11.76	0.0001
May98	9.000	34	32	0.0500	0.0197	2.08	0.0452
Aug98	9.250	34	25	0.0743	0.0265	2.66	0.0119
Nov98	8.875	34	10	-0.0952	0.0252	-3.50	0.0014
Feb99	8.875	34	22	0.2254	0.0161	10.35	0.0001
May99	9.125	34	25	0.0925	0.0142	4.53	0.0001
Aug99	8.000	34	34	0.4639	0.0054	11.58	0.0001
Nov99	7.875	34	33	0.3240	0.0259	11.72	0.0001
Feb00	8.500	34	33	0.3635	0.0366	11.07	0.0001

Table XIV (cont.)

Month and Year of Maturity	Coupon (%)	No. of Obs- vations	No. of Mean Diff- erences > 0	Mean Diff- erence	Type of Bonds: Strippable Method: Reconstitution		T- Value	Probability
					Variance			
May00	8.500	34	27	0.2131	0.0362		6.52	0.0001
Aug00	8.750	33	30	0.3615	0.0540		8.93	0.0001
Nov00	8.500	33	29	0.0317	0.0667		6.49	0.0001
Feb01	7.750	28	28	0.9745	0.0879		17.38	0.0001
Feb15	11.250	34	0	-0.3976	0.0226		-15.40	0.0001
Aug15	10.625	34	0	-0.3283	0.0535		-8.28	0.0001
Nov15	9.875	34	0	-0.4596	0.0524		-11.70	0.0001
Feb16	9.250	34	0	-0.2771	0.0139		-13.72	0.0001
May16	7.250	34	20	-0.0022	0.0183		-0.10	0.9226
Nov16	7.500	34	2	-0.1499	0.0167		-6.77	0.0001
May17	8.750	34	0	-0.2513	0.0195		-10.48	0.0001
Aug17	8.875	34	0	-0.1992	0.0172		-8.86	0.0001
May18	8.000	34	2	-0.2670	0.0255		-9.75	0.0001
Nov18	9.000	34	1	-0.1989	0.0627		-4.63	0.0001
Feb19	8.875	34	1	-0.2262	0.0210		-9.09	0.0001
Aug19	8.125	34	1	-0.2159	0.0168		-9.69	0.0001
Feb20	8.500	34	1	-0.2224	0.0223		-8.67	0.0001
May20	8.750	34	4	-0.2044	0.0376		-6.14	0.0001
Aug20	8.750	33	1	-0.2332	0.0287		-7.90	0.0001
Feb21	7.785	28	28	0.8767	0.0282		27.57	0.0001
May21	8.125	34	7	-0.2349	0.0288		-3.66	0.0105

Table XIV (cont.)

		Type of Bonds: Strippable Method: Reconstitution				
Month and Year of Maturity	Coupon (%)	No. of Obser- vations	No. of Mean Diff- erences > 0	Mean Diff- erence	Variance	T- Value Probability
Aug21	8.125	3	1	-0.1298	0.3077	-0.40 0.7244

Table XV

Bond Mean Difference (BMD): Price of Underlying Bond - Replicating Portfolio of Strips of Non-Strippable Bonds by Reconstitution Method

Month and Year of Maturity	Coupon (%)	No. of observ- ations	No. of Mean Diff- erences>0	Mean Diff- erence	Variance	T- Value	Probability
Mar91	9.750	26	0	-0.3287	0.0461	-7.81	0.0001
Mar91	6.750	26	0	-0.2494	0.0202	-8.94	0.0001
Apr91	9.250	27	0	-0.6001	0.0728	-11.56	0.0001
Apr91	12.375	27	0	-0.5346	0.1279	-7.62	0.0001
May91	8.750	27	1	-0.1186	0.0009	-20.31	0.0001
May91	14.500	27	1	-0.9884	0.4741	-7.46	0.0001
May91	8.125	27	0	-0.7534	0.1379	-10.54	0.0001
Jun91	8.250	29	0	-0.1381	0.0075	-8.57	0.0001
Jul91	13.750	30	0	-0.2394	0.1458	-3.43	0.0018
Aug91	7.500	30	2	-0.1522	0.0618	-3.35	0.0022
Aug91	8.750	30	0	-0.1743	0.0611	-3.86	0.0006
Aug91	14.875	30	7	-0.1411	0.0814	-2.71	0.0112
Sep91	9.125	32	0	-0.1798	0.0066	-12.50	0.0001
Oct91	12.250	32	0	-0.2499	0.0126	-12.61	0.0001
Nov91	6.500	34	0	-0.2625	0.0329	-8.44	0.0001
Nov91	8.500	34	0	-0.2845	0.0312	-9.39	0.0001
Nov91	14.250	34	1	-0.2769	0.0813	-5.66	0.0001
Dec91	8.250	34	0	-0.1009	0.0099	-5.89	0.0001
Jan92	11.625	34	0	-0.1247	0.0043	-11.04	0.0001
Feb92	6.625	34	0	-0.1122	0.0038	-10.67	0.0001
Feb92	6.625	34	0	-0.1122	0.0038	-10.67	0.0001
Mar92	7.875	34	4	-0.0344	0.1112	-0.60	0.5514
Apr92	11.750	34	0	-0.2400	0.0051	-19.47	0.0001

Table XV: (cont.)

Type of Bonds:Non-Strippable Method:Reconstitution							
Month and Year of Maturity	Coupon (%)	No. of obser- vations	No. of Mean Diff- erences>0	Mean Diff- erence	Variance	T- Value	Probability
May92	6.625	34	0	-0.1946	0.0046	-16.78	0.0001
May92	13.750	34	0	-0.3415	0.0100	-19.87	0.0001
Jun92	8.250	34	5	-0.1282	0.0084	-8.16	0.0001
Jul92	10.375	34	0	-0.1990	0.0030	-21.16	0.0001
Aug92	7.250	34	18	0.1606	0.0117	0.87	0.3928
Sep92	8.750	34	3	-0.1279	0.0066	-9.17	0.0001
Oct92	9.750	34	0	-0.2641	0.0123	-13.89	0.0001
Nov92	8.375	34	0	-0.3138	0.0150	-14.92	0.0001
Nov92	10.500	34	0	-0.3548	0.0145	-17.18	0.0001
Dec92	9.125	34	1	-0.1765	0.0073	-12.02	0.0001
Jan93	8.750	34	1	-0.1559	0.0062	-11.49	0.0001
Feb93	8.250	34	1	-0.0986	0.0044	-8.63	0.0001
Feb93	10.875	34	0	-0.1392	0.0061	-10.41	0.0001
Mar93	9.625	34	1	-0.1762	0.0092	-10.68	0.0001
Apr93	7.375	34	5	-0.0864	0.0084	-5.50	0.0001
Jul93	7.250	34	17	-0.0366	0.0320	-1.19	0.2415
Aug93	8.750	34	9	-0.0774	0.0132	-3.92	0.0004
Oct93	7.125	34	2	-0.1532	0.0097	-9.08	0.0001
Nov93	9.000	34	1	-0.3117	0.0203	-12.74	0.0001
Jan94	7.000	34	21	-0.0045	0.0094	-0.27	0.7864
Feb94	8.875	34	26	0.0443	0.0130	2.27	0.0301
Apr94	7.000	34	28	0.1279	0.0111	7.07	0.0001

Table XV: (cont.)

Month and Year of Maturity	Coupon (%)	No. of obser- vations	No. of Mean Diff- erences > 0	Type of Bonds: Non-Strippable Method: Reconstitution			T- Value	Probability
				Mean Diff- erence	Variance			
Jul94	8.000	34	29	0.0606	0.1888	0.81	0.4217	
Oct94	9.500	34	2	-0.2254	0.0175	-9.92	0.0001	
Jan95	8.625	34	15	-0.0536	0.0526	-1.36	0.1823	
Apr95	8.375	34	2	-0.0713	0.1077	-1.27	0.2139	
Jul95	8.875	34	16	-0.0429	0.0113	-2.36	0.0246	
Oct95	8.625	34	4	-0.1749	0.0463	-4.74	0.0001	
Jul96	7.875	34	29	0.1041	0.0138	5.18	0.0001	
Oct96	8.000	34	9	-0.0272	0.0334	-0.87	0.3907	
Jan97	8.000	34	26	0.1239	0.0380	3.70	0.0008	
Apr97	8.500	34	26	0.1068	0.0189	4.52	0.0001	
Jul97	8.500	34	4	0.1365	0.0155	6.39	0.0001	

Table XVI

Difference of Means Test Results between Types of Bonds for DMD Values

Sample	No. of obser- vations	Mean Diff- erence	Variance	T- Value	Probability
Strippable	1384	-0.3550	0.3475	-18.22	0.0001
Non-Strippable	1871	-0.0766	0.0851		

Table XVII

Frequency Distribution and Means of DMD Values for Arbitrage Opportunities by Stripping and Reconstitution for all Bonds

Arbitrage by	N	Mean	Variance	T-value	Probability
Stripping	1149	-0.2471	0.0722	-30.75	0.0001
Reconstitution	984	0.3766	0.0858	40.32	0.0001
Neither method	1122	-0.0021	0.0098	-0.740	0.4593

Table XVIII

Arbitrage Opportunities for Non-Strippable Bonds

Arbitrage Method	N	% of Bond Type	Mean	Variance	T- Value	Probability
Stripping	968	0.51	-0.2393	0.2825	-26.36	0.0001
Reconstitution	415	0.22	0.4059	0.0841	18.30	0.0001
Neither	488	0.27	-0.0169	0.1155	-2.87	0.0043

Note: (i) The Mean Values are DMD values reported by the Average Method. Hence,
the Mean Values are negative by the stripping method.

Table XIX

Holdings of Treasury Securities in Stripped Form

Date	Principal Amount Outstanding (\$ Million)	% of Par Value Stripped	Amount Stripped (\$ Million)	% of Par Value Recon- stituted (\$ Million)	Amount Recon- stituted (\$ Million)
1990	February 28	22.10	90,374	0.07	3,084
	May 31	23.50	101,270	0.04	1,983
	August 31	24.28	109,549	0.99	4,473
	November 30	24.03	113,770	0.98	4,633
1991	February 28	24.26	120,322	1.16	5,774
	May 31	24.15	125,663	0.57	2,978
	August 31	24.12	131,407	0.08	4,488
	November 30	23.33	132,952	0.69	3,933
1992	February 29	22.65	133,965	0.95	5,601
	May 31	23.56	144,540	1.54	9,437

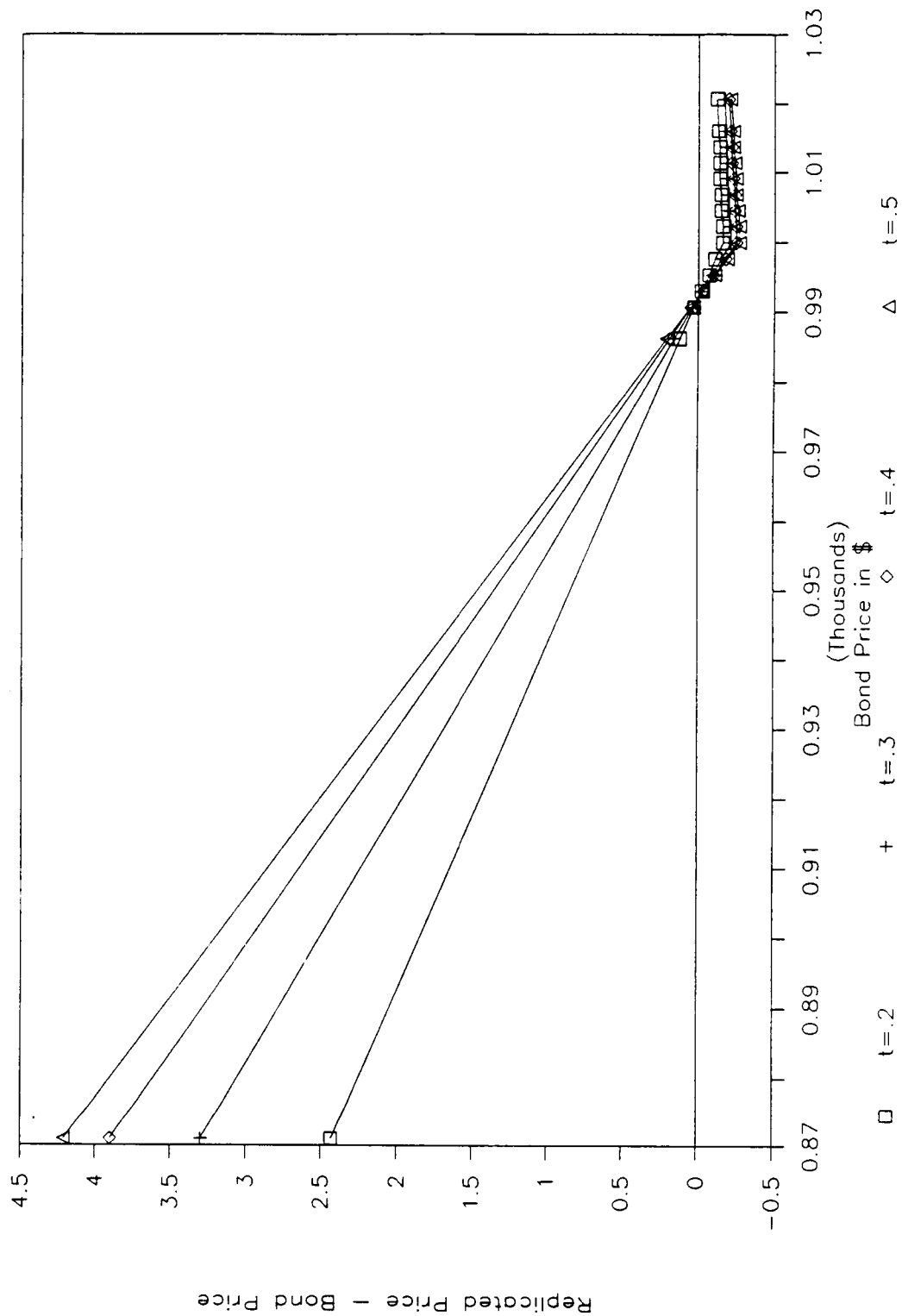


Figure 1. Replicated Bond v/s Bond Price
Upward Sloping Term Structure

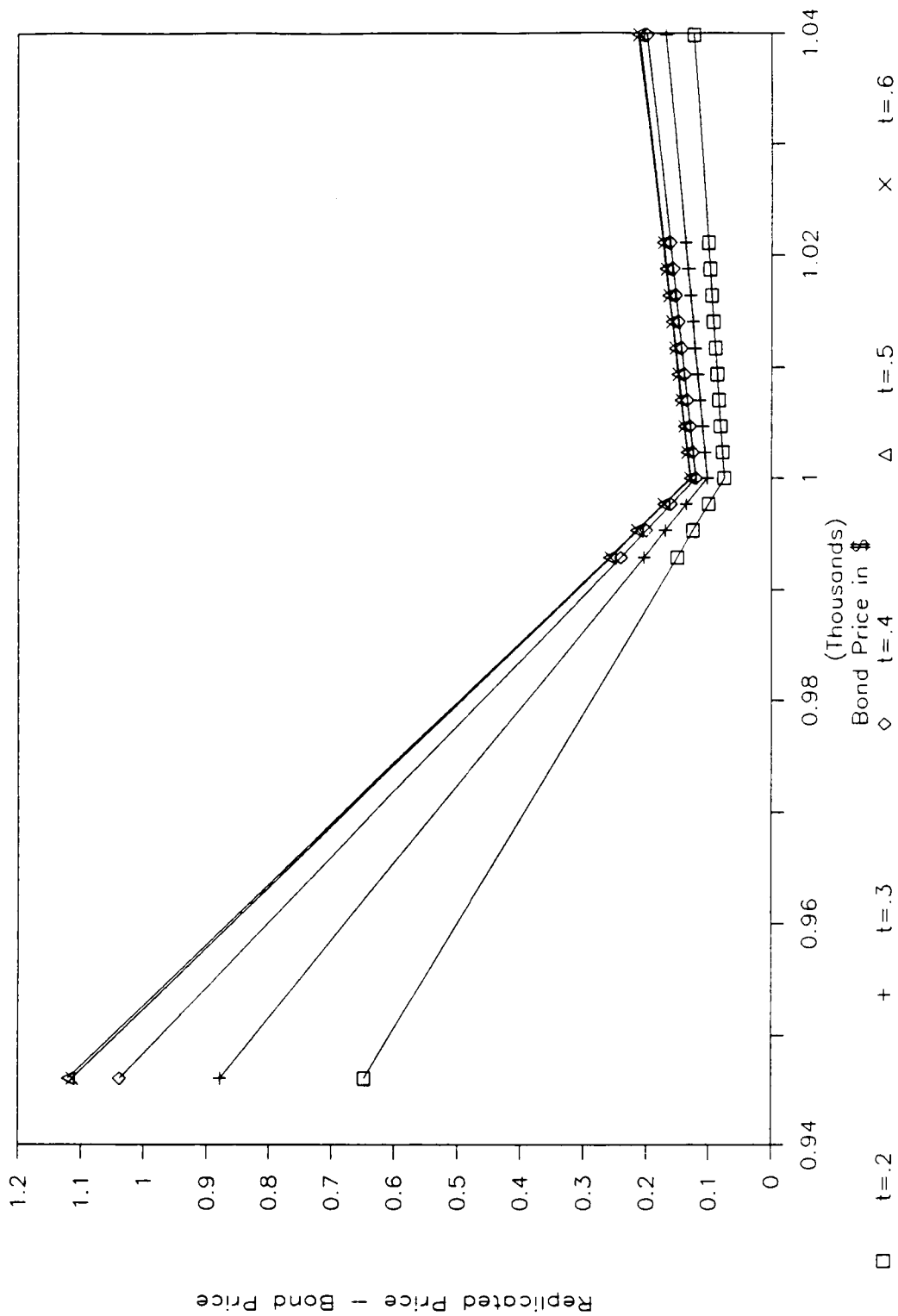


Figure II. Replicated Bond v/s Bond Price
Downward Sloping Term Structure



Figure III. OMD v/s Year of Maturity, Maturity upto Year 2001

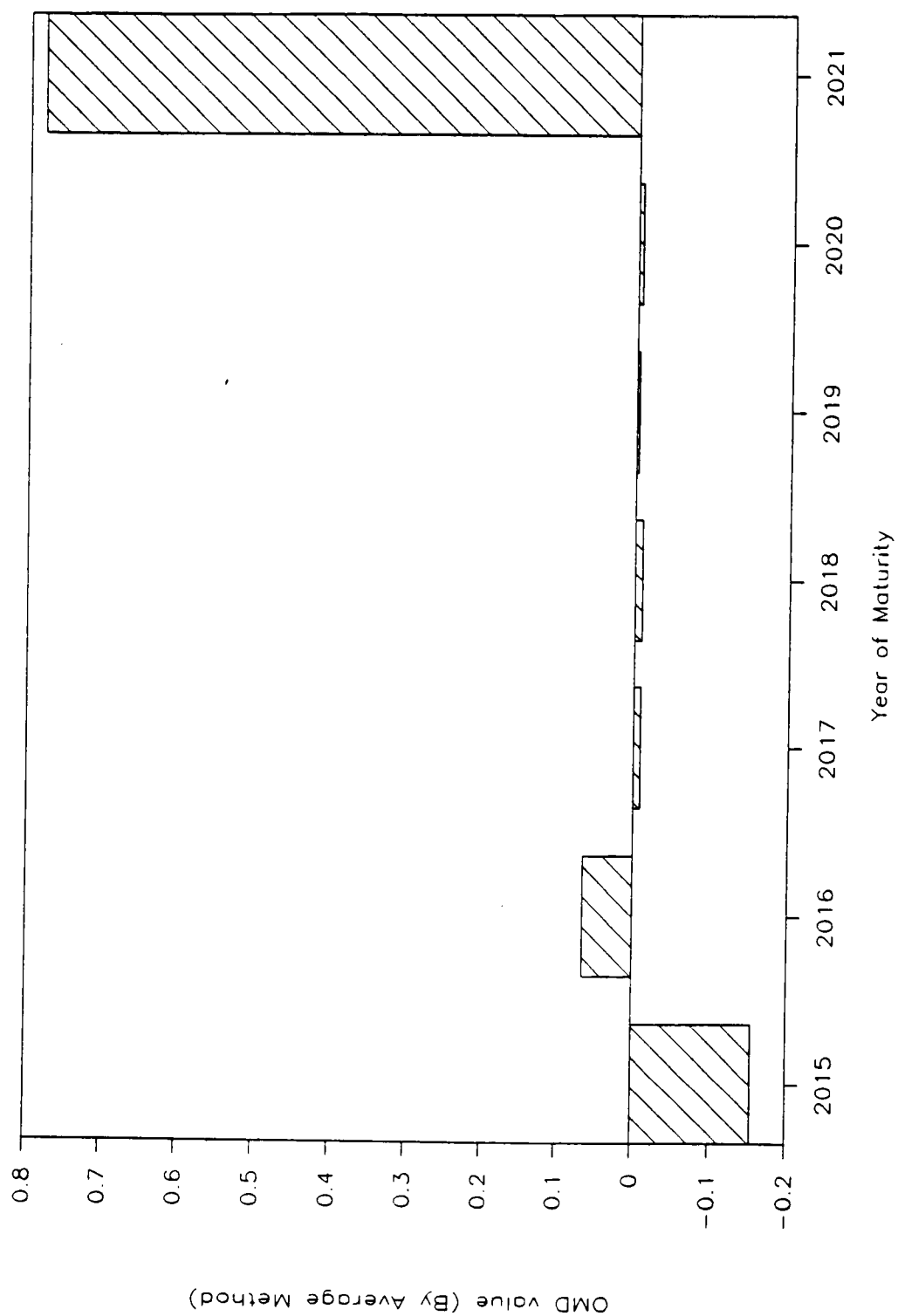


Figure IV. OMD v/s Year of Maturity, Maturity upto year 2021

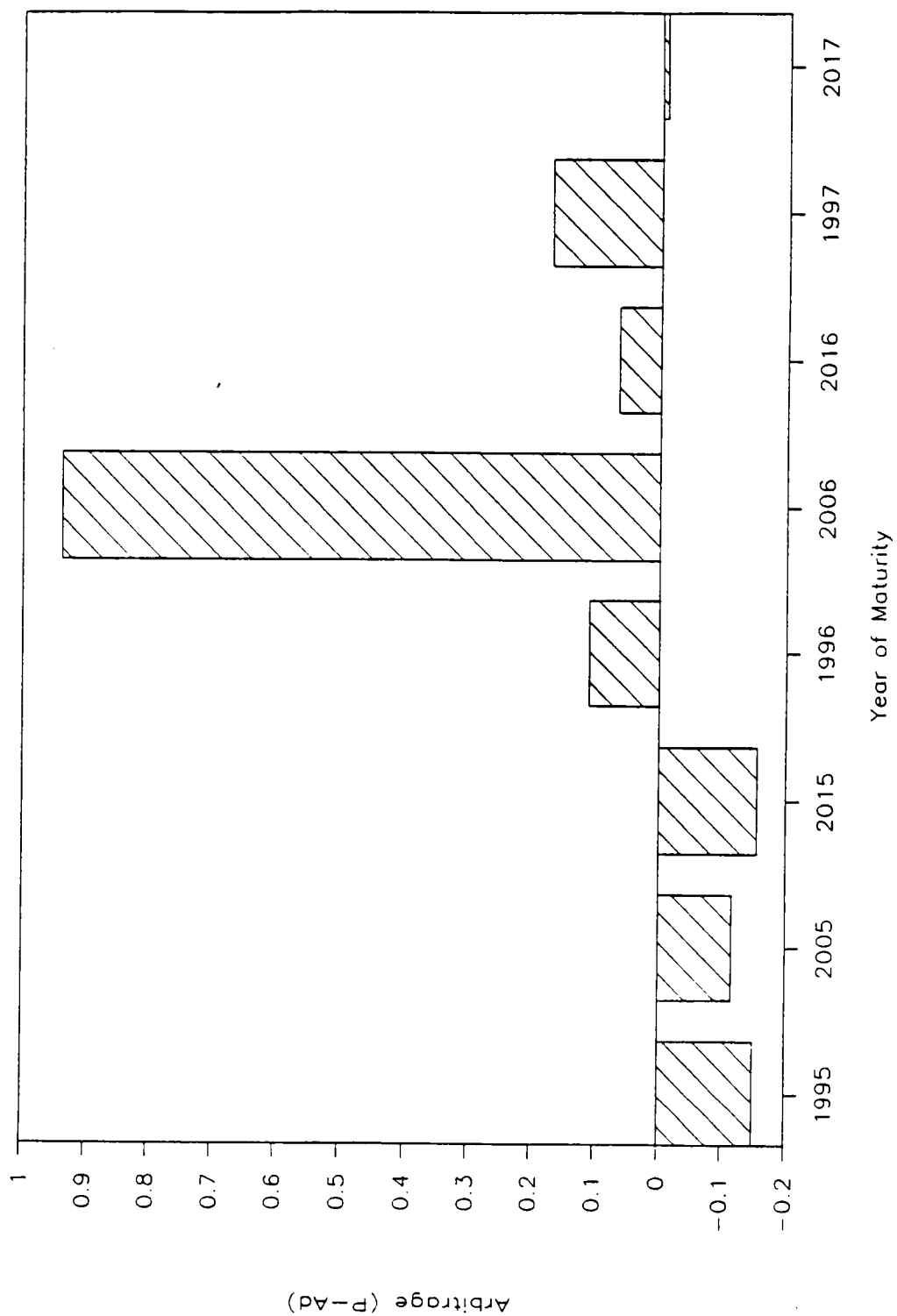


Figure V. Arbitrage v/s Year of Maturity for Strippable Bonds Issued between Years 1985 and 1987

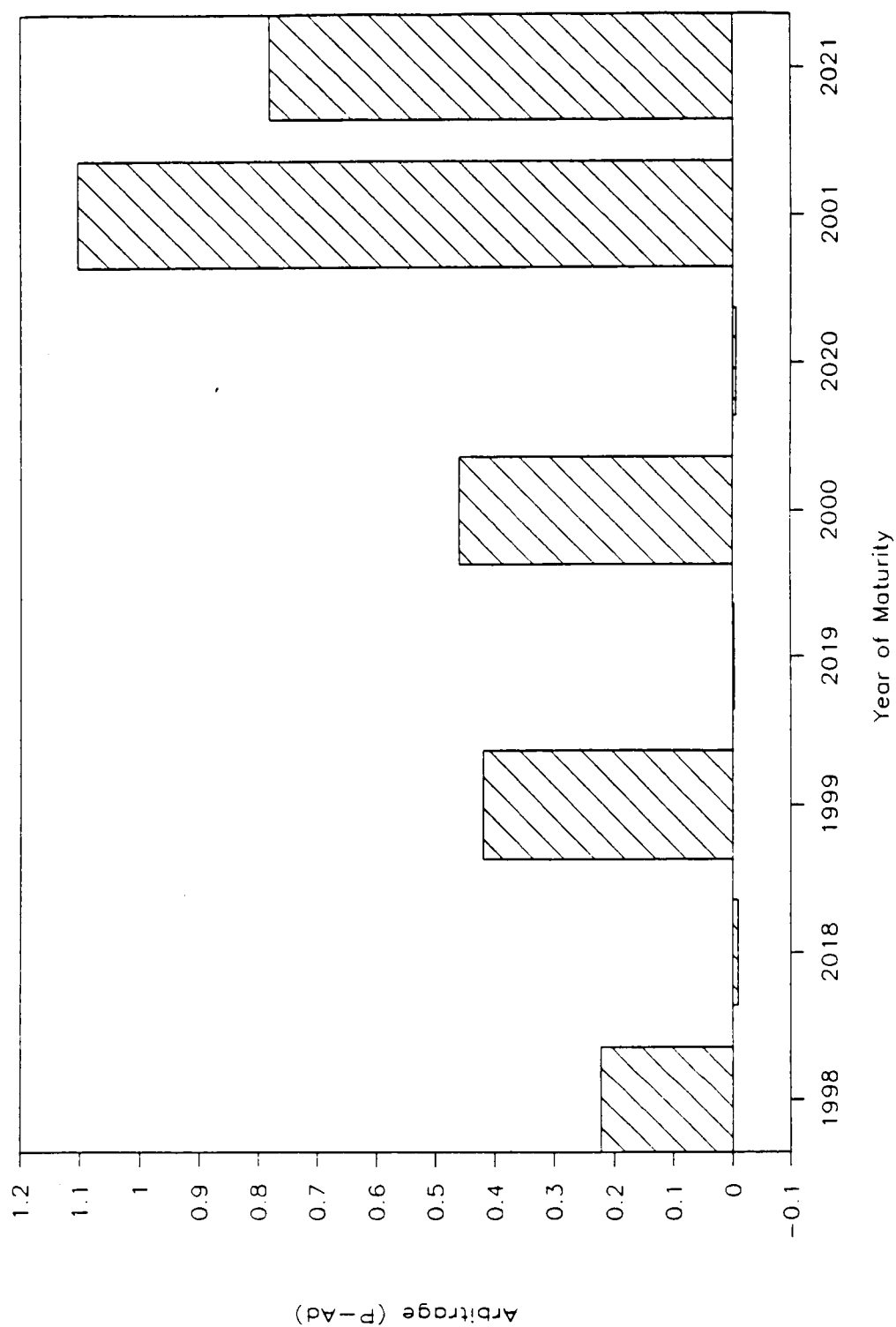


Figure VI. Arbitrage v/s Year of Maturity for Strippable Bonds Issued between Years 1988 and 1991

VITA

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