Tax-Loss Harvesting under Uncertainty

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Abstract

Numerical calculations imply that tax-loss harvesting is valuable to holders of taxable stock accounts. These calculations are based on the assumption that a capital loss on a stock portfolio can always be netted against ordinary income (up to a limit) or a capital gain on the same stock portfolio. We provide market-based evidence that a capital loss that is realized in the beginning of the year is substantially less valuable than a loss that is taken at the end of the year. A simple binomial tree model that captures the resolution of tax rate uncertainty closely mimics observed market prices. Allowing investors to postpone unused losses into the future does not alter the conclusion that realized losses are less valuable early in the year.

Keywords: capital gains tax, tax options, tax planning, seasonality, real options.
JEL Classification Numbers: G12, H24, H26, H31

1 Introduction

A simple trading rule under personal income tax is to defer capital gains indefinitely and to realize capital losses when they occur. Constantinides (1983) sets out the conditions under which deferral of capital gains and realization of losses is optimal. Furthermore, when the tax rate on long-term gains is lower than the tax rate on short-term gains, an investor can benefit from realizing a long-term capital gain in order to restart the short-term tax status of the stock and realize losses at the higher short-term rate.[1] Numerical calculations suggest that timing options have substantial value for the holder of a taxable account. Based on the observed time-series of US stock returns, Chaudhuri, Burnham, and Lo (2020) estimate the alpha from tax-loss harvesting to approximately 1% per annum.

Analytical work and empirical estimates of the value tax-loss harvesting are based on the assumption that the investor at any point of time throughout the year can fully offset a capital loss against ordinary income (up to a fairly low statutory limit) or capital gains on other stocks.[2] In support of this assumption, more than 60% of investors report positive net gains on their tax returns and only a few hit the offset limit for ordinary income (Poterba (1987)). In contrast, many researchers propose that intensified tax-loss selling can explain why stock prices systematically increase over the turn of the year, especially the prices of small-cap stocks with poor past performance.[3] Based on transactions data, a number of studies provide direct evidence of increased tax-loss selling towards the end of the year.[4] There are compelling reasons why tax planning towards the end of the calendar year may dominate tax-loss harvesting throughout the year: *(i)* a capital loss in the beginning of the year does not benefit the investor until the end of the year with a resulting loss of time value, and *(ii)* the loss deduction is either wasted, if the investor does not realize capital gains on his stock portfolio, or the value of the loss deduction is reduced, if it must be carried forward.

Whether holders of taxable stock accounts realize losses throughout the year or concentrate

[1] Constantinides (1984), Dammon, Dunn, and Spatt (1989), and Dammon and Spatt (1996)

[2] The offset limit for capital losses against ordinary income has been $3,000 since 1978. Non-indexing and inflation over more than 40 years has watered down the value of the loss deduction.

[3] E.g., Branch (1977), Keim (1983), Reinganum (1983), Poterba and Weisbenner (2001).

[4] Badrinath and Lewellen (1991), Odean (1998), and Grinblatt and Keloharju (2004).

tax-loss selling to the end of the year depends on preferences. We imagine that an actively traded fund has sufficient trading gains to harvest losses as they occur, while a passive fund by construction renders all benefits of tax timing options. Horan and Adler (2009) conduct a survey among the members of the CFA Institute of whom 28.9% state that they harvest losses continuously, 42.9% periodically, 24.6% year-end only, and 3.4% never. These responses suggest that numerical calculations and empirical estimates of the value of tax-loss harvesting, which assume that losses are harvested continuously, are upward biased for many holders of taxable accounts.

We investigate the issue of seasonal tax planning in the market for Swedish lottery bonds. Lottery bonds are Swedish Government obligations that pay interest by lottery. Due to the random payments of interest, lottery bond prices are quoted inclusive of accrued interest (as for common stocks). For tax purposes, the precipitous price drop over the coupon lottery is treated as a capital loss that is deductible from capital gains on stocks. A stock-market investor with capital gains on his stock portfolio can shield those taxes by purchasing bonds before the lottery, sell the bonds at a loss after the lottery, and participate in the lottery of tax-free interest payments. Green and Rydqvist (1999) demonstrate that marginal tax rates that vary systematically with changes in the tax code can be imputed from the price change over the coupon lottery. Following the literature on tax options, they assume that the marginal investor always has sufficient capital gains on stocks to fully benefit from capital losses on lottery bonds. As coupon lotteries are spread out evenly over the calendar year, this assumption implies that the average drop-off ratio, i.e., the price drop divided by the expected proceeds from the coupon lottery, does not vary over the calendar year. This prediction contrasts with the actual observation in our data set that the average drop-off ratio increases from 170 percent of the expected coupon payment in the first quarter to 300 percent in the fourth quarter. Trading volume during the time period that surrounds the coupon lottery also increases over the course of the year. We conclude from these observations that tax planning in the lottery bond market is concentrated to the end of the year.

We develop a binomial tree model of the term structure of drop-off ratios. The binomial tree captures *(i)* the loss of time value of a tax-loss deduction that does not benefit the investor before the end of the year, and *(ii)* the resolution of uncertainty of the final tax liability throughout the year. The tax rate is uncertain because it depends on the investor's realization policy. If the investor does not realize any stock market gains, the marginal tax rate is zero and a capital loss in the lottery bond market early in the year is wasted or it must be carried forward. The predicted term structure of drop-off ratios is upward-sloping, and the model closely mimics a regression line through the scatter of observed data points. We use the model to decompose the observed slope of the term structure into 20 percentage points that are due to discounting and 110 percentage points that result from the resolution of uncertainty. We assume risk neutrality, and the resolution of uncertainty enters the model through convexity and Jensen's inequality. Some readers may find it noteworthy that lottery bond investors are capable of figuring out the implications of Jensen's inequality as suggested by the close goodness of fit between our model and the data.

Tax-loss selling resembles an American-style put option: investors pay off an uncertain tax liability in advance. Extending the time to maturity of an American option unambiguously raises its value. When a legislative change in Sweden allows tax payers to carry forward unused lottery bond losses five years, the term structure of drop-off ratios shifts up. By comparing the output from the carry-forward version of the model with the one-year model, we find that the value of the carry-forward provision is 75 percent of the expected lottery proceeds.

Tax-loss trading in lottery bonds differs from tax-loss harvesting in the stock market. Whereas stock market investors generate a tax-deductible accounting loss by selling a stock that has depreciated in value below its basis, lottery bond investors generate a real capital loss by purchasing bonds at a high price before the lottery and reselling those bonds at low price after the lottery. One would expect that there is a pecking order such that investors first exhaust the opportunities for accounting losses in the stock market before they revert to generating real losses in the lottery bond market. Based on this line of reasoning, seasonal tax-loss harvesting in the stock market may not be quite as pronounced as the calendar effect in the lottery bond market. To the extent that tax-loss harvesting is costless, savvy investors might as well harvest precautionary loss deductions continuously throughout the year. Furthermore, continuous as opposed to year-end tax planning has become more advantageous over time with the reduced cost of trading and new software that cuts the administrative cost of filing lengthy tax returns.

We are not first to analyze stock market investments and tax rate uncertainty. Ehling, Gallmeyer, Srivastava, Tompaidis, and Yang (2018) analyze optimal asset allocation with capital gains tax and tax-loss limitations. In their model, investors trade for diversification purposes. The willingness to re-balance a stock portfolio depends on the tax cost of re-balancing and the availability of carry-forward losses. An investor who enters the stock market right before a market-wide upswing exhausts harvested losses against realized capital gains within a few years with the result that the marginal tax rate on gains and losses becomes certain and positive. This scenario contrasts with that of an investor who enters the stock market right before a general downturn. This investor may carry forward losses for a long time, when the marginal tax rate on gains and losses is either positive or zero. In their analysis, trade is restricted to the turn of the year, which rules out seasonal tax planning.

Tax rate uncertainty may also matter to the corporate manager. In the original analysis of capital structure and taxes, Modigliani and Miller (1963) assume that the corporation is always profitable and, as such, can always use the interest-rate deduction to shield corporate income tax. Subsequent work by DeAngelo and Masulis (1980) and Graham (2000) among others stress that the value of the interest-rate deduction is reduced by the possibility that the company does not make enough money to take full advantage of the debt tax shield.

The rest of the paper is organized as follows: Section 2 describes the data set and the institutional background, Section 3 presents basic empirical results, Section 4 develops and calibrates the binomial tree model to the observed term structure of drop-off ratio, and Section 5 concludes the paper. Appendix A describes the primary market for lottery bonds.

2 Institutional Background & Data

We focus on lottery bond issues from 1960–1980. Those lottery bonds share the common feature that capital losses on lottery bonds fully offset capital gains on stocks. The last of those bond matured in 1990. During this time period, lottery bonds were a significant source of funding for the Swedish Government; the lottery bond stock oscillated around 10% of Swedish Government debt or 3% of GDP. We retrieve institutional information about the lottery bond market from the Annual

Yearbook of the Swedish National Debt Office 1960–1980, issue prospectuses for the various loans, and the two editions of Akelius (1974) and Akelius (1980). Henceforth, we refer to the Swedish National Debt Office as the Treasury.

2.1 Bond Characteristics

Lottery bonds are designed for the retail market and issued in small denominations of 100 kronor (bond issues 1960–1974) and 200 kronor (bond issues 1975–1980).[5] Between one and three loans are issued each year. Lottery bonds are bearer securities, time to maturity is approximately ten years, coupon payments are semi-annual, and bonds are non-callable. At maturity, lottery bond holders can convert maturing bonds into new lottery bonds at par. The conversion option means that lottery bonds are floating rate securities with the interest rate being reset at conversion.

Table 1: Coupon Lottery

Prize (kronor)	Number	Probability	Expectation (kronor)	Variance (kronor)
320,000	2	0.0000003	0.107	34,133
80,000	12	0.0000020	0.160	12,799
40,000	20	0.0000033	0.133	5,333
20,000	42	0.0000070	0.140	2,799
8,000	230	0.0000383	0.307	2,452
4,000	550	0.0000917	0.367	1,465
800	1,400	0.0002333	0.187	148
400	2,600	0.0004333	0.173	68
50	120,000	0.0200000	1.000	45
0	5,875,144	0.9791907	0.000	6
Sum:	6,000,000	1.0000000	2.575	59,249

The table displays the structure of the semi-annual coupon lottery for the first bond of 1974. Prizes are quoted net of 20% lottery tax. Data source: issue prospectus.

The first lottery bond issue of 1974 consists of six million bonds across 6000 series with 1000

[5] Purchasing power has decreased by approximately eight times since 1975 and the exchange rate between the krona and the US dollar has varied around eight kronor to the dollar, so we can think of the purchasing power of 100 kronor in 1975 as 100 US dollars in 2020.

order numbers within each series (Table 1). There are 4,856 prizes between 400 kronor and 320,000 kronor. Each of those prizes is awarded by the drawing of one series number and one order number without replacement. The lottery also pays 120,000 small prizes in the amount of 50 kronor each. The small prizes are randomized across the 1000 order numbers in each series. Since there are 6000 series and 120,000 small prizes, a total of 20 small prizes are distributed among the 1000 order numbers of each series. The holder of a complete bond sequence that covers all order numbers from 1–1000 is certain to win the 20 small prizes of 50 kronor. For the first bond issue of 1974, the annualized certain return from the small payments is 2% of par compared to the annualized expected return from the coupon lottery of 5.15%. The notional value of a 1000-bond sequence is 100,000 kronor. The coupon lotteries of the other bond issues from 1960–1980 are similar except that the coupon rate changes with market conditions.

2.2 Secondary Market Data

Lottery bonds are traded at the Stockholm Stock Exchange. Trading opens with a call auction in the morning and continues on the floor throughout the day (aftermarket). Data reporting is manual, and prices and transaction volume are recorded with a typewriter. The Stockholm Stock Exchange publishes prices for mixed bonds and bonds with unbroken sequences of order numbers, while trading volume is aggregated across mixed and sequenced bonds. A bond sequence must have the same series number and a specific range of order numbers (Table 2). A 50-bond sequence has order numbers 1–50, 51–100, 101–150, ..., a 100-bond sequence has order numbers 1–100, 101–200, ..., and a 500-bond sequence covers order numbers 1-500 or 501–1000. Complete 1000-bond sequences that cover all order numbers from 1-1000 exist in three forms: ten 100-bond sequences with different series numbers (1000 C from the Roman numeral for one hundred), two 500-bond sequences with different series numbers (1000 D from the Roman numeral for five hundred), and one 1000-bond sequence with the same series number (1000 S from the first letter of "series"). All lottery bond sequences other than those listed in Table 2 are referred to as mixed bonds.

From 1960–1980, we scan hard copies of the Official Quotation List at the daily frequency, and we use OCR technology to extract prices and trading volume from the images into Excel. For

Table 2: Bond Sequences

Sequence	Series numbers	Order numbers
50	1	1–50, 51–100, 101–150, $\cdots$, 951–1000
100	1	1–100, 101–200, 201–300, $\cdots$, 901–1000
500	1	1–500, 501–1000
1000 C	10	1–1000
1000 D	2	1–1000
1000 S	1	1–1000

A bond sequence has a common series number and the range of order numbers indicated in the table. A C-sequence is composed of ten 100-bond sequences from different series, a D-sequence of two 500-bond sequences from different series, and a S-sequence of one 1000-bond sequence from the same series. Source: Official Quotation List of the Stockholm Stock Exchange.

the analysis, we use the last transaction price of the day for mixed bonds (from the call auction or the aftermarket), and the average of high and low transaction prices for bond sequences (from the aftermarket). From 1981–1990, data reporting becomes electronic, but the records from 1981–October 1986 have been lost. Data reporting increases multifold, and we limit ourselves to manually collect the best buy limit order at the end of the day (close) and the daily transaction volume for mixed bonds and each bond sequence. From November 1986–1990, Findata stores electronically the best buy limit order and trading volume for mixed bonds and bond sequences. This part of our data set overlaps with the data that was previously analyzed by Green and Rydqvist (1999).

Trading of lottery bonds creates practical problems for banks that must register the numbers of lottery bonds in deposit. To give banks ample time to register and check lottery bond numbers, the Stockholm Stock Exchange suspends trading between eight to thirteen business days around the coupon lottery. Trading costs in the secondary market are fairly low, and we shall ignore them in the analysis.[6]

[6] Buyers and sellers pay brokerage commission 0.3 percent of par, and from 1989–1990, the seller must also pay a transfer tax in the amount of 0.15 percent of the price. The bid-ask spread is mostly equal to one or two multiples of one price tick, which is 0.10 kronor.

2.3 Taxation

Coupon income from lottery bonds is exempt from personal income tax. Capital gains and losses on lottery bonds are netted against each other. Net gains are lumped together with wages, dividends, interest, and other income and taxed as ordinary income. Net losses on lottery bonds are deductible against capital gains on stocks, but they are not deductible against ordinary income.[7] Before 1977, capital losses on lottery bonds must be used the same year. From 1977, losses on lottery bonds can be carried forward five years.

Dividends on stocks are taxed as ordinary income. Capital gains and losses on stocks are netted against each other, and positive net gains on stocks are deductible against losses on lottery bonds. Any residual capital gain is taxed as ordinary income. The tax code separates between short- and long-term capital gains as defined by a holding period of two years. Short-term capital gains are fully taxable as ordinary income. A portion of long-term gains is exempt from income tax. Before 1977, the taxable portion is 75 percent for a holding period between two and three years, 50 percent from three to four years, 25 percent from four to five years, and 0 percent after five years. Stocks that have been held longer than five years do not escape taxation because 10% of the selling price is taxed as ordinary income. From 1977–1990, the taxable portion is 40 percent after two years.

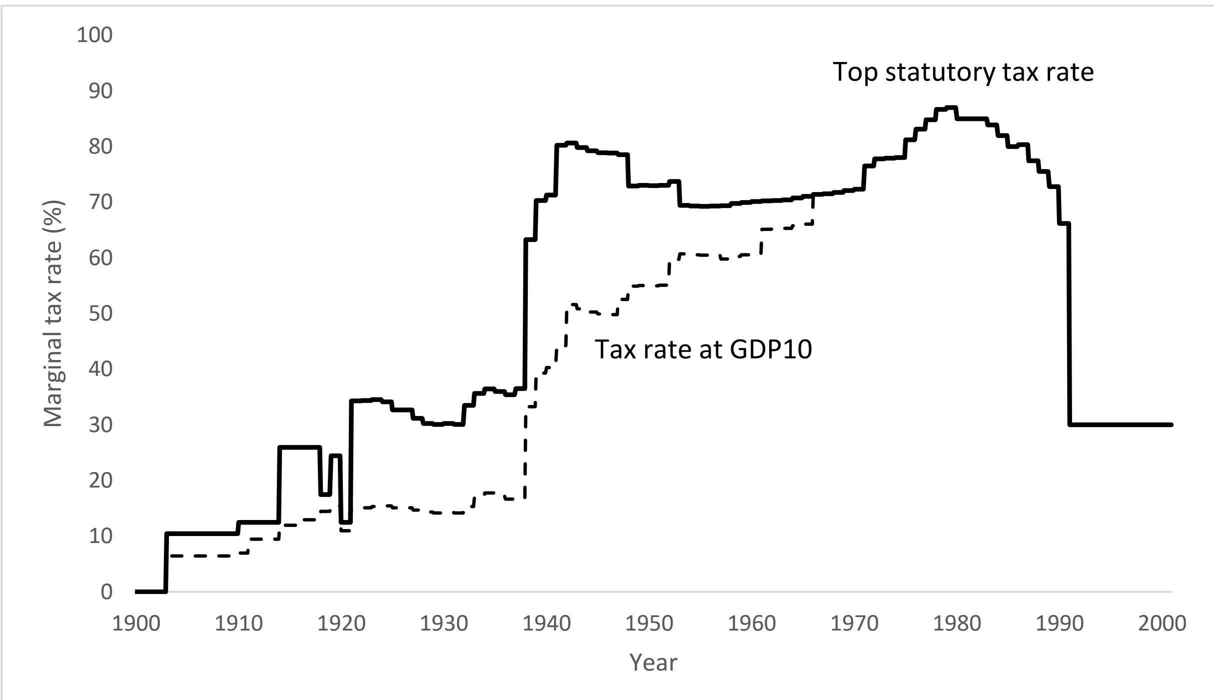
Short-term losses offset short-term gains one for one, and short-term losses offset the taxable portion of long-term gains one for one. For example, if the taxable portion of a long-term gain is 40%, a short-term loss of 1000 kronor fully offsets the tax liability of a long-term gain of 2500 kronor. This tax rule means that a stock market investor with either short- or long-term capital gains in his portfolio shields taxes at the full statutory tax rate on ordinary income by generating losses in the lottery bond market.[8]

The top statutory tax rate on ordinary income is extremely high throughout the time period we study (Figure 1). Through inflation and non-indexing of tax tables, many taxpayers face marginal

[7]Before 1981, lottery bond losses also offset taxable gains from real estate, artwork, etc. From 1981, lottery bond losses on old bond issues from 1960–1980 offset gains on capital gains on publicly traded stocks, but no other taxable gains. For all new bond issues from 1981–1990, capital losses on lottery bond offset capital gains on other lottery bonds, but no other capital gains.

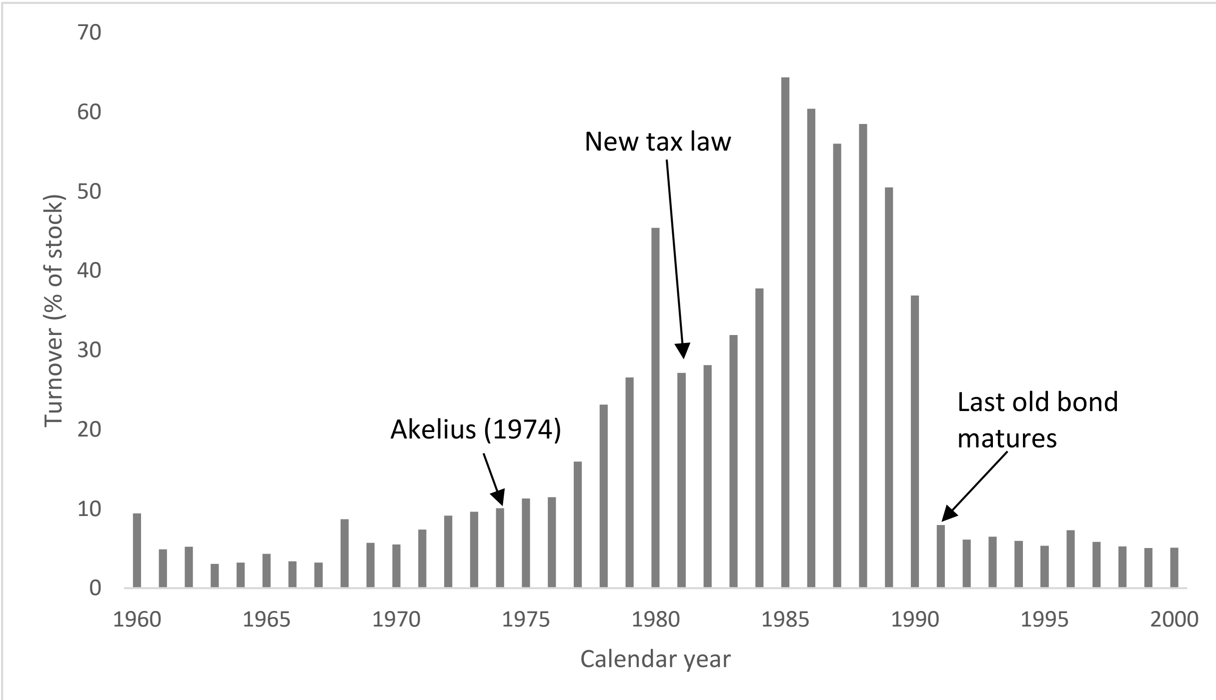
[8]The Swedish tax treatment of netting short-term losses and long-term gains is different from that of the United States, where short-term losses and long-term gains offset each other one for one. Under the US tax treatment, a lottery bond investor would have to generate a short-term loss of 2,500 kronor to net out a long-term gain of 2,500 kronor.

Figure 1: Evolution of Marginal Tax Rates



The figure reports the top statutory tax rate on ordinary income (solid line above) along with the marginal tax rate that applies to a person with taxable income equal to 10 times GDP per capita (dashed line below). The tax rate from 1991 and forward is the marginal tax rate on investment income. Ordinary income is subject to state-level taxes (progressive) and county-level taxes (proportional). We use the average county-level tax as computed by Statistics Sweden.

Figure 2: Lottery Bond Market Turnover



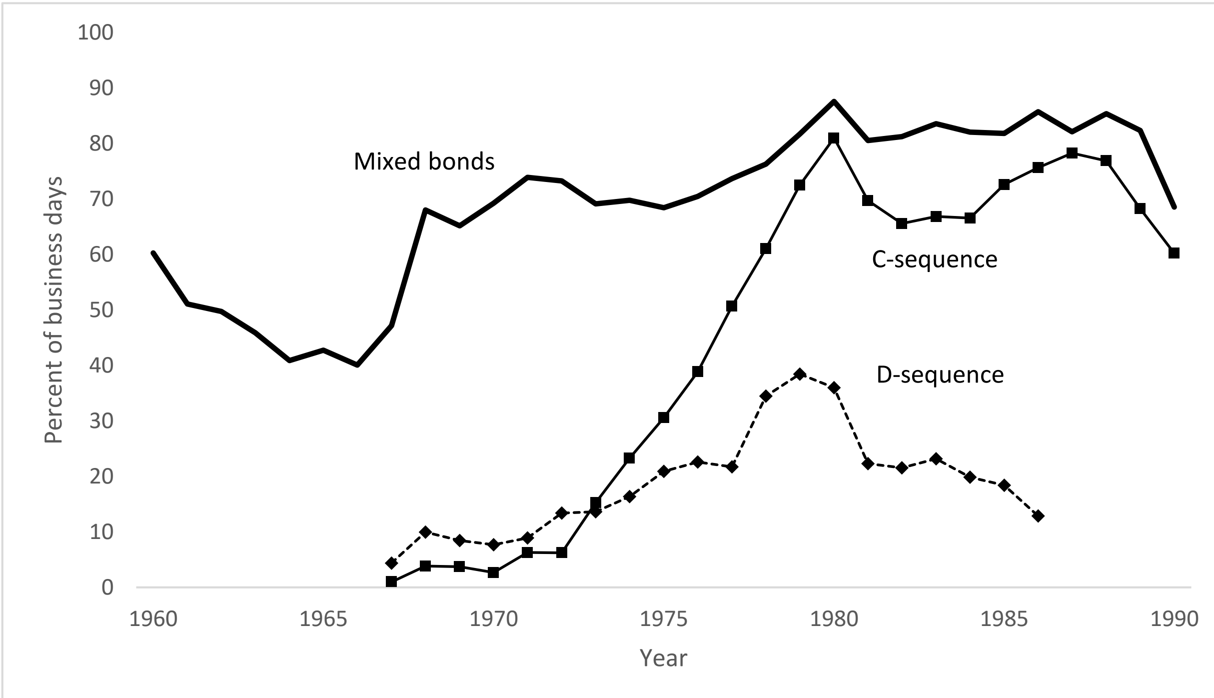
The figure plots the equal-weighted average turnover of lottery bond issues from 1960–1990 (old bonds), and for all outstanding bonds from 1991–2000 (new bonds). The figure highlights the publication of Akelius (1974), a proposed tax legislation in November 1980, and the maturity of the last old bond.

tax rates up to 87 percent. The marginal tax rate of an individual with taxable income equal to 10 times GDP per capita increases from less than 20 percent before World War II to above 70 percent by the mid-1960s. The tax payer with income of 10 times GDP per capita pays the top marginal tax rate from 1967–1990. From 1991, the tax code separates between ordinary income and investment income, and the relevant marginal tax rate decreases to 30 percent for capital gains and 21 percent for capital losses.

2.4 Institutional Responses

Market participants adapt to the tax environment. Trading of lottery bonds picks up after the publication of Akelius (1974), who explains in a simple manner how high-income individuals can use lottery bonds to avoid personal income tax (Figure 2). From 1980–1990, the volume is very large;

Figure 3: Trading Frequency



The figure plots the annual frequency of business days with transaction volume. A C-sequence is composed of ten 100-bond sequences, and a D-sequence of two 500-bond sequences. Trading frequency of mixed bonds is based on transactions of bond issues from 1960–1980, D-sequences of bond issues from 1960–1976 (first issue), and C-sequences of lottery bond issues from 1960–1980.

the annual turnover of lottery bonds exceeds 1.5 percent of GDP. Politicians notice the increased activity in the lottery bond market and propose to the parliament to limit the tax deductability of lottery bond losses to capital gains on lottery bonds. The final version of the proposal grandfathers outstanding lottery bonds (old bonds issued before 1981), and trading in lottery bonds for tax purposes continues until the last old bond matures in 1990. When the tax reform of 1991 reduces the marginal tax rate of lottery bond losses to 21 percent, trading of lottery bonds reverts back to its low historical level.

Prices for C- and D-sequences appear for the first time on the Official Quotation List in 1967, and the daily frequency of trading C- and D-sequences increases rapidly thereafter (Figure 3). C- and D-sequences offer two advantages over mixed bonds: *(i)* the owner of a complete bond portfolio that covers all order numbers from 1–1,000 earns the small prizes with certainty (partial guarantee), and *(ii)* lottery number checking of a longer bond sequence requires less effort. The price difference between bond sequences and mixed bonds is substantial (Green and Rydqvist (1997)). For all lottery bond issues from 1963–1980, the Treasury breaks up the original series and disperses the series numbers across the banking sector. The best banks can do to mimic a complete S-sequence is to combine ten 100-bond sequences from different series into a C-sequence and two 500-bond sequences from different series into a D-sequence.[9] From the second lottery bond issue of 1976 to 1980, the Treasury does not issue unbroken 500-bond sequences either. For those bond issues, only C-sequences remain in the secondary market as neither D- nor S-sequences can be constructed from scattered 100-bond sequences. The activity of putting together broken-up lottery bond series is an example of financial innovation in response to regulation. In the analysis of Section 3, we focus on the prices of C-sequences, which represent 76 percent of the daily trading volume.[10] In Appendix A, we explain the issuance process of new lottery bonds in more detail.

3 Price Formation and Trading Volume Around the Lottery

Green and Rydqvist (1999) analyze how income tax influences price formation and trading volume around the coupon lottery. We add two new empirical results: *(i)* the price drop over the coupon lottery exhibits a pronounced calendar effect, and *(ii)* the term structure of price drop-off ratios shifts up after 1976, when unused lottery bond losses can be carried forward five years.

3.1 Prices

Following the extant literature on the ex-dividend day, we define the drop-off ratio as the change in the price from the last day cum lottery P^c to the price from the first day ex lottery P^e divided by the expected proceeds from the coupon lottery $E(C)$:

$$\Delta = \frac{P^c - P^e}{E(C)}. \tag{1}$$

[9] Occasionally, two 500-bond sequences from the same series find their match in the secondary market, and the original S-sequence can be re-created. The number of transactions of S-sequences in the entire data set is 231 of which 53 emerge from putting together 500-bond sequences in the secondary market.

[10] We base this estimate on data from 1981–1990, when we have disaggregate trading volume for mixed and sequenced bonds.

The holding-period return from the last price cum lottery to the first price ex lottery is defined in a standard fashion:

$$r = \frac{P^e + E(C) - P^c}{P^c}. \tag{2}$$

We base our calculations of each measure using the prices of C-sequences of bond issues 1960–1980.

The lottery bonds from 1967–1973 are issued in two tranches per year, and lottery bonds from 1974–1980 are issued in three tranches. With the exception of the initial coupon lottery of the first tranche of each issue, coupon lotteries are synchronized across the two or three tranches of each bond issue. When two or three lotteries take place on the same day, we base our calculations on the equal-weighted average of cum and ex prices across tranches. This empirical procedure results in a total number of 300 unique coupon lottery dates.

Table 3: Drop-Off Ratios and Ex-Coupon Returns by Quarter

	Quarter			
Time period	I	II	III	IV
	A. Drop-off ratio (%)			
1967–1976	169.2 (13.1)	265.1 (27.3)	311.8 (36.9)	294.1 (29.0)
1977–1990	198.8 (16.3)	285.8 (17.4)	373.1 (23.5)	343.0 (27.2)
	B. Ex-coupon return (%)			
1967–1976	–1.48 (0.28)	–3.44 (0.51)	–4.07 (0.63)	–4.14 (0.60)
1977–1990	–2.34 (0.36)	–4.56 (0.37)	–6.27 (0.45)	–5.96 (0.55)
	C. Number of lotteries			
1967–1976	24	20	32	30
1977–1990	43	54	48	49

The table reports quarterly average drop-off ratios in percent of the expected proceeds from the coupon lottery and two-week holding period returns from the last price cum lottery to the first price ex lottery. Standard errors are reported in parentheses below each average. We base the estimation on the lottery bond prices for C-sequences.

Quarterly average drop-off ratios and holding-period returns are economically large, and they are accurately estimated (tight standard errors) despite small sample sizes (Table 3). Average drop-off ratios amount to hundreds of percent of the expected proceeds from the coupon lottery, and average ex-coupon returns vary between -1.48 percent and -6.27 percent.[11] Coupon buyers experience negative before-tax returns, and coupon sellers earn positive before-tax returns.

The quarterly average drop-off ratio increases over the course of the year: the difference between the fourth and the first quarter average drop-off ratios equals 124.9 and 144.2 basis points in respective subperiods. Ex-coupon returns display a similar calendar effect. There is also a time-series effect that coincides with the carry-forward provision. The term structure of drop-off ratios shifts up, and ex-coupon returns decrease. To assess the statistical significance of the calendar effect and the time-series effect, respectively, we estimate the following regression model:

$$\Delta = \gamma_0 + \gamma_1 DAY + \gamma_2 POST76 + u. \tag{3}$$

The dependent variable is the drop-off ratio, the first independent variable $DAY \in [1, 365]$ is a calendar-day-count variable, and the second independent variable $POST76$ is an indicator variable, which equals one if the lottery takes place from 1977-1990 and zero otherwise. The regression

Table 4: Regression of Drop-Off Ratios on Indicator Variables

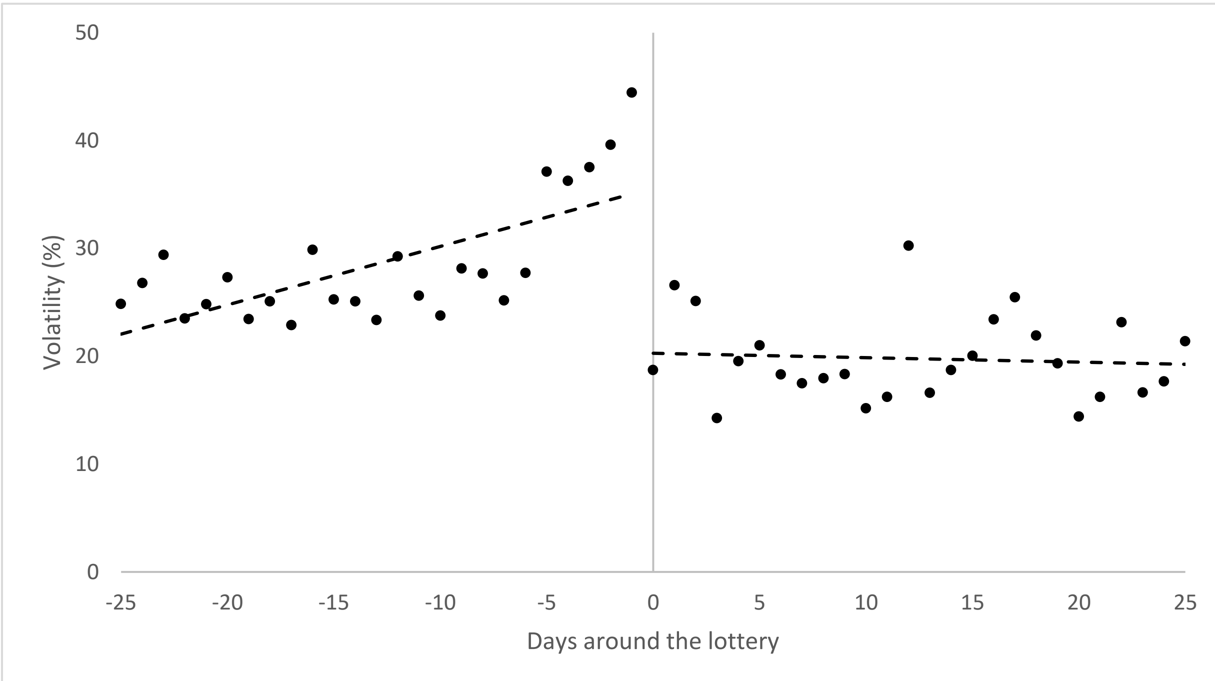
	Intercept γ_0	Day γ_1	Post 1976	R^2	#Obs.
Coefficient (%)	169.3	0.52	42.9	12.0	300
t-statistic	$(7.2)^{***}$	$(6.0)^{***}$	$(2.3)^{**}$		

The table reports the results of ordinary least squares regressions of the drop-off ratio on an indicator variable for the calendar day of the year and an indicator variable which equals one for lotteries that take place from 1977–1990, and zero otherwise. The dependent variable is expressed in percent of the expected lottery proceeds. The symbols ** and *** denote statistical significance at the 5% and 1% level, respectively.

coefficients are statistically significant (Table 4). The regression coefficient of the day-count variable implies that the average drop-off ratio increases by 189.8 percentage points over the course of the

[11] We report raw returns. Subtracting accrued interest would further raise drop-off ratios and reduce ex-coupon bond returns.

Figure 4: Volatility Near the Lottery



The figure plots daily volatility in percent of the expected coupon around the ex-lottery day 0. For each bond and day with adjacent prices, we square the price change over the expected coupon. Then, we compute the equal-weighted average across bonds conditional on the day relative to the coupon lottery day. Finally, we compute the square root of each average volatility. The dashed lines are linear trends.

calendar year, and the regression coefficient of the time-series variable suggests that the carry-forward provision raises the value of the tax-loss option by 42.9 percentage points across the term structure. These interpretations rest on the assumption that everything else is equal as there are no control variables in the regression.

3.2 Volatility

Volatility in the secondary market increases towards the coupon lottery (Figure 4). Right before the lottery, volatility peaks above 40 percent of the expected coupon or one percent of the price. After the lottery, volatility levels out at around 20 percent of the expected coupon. Hence, there is more uncertainty about the level of the market price right before the lottery. Presumably, investors with different valuations enter the market right before the lottery. We refer to these volatility estimates in Subsection 4.6 below, where we analyze the cross-section distribution of drop-off at the end of the calendar year.

3.3 Volume

We measure trading volume as the number of bonds traded divided by the number of bonds outstanding (turnover). We center the data around the ex-coupon day 0 and compute the equal-weighted average daily turnover for each day around the coupon lottery. Turnover increases as the day of the coupon lottery gets closer, it spikes on the ex-coupon day 0, and it decreases to its normal level afterwards (Figure 5). The spike in trading volume is the likely result of repurchase agreements (forward contracts), when coupon buyers sell back their bonds to market makers (banks). Abnormal trading volume increases over the course of the year, especially the spike on the ex-lottery day.

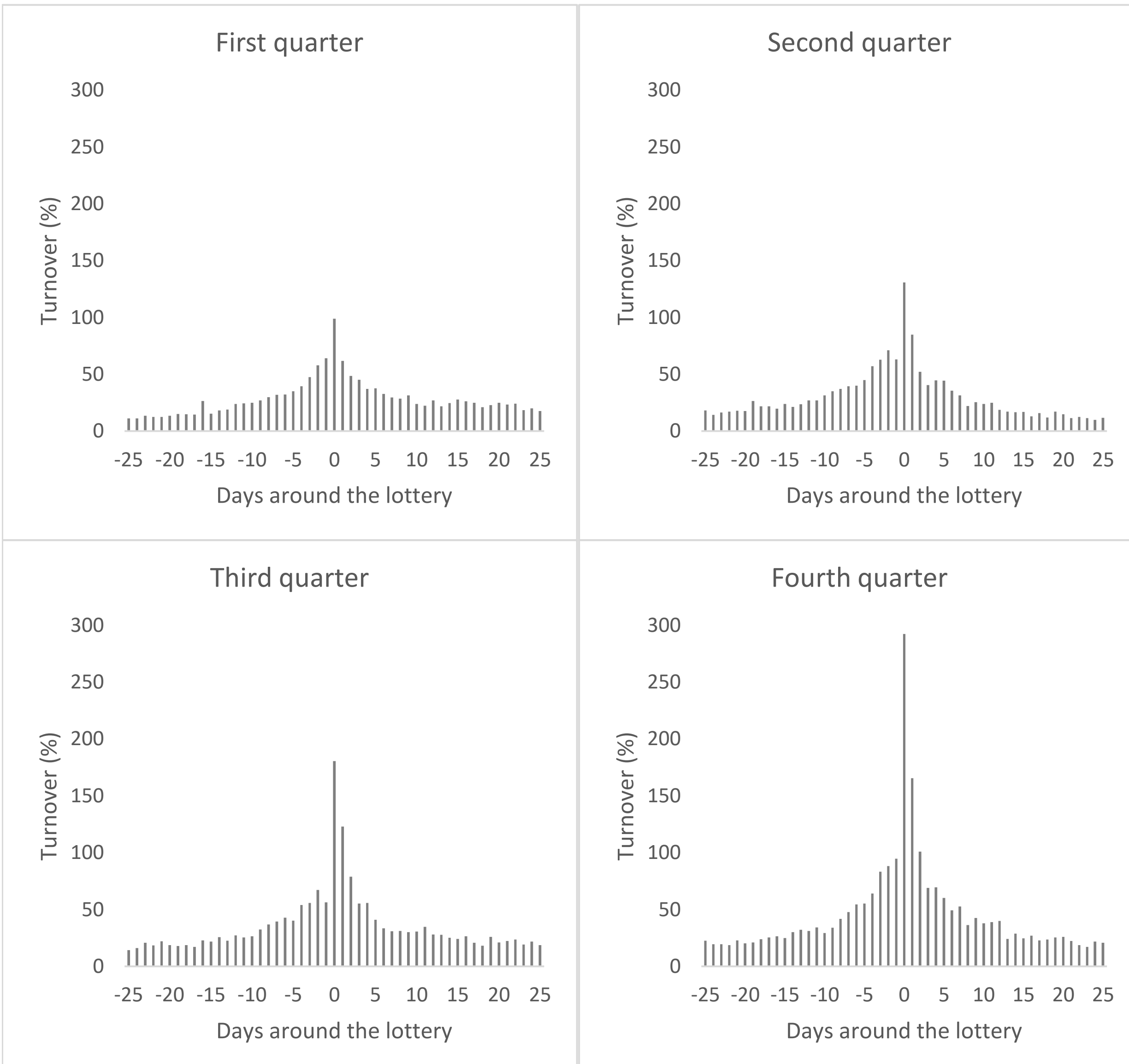
4 Model

Our objective is to model the upward-sloping term structure of drop-off ratios. We begin with the full certainty case as in Green and Rydqvist (1999) by assuming that the coupon buyer receives a certain tax credit at the time of the trade. Then, we assume that the tax-loss trader does not know until the end of the year whether he will realize capital gains on his stock portfolio to fully benefit from the capital loss in the lottery bond market earlier in the year. The change of assumption introduces uncertainty and time value.

4.1 Certainty

An investor with marginal tax rate τ purchases a lottery bond at cum-lottery price P^c and sells it back at ex-lottery price P^e. The known proceeds from the coupon lottery are C. We ignore transaction costs and discounting over the two-week period that surrounds the coupon lottery. Taxes are paid and tax credits are received at the time of the trade. We impose Bertrand competition

Figure 5: Trading Volume by Quarter



The figure plots annualized daily average trading volume in percent of the outstanding stock of lottery bonds around the ex-lottery day 0.

among coupon buyers. The short-term trader breaks even when:

$$-P^c + P^e + C + \tau(P^c - P^e) = 0. \tag{4}$$

The first two terms are the transaction prices, the third term is the coupon payment, and the fourth term is the tax credit from netting the loss on the lottery bond against capital gains on stocks. Rearranging gives us:

$$\Delta(\tau) = \frac{P^c - P^e}{C} = \frac{1}{1-\tau}. \tag{5}$$

The drop-off ratio $\Delta(\tau)$ is a convex and increasing function of the tax credit associated with a one krona loss deduction at the marginal tax rate τ. The drop-off ratio exceeds the coupon C. In the extreme tax environment of the Swedish lottery bond market from 1960–1990, the drop-off ratio equals 500% for a marginal tax rate of $\tau = 80\%$.

The rate of return over the coupon lottery is negative:

$$r(\tau) = \frac{P^e + C - P^c}{P^c} = -\frac{\tau}{1-\tau} \times \frac{C}{P^c}. \tag{6}$$

For a marginal tax rate of $\tau = 80\%$ and a semi-annual coupon rate of $C/P^c = 2\%$, the rate of return from buying the bond cum lottery and re-selling it ex lottery is $r(\tau) = -8\%$. Tax-neutral market makers and lottery bond investors with lower marginal tax rates would want to avoid this negative return by selling lottery bonds cum lottery and buying them back ex lottery. We assume that short sales of lottery bonds is not possible, which rules out arbitrage by tax-neutral market makers. Green and Rydqvist (1999) discuss the institutional features that prevent short sales of lottery bonds.

4.2 Uncertainty

We change the model by assuming that taxes are paid and tax credits are received at the end of the year, when the investor knows his final tax liability from realizing capital gains and losses in the stock market throughout the year. If the investor's net capital gain is positive, the marginal tax rate is τ; otherwise it is zero. We ignore intermediate values of the statutory tax rate schedule. We also assume that the investor is risk neutral with respect to the uncertain use of the tax-loss deduction and the outcome of the coupon lottery with expected value $E(C)$. The present value of the cash flows from purchasing the bond cum lottery and immediately selling it ex lottery subject to the zero-profit condition is:

$$-P^c + P^e + E(C) + PV\left[E(\tau|v_t)(P^c - P^e)\right] = 0, \tag{7}$$

where PV denotes the present value operator, and $E(\tau|v_t)$ is the expectation conditional on the node (vertex) v_t, which captures the time and path dependency of the marginal tax rate. Rearranging the equation yields:

$$\Delta(v_t) = \frac{P^c - P^e}{E(C)} = \frac{1}{1 - PV\left[E(\tau|v_t)\right]}. \tag{8}$$

The drop-off ratio is an increasing and convex function of the present value of a one krona loss deduction that is earned at the end of the year at a tax rate, which is either τ or zero. Tax rate uncertainty and discounting reduce the value of the loss deduction relative to the certainty case. For example, a marginal tax rate of $\tau = 80$ percent that occurs with a probability of 50 percent results in a drop-off ratio of 167 percent without discounting and 162 percent with discounting at the 5 percent interest rate. These numbers are substantially smaller than the drop-off ratio of 500% at the full marginal tax rate and no discounting.

We connect the set of nodes through a reconvening binomial tree, where each node occurs with probability $\pi(v_t)$. For each time t, we compute the weighted average drop-off ratio across nodes:

$$E(\Delta_t) = \sum_{v_t} \pi(v_t) \times \Delta(v_t). \tag{9}$$

The weighted average drop-off ratio increases over the calendar year as a result of discounting and the resolution of uncertainty:

$$E(\Delta_t) \leq E(\Delta_{t+1}), \quad \text{for all } t < T, \tag{10}$$

where T denotes the end of the year. The average drop-off ratio increases over year as a result of discounting and the resolution of uncertainty. The latter effect is an implication of convexity and Jensen's inequality.

4.3 Numerical Example

Equation (11) provides a one-step example. The end-nodes are $\tau = 0$ and $\tau = 80$ percent, the probability of an up-move is $p = 50$ percent, and the discount rate is zero. Each node displays a marginal tax rate and a drop-off ratio. The term structure of weighted average drop-off ratios is displayed below. In this example, the average drop-off ratio increases from 167 percent at $t = 0$ to 300 percent at $t = 1$.

$$\begin{array}{ccc} & & \Delta = 500,\ \tau = 80 \\ & \nearrow & \\ \Delta = 167,\ E(\tau|v_0) = 40 & & \\ & \searrow & \\ & & \Delta = 100,\ \tau = 0 \\ & & \\ E(\Delta) = 167 & & E(\Delta) = 300 \\ t = 0 & & t = 1 \end{array} \tag{11}$$

Equation (12) adds the option to carry forward unused losses one year. If the investor moves up the first year, he exercises the option to offset gains and losses at the end of the first year. If there is a down-move during the first year, the investor carries forward the tax-loss deduction to the end of year two.

$$
\begin{array}{ccccc}
 & & \Delta = 500,\ \tau = 80 & & \\
 & \nearrow & & & \\
\Delta = 250,\ E(\tau|v_0) = 60 & & & & \Delta = 500,\ \tau = 80 \\
 & \searrow & & \nearrow & \\
 & & \Delta = 167,\ E(\tau|v_1) = 40 & & \\
 & & & \searrow & \\
 & & & & \Delta = 100,\ \tau = 0 \\
E(\Delta) = 250 & & E(\Delta) = 333 & & \\
t = 0 & & t = 1 & & t = 2
\end{array}
\tag{12}
$$

The term structure of drop-off ratios increases from 167 and 300 percent without carry forward to 250 and 333 percent with one-year carry forward. The carry-forward provision reduces the probability that the capital loss is wasted.

The general method to construct a binomial tree of marginal tax rates includes six parameters: *(i)* time to expiration, *(ii)* number of steps, *(iii)* number of end-nodes when the tax-loss option is in the money, *(iv)* marginal tax rate when the tax-loss option is in the money, *(v)* probability of an up-move, and *(vi)* a risk-free rate. We start by determining which end-nodes are in the money and the associated marginal tax rate. Then, we move backward through the tree. At each intermediate node, we compute the expected marginal tax rate and take the present value of the expected tax rate. Once we have completed the tax-rate tree, we compute the drop-off ratio at each node according to Equation (8). Finally, we compute the weighted average drop-off ratio across nodes at time t as in Equation (9).

4.4 Comparative Statics

We are interested in how the term structure of drop-off ratios varies with changes in the exogenous parameters. As our base case, we fix the time to expiration to one year (no carry forward), the number of steps to 365 (days in the year), the number of end-nodes in the money to 183 (50 percent of 366), the marginal tax rate to $\tau = 0.762$, the interest rate to $r = 0.059$, and the probability of an up-move to $p = 0.51$. The base-case marginal tax rate equals the average top statutory tax rate from 1967–1976, when the tax code stipulates that a loss deduction must be used the same year, and the base-case interest rate equals the time-series average of the discount rate of the Central Bank from 1967–1976 (monthly data).[12] The probability $p = 0.51$ implies that the tax-loss option ends up in the money 64.9 percent of the time. The probability of an up-move depends on stock market performance, but it also depends on the investor's realization policy. We do not take a stand on what determines the decision to realize a capital gain, but we think it is reasonable that the probability of realizing a capital gain increases with time because more can happen as time passes.

An increase in the marginal tax rate raises the term structure of drop-off ratios for the obvious reason that a higher marginal tax rate makes the tax-loss option more valuable (Panel A of Table 5). A higher tax rate also increases the slope because the convexity of the drop-off function increases with the marginal tax rate. When the marginal tax rate decreases to levels that are closer to the taxation of capital gains in modern times, the effect from convexity becomes small. Accordingly, we would expect that a calendar effect from convexity is not observable for stock returns over the ex-dividend day, and we are not aware of any study that reports such a result.

An increase in the interest rate decreases the term structure of drop-off ratios because we assume that the tax-loss option does not benefit the trader until the end of the year (Panel B). Increasing the interest rate from zero to five percent raises the slope by $189.2 - 181.3 = 7.9$ percentage point. This change is small relative to the slope of the term structure at the five percent interest rate, which is 116.8 percentage points. Hence, the resolution of uncertainty is quantitatively more important than discounting.

The tax-loss option becomes more valuable as we increase the probability of an up-move (Panel C). When $p = 0.46$, the probability that the option is in the money at expiration is only 6.3 percent. As we increase the probability of a daily up-move to $p = 0.50$, the probability to end up in the money equals 50 percent, and when $p = 0.56$, the probability to end up in the money is 98.9 percent.[13] The year-end value for $p = 0.56$ in the amount of 416.8 percent is close to the maximum

[12] A secondary market for treasury securities begins in 1983.

[13] With five-year carry forward, these probability to end up in the money increases to 7.1 percent (for $p = 0.46$),

Table 5: Comparative Statics

	Drop-off ratio (%)			
	Beginning	End of year	Difference	In the money (%)
	A. Marginal tax rate			
$\tau = 0.30$	122.0	127.8	5.8	64.9
$\tau = 0.50$	141.7	161.9	20.2	64.9
$\tau = 0.70$	169.5	244.4	74.9	64.9
$\tau = 0.90$	210.5	656.8	446.3	64.9
	B. Interest rate			
$r = 0.00$	189.2	298.1	108.9	64.9
$r = 0.05$	181.3	298.1	116.8	64.9
$r = 0.10$	174.4	298.1	123.7	64.9
$r = 0.15$	168.3	298.1	129.8	64.9
	C. Probability of up-move			
$p = 0.46$	104.7	120.1	15.4	6.3
$p = 0.50$	156.0	260.1	104.1	50.0
$p = 0.52$	226.6	349.0	122.4	77.8
$p = 0.56$	345.6	416.8	71.2	98.9
	D. Time to expiration			
$T = 1$	157.8	263.3	105.5	64.9
$T = 6$	243.8	309.2	65.4	94.1
$T = 30$	262.1	322.2	60.1	99.1
$T = \infty$	263.1	323.0	59.8	100.0

The table reports numerical comparative static results with respect to the drop-off ratio in the beginning of the year, the end of the year, the difference between the two (slope of the term structure), and the probability that the tax-loss option is in the money ($\tau > 0$). Base case: time to expiration one year, the number of steps 365, number of end-nodes in the money 183 of 366, marginal tax rate 76.2 percent, interest rate 5.9 percent, and probability of an up-move 51 percent. Comparative statics for time to maturity longer than six years have been evaluated with one-step trees.

drop-off ratio of 420 percent that we obtain under full certainty.

Finally, as we allow investors to carry forward unused losses farther into the future, the value of the tax-loss option increases (Panel D). The slope of the term structure decreases with time to maturity, but there is a calendar effect also with indefinite deferral of unused losses. The beginning-of-the-year value converges to 263.1 percent and the year-end value to 323 percent. Infinite deferral of unused losses completely resolves uncertainty (the probability that the tax-loss option is in the money is 100%). With zero interest and infinite deferral, there is no calendar effect.

4.5 Calibration

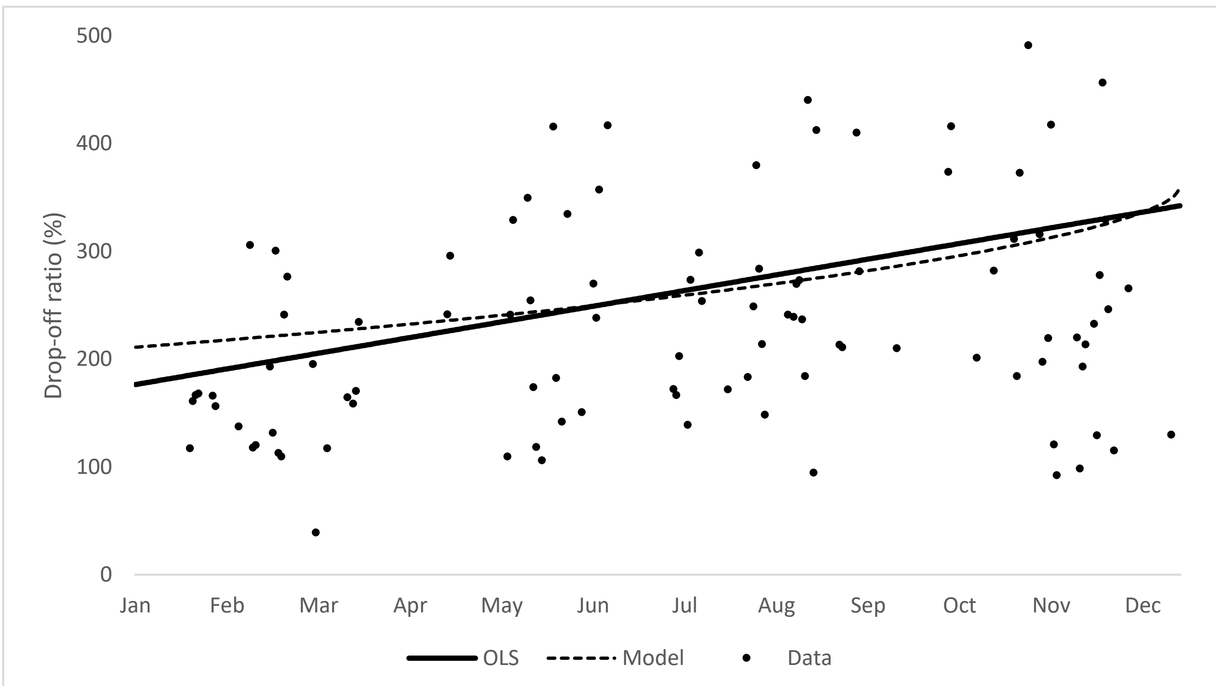
We assume 365 steps and 183 end-nodes in the money. From 1967–1976, we set one year to expiration, we fix the interest rate to the observed average of $r = 0.059$, and we calibrate the probability of an up-move to $\hat{p} = 0.515$ and the marginal tax rate to $\hat{\tau} = 0.784$ using the procedure of least squares. The model captures the upward-sloping term structure of drop-off ratios well (Figure 6). $\mathrm{R}^2 = 0.073$ from the model is close to $\mathrm{R}^2 = 0.085$ from ordinary least squares. From 1977–1990, we assume six years to expiration, we fix the interest rate to the observed average of 10.4 percent, and we calibrate the probability of an up-move to $\hat{p} = 0.503$ and the marginal tax rate to $\hat{\tau} = 0.839$. The corresponding plot is similar, and $\mathrm{R}^2 = 0.100$ from the model is close to $\mathrm{R}^2 = 0.124$ from ordinary least squares.

We asses the value of the carry-forward provision by feeding the parameters of the six-year model into the one-year model and measure the difference between model outputs in the data set from 1977–1990. The one-year model is located, on average, 75 percentage points below the six-year model (Figure 7). $\mathrm{R}^2 = -0.078$ from the one-year model, which means that the goodness of fit of the one-year model is below that of the unconditional mean. The two estimates of the value of the carry-forward provision, 42 percent from the regression analysis and 75 percent from the model, are of the same order of magnitude.

The scatter of data points in Figures 6 and 7, and the standard errors of the quarterly drop-off ratios in Table 3 above display heteroscedasticity. Increasing volatility of the error term over the

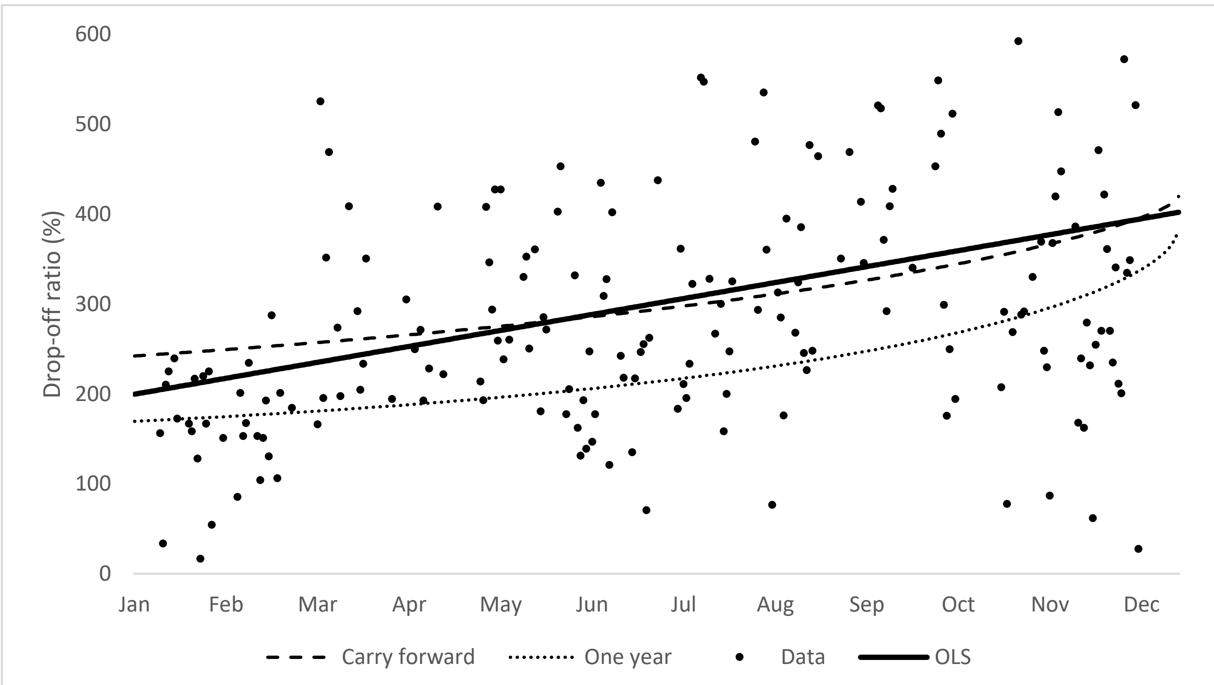
78.9 percent (for $p = 0.50$), and 100 percent (for $p = 0.56$).

Figure 6: Goodness of Fit 1967–1976



The figure plots the scatter of observed drop-off ratios from 1967–1976 along with a line estimated by ordinary least squares and the output from the model assuming: *(i)* one year to expiration, *(ii)* 365 steps, *(iii)* 183 end-nodes in the money, and *(iv)* a risk-free rate 5.9%, and endogenously solving for by least squares *(v)* the top marginal tax rate equal to 78.4% and *(vi)* the probability of an up-move 51.8 percent. The vertical axis has been truncated at 500 percent. The number of observations is 106.

Figure 7: Value of Carry-Forward Provision 1977–1990



The figure plots the scatter of observed drop-off ratios from 1977–1990 (when the tax code permits five-year carry forward of losses in the lottery bond market) along with the model extended with five-year carry forward (solid line) and the model without carry forward (dashed line). We get the output from the carry-forward model by assuming: *(i)* six years to expiration, *(ii)* 365 steps, *(iii)* 183 end-nodes in the money, and *(iv)* a risk-free rate 10.4%, and endogenously solving for by least squares *(v)* the top marginal tax rate equal to 83.9% and *(vi)* the probability of an up-move 50.3 percent. The output from the one-year model without carry forward has been determined by the same set of parameters except *(i)* one year to expiration. The vertical axis has been truncated at 600 percent. The number of observations is 194.

course of the year is an implication of the resolution of tax rate uncertainty and a property of the model.

Table 6: Robustness to Parameter Choices

	Free parameter				
	None	p	τ	p, τ	OLS
	A. No carry forward (1967–1976)				
Probability up-move p (%)	51	**51.8**	51	**51.5**	
Marginal tax rate τ (%)	76.2	76.2	**81.1**	**78.4**	
Interest rate (%)	5.9	5.9	5.9	5.9	
R^2 (%)	2.4	7.1	6.9	7.3	8.5
Probability in the money (%)	64.9	75.3	64.9	71.1	
	B. Five-year carry forward (1977–1990)				
Probability up-move p (%)	51	**50.6**	51	**50.3**	
Marginal tax rate τ (%)	80.8	80.8	**86.3**	**83.9**	
Interest rate (%)	10.4	10.4	10.4	10.4	
R^2 (%)	6.0	9.5	8.7	10.0	12.4
Probability in the money (%)	94.1	89.5	94.1	84.4	

The table reports parameter values and goodness of fit conditional on combinations of free parameters. We fix the number of steps to 365 and the number of end-nodes in the money to 183. Time to expiration is one year (Panel A) and six years (Panel B), respectively. The interest rate equals the time-series average interest of the Central Bank's discount rate from 1967–1982 and the three-month treasury rate from 1983–1990. The tax rate equals the statutory top marginal tax rate. We use normal font to mark exogenous parameters and boldface for estimated parameters subject to least squares errors. The number of observations is 106 and 194 in respective subperiods.

We conclude the calibration analysis by examining the robustness of our results to parameter choices. The goodness of fit increases with the number of free parameters, but the difference in R^2 between one and two free parameters is small (Table 6). One free parameter is sufficient to bring the model close to ordinary least squares in both subperiods. However, it is reassuring that we cannot simultaneously fit the one-year model and the six-year model with a common set of parameters in the new data from 1977–1990 (Figure 7), or the old data from 1967–1976.

4.6 Cross-Sectional Distribution

Without carry forward, the distribution of drop-off ratios in the beginning of the year is a single point (212.7 percent) and, at the end of the year, after all uncertainty has been resolved, it consists of two points (100 percent and 463 percent). We cannot test such sharp predictions from the model because we do not observe the cross-section distribution of drop-off ratios at the beginning or at the end of the year. However, we observe the distribution of drop-off ratios towards the end of the year, when the model predicts that the cross-section distribution is bimodal with minima and maxima between the present value of the two extremes at the end of the year. Before we investigate this prediction from the model, we introduce an error term. Noise arises from microstructure effects and interest rate changes over the two-week suspension period around the coupon lottery.

A coupon buyer forms an expectation of the resale price $\bar{P}^e$. The indifference condition with the expected resale price is:

$$\Delta(\tau, \bar{P}^e) = \frac{P^c - \bar{P}^e}{E(C)} = \frac{1}{1-\tau}. \tag{13}$$

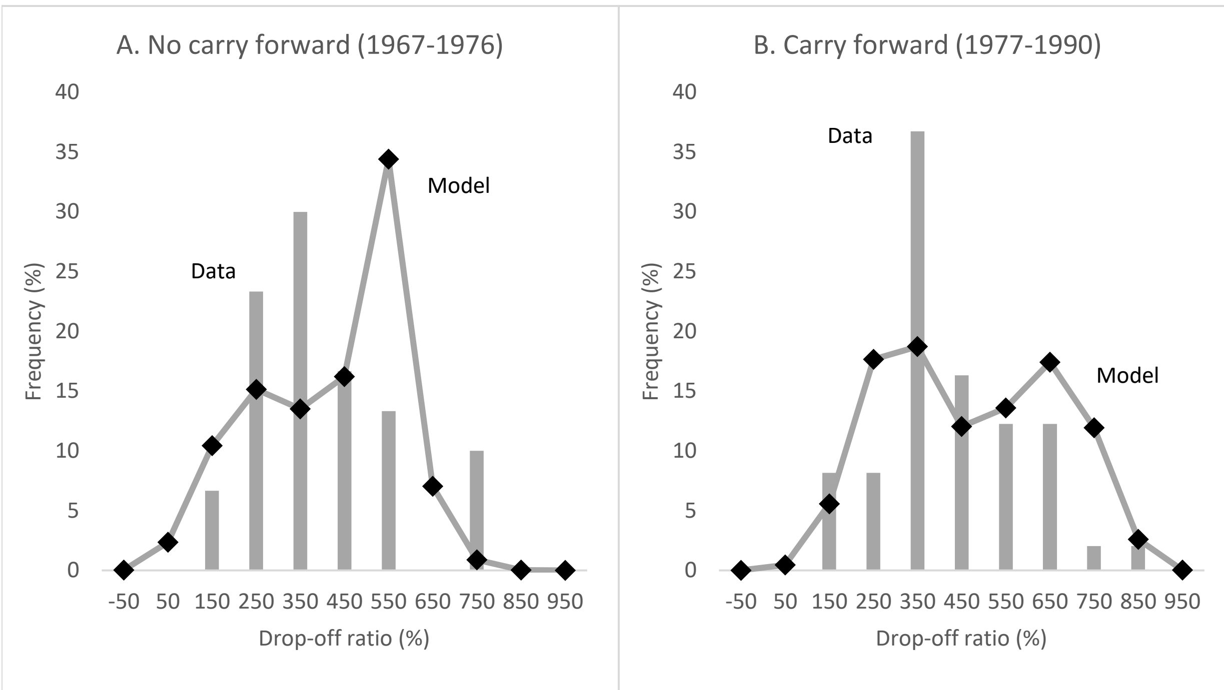
We substitute in the noisy spot price from the secondary market: $P^e = \bar{P}^e + u$. The drop-off ratio with noise equals:

$$\Delta(\tau, u) = \frac{P^c - P^e}{E(C)} = \frac{1}{1-\tau} + \frac{u}{C}. \tag{14}$$

We assume that the error term is normally distributed with zero mean and standard deviation 75.6 percent, which we estimate from the time-series of daily price changes (subsection 3.2).

The observed distribution of drop-off ratios in the fourth quarter is unimodal (Figure 8). The joint distribution of the one-year binomial tax-tree model and the normally distributed error term is also unimodal, but the peak of the observed distribution is located to the left (Panel A). The distribution of the six-year model with noise is flatter than the observed distribution with a heavy mass point around 350 percent (Panel B). A Kolgomorov-Smirnov test rejects the null hypothesis that the data are generated by the model with a p-value of 0.0395 for the one-year model and a p-value of 0.0995 for the six-year model. The low p-values suggest that something is missing from the model, but since our objective is to analyze the calendar effect with the simplest possible model, we abstain from looking further into what we have left out.

Figure 8: Fourth-Quarter Distribution of Drop-Off Ratios



The figure plots the frequency distribution of observed drop-off ratios in the fourth quarter (grey column bars) against the predicted distribution by the binomial tax-tree model extended with noise (solid grey lines between diamond markers). At each lottery date, we generate the cross-section distribution of drop-off ratios. We add noise by multiplying through each node of the tree by 10 quadrature points from the normal distribution with mean zero and standard deviation 75.7 percent. We estimate the standard deviation from the time-series of daily price changes in the secondary market. To accommodate for the effect of trade suspension around the lottery, we multiply the daily standard deviation by the square root of 14 days. The number of observations is 30 (from 1967–1976) and 49 (1977–1990), respectively.

5 Conclusions

We conclude that the calendar effect in the lottery bond market is the result of discounting and the resolution of tax rate uncertainty. Early in the year, the marginal tax rate that the investor will face at the end of the year is uncertain because investors do not know ex ante whether they will realize any taxable net gains from their stock market investments over the course of the year. This uncertainty is resolved over the course of the year, which leads to seasonality in tax planning.

Investors may have various reasons for realizing taxable capital gains. If escaping capital gains tax were the investors only concern, indefinite deferral of embedded gains would be the optimal realization strategy. The evidence from the lottery bond market suggests that there is seasonality in an investors decision to realize or defer capital gains on his stock portfolio. Is this seasonality the outcome of careful risk management, is it the optimal response to background risk, or is it something an active portfolio manager would do? We hope that the evidence of seasonal tax planning from the lottery bond market will inspire further research on why investors trade in the presence of capital gains tax.

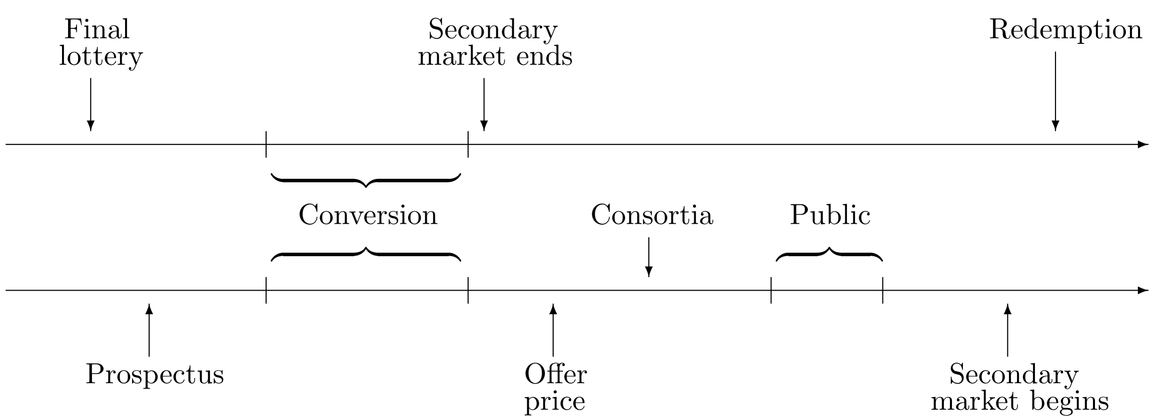
A Primary Market 1960–1980

The primary market for the lottery bonds is strictly regulated. The basic regulatory tools are underpricing and rationing. Akelius (1980) reports from conversations with Treasury officials at the time that the Treasury aims at holding back supply by 10-15% below anticipated demand. The stated objective is to disperse lottery bond ownership with the intention to stabilize long-term demand for new lottery bond issues. The many forms of mixed and sequenced bonds in the secondary market emerge from rationing in the primary market.

A.1 Underpricing

Lottery bonds trade in the secondary market for a substantial period of time after the final coupon lottery (Figure A1). While the old bond continues trading, the Treasury distributes an offer prospec-

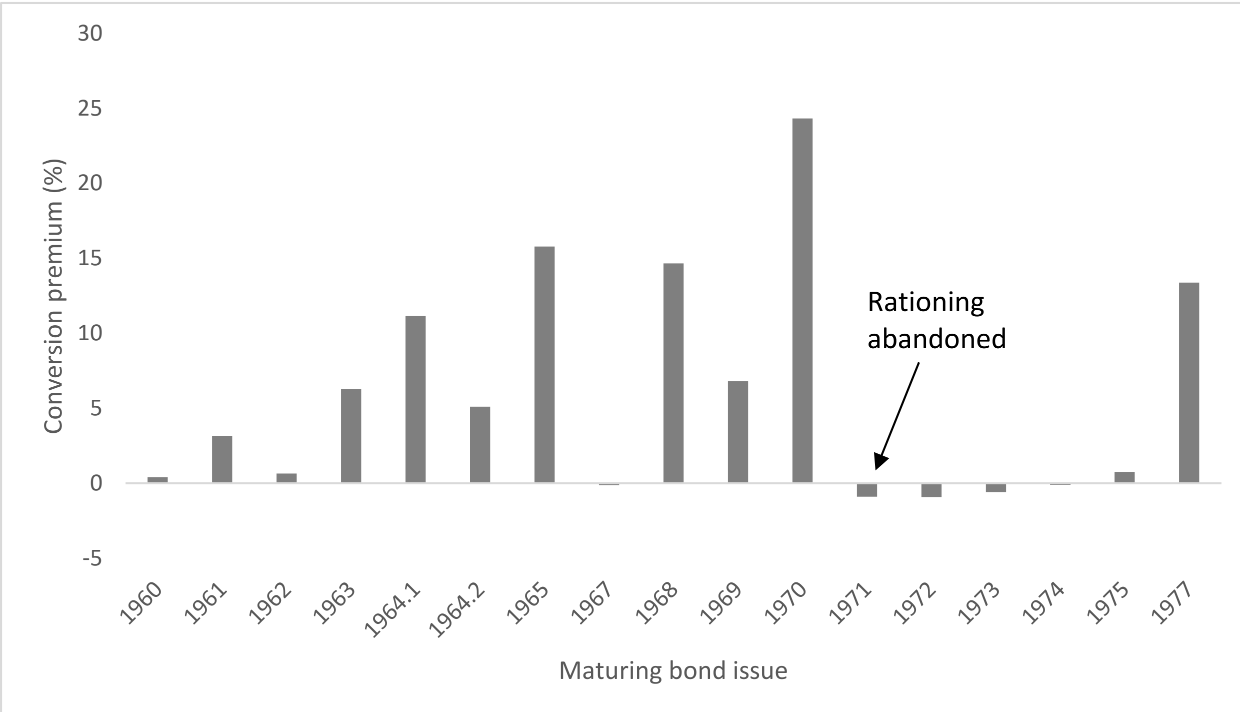
Figure A1: Time Line



The upper vector represents the time line for a maturing bond, and the lower vector is the time line for a new bond. On average, four months elapse from the final lottery to redemption, and two months from the issuance of the prospectus to the opening of the secondary market.

tus, which specifies the par value of the new bonds, the structure of the coupon lottery, the redemption year, and the approximate number of lotteries over the life time of the bond. The Treasury invites old bondholders to convert old bonds into new bonds at par. The exchange takes place during a two-week conversion period after which the old bond stops trading. After completing

Figure A2: Conversion Premium



The conversion premium equals the average market price of mixed and sequenced bonds minus par during the conversion period.

the exchange offer, the Treasury determines the offer price and sells the remaining lottery bonds to lottery bond consortia and the general public. The secondary market for the new bond begins shortly after.

New lottery bonds are underpriced. The average market price of maturing bonds exceeds the redemption value (par) by 5.9% with a maximum of 24.3% (Figure A2). When rationing is abandoned in 1981, the conversion premium decreases to zero with the exception of the conversion of the maturing lottery bond issues of 1977 and 1982 into new lottery bond issue 1987, which is exclusively reserved for old bondholders. The average take-up ratio of the right to convert old bonds into new bonds is 80%.

The Treasury aims at selling the remaining bonds at par value. However, following an increase in the interest level between the issuance of the offer prospectus and the beginning of the general sales, the Treasury may raise the offer price above par. When bonds are sold at a premium, the average premium is 1.6% with a maximum of 4% above par. Since the average conversion premium of 5.9% exceeds the average offer premium, lottery bonds are underpriced in the primary market. In the context of initial public offerings of stocks, Hanley (1993) refers to the partial-adjustment phenomenon to describe the practice to partially raise the offer price in response to demand.

A.2 Rationing

The Treasury allocates the new lottery bonds among old bondholders (conversion), lottery bond consortia, and the general public. Mixed old bonds are exchanged for mixed new bonds, and sequenced old bonds are exchanged for sequenced new bonds. From 1963–1980, the Treasury does not issue unbroken S-sequences. The Treasury stops issuing unbroken S-sequences after a price spread emerges between S-sequences and mixed bonds in the secondary market for the lottery bond issue of 1961. According to a Treasury official, the purpose is to eliminate the inequality that arises between those who convert mixed old bonds into mixed new bonds and those who receive the more valuable sequenced new bonds in exchange for sequenced old bonds. Instead, the bondholders of S-sequences of maturing lottery bond issues 1960–1962 receive D-sequences of new lottery bond issues 1970–1972. From the second tranche of the lottery bond issue of 1976 to 1980, the Treasury does not issue D-sequences either, and holders of D-sequences of maturing lottery bond issues 1963-1970 receive C-sequences of new bonds. Hence, the supply of D- and S-sequences through conversion diminishes over time.

A lottery bond consortium must register with the Treasury, it must have a minimum number of members, and it must express in writing that it intends to become a long-term bondholder. In return for these restrictions, a lottery bond consortium can finance the lottery bond purchase with a (subsidized) loan from the Central Bank, it can submit the purchase order by mail, and it can purchase bond sequences. A lottery bond consortium with ten members is allowed to purchase 100-bond sequences, a consortium with 15 members can purchase 500-bond sequences, and a consortium of 20 members with no single member owning more than 10% can purchase D-sequences that cover all order numbers from 1–1000. On average, 500 lottery bond consortia register per lottery bond issue. The Treasury stopped issuing unbroken 500-bond sequences in 1976 after many lottery bond consortia that had agreed to become long-term lottery bondholders sold their bonds shortly after the secondary market opened (bond flipping).

The Treasury sells the remaining bonds through the banking system or in person at the Treasury's sales office. The Annual Yearbook of the Swedish National Debt Office explains in detail the rationing that takes place at the Treasury's sales office. Depending on market conditions, the Treasury sets an initial quota between 25 and 300 bonds per investor, and then decreases the quota as the sales proceed. The mode of the initial quota is 50 bonds per buyer, the first revised quota is 20 bonds per buyer, and the final quota is 10 bonds per buyer. Akelius (1980) describes how investors line up in person over night outside the Treasury' sales office for the opportunity to buy new lottery bonds the next day. These quotas apply to direct sales. We do not know to what extent banks ration supply among their customers, but a reasonable guess is that banks favor good customers as they do in initial public offerings of stocks.[14]

Table A1: Primary Market Shares 1963–1980

	Conversions	New offers	Supply restrictions
Old bondholders	51.0	n/a	Sequence for sequence, mixed for mixed
Consortia	5.7	9.3	500-sequences (1968–1975); 100-sequences (1976–1980)
Bank customers	40.1	84.4	100-sequences
Direct sales	3.2	6.3	Mixed bonds only
Sum	100.0	100.0	

The table reports average market shares in percent for 19 exchange offers and 17 new offers from 1963–1980. The table also lists supply restrictions for old bondholders, lottery bond consortia, bank customers, and direct sales by the Treasury. A complete bond sequence can be exchanged for two 500-bond sequences from different series (1963–1975) or ten 100-bond sequences from different series (1976–1980). Shorter sequences are exchanged quid pro quo.

From the information in the Annual Yearbook, we can estimate the primary market shares (Table A1). New lottery bond issues that include conversion of old into new lottery bonds are taken up by old bondholders 51 percent, lottery bond consortia 5.7 percent, bank customers 40.1 percent, and direct sales 3.2 percent. The market share of bank customers increases to 84.4 percent

[14]See Rydqvist (1997) for Sweden and Ritter and Welch (2002) more generally.

in lottery bond issues without conversion.

References

Akelius, Roger, 1974, *Tjäna på premieobligationer.* (Akelius Publishing Jönköping, Sweden).

Akelius, Roger, 1980, *Tjäna mycket mera på premieobligationer.* (Akelius Publishing Jönköping, Sweden).

Badrinath, S.G., and Wilbur G. Lewellen, 1991, Evidence on Tax-Motivated Securities Trading Behavior, *Journal of Finance* 46, 369–382.

Branch, Ben, 1977, A Tax Loss Trading Rule, *Journal of Business* 50, 198–207.

Chaudhuri, Shomesh E., Terence C. Burnham, and Andrew W. Lo, 2020, An Empirical Valuation of Tax-Loss Harvesting Alpha, *Financial Analysts Journal* 76, 99–108.

Constantinides, George M., 1983, Capital Market Equilibrium with Personal Tax, *Econometrica* 51, 611–636.

Constantinides, George M., 1984, Optimal Stock Trading with Personal Taxes: Implications for Prices and the Abnormnal January Return, *Journal of Financial Economics* 13, 65–89.

Dammon, Robet M., Kenneth B. Dunn, and Chester S. Spatt, 1989, A Reexamination of the Value of Tax Options, *Review of Financial Studies* 2, 341–372.

Dammon, Robet M., and Chester S. Spatt, 1996, The Optimal Trading and Pricing of Securities with Asymmetric Capital Gains Taxes and Transaction Costs, *Review of Financial Studies* 9, 921–952.

DeAngelo, Harry, and Ronald W. Masulis, 1980, Optimal Capital structure under Corporate and Personal Taxation, *Journal of Financial Economics* 8, 3–29.

Ehling, Paul, Michael Gallmeyer, Sanjay Srivastava, Stathis Tompaidis, and Chunyu Yang, 2018, Portfolio Tax Trading with Carryover Losses, *Management Science* 64, 3971–4470.

Graham, John R., 2000, How Big Are the Tax Benefits of Debt?, *Journal of Finance* 55, 1901–1941.

Green, Richard C., and Kristian Rydqvist, 1997, The Valuation of Non-Systematic Risks and the Pricing of Swedish Lottery Bonds, *Review of Financial Studies* 10, 447–479.

Green, Richard C., and Kristian Rydqvist, 1999, Ex-Day Behavior with Dividend Preference and Limitations to Short-Term Arbitrage: The Case of Swedish Lottery Bonds, *Journal of Financial Economics* 53, 145–187.

Grinblatt, Mark, and Matti Keloharju, 2004, Tax-Loss Trading and Wash Sales, *Journal of Financial Economics* 71, 51–76.

Hanley, Kathleen Weiss, 1993, The Underpricing of Initial Public Offerings and the Partial Adjustment Phenomenon, *Journal of Financial Economics* 34, 231–250.

Horan, Stephen M., and David Adler, 2009, Tax-Aware Investment Management Practice, *Journal of Wealth Management* 12, 71–88.

Keim, Donald, 1983, Size-Related Anomalies and Stock Return Seasonality, *Journal of Financial Economics* 12, 13–32.

Modigliani, Franco, and Merton H. Miller, 1963, Corporate Income Taxes and the Cost of Capital: A Correction, *American Economic Review* 53, 433–443.

Odean, Terrance, 1998, Are Investors Reluctant to Realize Their Losses?, *Journal of Finance* 53, 1775–1798.

Poterba, James M., 1987, How Burdensom are Capital Gains Taxes? Evidence from the United States, *Journal of Public Economics* 33, 157–172.

Poterba, James M., and Scott M. Weisbenner, 2001, Capital Gains Tax Rules, Tax-Loss Trading, and Turn-of-the-year Returns, *Journal of Finance* 56, 353–368.

Reinganum, Mark, 1983, The Anomalous Stock Market Behavior of Small Firms in January: Empirical Tests for Tax-Loss Selling Effects, *Journal of Financial Economics* 12, 89–104.

Ritter, Jay R., and Ivo Welch, 2002, A Review of IPO Activity, Pricing, and Allocations, *Journal of Finance* 57, 1795–1818.

Rydqvist, Kristian, 1997, IPO Underpricing as Tax Efficient Compensation, *Journal of Banking and Finance* 21, 295–313.