Swedish Lottery Bonds

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Abstract

Swedish lottery bonds are valuable tax shelters before the tax reform of 1991. By trading around the coupon lottery, taxable gains and losses from the stock market are netted across investors in the lottery bond market. However, the uncertainty of the coupon lottery and the effort of verifying the winning lottery bond numbers are a nuisance to tax traders. We investigate how the Treasury (issuer), market makers (banks), and lottery bond investors respond to those frictions.

Keywords: tax progressivity, coupon lottery, lottery number checking, ex-dividend day, turn-of-the-year effect, rationing, underpricing.
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1 Introduction

Swedish lottery bonds are government obligations that make coupon payments by lottery. The aggregate payment to all lottery bond holders is a fixed contractual amount that does not depend on the state of the economy. Therefore, the uncertain outcome of the coupon lottery is diversifiable risk that, according to standard asset pricing theory, should not matter to lottery bond prices. Contrary to this prediction, Green and Rydqvist (1997) conclude that the marginal lottery bond investor is risk averse. Their conclusion is also curious from a practical point of view because the coupon lottery has been constructed to attract investors with lottery preferences. If the marginal investor is risk averse, then the issuer loses from issuing bonds with coupon payments determined by lottery.

In a subsequent paper, Green and Rydqvist (1999) show that marginal tax rates can be imputed from lottery bond prices around the coupon lottery. The tax arbitrage is a simple coupon-capture strategy. An investor with a capital gain from the stock market purchases lottery bonds cum-lottery, sells them at a loss ex-lottery, and covers the loss with the tax-free proceeds from the coupon lottery. The other side of the trade is taken by an investor with a capital loss from the stock market. The capital loss from the stock market offsets the price appreciation between coupon lotteries. Through these transactions in the lottery bond market, capital gains and losses from the stock market are netted across investors, thus resulting in an overall tax reduction.

At glance, the two previous studies of the Swedish lottery bond market analyze unrelated economic problems. However, we argue in this paper that the marginal lottery bond investor is a risk averse tax trader. A simple way to diversify the uncertainty of the coupon lottery is to form a lottery bond mutual fund and sell mutual fund shares to lottery bond investors. This strategy works for buy-and-hold investors, and banks do supply lottery bond mutual funds during the high days of the 1980s (Akelius (1987)). However, a buy-and-hold mutual fund does not meet the demand of tax traders, who must coordinate with other investors with a need to shield tax liability at a particular point of time. Therefore, a tax trader must cope with the uncertainty of the coupon lottery himself. Accordingly, if the marginal investor is a tax trader, we expect that lottery bond prices exhibit risk aversion.

Tax-motivated trading of lottery bonds begins on a large scale with the publication of Akelius (1974), and it ends with the tax reform of 1991. Green and Rydqvist (1997) study the electronically available time-series from November 1986–1990 that covers a small portion of the high-activity period. We purchase hard copies of transaction records and backdate the time-series to cover the entire 1970–1990 period. With the extended data set, we can statistically support the main thesis of this paper by relating market-based measures of risk aversion to statutory marginal tax rates and stock market performance. Many other new results can also be generated from the extended data set.

One novel feature is the calendar-time behavior of ex-day returns. In the first quarter, tax traders are willing to incur capital losses in the amount of 1.9 times the expected coupon payment while, in the fourth quarter, the average capital loss is 3.4 times the lottery mean. The marginal tax rate that can be imputed from those numbers is 46% in the first quarter and 70% in the fourth quarter. Clearly, competition for tax shelters increases towards the end of the year. The calendar-time effect in ex-lottery day returns resembles the turn-of-the-year effect for small cap stocks (e.g., Keim (1983) and Reinganum (1983)), and we offer a real-option explanation.[1]

Second, our study is an example of financial intermediation and innovation in response to regulation. Each lottery bond has a series number and an order number. The holder of a complete bond series that covers all order numbers from 1–1000 earns a portion of the expected coupon with certainty. Short-term tax traders prefer to work with complete bond sequences, but the Treasury does not supply them. Most lottery bonds are issued in blocks of unbroken 100-bond sequences. The best investors can do is to put together 100-bond sequences into packages that mimic a complete bond sequence. A package of ten 100-bond sequences that covers all order numbers from 1–1000 is referred to as a C-sequence (Roman numeral for 100). In the beginning of the time-series, C-sequences barely exist, but as soon as tax trading takes off, banks supply new C-sequences to meet demand. Within a few years, 75% of lottery bond turnover is concentrated to C-sequences.

Third, the rich structure of lottery bond prices makes it possible to estimate the market price

[1]There are other examples of increased tax planning towards the end of the fiscal year. For example, contributions to individual retirement accounts (IRA) are higher after the end of the income year but before the tax return is due on April 15 (see Feenberg and Skinner (1989)).

of effort. A subset of each lottery bond is issued in blocks of unbroken 500-bond sequences. A package of two 500-bond sequences that covers all order numbers from 1–1000 is called a D-sequence (Roman numeral for 500). In matched intra-day comparisons, D-sequences trade above or equal to C-sequences. The D-premium emerges in the early 1970s and, for a short period from 1973–1975, it averages 2% of par value. We interpret this price difference as an effort premium because manually verifying the winning lottery bond numbers of two 500-bond sequences requires less effort than dealing with ten 100-bond sequences. The D-premium disappears when trading volume becomes large enough for Swedish banks to service investors with lottery number checking. For a professional lottery number checker, a D-sequence is a perfect substitute for a C-sequence.[2] The D-premium may appear esoteric to non-lottery-bond scholars, but it provides an example of the price effects of information and how financial institutions arise to solve information problems. In *Wealth of Nations*, Adam Smith tells the story of the Bank of Amsterdam, which was established in 1609 to verify the intrinsic metal content of some 300 silver coins and 500 gold coins that circulated in the Netherlands at the time. In the spirit of the Bank of Amsterdam, Swedish banks provide lottery number checking when demand justifies the institutional set-up costs.

Fourth and finally, our paper is a case study of the performance of a regulated financial market. Before 1981, supply is rationed and new lottery bonds are underpriced. We estimate that lottery bonds are sold in the primary market at prices that are approximately 6% below the secondary market price. From 1981, when the primary market is allowed to clear, there is no underpricing. These findings complement the evidence from numerous studies of initial public offerings of stocks (see, e.g., Ritter (2003) for a survey), and the reason for underpricing may be the same. According to Treasury officials, the purpose of rationing is to disperse bond ownership, which is believed to stabilize demand for future lottery bond issues (Akelius (1980)).[3] In other words, the issuer is willing to incur the cost of rationing in return for long-term liquidity provision.[4] Ownership dispersion and liquidity provision is also the motivation for the policy to break up complete bond sequences and scatter 100-bond sequences among investors. The mixed-bond policy is also costly

[2]The D-premium resembles the higher commission charged by odd-lot stock brokers.

[3]The official name is the Swedish National debt Office, which we refer to the Treasury for convenience.

[4]For similar reasons, bidding in US Treasury auctions is restricted to a small set of primary dealers who, in return for this favor, must promise to purchase securities in future auctions.

to the issuer. A price spread between sequenced and mixed bonds in the amount of 4% of par value emerges at the opening of the secondary market. In the deregulated post-1980 market, the sequenced-bond premium does not emerge until several months later. Then, lottery bond investors pay the full sequenced bond price when they purchase mixed bonds in the secondary market, and the sequenced-bond premium does not arise until the mixed bonds are resold in the secondary market. Hence, from 1981, the cost of breaking up sequenced bonds into mixed bonds is borne by the buyers of mixed bonds in the secondary market and not by the issuer (Green and Rydqvist (1997)).

Lottery bonds were widespread in the 1800s (Levy-Ullman (1896)). They were issued by states and municipalities or under state sanction granted to companies such as the Panama Canal Company and the Suez Canal Company. However, lottery bonds have largely disappeared from modern financial markets, and the academic literature on lottery bonds is limited to a few studies of Denmark, pre-revolution Russia, and Sweden.[5] Why were lottery bonds issued in the past? There is a longstanding tension between the government's desire to control gambling and citizens' demand for gambling. In the 1800s, governments exploited their monopoly power over gambling to borrow at favorable terms. As state lotteries became abundant during the 1900s, the primary reason to bundle loans and lottery tickets no longer existed and, as illustrated by the evidence in our paper, those interested in purchasing the loan (tax traders) are not particularly interested in purchasing the lottery tickets (risk aversion). Accordingly, lottery bonds may remain condemned to financial history. For a different view on the future of prize-linked savings products, we refer the reader to Kearney, Tufano, Guryan, and Hurst (2010).[6]

The rest of the paper is organized as follows: Section 2 describes the institutional background and the data. The section outlines the regulations, estimates underpricing, and explains how banks respond to regulation. The tax rules, the tax arbitrage, and its implications for price formation and trading volume around the coupon lottery is analyzed in Section 3. The empirical investigation

[5] See, respectively, Florentsen and Rydqvist (2002), Ukhov (2005), and elsewhere cited Green and Rydqvist (1997) and Green and Rydqvist (1999).

[6] While lottery bonds have largely ceased to exist, governments in some countries supply savings accounts with interest determined by lottery, e.g., Argentina, Denmark, France, and United Kingdom (Lobe and Hölzl (2008)). Bonds with redemption lottery, e.g., corporate bonds with sinking fund provision, continue to be issued. Studies of redemption lottery bonds include Schilbred (1973) and Bühler and Herzog (2008).

ends by linking the tax arbitrage to the sequenced bond premium in Section 4. This section also provides evidence on how effort aversion influences lottery bond prices. Section 5 summarizes our findings.

2 Institutional Background & Data

2.1 Swedish Lottery Bonds 1970–1990

The Swedish lottery bond market becomes active during a short period from 1970–1990, when annual turnover of lottery bonds increases from a few percent per year to above 50% in the mid-1980s before turnover reverts back to its low historical level after 1990. The interest for trading in lottery bonds begins with the publication of Akelius (1974), who explains in a simple manner how investors can take advantage of tax features of lottery bonds to reduce personal income tax. When tax trading of lottery bonds begins, Swedish financial markets are inactive. Before 1980, when the process of removing capital and credit controls begins, the stock market is in deep sleep and the bond market is non-existent. The lottery bond market is the only secondary market for fixed-income securities.[7]

Lottery bonds are non-callable government obligations that make coupon payments by lottery.[8] Each bond makes two or three coupon payments per year. Time to maturity from issuance varies between five and ten years, so over its life time, a lottery bond conducts between 10 and 30 coupon lotteries. The principal is paid back to investors at maturity. Alternatively, holders of maturing bonds can convert old bonds into new bonds at par. The conversion option means that lottery bonds are floating rate securities with the interest rate being reset every five or ten years.[9] Furthermore, lottery bonds are bearer securities. They are designed for the retail market and issued in small denominations of 50, 100, and 200 kronor.[10] Recent lottery bonds have par values 1,000 and 10,000

[7]During the regulation period, the discount rate of the Central bank is the only interest-rate time-series against which to compare lottery bond coupon rates and yields. The discount rate does not respond to short-term changes in market conditions.

[8]Lottery bonds 1942–1955 with either 20 years to maturity or no pre-set time to maturity are callable after ten years.

[9]From 1986, some maturing bonds are redeemed for cash. Green and Rydqvist (1999) study the behavior of lottery bond yields after the change of redemption policy.

[10]Purchasing power has decreased by approximately eight times since 1975 and the exchange rate between the

kronor. Between one and three loans are issued each year. We refer to each bond by issue year and loan number. For example, bond 1974:1 denotes the first loan of the bond issued in 1974. From 1970–1990, the outstanding loan stock averages 9% of Swedish Government debt and 3.5% of Gross Domestic Product. Institutional information about the lottery bond market is taken from the Annual Yearbook of the Swedish National Debt Office 1920–1984, issue prospectuses for the various loans, and the two editions of Akelius (1974) and Akelius (1980). The Annual Yearbook of the Swedish National Debt Office is extremely detailed and informative during the regulation period. Once the lottery bond market is de-regulated in 1981, most information is omitted.

2.2 Coupon Lottery

Each bond within a lottery bond issue has a series number and an order number. The structure of the coupon lottery of 1974:1 is shown in Table 1. There are 6,000 series with 1,000 order numbers within each series, so the number of bonds outstanding is six million. The coupon lottery pays 4,856 prizes between 400 kronor and 320,000 kronor. These prizes are randomized across all bonds without replacement. Each such prize is awarded by drawing one series number and one order number. 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 6,000 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 with all order numbers 1–1000 is certain to win the 20 small prizes of 50 kronor. We refer to this feature as the partial guarantee. For 1974:1, the annualized certain return from the small payments is 2% of par, and the annualized expected return from the coupon lottery is 5.15%. The guaranteed portion to the holder of a complete 1000-bond sequence is 38.83% (the ratio of 2% and 5.15%). The par value of a 1000-bond sequence is 100,000 kronor.

The dual structure of the coupon lottery with series numbers and order numbers has its roots in the technology to generate and distribute the winning lottery bond numbers. The payments of the 4,856 large prizes between 400 kronor and 320,000 kronor require that the issuer generates

krona and the dollar has varied around eight kronor to the dollar, so we can think of the purchasing power of 100 kronor in 1975 as 100 dollars in 2010.

Table 1: Coupon Lottery of Bond 1974:1

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 shows the structure of the semi-annual coupon lottery for bond 1974:1. Prizes are quoted net of 20% lottery tax.

4,856 series numbers and 4,856 order numbers, while the payments of the 120,000 small prizes require only 20 order numbers that are equal across all series. Before 1963, the winning numbers are generated manually by drawing numbered balls from two cylinders, one for series numbers and one for order numbers. Generating the numbers could last more than one day (Akelius (1980)). From 1963, the winning lottery bond numbers are computer generated and the marginal cost of generating additional numbers is zero. However, distributing a large set of winning numbers is costly. The winning numbers are printed in a pamphlet and mailed to bondholders. From 1982, banks also receive the list of winning numbers on floppy disk. The winning numbers are put into a table that covers four pages (approximately letter size). An excerpt of the prize list for the second lottery of 1974:1 is reproduced in Table 2. In each section of the prize list, the first column denotes the series number and the second column the order number. The third column provides a letter code that indicates the prize. The list of the 20 order numbers that identify the winners of the small prizes are put in a separate table at the end of the pamphlet. Distributing 120,000 small prizes with only 20 order numbers reduces the costs of generating, printing, and mailing. With

Table 2: Excerpt from a Prize List

Series	Order	Prize	Series	Order	Prize	Series	Order	Prize	Series	Order	Prize
1	674	H	133	259	K	255	874	K	378	135	K
2	62	K	135	216	K	256	83	H	378	430	K
2	609	K	135	396	K	257	520	K	380	406	H
3	686	K	137	560	K	258	612	K	383	603	K
4	653	J	141	109	J	258	840	K	383	812	K
4	888	J	143	3	J	260	420	K	386	93	K
9	496	K	143	91	K	261	620	J	386	187	J
9	497	J	144	982	J	262	588	K	386	804	H
12	525	K	145	402	J	266	430	K	388	460	J
13	336	K	146	611	K	267	398	H	388	755	K
13	905	K	148	199	J	273	965	J	389	780	J
15	152	K	150	940	K	274	557	J	390	636	J
17	227	K	154	172	K	275	668	K	392	163	J
19	341	K	157	857	K	277	15	K	395	89	J
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

The upper left corner of the first page of the pamphlet with the winning lottery bond numbers from the second coupon lottery of bond 1974:1 held on November 26, 1974. In each section of the prize list, the first column denotes the series number and the second column the order number. The third column provides a letter code that indicates the amount: Y=320,000 kronor, C=80,000 kronor, D=40,000 kronor, E=20,000 kronor, G=8,000 kronor, H=4,000 kronor, J=800 kronor, and K=400 kronor. The 20 order numbers of the small prizes in the amount of 50 kronor are listed at the end of the prize list.

expanding issue volume and increasing number of prizes, the two smallest prizes of lottery bonds 1975–1978 (prizes of 50 and 100 kronor) and the three smallest prizes of lottery bonds 1979–1980 (prizes of 50, 100, and 400 kronor) are distributed by drawing order numbers only.

From 1981–1990, a bond sequence with the partial guarantee is reduced to 100 bonds. To illustrate the new procedure, suppose there are 20 small prizes as in Table 1 above. Two order numbers $a, b \in [1, 100]$ are generated. The small prizes are paid to owners of lottery bonds with order numbers:

$$a, b, 100 + a, 100 + b, 200 + a, 200 + b, \cdot \cdot \cdot \cdot, 900 + a, 900 + b.$$

Accordingly, the owner of a 100-bond sequences earns two of the 20 small prizes with certainty.

2.3 Primary Market

Lottery bonds are sold through a fixed-price offer. Before the general sales begin, holders of maturing bonds can convert old bonds into new bonds at par. The average take-up ratio is 82%. Old bondholders also have an option to purchase one new bond for each old bond at par.[11] This option is exercised by 68% of old bondholders. From 1970–1980, on average, 23% of the new lottery bond issue is placed with old bondholders, 9% is sold to lottery bond consortia, and 68% is sold to the general public.[12]

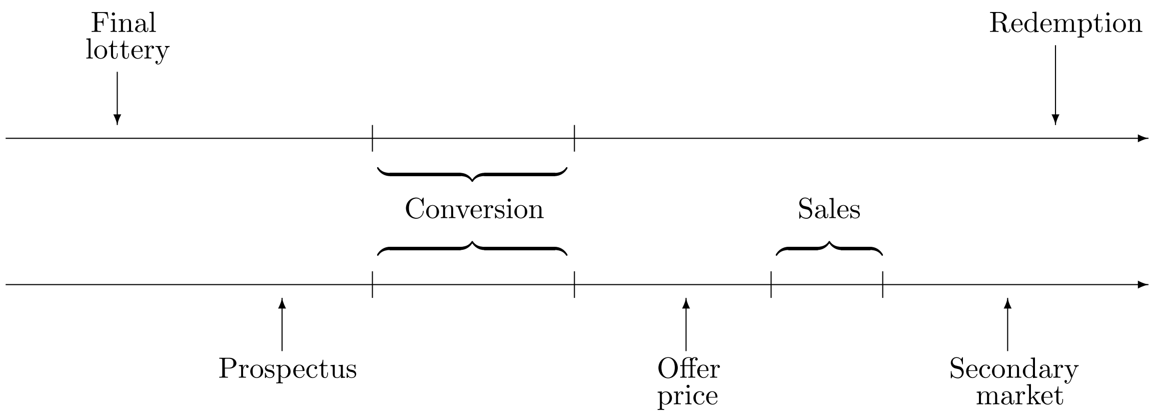


Figure 1: Time Line around Redemption and Flotation: The upper vector represents the time line for a maturing bond, and the lower vector the time line for a new bond. On average, four months elapse from the final lottery to redemption, and two months from the issuance of the offer prospectus to the opening of the secondary market.

A time line around the redemption of an old bond and the flotation of a new bond is shown in Figure 1. After the final coupon lottery, old bondholders can convert maturing bonds into new bonds during a two-week conversion period. An offer prospectus with the terms of the new bond is presented to the market shortly before the conversion period. The offer prospectus specifies the par

[11]When 50-kronor bonds are converted into 100-kronor bonds, the bondholder can choose to pay for one new bond with two 50-kronor bonds or one 50-kronor bond plus 50 kronor cash. The same principle applies to the conversion of 100-kronor bonds into 200-kronor bonds. When 50-kronor bonds are converted into 200-kronor bonds, the bondholder chooses between paying with four 50-kronor bonds and one 50-kronor bond plus 150 kronor cash.

[12]A lottery bond consortium must have a minimum number of members, it must register with the Treasury and express in writing that it intends to become a long-term bondholder. In return for these restrictions, lottery bond consortia can finance the lottery bond purchase with a loan from the Central Bank, they can order by mail, and they can purchase sequenced bonds (more in the text below). From 1968:2–1980, on average, 500 lottery bond consortia purchase lottery bonds in each new offering.

value, coupon rate, lottery structure, redemption year, and the approximate number of lotteries over the new bond's life time. Shortly before the general sales, the offer price is determined. Most bonds issued in 1970–1980 are sold at a premium above par. The average offer premium is 1.9% with the range of the offer premium being 0–4%. The Treasury sells 6% of the new bonds to the general public itself. Banks sell the remaining 62% on commission (best-effort contract).[13] Secondary market trading begins approximately two months after the offer prospectus has been issued.

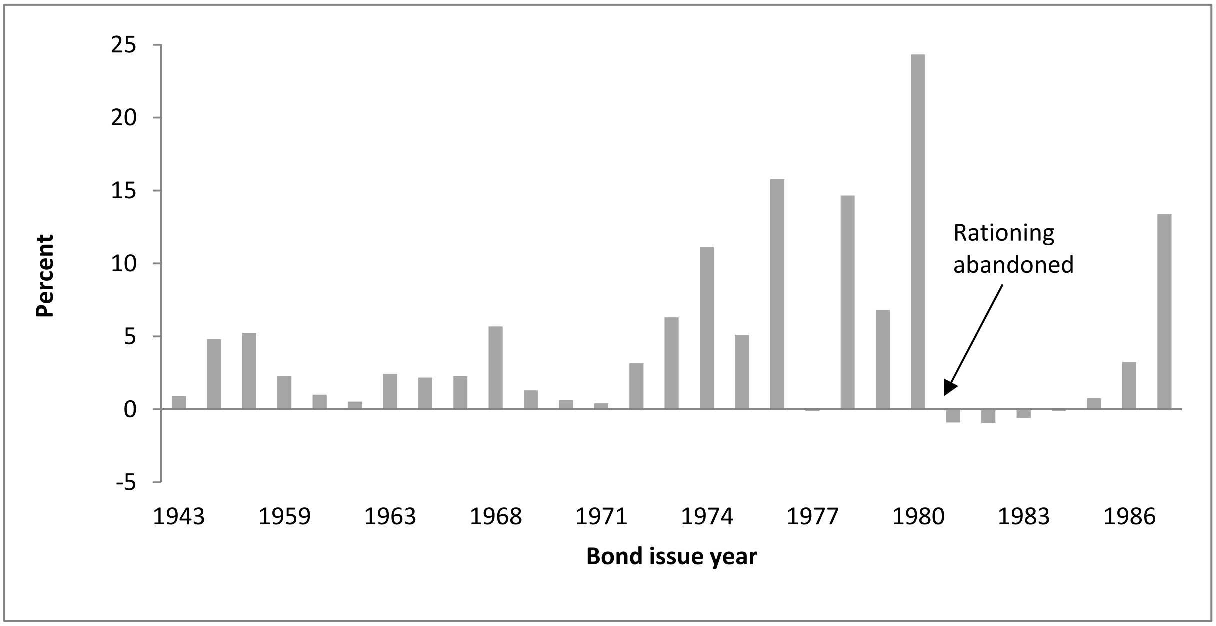
From 1963–1980, the Treasury rations supply. The objective of rationing is to disperse ownership, which the Treasury believes stabilizes long-term demand. Akelius (1980) reports from conversations with Treasury officials that the Treasury aims at holding back supply by 10-15% below anticipated demand. In direct sales by the Treasury to the general public, the Treasury offers a small number of bonds per buyer. The initial quota is 25 or 50 bonds per buyer, but the quota is often reduced during the first day of sales. Akelius (1980) describes how investors line up in person over night for the opportunity to buy new bonds the next day. It is not known how the banks allocate the new bonds among its customers, but we conjecture that banks favor their best customers as they tend to do in initial public offerings of stocks. Rationing ends in 1981.

Effective rationing requires that lottery bonds are underpriced. Underpricing can be estimated as the market price of old bonds over par during the conversion period. The time-series of the conversion premium is shown in Figure 2. From 1970–1980, the conversion option is in the money most of the time. The average conversion premium is 8% and the range is -0.1% to 24.3%. Since the average conversion premium exceeds the average offer premium in the general sales, we conclude that the new bonds are underpriced. After rationing is abandoned, the conversion premium is near zero. Rationing is temporarily reinstated for the two lottery bond issues in 1987, which are reserved for the holders of maturing bonds 1977:1–3 and 1982:1–3. The average conversion premium for those two bonds is 12%.

From 1963–1980, the Treasury also pursues a mixed-bond policy. Fresh out of prints, lottery bonds come in ordered sequences. However, the Treasury breaks up all lottery bond series into

[13] In the 1950s, new lottery bond issues were partly underwritten.

Figure 2: Conversion Premium



The figure shows the time-series of the conversion premium in percent of par. The conversion premium is estimated as the average market price of mixed and sequenced bonds over par.

sequences of 100 bonds and disperses 100-bond sequences among the banks. The best a bank can do to replicate a complete bond series is to combine 100-bond sequences from ten different series into a broken 1000-bond sequence that covers all order numbers from 1–1000. This package is named a C-sequence. It is an example of a financial innovation in response to regulation. From 1967–1976:1, the Treasury makes an exception for holders of complete series of maturing bonds. These are labeled S-sequences.[14] Old bondholders can convert an old S-sequence into two 500-bond sequences that cover all order numbers from 1–500 and 501–1000. This package is referred to as a D-sequence.[15] Under certain conditions, from 1968:2–1976:1, lottery bond consortia can also purchase unbroken 500-bond sequences and D-sequences.[16] From 1976:2–1980, the mixed-bond

[14]New S-sequences are not issued from 1963 after a conspicuous price spread emerges between S-sequences and mixed bonds for bond 1961. S-sequences rarely trade except for this bond where 25% of the loan amount are S-sequences. According to a Treasury official, S-sequences are abolished because the Treasury thinks it is inequitable that only wealthy households can purchase the higher valued package.

[15]The par amount of old S-sequences converted into new D-sequences averages to 5% of the new par amount. The range of this statistic across lottery bond issues is 1–17%.

[16]A lottery bond consortium with ten members can purchase unbroken 100-bond sequences. If the number of members is 15, the consortium can purchase 500-bond sequences, and a consortium of 20 members with no single

policy is tightened. Unbroken 500-bond sequences and D-sequences are not issued because many lottery bond consortia that have agreed to become long-term bondholders sell their bonds shortly after the secondary market opens (bond flipping). Henceforth, lottery bond consortia can only purchase C-sequences, and maturing D-sequences are converted into C-sequences. The mixed-bond policy also ends in 1981.

Table 3: Standard Bond Sequences of 1974:1

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

A standard bond sequence has one series number and the range of order numbers indicated in the table. A C-sequence is composed of 10 sequences of 100 bonds from different series, a D-sequence of two sequences of 500 bonds from different series, and a S-sequence of one sequence of 1000 bonds. All other combinations are referred to as mixed bonds.

As a result of Treasury policy, lottery bonds trade in many forms. Table 3 lists standard bond sequences of 1974:1. A standard bond sequence must have the same series number and a specific range of order numbers. A complete 1000-bond sequence that covers all order numbers from 1-1000 consists of ten 100-bond sequences with different series numbers (C-sequence), two 500-bond sequences with different series numbers (D-sequence), or one 1000-bond sequence with the same series number (S-sequence).[17] Bondholders can also construct non-standard combinations such as twenty 50-bond sequences that cover all order numbers from 1–1000, but this combination is treated as a portfolio of 50-bond sequences in transactions with other investors.

member owning more than 10% can purchase D-sequences.

[17]S-sequences of 1974:1 are not issued in the primary market and must, therefore, be constructed in the secondary market by pairing two 500-bond sequences from the same series. S-sequences of 1974:1, if they exist, never trade.

2.4 Secondary Market & Data

Lottery bonds are traded on the Stockholm Stock Exchange. From 1970–1980, mixed bonds are traded in a call auction in the morning. The Stockholm Stock Exchange publishes four prices from the call auction: the highest uncleared buy limit order, the lowest uncleared sell limit order, the highest transaction price, and the lowest transaction price. Trading continues on the floor throughout the day. Both mixed and sequenced bonds are traded in the aftermarket. For mixed bonds, the Stockholm Stock Exchange records the daily high, low, and last transaction prices from the after-market. For sequenced bonds, the daily high and low transaction prices are stored. The daily aggregate transaction volume across mixed and sequenced bonds is also published. The publications are archived by the National Library of Sweden. The price and volume information is typed on large paper format (A3) with plenty of space between rows and columns to fit a grid. We purchase hard copies and scan the data. In the analysis below, average daily transaction prices are used.

From 1981–1990, data reporting increases multifold.[18] Data are printed electronically on small paper format (A4) with little space between rows and columns. It is not suitable for scanning, and the magnetic tape that was used to print the hard copies has disappeared. For mixed and sequenced bonds, we collect manually the best buy limit order at the end of the day and the number of bonds traded during the day. From November 1986, a subset of the data are stored electronically by Findata. These data are used by Green and Rydqvist (1997). We merge the manually collected time-series with the corresponding numbers from Findata.

Table 4 lists standard bond sequences of bonds traded in 1970–1990. Important institutional changes take place in 1980. Henceforth, we highlight the difference between old bonds issued before 1981 and new bonds issued from 1981 by putting them into separate panels. Boldface marks a bond sequence with the partial guarantee. For bonds issued before 1960, the partial guarantee requires ownership of bonds with order numbers 1–2000.[19] For bonds issued from 1960–1980, the

[18]For mixed bonds and each bond sequence, the publications contain the best buy and sell limit orders from open and from close (four prices). In addition, for mixed bonds and each bond sequence, low and high transaction prices from the call auction are reported along with high, low, and last transaction prices from the aftermarket (five prices). Finally, for mixed bonds and each bond sequence, the number of bonds traded is recorded.

[19]A 2000-bond sequence consists of 2000 bonds with the same series number (S-sequence) or two sequences of 1000

Table 4: Traded Bond Sequences 1970–1990

	Standard bond sequence						
<u>A. Old bonds</u>							
1951–1954	Mix	50	100	500	1,000	**2,000 M**	**2,000 S**
1960–1976:1	Mix	50	100	500	**1,000 C**	**1,000 D**	**1,000 S**
1976:2–1980	Mix	50	100		**1,000 C**		
<u>B. New bonds</u>							
1981–1987	Mix	50	**100**	**500**	**1,000 C**		**1,000 M**
1986:1	Mix						
1988–1989:1	Mix	50	100				
1989:2–1990	Mix	50	**100**				

The table lists traded bond sequences. Boldface means that the sequence is entitled to the partial guarantee. For 50-kronor bonds, a M-sequence consists of two 1000-bond sequences and a S-sequence of one 2000-bond sequence. For old 100-kronor and 200-kronor bonds, a C-sequence is composed of 10 sequences of 100 bonds, a D-sequence of two 500-bond sequences, and a S-sequence of one 1000-bond sequence. For new 200-kronor bonds, a M-sequence consists of one 1000-bond sequence.

small prizes are distributed across order numbers 1–1000 (C-, D-, or S-sequence). For new bonds, ownership of a 100-bond sequence is entitled to the partial guarantee.[20] A complete 1000-bond sequence is labeled M-sequence (Roman numeral for one thousand).

Most lottery bond issues within the same year are very similar as they have the same coupon rate, coupon payment dates, and maturity date. To eliminate this almost perfect dependency across bonds and to fill in gaps in the time-series, we compute the equally weighted average price across the two or three bond issues within the same year and use the average price for the statistical analysis.[21]

bonds with different series numbers (M-sequence).

[20] Bond 1986:1 does not have a guarantee and the three bonds 1988–1989:1 require ownership of a complete 1000-bond sequence. The latter 1000-bond sequences are not traded because they are too expensive for most investors (one million kronor).

[21] Some years, the second and third lottery bond issue has an initial lottery that is not synchronized with the lotteries of the first bond issue of the year. Then, we delete the price series before the initial lottery. Averaging is not used for the two lottery bond issues in 1964 and the two or three lottery bond issues in 1983:3–1986:2 for which the coupon payment dates are not synchronized.

3 Tax Arbitrage

3.1 Tax Rules

Personal income is subject to progressive income tax. In 1974, the marginal tax rate at an annual income of 30,000 kronor is 52%, and the top marginal tax rate of 78% kicks in at 150,000 kronor. Personal income includes wages, interest, dividends, and short-term capital gains, but coupon income from lottery bonds is tax exempt and long-term capital gains are partially or fully exempt from personal income tax.[22] Capital losses are deductible against capital gains, but excess capital loss cannot offset personal income. Initially, the loss deduction must be taken the same income year but, from 1977, capital losses can be carried forward six years. Brokerage costs and interest expense associated with holding securities are fully deductible against personal income.[23]

The offset rules for lottery bonds change in 1981. The new rules stipulate that capital losses on lottery bonds can only offset capital gains on other lottery bonds. Outstanding lottery bonds are grandfathered one year, and capital losses on old bonds continue to offset capital gains on publicly-traded stocks, but capital losses can no longer be deducted from capital gains on closely-held stocks, real estate, and other assets. The tax law passes the Parliament in October 1980. One year later, after a political agreement that sets out the principles for the tax reform of 1991, the grandfather clause is made permanent.[24] This means that losses on old bonds continue to offset capital gains on publicly-traded stocks until 1990 when the last old bond matures.

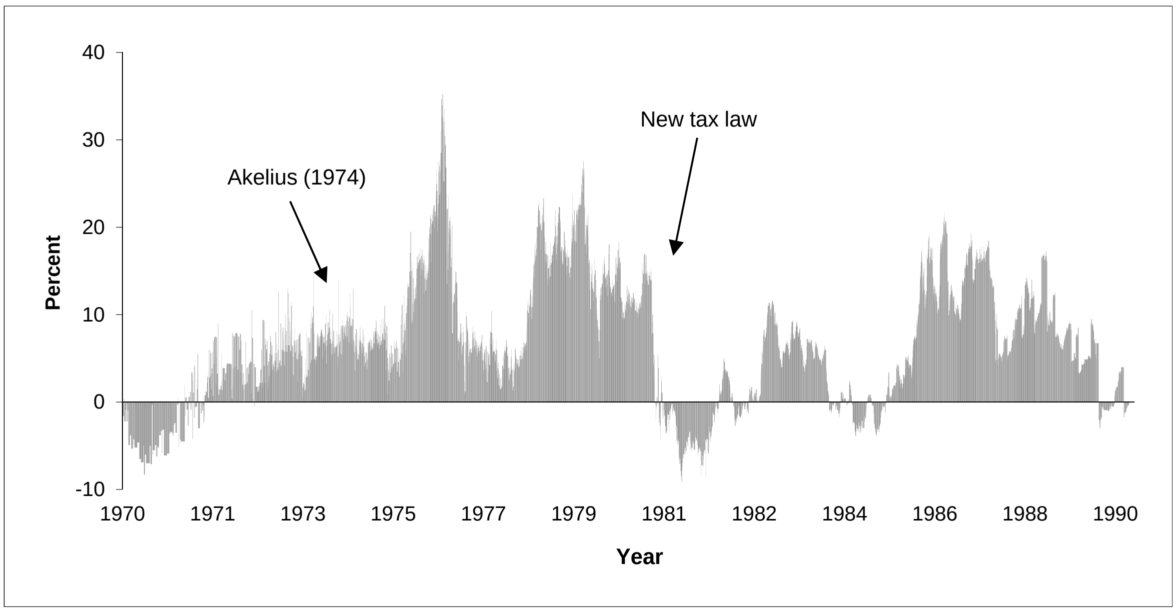
The tax law change has a dramatic impact on the lottery bond market. Figure 3 plots the average lottery bond price for C-sequences in percent of par value. The tax law change is marked. Lottery bond prices fall by 25%, trading volume is cut in half, and demand for new lottery bonds

[22] Capital gains on stocks, lottery bonds, and various other assets are taxed as personal income according to a decreasing scale: 100% of the capital gain is taxable income if the holding period is 0–2 years, 75% if 2–3 years, 50% if 3–4 years, 25% if 4–5 years, and 0% if the holding period exceeds five years. The taxation of stocks changes in 1977. The decreasing scale is replaced by a two-step scale where short-term capital gains are fully taxed and 40% of long-term capital gains defined by a holding period of two years is taxable income.

[23] A simple tax arbitrage that we do not study further in this paper is to lever up a buy-and-hold portfolio of lottery bonds. At a high enough marginal tax rate, the after-tax interest expense offsets the guaranteed interest income from ownership of a complete bond sequence and, in addition, the lottery bond investor participates in the coupon lottery for the non-guaranteed prizes.

[24] In 1991, the marginal tax rate on capital losses on lottery bonds is reduced to 21%. This change largely removes the incentive to generate capital losses in the lottery bond market (see Green and Rydqvist (1999)).

Figure 3: Lottery Bond Price Index 1970–1990



The figure plots the average daily market price over par for C-sequences of old bonds (issued before 1981). The new tax law stipulates that capital losses on lottery bonds can only offset capital gains on other lottery bonds.

collapses. The Treasury responds with a number of changes to re-stimulate demand. *(i)* Supply is cut back from 4,300 million kronor in 1980 to only 600 million kronor in 1981. *(ii)* The coupon rate is raised from 6.48% to 7.40%. Since borrowing costs are higher, time to maturity is reduced from ten to five years. *(iii)* The rationing and mixed-bond policies are abandoned. Henceforth, investors can purchase any number of bonds in sequence they want, lottery bonds are not underpriced (see Figure 2 above), and new lottery bond consortia are not formed. *(iv)* The par value of a guarantee sequence is reduced from 200,000 kronor to 20,000 kronor to make the partial guarantee affordable to a broader investor population (Section 2.2).

3.2 A Stylized Model of Price Formation

For apparent reasons, lottery bond prices are quoted inclusive of accrued interest. This means that lottery bond prices, on average, increase between coupon lotteries and decrease over the coupon lottery just like prices of common stocks drop over the ex-dividend day. The asymmetric taxation of coupon income (tax free) and capital gains (taxed) makes it possible to shift tax liability from high-tax to low-tax investors.

Consider two stock market investors G (gain) and L (loss). Each investor reduces tax liability by netting capital gains and losses within his own stock portfolio, but the capital gain from portfolio G cannot be transferred to portfolio L by trading within the stock market itself. However, the lottery bond market makes the transfer possible. Investor G purchases lottery bonds cum-lottery, generates a capital loss over the coupon lottery, and covers his loss through the tax-free coupon payment. Denote the last price cum-lottery with P^c, the first price ex-lottery with P^e, the lottery mean with $E(C)$, and the marginal tax rate of Investor G with τ. We ignore transaction costs and discounting. Investor G breaks even when the after-tax capital loss equals the expected proceeds from the coupon lottery:

$$(P^e - P^c)(1 - \tau) + E(C) = 0. \tag{1}$$

Investor L takes the other side of the trade. He purchases lottery bonds ex-lottery, sells them cum-lottery, and offsets the lottery bond capital gain against the stock market loss. If there are more coupon buyers than coupon sellers in the market, then sellers capture the gain from trade and equilibrium prices are determined by Equation (1).

A numerical example illustrates the equilibrium. Suppose the stock market gain is $G = 10$, the stock market loss $L = -10$, and the expected coupon payment $E(C) = 2.50$. We normalize the ex-coupon lottery bond price to $P^e = 0$ and assume that the marginal tax rate on personal income is $\tau = 75\%$, so that $P^c = 10$. Investor G generates a capital loss in the amount of –10 by holding the bond over the coupon lottery. The lottery bond loss offsets the stock market gain, and Investor G escapes tax liability. The tax-free coupon 2.50 equals the after-tax stock market gain $10 \times (1 - 0.75) = 2.50$. Investor L generates a capital gain +10 by holding the bond between coupon lotteries. The stock market loss offsets the lottery bond gain, so Investor L escapes tax liability as well. The gain from trade equals the avoided personal income tax on the stock market gain $10 \times 0.25 = 7.50$. By assumption, Investor G breaks even and Investor L gets the surplus. Through these transactions, the tax liability of Investor G is netted against the tax credit of Investor L resulting in a complete elimination of tax liability.[25] The outcome mimics that of a joint tax return. Investors benefit due to tax progressivity.

3.3 Ex-Day Price Behavior

The model implications for ex-day returns, lottery bond yields, and trading volume are studied by Green and Rydqvist (1999). Here, we extend the time-series. The calendar-time effect is a new result.

We solve Equation (1) for the marginal tax rate:

$$\tau = 1 - \left(\frac{P^c - P^e}{E(C)} \right)^{-1}. \tag{2}$$

The term within brackets on the right hand side is the price drop scaled by the lottery mean. This variable, often referred to as the drop-off ratio, is the variable of interest in the literature on the ex-dividend day (Elton and Gruber (1970)). Table 5 reports average drop-off ratios and imputed marginal tax rates for mixed and sequenced bonds. Standard errors are reported below

[25] There are other possible trades. Tax-neutral market makers and tax-exempt investors such as pension funds and certain foundations have an incentive to earn the positive lottery bond return between coupon lotteries and avoid the negative return over the coupon lottery.

Table 5: Drop-Off Ratios and Marginal Tax Rates

	Mix	50	100	500	1,000 C	1,000 D	1,000 M
A. Old bonds							
Drop-off ratio	1.88	2.34	2.63	3.08	2.92	3.10	n/a
	(0.07)	(0.07)	(0.09)	(0.15)	(0.10)	(0.13)	
Marginal tax rate (%)	46.7	57.4	62.0	67.5	65.8	67.8	n/a
	(1.9)	(1.3)	(1.2)	(1.6)	(1.1)	(1.4)	
B. New bonds							
Drop-off ratio	1.09	1.22	1.33	1.16	1.38	n/a	1.35
	(0.08)	(0.08)	(0.08)	(0.11)	(0.09)		(0.12)
Marginal tax rate (%)	8.6	18.3	24.6	13.7	27.6	n/a	25.7
	(6.8)	(5.5)	(4.5)	(8.5)	(4.5)		(6.6)

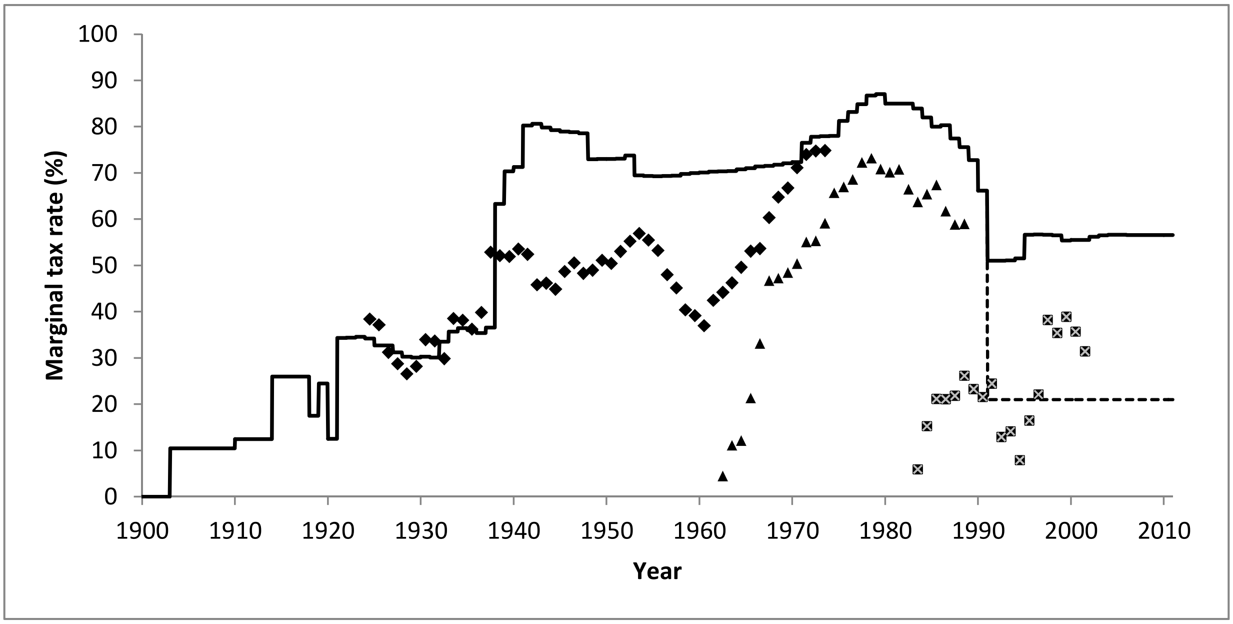
The drop-off ratio is the price change over the coupon lottery divided by the expected coupon payment. The marginal tax rate has been imputed from the drop-off ratio using Equation (2). Robust standard errors are reported in parentheses below. The standard errors of the marginal tax rates are computed with the delta method. The estimation is based on 365 lottery days in Panel A and 159 lottery days in Panel B.

in parentheses. The average drop-off ratio exceeds one, which means that the pre-tax capital loss exceeds the lottery mean. Drop-off ratios for old bonds exceed those of new bonds, and drop-off ratios for longer bond sequences exceed those of shorter bond sequences and mixed bonds. In Panel A, (old bonds), the average drop-off ratio for mixed bonds is about two times the lottery mean compared to three times the lottery mean for 1000-bond sequences (C- and D-sequences). Marginal tax rates for old bonds range from 46.7% for mixed bonds to 67.8% for D-sequences. Marginal tax rates for new bonds are less and range from 8.6% for mixed bonds to 27.6% for C-sequences.

Figure 4 displays the time-series of top statutory tax rates (solid line) along with marginal tax rates of old bonds (filled diamonds) and new bonds (open diamonds) imputed from C-sequences. Marginal tax rates of old bonds fall below top statutory rates, they increase with statutory rates in the 1970s, and they decrease in the 1980s. We also see that marginal tax rates of new bonds fall below those of old bonds.

While there are many reasons why marginal tax rates can fall below top statutory rates, we offer a real-option explanation based on the calendar-time effect reported in Table 6. The table reports drop-off ratios and marginal tax rates by quarter. In the first quarter, investors pay less than two

Figure 4: Evolution of Marginal Tax Rates



The figure plots top statutory tax rates along with imputed marginal tax rates from prices of C-sequences using Equation (2).

Table 6: Calendar-Time Effect

	Quarter				
	First	Second	Third	Fourth	F-test
A. Old bonds					
Drop-off ratio	1.86 (0.11)	2.81 (0.15)	3.51 (0.21)	3.35 (0.21)	16.22 (0.000)
Marginal tax rate (%)	46.4 (3.3)	64.4 (1.9)	71.5 (1.7)	70.2 (1.8)	
B. New bonds					
Drop-off ratio	1.09 (0.10)	1.25 (0.14)	1.40 (0.22)	1.80 (0.17)	3.34 (0.021)
Marginal tax rate (%)	8.4 (8.7)	20.1 (9.1)	28.7 (11.3)	44.4 (5.2)	

The table reports average drop-off ratios and imputed marginal tax rates for C-sequences by quarter. Robust standard errors are reported below in parentheses. The standard errors of the marginal tax rates are computed with the delta method. The F-statistic tests the null hypothesis that the means are equal across quarters. P-values are reported below. The estimation is based on 365 lottery days in Panel A and 159 lottery days in Panel B.

times the lottery mean compared to the last quarter when investors pay more than three times the lottery mean (Panel A). Accordingly, imputed marginal tax rates increase from 46.4% in the first quarter to 70.2% in the last quarter. This means that competition for tax shelters increases over the calendar year. There is a calendar-time effect also for new bonds (Panel B). Marginal tax rates increase from 8.4% in the first quarter to 44.4% in the last quarter.

Generating a capital loss in the lottery bond market is a real option, which expires with the last coupon lottery in December. In January, investors are reluctant to exercise the option because they do not know if they will have a stock market gain at the end of the fiscal year. The situation is different in December, when uncertainty about stock market performance has been resolved, and generating a capital loss in the lottery bond market may be one of the few remaining options to avoid personal income tax on the stock market gain. On average, during the course of the year, the real option has value and, as a consequence, imputed marginal tax rates fall below top statutory tax rates. A corresponding calendar-time effect in ex-dividend day returns is not known from the stock market. A leading explanation of abnormal ex-dividend day returns is that those returns reflect the transaction costs of market makers (Kalay (1982) and Boyd and Jagannathan (1994)). Since there is no reason for transaction costs to vary over the calendar year, ex-dividend day returns do not vary either.

Among other reasons why imputed marginal tax rates fall below top statutory rates, the marginal investor may not be in the top income bracket. Lower marginal tax rates for new bonds certainly means that the marginal investor is not in the top income bracket. Presumably, low-tax investors supply old bonds cum-lottery and shield capital gains tax liability with capital losses from new bonds. Furthermore, the stylized model ignores transaction costs, and it assumes risk neutrality. Given the multitude of possible explanations, we do not attempt to calibrate a real-option model, a transaction-costs model, or a risk-averse utility function to the observed difference between top statutory and imputed marginal tax rates.

3.4 Trading Volume

The effects of the tax arbitrage can also be seen in the trading volume data. Table 7 reports the percent of business days with transaction volume (first row) and annualized turnover in percent of the number of bonds outstanding (second row).[26] Due to data limitations, turnover is measured

Table 7: Trading Volume

	Period	Mix	50	100	500	1,000 C	1,000 D	1,000 S/M
A. Old bonds								
Days with trade	1970–90	78.2	68.2	81.2	5.8	56.3	21.4	0.6
Turnover	1981–90	2.8	1.9	5.0	0.2	31.6	1.6	0.0
B. New bonds								
Days with trade	1970–90	73.0	79.4	95.9	27.5	41.8	n/a	55.4
Turnover	1981–90	0.7	0.8	3.9	0.5	5.9	n/a	7.8

The first row of each panel shows the percent of business days with transaction volume measured over 1970–1990. The second row reports annualized turnover in percent of bonds outstanding in 1981–1990. A C-sequence is composed of 10 sequences of 100 bonds, a D-sequence of two sequences of 500 bonds, and a S/M-sequence of one sequence of 1000 bonds.

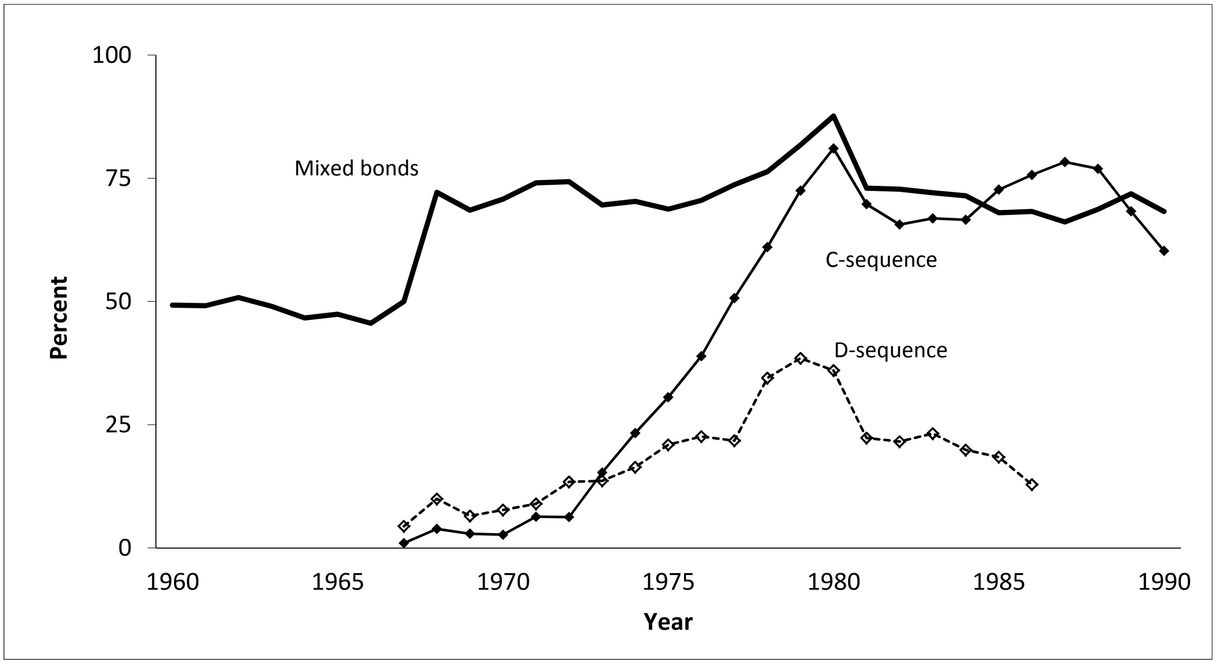
from 1981–1990. Starting with the trading of old bonds (Panel A), we see that mixed bonds and short bond sequences trade more frequently than long bond sequences (first row), but that turnover is heavily concentrated to C-sequences (second row). We see furthermore in Figure 5, that trading of C-sequences of old bonds increases over time as banks increase supply to meet demand from tax traders. Trading of 500-bond sequences, D-sequences, and S-sequences is sparse as a result of the Treasury's mixed-bond policy.[27] Trading frequency and turnover of new bonds (Panel B) is similar across mixed and sequenced bonds. We notice that banks supply C-sequences also in the new bond market despite that there are no supply restrictions on M-sequences in the primary market.

The calendar-time effect is also visible in the trading volume data. Figure 6 plots annualized

[26] Statistics on trading volume are based on individual lottery bond series. Due to space limitations, we omit the few transactions of 1000- and 2000-bond sequences of 1951–1955. There are 12 transactions of 1000-bond sequences, zero transactions of M-sequences, and 66 transactions of S-sequences.

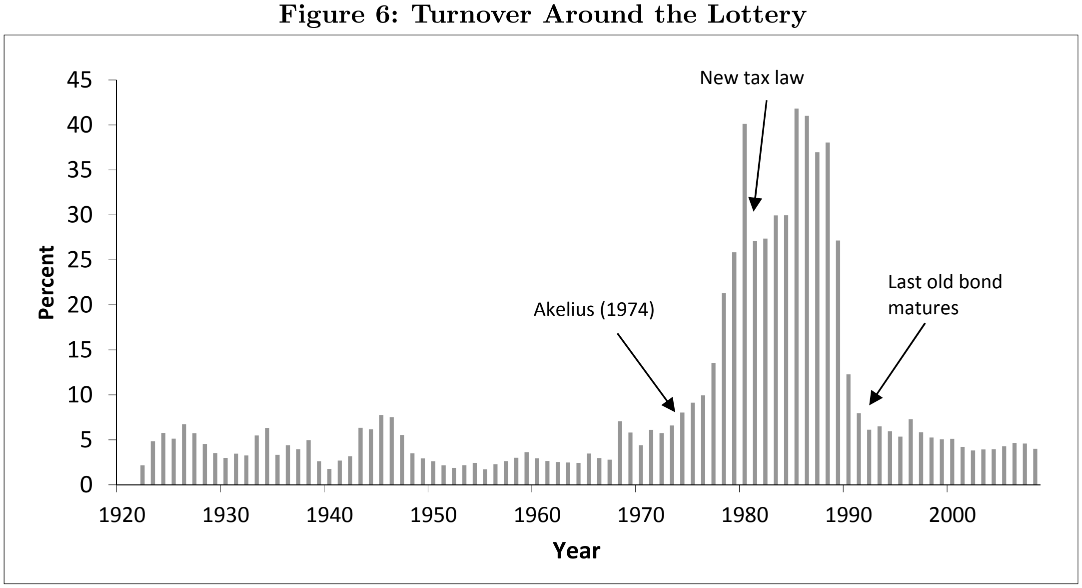
[27] New 500-bond sequences cannot be constructed in the secondary market. Some D-sequences arise from combining 500-bond sequences in the secondary market and, occasionally, S-sequences are formed when lottery bond consortia exchange matching 500-bond sequences with each other. The entire data set contains 231 transactions of S-sequences. In 53 instances, the S-sequences originate from the secondary market.

Figure 5: Trading of Old Bonds



The figure plots the percent of business days in a year with transaction volume for old bonds. A C-sequence is composed of 10 sequences of 100 bonds, and a D-sequence of two sequences of 500 bonds.

Figure 6: Turnover Around the Lottery



The figure shows annualized daily turnover of old bonds around the lottery in percent of the number of bonds outstanding. Day 0 is the first day ex-lottery.

average daily turnover around the coupon lottery in percent of the number of bonds outstanding. Turnover of old bonds increases around the lottery, in particular in the fourth quarter. The spike on the first ex-lottery day is indicative of forward contracting.

4 Sequenced Bond Premium

4.1 Univariate Analysis

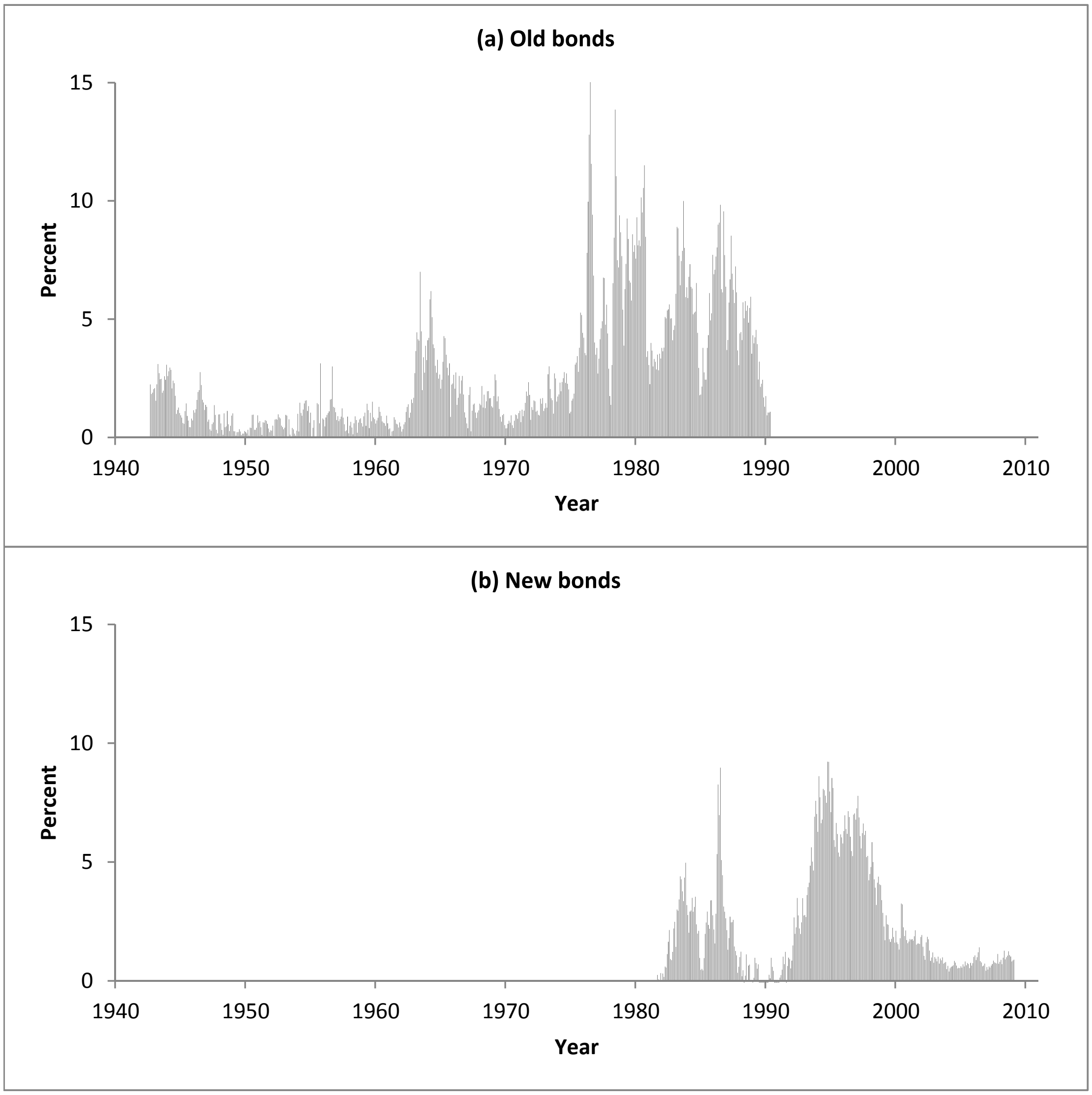
Sequenced bonds are generally priced above mixed bonds. Figure 7 plots the average daily price difference between C-sequences and mixed bonds for old lottery bonds. The sequenced bond premium is small in the beginning of the time-series. Subsequently, it increases and peaks above 25% of par value in 1976. The premium decreases by approximately 10 percentage points in response to the tax law change. Afterwards, the premium oscillates between five and ten percent of par value until the last old bond matures in 1990. The time-series variation reflects the supply of C-sequences. In the beginning of the time-series in 1970, C-sequences barely exist. As the sequenced bond premium increases, banks increase supply of C-sequences (see Figure 5 above). The sequenced bond premium peaks in 1976 after Akelius (1974) has become well known, but before banks are able to meet demand.

The sequenced bond premium for C-sequences transmits to corresponding premia for all bond sequences. Table 8 reports average price differences between sequenced and mixed old bonds (top row) and new bonds (bottom row). We notice the following general patterns: *(i)* Sequenced bonds are worth more than mixed bonds. *(ii)* Sequenced bond premia of old bonds are larger than sequenced bond premia of new bonds.[28] *(iii)* Longer sequences of old bonds are worth more than shorter bond sequences, while longer sequences of new bonds are worth approximately the same as shorter bond sequences.[29] *(iv)* Controlling for the partial guarantee (old bonds: C and D; new bonds: 100, 500, C, and M), the sequenced bond premium is approximately equal.

[28]We omit standard errors from the table, but we are confident that the averages are statistically different from zero. More than 90% of the observations for old bonds and 60% for new bonds are positive.

[29]The few observations of S-sequenced bonds have been omitted from the table. They are concentrated to 1970 when the sequenced bond premium is small. In paired transactions, S-sequences always command a premium above shorter bond sequences and mixed bonds.

Figure 7: Sequenced Bond Premium



The figure plots the time-series of the daily average price difference between C-sequences and mixed bonds for old bonds in percent of par.

Table 8: Market Value of Sequenced over Mixed Bonds

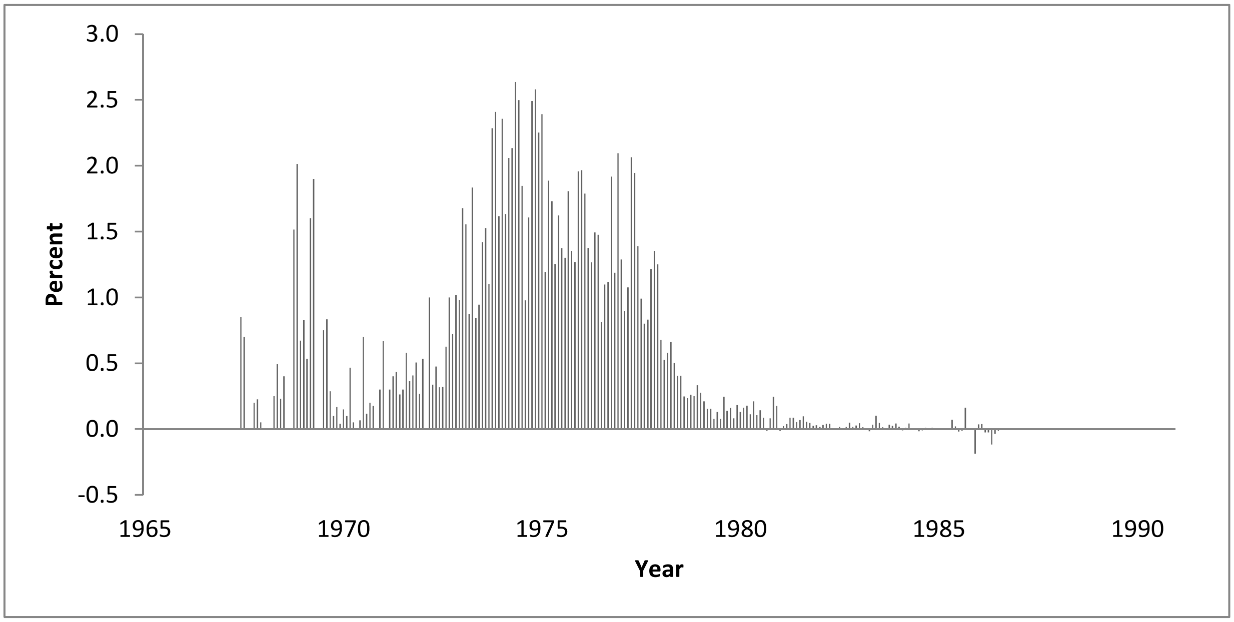
	50	100	500	1,000 C	1,000 D	1,000 M
Old bonds	2.21	4.02	4.40	5.48	5.45	n/a
New bonds	1.27	1.80	1.90	2.01	n/a	2.47

The table reports the average price difference between sequenced and mixed bonds in percent of par. A C-sequence is composed of 10 sequences of 100 bonds, a D-sequence of two sequences of 500 bonds, and a M-sequence of one sequence of 1000 bonds.

The averages mask important time-series variation. Figure 8 plots the average daily price difference between D- and C-sequences. The D-premium begins near zero, it averages above two percent from 1973–1975, and it reverts back to near zero from 1978–1986. Prices converge when lottery bond turnover increases from previously less than 10% per year to between 25% and 50% per year. The handling cost advantage of a D-sequence is a natural explanation for the price difference between D- and C-sequences. Manual verification of the winning lottery bond numbers of a large lottery bond portfolio can be a non-trivial task. The bondholder must check the numbers of the lottery bonds in his portfolio against the list of winning lottery bond numbers in the pamphlet. Lottery number checking of a complete S-sequence is relatively easy because the bondholder is done after checking only one series number. The holder of a D-sequence must check two series numbers, while the holder of a C-sequence must work through the table ten times. If one series number matches, the lottery bond investor must also check the order numbers. Banks begin using computers for lottery number checking in 1982. Computers raise accuracy and reduce the risk that a prize is not claimed, but banks must continue to register lottery bond numbers manually. To allow banks to register lottery bond numbers, trade is suspended about two weeks around the coupon lottery. Electronic lottery number checking reduces handling costs for buy-and-hold investors, but it may not do much good for a tax trader who purchases the bond right before the coupon lottery and sells it back afterwards. The disappearance of the D-premium when trading volume shoots up, suggests that there are economies of scale in lottery number checking.

Risk aversion, effort aversion, and liquidity preferences are likely contributors to the sequenced bond premium, but the data do not allow us to decompose the sequenced bond premium into risk,

Figure 8: Market Value of D-Sequences over C-Sequences



The figure plots the time-series of the daily average price difference between D-sequences and C-sequences of old bonds.

effort, and liquidity premia. The sequenced bond premium is difficult to reconcile as a risk premium because the difference in uncertainty between a bond sequence and a mixed-bond portfolio is small. For example, a portfolio of 1000 mixed bonds of 1974:1 that covers 500 order numbers has an expected payoff from the small prizes in the amount of 1000 kronor per lottery and a standard deviation of 225 kronor.[30] The distribution of the small prizes is approximately normal, so the holder of the mixed-bond portfolio earns between 550 kronor and 1450 kronor with 95% probability compared to a 1000-bond sequence, which earns 1000 kronor with certainty. Furthermore, as discussed in Green and Rydqvist (1997), both sequenced and mixed bonds are liquid. The aggregate trading volume data do not reveal average trade size, but there are good reasons to believe that mixed bonds trade in packages. About 75% of the days with transaction volume, aggregate trading volume of mixed bonds is a multiple of 50 bonds. This clustering of trade sizes suggests that bond dealers package and sell mixed bonds as "round trading lots". Many mixed-bond packages are large. The aggregate daily volume of mixed bonds exceeds 1000 bonds about 20% of the time.

[30]In these calculations, we assume that the mixed portfolio is uniformly distributed across the 500 order numbers and we ignore that the lottery is without replacement.

Hence, neither the difference in uncertainty nor liquidity appear important enough to generate a price wedge between sequenced and mixed bonds in the order of 25% of par. Perhaps, lottery number checking is the main advantage of sequenced bonds over mixed bonds, but we leave this conjecture for future research.

4.2 Multivariate Analysis

We use multivariate regression analysis to establish a statistical link between the sequenced bond premium and variables that capture the price effects of the tax arbitrage. The dependent variable is the premium for C-sequences over mixed bonds in percent of par value. A central variable in Green and Rydqvist (1997), the guaranteed portion of the expected coupon, is omitted from the list below because it is approximately equal to 40% across old bonds.

GAIN is a proxy variable for capital gains tax liability from the stock market. It is measured as lagged stock price growth computed from end-of-month stock market index values over the previous twelve months. We expect that the sequenced bond premium increases with lagged stock price growth because better stock market performance raises demand for tax shelters. Lagged stock price growth averages about 1% per year in the 1970s and 10% per year in the 1980s.

TIME measures calendar time from the last lottery of the previous calendar year to the last lottery of the current year. We use separate time counts for old and new bonds. After scaling by 365 days in a year, TIME increases linearly from from zero to one. The calendar-time effect in drop-off ratios in Table 6 suggests that the sequenced bond premium peaks in December, so the expected sign of the coefficient is positive.

CUM captures time between lotteries. It is measured as:

$$\text{CUM} = \begin{cases} 1 - t_{cum}/120, & \text{if } N \geq 1 \text{ remaining lotteries,} \\ 0, & \text{if } N = 0 \text{ remaining lotteries,} \end{cases} \tag{3}$$

where t_{cum} measures the number of business days remaining to the next lottery. CUM is uniformly distributed from zero right after the previous lottery to one right before the next lottery. We expect that sequenced bonds are most valuable right before the uncertainty of the coupon lottery is resolved.

POST74 is a dummy variable which equals one from 1975–1990 and zero otherwise. It captures the impact of Akelius (1974). Its effect on the sequenced bond premium is apparent from Figure 7.

TAX81 is a dummy variable which equals one from mid-October 1980 to mid-October 1981. This is the approximate time between the initial and the final tax law change. The expected, negative effect of this variable is also apparent from Figure 7.

PACK is the proportion of a lottery bond issue that is pre-packaged into 100-bond sequences, i.e., one ownership certificate represents a complete 100-bond sequence. The variable is zero except for new bonds issued in 1984–1987, for which it ranges from 0.25 to 0.78. Pre-packaged bonds cannot be broken up and sold as mixed bonds. Excess supply of bond sequences sometimes depress sequenced bond prices below those of mixed bonds (Green and Rydqvist (1997)).

BEG0–BEG2 and END2–END0 are dummy variables. BEG0–BEG2 equal one when zero, one, or two lotteries has elapsed. Similarly, END2–END0 are dummy variables which equal one

Table 9: Seasoning and Maturity

	#Elapsed lotteries			#Remaining lotteries		
	0	+1	+2	–2	–1	0
Old bonds	4.38	3.78	3.37	4.67	2.36	0.07
New bonds	0.68	1.83	1.44	2.01	1.19	–0.04

The table reports the average premium for C-sequences over mixed bonds in percent of par shortly after seasoning and near maturity.

when there is two, one, or zero remaining lotteries. The seasoning and maturity effects can be seen in Table 9. We see in the left section that old C-sequences trade at a premium from the beginning of the secondary market, while the price difference between new C-sequences and mixed bonds is small. The different seasoning effect of old versus new bonds is a new result. We see in the right section that the premium for both old and new C-sequences decreases towards maturity and vanishes after the final lottery. This pattern suggests that the sequenced bond premium is related to the coupon lottery and not to a liquidity difference between sequenced and mixed bonds. Once the uncertainty of the coupon lottery has been resolved, sequenced and mixed bonds are perfect substitutes (Green and Rydqvist (1997)).

We estimate a panel regression with 14 cross-sections of old bonds and 12 new bonds. The error term is adjusted for first-order autocorrelation and heteroscedasticity using the POOL command in Shazam. The regression results for old bonds are reported in Table 10. Using the entire data set (Panel A), the coefficients of the three central variables GAIN, TIME, and CUM are positive and statistically different from zero. The coefficients mean that a 100% run-up in stock prices raises the sequenced bond premium by two percentage points, that the sequenced bond premium increases over the calendar year by 0.3 percentage points, and that the sequenced bond premium increases between lotteries by about three percentage points. These regression results link the

Table 10: Determinants of the Sequenced Bond Premium for Old Bonds

Intercept	GAIN	TIME	CUM	END2	END1	END0	POST74	TAX81	R^2
A. 1970–1990									
2.17	1.89	0.27	3.12	–1.32	–2.06	–1.47	1.54	–0.60	0.169
(6.5)	(3.5)	(3.9)	(59.5)	(–7.0)	(–8.2)	(–4.7)	(4.8)	(-4.0)	
B. 1982–1990									
4.20	4.14	0.09	2.67	–2.05	–3.45	–3.17	n/a	n/a	0.189
(25.7)	(7.3)	(0.9)	(34.0)	(–11.8)	(–17.1)	(–12.3)			

The table reports the results of regressing the sequenced-bond premium on explanatory variables. The dependent variable is the price difference between C-sequences and mixed bonds in percent of par. GAIN is one-year lagged stock price growth. TIME$\in [0,1]$ measures time from the last lottery of the previous year. CUM$\in [0,1]$ measures time to next lottery. END2, END1, and END0 are dummy variables that capture the number of remaining lotteries. POST74 is a dummy variable which is one from 1975–1990 and zero otherwise. TAX81 is a dummy variable which is one from mid-October 1980 to mid-October 1981. The standard errors are adjusted for first-order autocorrelation and heteroscedasticity using the POOL command from Shazam. t-statistics are reported in parentheses below the coefficients. There are 14 cross-sections with a total of 21,662 observations in Panel A, and nine cross-sections with 9,534 observations in Panel B.

sequenced bond premium to stock market performance (GAIN), to the calendar-time effect of ex-day returns (TIME), and to the coupon lottery (CUM). The correlation between the sequenced bond premium and stock market performance (GAIN) is stronger in recent years (Panel B). The coefficients of END2–END0 capture the maturity effect, and the coefficients of POST74 and TAX81 the time-series effects of Akelius (1974) and the tax law change in 1981, respectively.

Table 11: Determinants of the Sequenced Bond Premium for New Bonds

Intercept	GAIN	TIME	CUM	END2	END1	END0	BEG0	BEG1	BEG2	PACK	R^2
1.86	5.74	0.08	1.33	–0.50	–0.33	–0.33	0.17	0.42	–0.25	–0.47	0.045
(9.9)	(9.9)	(0.8)	(14.8)	(–2.6)	(–1.3)	(–0.9)	(0.5)	(1.8)	(–1.3)	(–12.1)	

The table reports the results of regressing the sequenced-bond premium on explanatory variables. The dependent variable is the price difference between C-sequences and mixed bonds in percent of par. GAIN is one-year lagged stock price growth. TIME$\in [0,1]$ measures time from the last lottery of the previous year. CUM$\in [0,1]$ measures time to next lottery. END2, END1, and END0 are dummy variables that capture the number of remaining lotteries, and BEG0, BEG1, and BEG2 are dummy variables for the initial lotteries. PACK$\in [0,1]$ is the proportion of the lottery bond issues 1984–1987 that is pre-packaged into 100-bond sequences. The standard errors are adjusted for first-order autocorrelation and heteroscedasticity using the POOL command from Shazam. t-statistics are reported in parentheses below the coefficients. There are 12 cross-sections with a total of 12,370 observations.

The regression results for the new bonds in Table 11 are qualitatively similar. The correlation between the sequenced bond premium and stock market performance (GAIN) is similar for new and old bonds (Table 10, Panel B). The calendar-time effect as captured by TIME is not statistically different from zero for either new or old bonds (Table 10, Panel B). The seasoning effect is apparent in the negative coefficients of BEG0–BEG2. The liquidity effect of pre-packaged 100-bond sequences (PACK) can also be seen.

5 Conclusions

Undoubtedly, demand for Swedish lottery bonds 1970–1990 is tax driven. The tax law change in 1981 and the market response to the tax law change are prima facie evidence. The time-series behavior of imputed marginal tax rates, the calendar-time effect in drop-off ratios, and trading volume around the coupon lottery also lead to this conclusion.

Sequenced bonds are worth more than mixed bonds. Several observations suggest that the sequenced bond premium is determined by the tax arbitrage around the coupon lottery: the sequenced bond premium increases with lagged stock price growth, it increases between lotteries, it increases over the calendar year, it increases after Akelius (1974), and it drops after the tax law change in 1981. In addition, the sequenced bond premium of new bonds with limited tax deductibility is much smaller. Sequenced bonds offer two advantages over mixed bonds: a portion of the expected coupon payment is guaranteed and lottery number checking requires less effort. For these reasons, tax traders prefer sequenced over mixed bonds.

When the tax benefit of old lottery bonds disappears with the redemption of the last old bond in 1990, one would expect the price difference between sequenced and mixed bonds to go away. However, the bond sequences of some new lottery bonds with a large portion guaranteed (about 80%) continue to trade at prices well above mixed bonds, while the sequences of other lottery bonds with a smaller guarantee portion (around 40%) trade at small premia above mixed bonds. Since these price effects are unrelated to taxation, we leave this asset pricing problem for future research.

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