Tax-Motivated Trading by Individual Investors

By Zoran Ivković, James Poterba, and Scott Weisbenner*

We analyze stock trades made by individuals holding stock in both taxable and tax-deferred accounts. By comparing trades across these two types of accounts, we uncover a capital gains lock-in effect in taxable accounts. The lock-in effect is more pronounced for large stock transactions and for stocks held for at least 12 months. Over shorter horizons, the disposition effect outweighs the lock-in effect. Comparison of loss realizations in taxable and tax-deferred accounts yields evidence of tax-loss selling throughout the year. Effective accrual tax rates for stocks that experience substantial appreciation are substantially below the statutory tax rate on long-term gains. (JEL C41, D14, G11, H20)

Capital gains in the United States are taxed only when investors sell assets and realize gains. A realization-based tax can distort investor behavior by discouraging the sale of appreciated assets. This "lock-in effect" is a standard tenet of capital gains tax discussions. By deferring the realization of gains, investors can reduce the present discounted value of the realization-based tax they must pay. Joseph E. Stiglitz (1983), George M. Constantinides (1984), and others have shown that, when realized capital losses can be used to offset realized gains or to reduce nongain taxable income, investors who seek to minimize their tax liability should realize capital losses as they accrue, while deferring the realization of capital gains for as long as possible. Investors following the latter strategy will not adjust their portfolio

holdings as often as they would in the absence of realization-based taxation. Leonard E. Burman (1999) discusses the potential efficiency costs of the resulting portfolio distortions, and notes the difficulty of trying to measure such costs.

Conceptual discussions of the capital gains tax invariably allude to the potential importance of lock-in effects, but direct empirical evidence is surprisingly limited. Donald W. Kiefer (1990) assesses this research in his discussion of how the capital gains tax increase in the 1986 Tax Reform Act affected taxpayer behavior and economic welfare. Many studies of the effective burden of the capital gains tax calculate asset-holding periods from aggregate capital gain realization rates, such as those developed by Martin J. Bailey (1969). Such estimates measure the capital gain realization rate on corporate stock, for example, by dividing the aggregate flow of capital gain realizations on corporate stock reported to the Internal Revenue Service (IRS) by an estimate of the gross flow of accruing capital gains on stock held by taxable households. This procedure may be subject to substantial measurement error. It offers no evidence on the pattern of capital gain realizations at different holding periods, although it is possible to generate a time profile of realizations by assuming that the realization rate is constant at all holding periods.

Estimates of the fraction of gains realized in a year are typically low, and other evidence suggests that a substantial fraction of capital gains are not realized until the death of the asset holder. Capital gains held until death qualify for special tax treatment, "basis step-up at death,"

which extinguishes capital gains tax liability. These factors combine to generate estimates of the effective capital gains tax burden that are lower than the statutory tax rate.

Poterba (2002) surveys a separate literature, based largely on the analysis of the realized gains reported on individual income tax returns, most of which finds a substantial positive elasticity linking capital gain realizations to the after-tax income that investors retain for each dollar of realized gain. Studies based on tax returns, however, offer only limited information on the holding periods at which gain realizations rise when capital gains tax rates fall. Moreover, because they lack information on the portfolio holdings and, consequently, the *unrealized gains* of taxpayers who realize gains, these studies cannot be used to estimate realization rates, the fraction of capital gains that are realized under different tax regimes.

The patterns of investor behavior that underlie the positive relation between reported realized gains and the after-tax value of a realized gain are not well documented, and are even a subject of controversy. Several studies, including Jay R. Ritter (1988), Poterba and Weisbenner (2001), and Mark Grinblatt and Tobias J. Moskowitz (2004), conclude that some taxable investors take advantage of year-end tax planning opportunities and harvest tax losses in December. This behavior may contribute to the abnormal stock return patterns at the turn of the year, and it is consistent with at least some investors changing their behavior as a result of tax incentives. A number of recent studies using data on individual investors, however, suggest that nontax considerations may outweigh tax factors in investor trading decisions. H. Nejat Seyhun and Douglas J. Skinner (1994) examine a panel of tax returns and find that most investors trade infrequently and fail to take advantage of opportunities to realize tax losses. More importantly, however, Hersh Shefrin and Meir Statman (1985), Terrance Odean (1998), and Brad M. Barber and Odean (2000, 2004) suggest that, rather than realizing losses and deferring gains, individual investors are more likely to realize *gains* than to realize losses. To explain this pattern, which they label the "disposition effect," Shefrin and Statman (1985) invoke Daniel Kahneman and Amos Tversky's (1979) prospect theory and framing. They argue that a stock's purchase price "frames" subse-

quent trading decisions and that investors are reluctant to dispose of assets at a loss. Other factors, such as portfolio rebalancing or investor belief in mean-reverting asset prices, could also explain this pattern.

The presence of a disposition effect in trading decisions is not necessarily inconsistent with the finding that capital gain realizations rise when marginal tax rates fall. Taxpayers facing higher marginal tax rates on realized gains may realize fewer gains than those with lower tax rates, even if both sets of taxpayers are realizing gains with higher probability than losses. The empirical evidence in support of the disposition effect nevertheless raises questions about the extent to which taxes affect asset sales.

This paper explores the impact of taxation on capital gains realization behavior, but does so using a dataset, described in detail in Barber and Odean (2000), which makes it possible to *simultaneously* evaluate the importance of tax incentives and the disposition effect. The dataset tracks investments made by a sample of individual investors at a large discount brokerage house during the period from 1991 to 1996. We compare trading behavior in taxable and tax-deferred accounts, and we allow the probability of stock sale to vary by holding period. We find a substantial capital gain lock-in effect which begins several months after a stock is purchased. At holding periods shorter than six months, the disposition effect seems to describe trading behavior in both types of accounts, although gain realization is more pronounced in tax-deferred than in taxable accounts. Once a stock has been held for at least 12 months, however, there is a strong negative relation *in taxable accounts* between accrued gain and sale probability. This is evidence of a lock-in effect, particularly because there is no such relation for stocks held in tax-deferred accounts. Our findings suggest that the positive correlation between accrued gains and stock-selling probabilities found in earlier studies is driven largely by trading behavior in the first few months after a stock is purchased.

Comparing taxable and tax-deferred accounts also enables us to shed new light on tax-loss selling. We find that while such selling is strongest at the end of the calendar year, it also takes place in other months. December tax-loss selling is particularly strong for stocks that qualify for short-term loss treatment, which provides

the largest potential tax saving for investors. We also find that tax-loss selling increases when the overall market is doing well, and thus the demand for loss offsets is likely to be high.

The dataset we analyze includes many stock purchases by the same investor, so we can allow for individual heterogeneity in realization rates, while also controlling for the effects of accrued gains, turn-of-the-year effects, and other factors that may affect stock trading. Allowing for individual heterogeneity enables us to rule out a potentially spurious source of the correlation between accrued returns and sale probabilities. If investors have different intrinsic probabilities of selling stocks, and those with a high probability of selling are more likely to buy stocks that appreciate, perhaps because they devote more attention to following their investments, then accrued gains and sale probabilities could exhibit a positive cross-sectional correlation, even if each investor were less likely to sell stocks with gains than those with losses. Controlling for heterogeneity in turnover rates across investors enables us to reject this possible explanation.

Our estimates of the probability of selling stock at different holding periods, and as a function of the stock's accrued gain or loss, allow us to estimate the burden of the realization-based capital gains tax on taxable investors. We compute effective marginal tax rates, as developed by Aris Protopapadakis (1983), under different assumptions about the underlying rate of appreciation of a hypothetical stock. Effective marginal tax rates are sensitive to the appreciation rate because it affects the probability of realizing the gain at various holding periods. We also find that, even though many stocks are sold in the first few months after they are purchased, most gains are realized on stocks that have been held for a long time. Because deferral reduces effective capital gains tax burdens, these findings imply that the gain-weighted average marginal effective tax rate on accruing capital gains may be much lower than the statutory long-term tax rate.

The paper is divided into five sections. The first describes the dataset we analyze and presents summary information on trading probabilities and holding periods for common stocks. Section II presents empirical evidence on the probability of selling individual stocks as a function of accrued gain or loss and calendar month. The third section examines the role of "wash-sale restrictions" in affecting investor trading, while Section IV examines the implications of our findings for effective capital gains tax rates. There is a brief conclusion.

I. Data Description and Summary

We analyze a dataset from a large discount brokerage house of individual investors' monthly positions and trades over a 71-month period from 1991 to 1996. Barber and Odean (2000) provide a detailed description of this dataset. It covers all the investments 78,000 households made through the brokerage house. Each household has at least one account, but some have many. The maximum is 21 and the median is two. Nearly 30,000 households have both taxable accounts and tax-deferred accounts, which are either IRAs or Keogh plans. This data file includes month-end summaries of account positions and detailed information on stock prices at times of purchase and, if applicable, sale. We use the Center for Research in Security Prices (CRSP) database to obtain information on stock prices in intervening periods.

We impose two restrictions in selecting a data subsample for analysis. First, we focus on trades of common stocks by households with both taxable and tax-deferred accounts, so that differences in trading activity between taxable and tax-deferred accounts are not the result of differences in the type of investors in taxable and tax-deferred accounts. We do not explore asset allocation patterns in taxable and tax-deferred accounts because that is best done with data on balance sheets, such as the Survey of Consumer Finances data used by Daniel Bergstresser and Poterba (2004), rather than with data on holdings at a single financial institution. Second, we restrict the sample to trades for which we can unambiguously match purchase and sale dates. Examples of trades that we could not match unambiguously include sales that do not have a preceding purchase of the same stock by the same household earlier in the sample period, and sales that are preceded by multiple purchases. When multiple sales follow a single purchase, we include only the first sale in our sample. If an investor bought 1,000 shares of Microsoft in June 1991, and sold 500 shares in January 1993, we would treat this as a sale of

TABLE 1—SUMMARY STATISTICS ON COMMON STOCK PURCHASES

	All accounts				Taxable accounts				Tax-deferred accounts			
	# Purchases	Mean $ amt.	≥ $10K (in %)	Sold (in %)	# Purchases	Mean $ amt.	≥ $10K (in %)	Sold (in %)	# Purchases	Mean $ amt.	≥ $10K (in %)	Sold (in %)
1991	61,808	7,902 (4,137)	19 [61]	69 [75]	39,337	8,712 (4,424)	22 [65]	70 [75]	22,471	6,485 (3,750)	15 [52]	67 [75]
1992	61,448	8,281 (4,375)	20 [63]	66 [74]	36,830	9,279 (4,748)	23 [67]	67 [74]	24,618	6,788 (3,866)	16 [54]	65 [75]
1993	66,117	8,694 (4,550)	22 [64]	62 [70]	38,522	9,865 (4,995)	25 [69]	62 [69]	27,595	7,059 (3,974)	17 [55]	60 [71]
1994	58,814	8,967 (4,620)	23 [66]	53 [64]	33,664	9,920 (5,000)	25 [69]	53 [62]	25,150	7,691 (4,125)	19 [60]	53 [65]
1995	74,581	10,272 (5,185)	26 [70]	49 [60]	41,500	11,635 (5,700)	30 [74]	49 [59]	33,081	8,562 (4,740)	22 [63]	48 [61]
1996	91,279	10,923 (5,350)	28 [72]	28 [38]	51,193	12,240 (5,712)	31 [76]	28 [38]	40,086	9,241 (4,974)	24 [66]	27 [37]
Total	414,047	9,329 (4,762)	23 [67]	52 [60]	241,046	10,404 (5,063)	26 [71]	53 [60]	173,001	7,831 (4,310)	20 [60]	51 [60]

Notes: Sample consists of 23,877 households that had both taxable and tax-deferred accounts and that purchased at least one stock between January 1991 and November 1996. The values in parentheses are median dollar amounts. The values in brackets are averages that weigh different purchases by the size of the purchase.

the stock position. Our analysis may consequently understate the actual holding period for some common stock investments, but because 93 percent of the sales in our sample involve selling a number of shares that matches an earlier purchase, we suspect that this effect is modest.

A. *Summary Statistics*

Table 1 presents summary information on the number of stock purchases, stock sales, and the dollar values of such trades for different years in the data sample we analyze. There are 414,047 stock purchases by 23,877 different households. The dataset is less than half as large as that analyzed by Barber and Odean (2000), largely because of our requirement that investors have both taxable and tax-deferred accounts. We often restrict the sample to the 97,266 stock purchases of $10,000 or more. These purchases represent 23 percent of the transactions, but they account for two-thirds of the aggregate dollar value of purchases. Just below three-fifths of all stock purchases, and two-thirds of those valued at more than $10,000, were executed in taxable accounts. Fifty-two percent of all stock purchases, and 60 percent on a value-weighted basis, were sold before the end of our sample period on November 30, 1996.

We focus on the interaction between holding period, accrued gain or loss, and the sale probability for each stock position. Our approach differs from Odean's (1998) analysis of the "proportion of gains realized" and the "proportion of losses realized" in various calendar months. These proportions aggregate positions held for many different holding periods, and are thus unable to identify differences in the disposition effect at different holding periods.

One concern about a dataset such as the one we analyze, which is drawn from investors at a single discount broker, is that it may be unrepresentative of the broader individual investor population. The IRS periodically publishes the distribution of the holding periods for sales of corporate stock reported on individual tax returns. Gerald Auten and Janette Wilson (1999) and Wilson (2002, 2003) report such data for 1985, 1997, 1998, and 1999. We can compare realization patterns in the IRS data with those in the data we analyze. Because tax returns record only trades, and they do not provide information on holdings, tax data can be used to benchmark the characteristics of assets that are sold, but not to study how the probability of selling an asset depends on the accrued return or other related characteristics.

Table 2 shows substantial agreement between summary statistics from the IRS data and from the dataset we analyze. Specifically, the left section of panel A in Table 2 reports the distri-

TABLE 2—HOLDING PERIOD DISTRIBUTION OF CORPORATE STOCK SALES

Panel A: Distribution by holding period, all sales

Length of time held (months)	Aggregate stock sales reported on tax returns (in percent)				Stock sales in taxable accounts during 1995 in brokerage data (in percent)	
	1985	**1997**	1998	1999	**Full sample**	Sales of $10,000+ purchases
1	14.0	**21.3**	27.2	34.6	**21.3**	37.7
2–3	11.8	**18.6**	14.6	15.4	**19.3**	22.9
4–6	11.8	**14.0**	13.8	12.7	**15.1**	13.7
7–12	15.8	**17.5**	17.3	14.6	**14.6**	10.0
13–18	13.7	**10.0**	10.3	8.9	**9.7**	6.0
19–24	12.3	**6.8**	6.1	5.0	**6.8**	3.7
25–36	14.4	**7.4**	7.3	5.8	**8.4**	4.1
37–48	6.3	**4.4**	3.4	3.0	**4.9**	1.9

Panel B: Distribution by holding period for stocks sold with gains and with losses

Length of time held (months)	Aggregate stock sales reported on tax returns in 1997 (in percent)		Stock sales in taxable account during 1995 in brokerage data (in percent)	
	Sold w/gain	Sold w/loss	Sold w/gain	Sold w/loss
1	20.4	22.9	21.2	21.3
2–3	17.4	20.6	19.7	18.5
4–6	13.1	15.7	15.8	13.7
7–12	17.4	17.8	15.7	12.6
13–18	10.8	8.6	9.4	10.1
19–24	7.4	5.9	62.0	8.0
25–36	8.7	5.3	7.6	9.8
37–48	4.9	3.3	4.4	5.9
	Percent of stock sales in December			
Short-term holding period	7.7	12.7	6.6	16.2
Long-term holding period	9.5	17.9	6.4	18.2
All holding periods	8.4	14.2	6.6	16.9

Notes: The aggregate sales of corporate stock reported on tax returns are provided by Auten and Wilson (1999), Wilson (2002, 2003), and authors' calculations. The table focuses on stocks held at most four years. Annual S&P 500 returns are as follows: 1985 = 32 percent; 1995 = 38 percent; 1997 = 33 percent; 1998 = 29 percent; and 1999 = 21 percent. The short-term holding period is 12 months or less and the long-term holding period is more than 12 months, except for part of 1997, when a "medium-term" capital gains rate applied to gains on assets held between 12 and 18 months.

bution of stock sales by holding period, focusing on stock held at most four years, from IRS Sales of Capital Assets datasets. The IRS data show a high percentage of short-term trades. Stocks held for less than one month accounted for 14 percent of sales in 1985. This percentage rose to 21 percent in 1997 and 35 percent in 1999. Similarly, the percentage of stocks sold with a holding period of one to four years has fallen from 47 percent in 1985, to 29 percent in 1997, to 23 percent in 1999.

We compare the IRS data with the dataset we analyze by focusing on stock sales during 1995, the last full year in the dataset. We focus on sales in 1995 that we can link back to the original purchase. Because the dataset starts in 1991, we cannot trace any sales with holding periods of more than four years. The right section of panel A in Table 2 reports the distribution of stock sales by holding period, again focusing on stocks held at most four years, for sales in taxable accounts during 1995 in the dataset we analyze. The IRS data that match the date and stock market environment for the 1995 data most closely are those for 1997. The return on the S&P 500 was 38

percent in 1995 and 33 percent in 1997. The holding period distributions for the brokerage account data for 1995 and the IRS data for 1997 are remarkably similar. The percentage of stocks sold with a holding period of one month or less is 21 percent in both datasets and the percentage with a holding period of one to four years is also very close: 29 percent in the IRS data and 30 percent in the brokerage account data. The share of sales with short holding periods is greater in the subsample of sales of stocks originally purchased for $10,000 or more, the sample of "large" purchases on which we will later focus attention. This anticipates the capital gains lock-in findings that we will document below.

Panel B of Table 2 reports the distribution of stock sales by holding period and by whether the stock had a capital gain or capital loss when it was sold. The distributions for gains and losses reported on tax returns in 1997 are very similar to the respective distributions for gains and losses recorded in the brokerage house data in 1995. In tabulations that are not reported in Table 2, we find that 16.9 percent of loss realizations occur in December in the dataset we analyze, compared to 14.2 percent of losses on tax returns. December realizations are 6.6 percent and 8.4 percent of all gain realizations, respectively.

B. *Graphical Summary of Holding Periods and Trading Probabilities*

We analyze how stock appreciation affects realization probabilities by calculating hazard functions for the probability of selling stock. Each stock purchase is indexed by i, and t denotes the number of months since purchase. To facilitate identification of end-of-year effects and other patterns that may be related to the calendar month, we start by analyzing the sample of all stocks purchased in the month of January. We estimate linear probability models of the form

$$(1) \quad \text{SELL}_{i,t} = \alpha_t + \beta_{1,t} * \text{I(GAIN)}_{i,t-1}$$

$$+ \beta_{2,t} * \text{I(LOSS)}_{i,t-1} + \varepsilon_{i,t}.$$

In this equation, $\text{I(GAIN)}_{i,t-1}$ and $\text{I(LOSS)}_{i,t-1}$ are indicator variables for stocks that have experienced an increase or decrease in price since

the date of purchase, respectively; the omitted category is stocks that have not changed in price; and $\text{SELL}_{i,t}$ is an indicator variable set to unity if stock position i is liquidated t months after it was purchased, and zero otherwise. The parameter α_t represents the hazard rate conditional on the stock price in period t being equal to the purchase price. The hazard rate conditional on the stock having appreciated is $\alpha_t + \beta_{1,t}$, while that conditional on depreciation is $\alpha_t + \beta_{2,t}$. These conditional hazard rates could also be estimated by counting the number of positions with gains and losses sold in a month, and dividing by the number of stock positions with gains or losses at the beginning of the month.

In estimating (1) we assume that the error terms are uncorrelated across all transactions, conditional on the nonparametric baseline hazard $\{\alpha_t\}$. In the hazard models that we estimate below, we allow for more general baseline hazards, but we still assume conditional independence and rule out the possibility of a single shock affecting trading decisions in several stocks. Given the large number of households in the sample, and the small probability of selling multiple stocks in the same month, the conditional independence assumption seems plausible. For example, in an average month, 71 percent of the households who sell some shares sell shares in only one stock, and an additional 17 percent sell shares in only two stocks. The probability of selling shares in multiple stocks is even lower if we condition on sales of at least $10,000 in the household's taxable account.

The probability that a stock with a gain in all months since purchase will still be held after T months is $\Pi_{s=1}^{T}(1 - \alpha_s - \beta_{1,s})$. This should be distinguished from the survival rate for all stocks with accrued gains in period T, because some stocks with accrued gains at T have experienced accrued losses in some intervening months. The hypothetical stock with accrued gains in all months up to T is thus a stylized case. We can only begin to condition on accrued gains or losses since purchase in the second month following purchase, so we assign the unconditional probability of sale in month one to all stocks when we compute the survival rate for appreciated and depreciated stocks.

Figure 1 reports the conditional hazard rates for stocks with accrued gains and accrued losses at holding periods between one and 36 months.
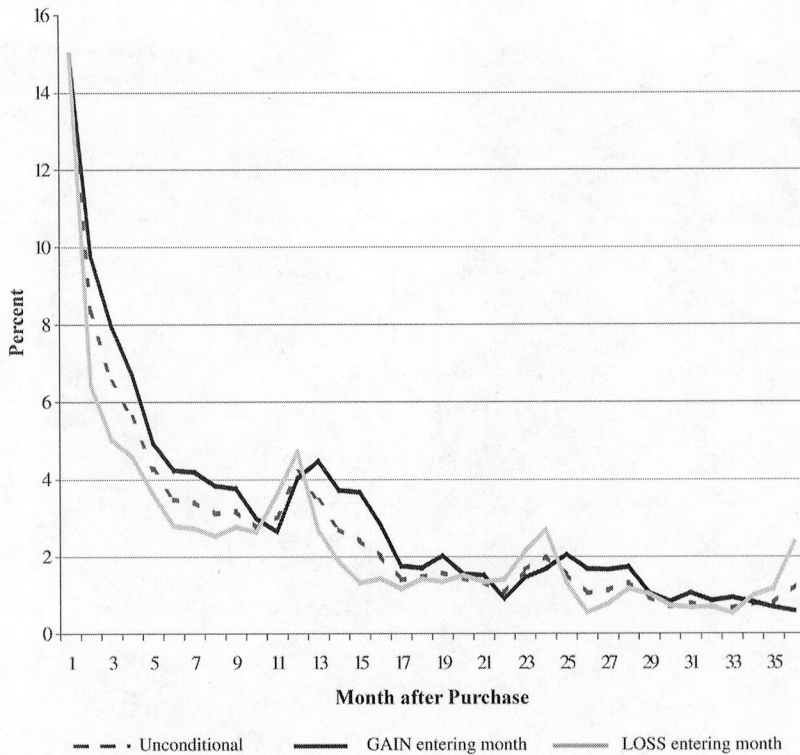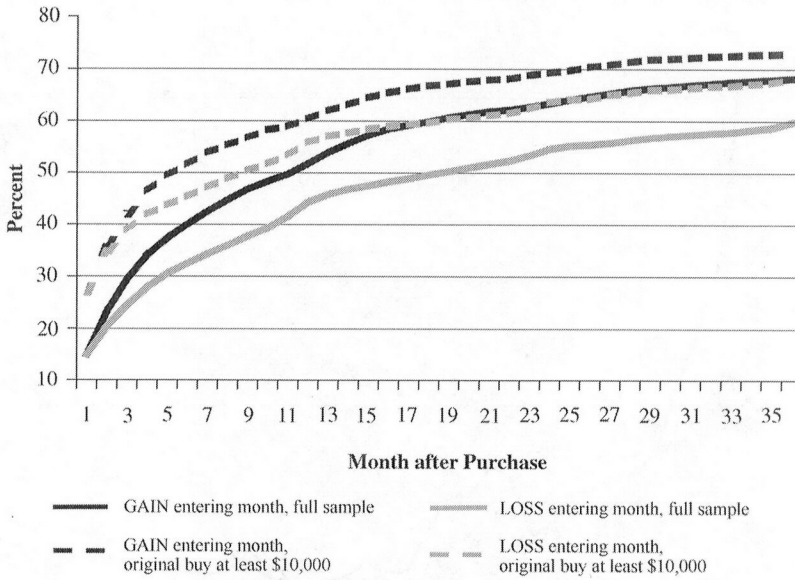
FIGURE 1. HAZARD RATE OF HAVING SOLD STOCK IN TAXABLE ACCOUNT, FULL SAMPLE

Notes: Sample is January purchases of stock from 1991 to 1996 in taxable accounts. The figure displays the hazard rate for stock purchases unconditional on the stock's price performance, as well as conditional on whether the stock has an accrued capital gain or loss entering the month.

Our restriction to January purchases does not affect the shape of the hazard function, except insofar as it determines the values of t that correspond to the months of December. The figure shows the conditional hazard rate for all stock purchases in taxable accounts (the dashed line), as well as the conditional hazard rate for all stocks in taxable accounts that have appreciated since the date of purchase (full black line). It also shows conditional hazard rates for stocks that have declined in value (full gray line). Turn-of-the-year trading is reflected in the hazard rate spikes in months 12, 24, and 36. The hazard rate for stock sales in taxable accounts drops quickly in the first six months after the date of purchase. It is 15 percent during the first month, but it drops to less than 5 percent per month after six months and continues to decline. It is less than 2 percent per month after 18 months. We observe this pattern both for stocks with gains and for stocks with losses. At most holding periods, the hazard rate for stocks with gains is higher than that for stocks with losses, except at the turn of the year when tax-loss selling is pronounced.

Figure 2A reports the cumulative probability that an investor who purchases stock in a taxable account will sell that stock prior to a given holding period. The hazard rate $h_i(t)$ is the probability that position i is liquidated t months after purchase, conditional on not having been sold until that date. In this notation, the probability that a stock is still held at the end of month t is $\Pi_{s=1}^{t}(1 - h_i(s))$, while the sale probability in month t is $h_i(t) * \Pi_{s=1}^{t-1}(1 - h_i(s))$. The cumulative probability of sale is calculated from the hazard function estimates. The two solid lines present sale probabilities calculated for all positions in the sample, while the two dashed lines correspond to the positions for which the investor's initial purchase

2A. Cumulative Probability of Having Sold Stock in Taxable Accounts
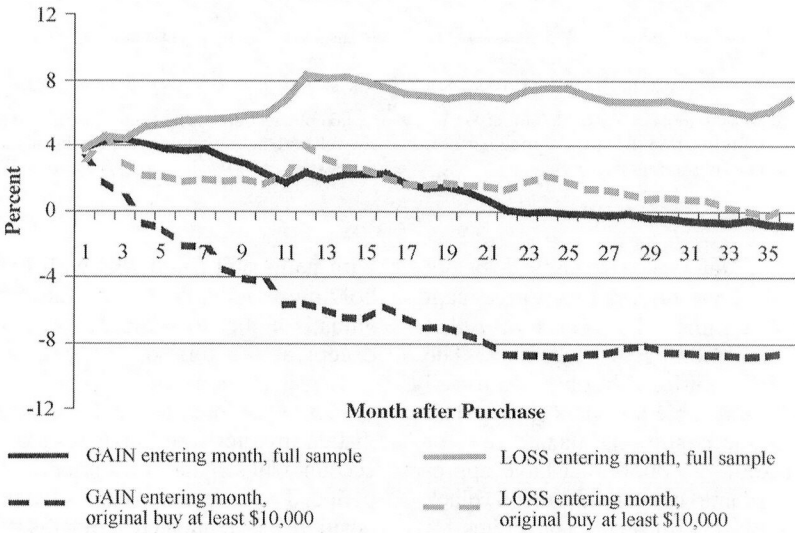
2B. Cumulative Probability of Having Sold Stock in Taxable Accounts *Relative* to Tax-Deferred Accounts

FIGURE 2. CUMULATIVE PROBABILITY OF STOCK SALE

Notes: Sample is January purchases of stock from 1991 to 1996. If $h(t)$ denotes the hazard rate in month t, the probability that the stock is sold by the end of month t is $[1 - (\Pi_{s=1}^{t}(1 - h(s)))]$. Figure 2A presents cumulative probability of sale in taxable accounts for each month since purchase. Figure 2B displays a cumulative probability of sale in taxable accounts relative to tax-deferred accounts for each month since purchase.

was at least $10,000. Our rationale for distinguishing transactions involving a purchase of at least $10,000 is that wealthy investors may be more conscious of, and more affected by, tax considerations than more modest investors. The absolute tax consequences of a large trade are also larger than those associated with a small trade.

Figure 2A suggests several conclusions. First, cumulative sale probabilities rise rapidly in the months just after purchase, but the rate of increase declines. By six months after purchase, roughly two-fifths of stocks have been sold, by one year after the date of purchase nearly one-half have been sold, and by three years after purchase nearly two-thirds have been sold. This is indicative of the reduced likelihood of sale in a given month as the holding period increases. Lei Feng and Mark Seasholes (2004) discover a similar pattern in their analysis of trading hazards for a large sample of Chinese investors. Second, sale probabilities for stocks with gains are higher than the corresponding probabilities for stocks with losses, both in the entire sample and in the sample of large purchases. By one year after the date of purchase, the probability that the stock has been sold is more than 50 percent if the stock had a capital gain at the beginning of every month since the time of purchase. The probability is lower, 44 percent, if the stock had a loss at the beginning of every month since purchase. This supports the disposition effect. Finally, sale probabilities are marginally higher for large stock purchases than for the entire sample. At the 24-month horizon, the cumulative sale probability for a stock with an initial $10,000 purchase that never had an accrued loss is 69 percent, compared with 63 percent for the sample of all purchases.

If the realization-based capital gains tax discourages investors from selling appreciated securities and encourages them to realize losses, then we should see differences in the cumulative sale probabilities between taxable and tax-deferred accounts. Figure 2B reports such differences. The solid black line is the differential cumulative sale probability for a hypothetical stock with an accrued gain at the beginning of every month since the date of purchase, and the dashed black line is the analogous plot for a similar stock with an initial purchase of more than $10,000. For large stock purchases, the sale probability after two years is 8 percentage points lower in taxable than in tax-deferred accounts, as the lock-in effect

would predict. The solid (dashed) gray line in Figure 2B represents the differential between the cumulative sale probabilities in taxable and tax-deferred accounts for a hypothetical stock purchased at $10,000 or more that had accrued losses at the beginning of every month since purchase. Consistent with the presence of tax-motivated trading, the probability of realizing losses is higher in taxable accounts than it is in tax-deferred accounts.

C. Hazard Rates as a Function of Amount of Gain or Loss

Equation (1) allows separate hazard rates for stocks with accrued gains and accrued losses, but it does not distinguish stock holdings based on the amount of gain or loss. Because large gains and losses may have a more substantial impact on trading probabilities than small gains and losses, we also estimate a hazard model of the form:

$$(2) \qquad \text{SELL}_{i,t} = \alpha_t + \beta_{1,t} * \text{GAIN}_{i,t-1}$$
$$+ \beta_{2,t} * \text{LOSS}_{i,t-1} + \varepsilon_{i,t}$$

where $\text{GAIN}_{i,t-1} = \max(\text{percentage price change}_{i,t-1}, 0)$ and $\text{LOSS}_{i,t-1} = \min(\text{percentage price change}_{i,t-1}, 0)$. The percentage change in stock price is measured from the purchase date and it incorporates all applicable stock splits. GAIN is nonnegative and LOSS is nonpositive, so a positive (negative) coefficient on GAIN (LOSS) raises the sale probability.

Table 3 reports estimates of equation (2) for the sample of stock purchases of $10,000 or more. The first column shows the baseline coefficients for the probability of selling a stock, held in a taxable account, with neither a gain nor a loss. There is a sharp decline in trading probabilities during the first nine months of ownership. The entries in column 4 show the difference between the sale probability for a stock with no price change held in a taxable and a tax-deferred account. Sales are more likely in taxable accounts for the first three months, but at longer holding periods, the sale probability is slightly higher in tax-deferred accounts. These findings suggest that, at least for stock purchases of $10,000 or more, Barber and Odean's (2004) discovery of higher trading in taxable rather than tax-deferred

TABLE 3—REGRESSION OF MONTHLY HAZARD RATE OF SELLING STOCK ON CUMULATIVE RETURN ON STOCK ENTERING THE MONTH, PURCHASES ≥ $10,000 (FIGURES 3A AND 3B)

Months since purchase	Probability of selling stock in taxable account			Probability of selling stock in taxable account *relative* to selling stock in tax-deferred account		
	Constant: baseline	GAIN	LOSS	Constant: baseline	GAIN	LOSS
1 month	23.4***			2.7**		
	(0.8)			(1.4)		
2 months	11.4***	21.7***	9.7***	1.0*	−19.4***	0.7
	(0.4)	(2.6)	(2.2)	(0.6)	(4.6)	(3.6)
3 months	8.7***	11.6***	8.2***	0.1	−8.9***	−2.5
	(0.3)	(1.8)	(1.5)	(0.5)	(3.2)	(2.5)
4 months	6.7***	5.8***	6.4***	−0.5	−6.2***	−1.6
	(0.3)	(1.3)	(1.2)	(0.4)	(2.4)	(2.0)
5 months	5.5***	4.7***	5.0***	−0.7*	−5.4***	−2.5
	(0.2)	(1.1)	(1.0)	(0.4)	(2.2)	(1.7)
6 months	5.4***	0.7	4.6***	−0.5	−6.6***	−0.6
	(0.2)	(0.8)	(0.9)	(0.4)	(1.8)	(1.7)
7 months	4.6***	1.3*	2.7***	−0.4	−4.5***	−2.8**
	(0.2)	(0.8)	(0.9)	(0.4)	(1.6)	(1.4)
8 months	3.7***	0.8	2.1***	−0.6*	−5.5***	−3.2**
	(0.2)	(0.5)	(0.8)	(0.4)	(1.5)	(1.4)
9 months	3.4***	−0.2	0.4	−0.7**	−3.5***	−3.8***
	(0.2)	(0.3)	(0.8)	(0.4)	(1.2)	(1.4)
10 months	3.1***	0.2	1.1	−0.8**	−1.9	−2.1
	(0.2)	(0.4)	(0.7)	(0.4)	(1.3)	(1.3)
11 months	2.9***	−0.4	0.9	−0.6**	−1.9**	−2.4**
	(0.2)	(0.3)	(0.7)	(0.3)	(0.8)	(1.1)
12 months	2.9***	−0.1	0.8	−0.6*	−1.2*	−3.6***
	(0.2)	(0.3)	(0.7)	(0.3)	(0.7)	(1.1)
13 months	3.0***	0.2	2.2***	−0.2	0.3	−0.5
	(0.2)	(0.4)	(0.7)	(0.3)	(0.6)	(1.2)

Notes: Sample restricted to stock purchases of at least $10,000. The specification is:

$$SELL_{i,t} = \alpha_t + \beta_{1,t} * GAIN_{i,t-1} + \beta_{2,t} * LOSS_{i,t-1} + \varepsilon_{i,t}$$

where GAIN = max(percentage price change, 0), LOSS = min(percentage price change, 0). Standard errors, which are shown in parentheses, allow for heteroskedasticity as well as correlation across observations of the same household. ***, **, * denote significance at the 1-percent, 5-percent, and 10-percent level, respectively.

accounts is largely attributable to short-horizon trades.

Figure 3A graphs the information in Table 3. The figure considers a hypothetical stock that exhibits an accrued gain of 25 percent since the date of purchase, and another hypothetical stock that exhibits an accrued loss of 25 percent. For assets held in taxable accounts, the disposition effect is particularly clear in the first few months after purchase. In the second month of ownership, for example, the sale probability for a stock with a 25-percent gain, shown as the leftmost black bar in Figure 3A, is 5 percentage points higher than the analogous probability for a stock that has experienced no change in value. The sale proba-bility for a stock with a 25-percent loss is 2.4 percentage points lower than that for a stock with

no price change. By six months after the date of purchase, the differential sale probabilities for stocks with gains and losses are small.

Figure 3B contrasts the sale probabilities for stocks with a 25-percent accrued gain and a 25-percent accrued loss in both taxable and tax-deferred accounts. The likelihood of sell-ing a position with an unrealized gain of 25 percent is greater in the tax-deferred than in the taxable account, particularly for short holding periods. Moreover, the probability of selling a position with a loss is higher in taxable than in tax-deferred accounts. Thus, while there is a positive correlation between returns and stock sales over holding periods of less than a year, it is less positive in taxable than in tax-deferred accounts. This finding is
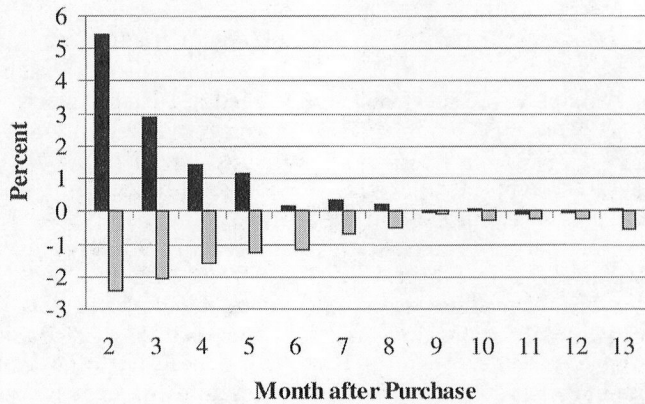
Gain of 25% entering month   Loss of –25% entering month

3A. Added Likelihood of Sale in Taxable Accounts with Respect to Stock with Zero Appreciation since Purchase Date, Purchase at Least $10,000
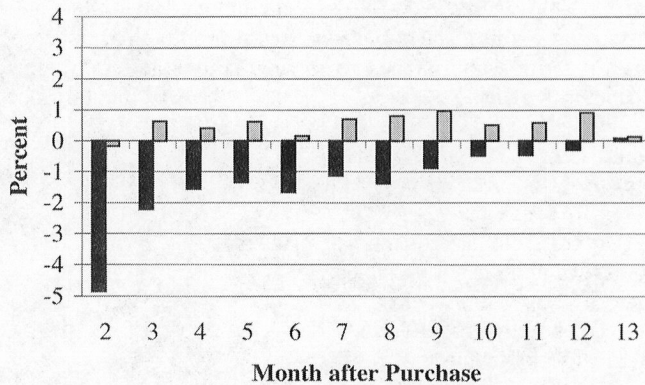
Gain of 25% entering month   Loss of –25% entering month

3B. Added Likelihood of Sale in Taxable Accounts *Relative* to Tax-Deferred Accounts with Respect to Stock with Zero Appreciation since Purchase Date, Purchase at Least $10,000

FIGURE 3. ADDED LIKELIHOOD OF STOCK SALE WITH RESPECT TO STOCK WITH ZERO APPRECIATION SINCE PURCHASE DATE.

Notes: Added likelihood of selling stock with a 25-percent gain (loss) since purchase with respect to a stock with zero appreciation is estimated from the following regression separately for taxable and tax-deferred accounts:

$$SELL_{i,t} = \alpha_t + \beta_{1,t} * GAIN_{i,t-1} + \beta_{2,t} * LOSS_{i,t-1} + \varepsilon_{i,t}$$

where $GAIN = \max(\text{percentage price change}, 0)$, $LOSS = \min(\text{percentage price change}, 0)$. The added likelihood of sale is expressed as $\beta_{1,t} * GAIN_{i,t-1}$ or $\beta_{2,t} * LOSS_{i,t-1}$. Figure 3A displays the results for taxable accounts. Figure 3B displays the results for taxable accounts relative to the results for tax-deferred accounts.

consistent with a lock-in effect in taxable, but not in tax-deferred, accounts.

II. Holding Periods, End-of-Year Selling, and Stock Sales

Barber and Odean (2004) report that the proportion of gains realized and the proportion of losses realized in taxable and tax-deferred accounts are very similar in all months except December, when the ratio for taxable accounts drops dramatically, while the ratio for tax-deferred accounts remains stable. Their findings, as well as those in earlier studies, suggest that tax-loss selling takes place in December. The "proportion of gains realized" method is unable, however, to disentangle the effects of accrued returns, holding periods, and calendar months on stock sale decisions, which prevents estimating the lock-in effect. We do this by estimating a variety of parametric and nonparametric hazard models. The mean (median) investor in the dataset we analyze makes 17 (6) stock purchases, so we can explore the robustness of our findings to various approaches to modeling household heterogeneity.

A. Cox Proportional Hazards Models with Nonparametric Baseline Hazards

We estimate a Cox proportional hazards model with GAIN, LOSS, and several indicator variables for the characteristics of the holding period as independent variables. The baseline hazard rate is estimated nonparametrically, following the methods of Aaron Han and Jerry A. Hausman (1990). The proportional hazards specification assumes that the hazard function takes the form

$$(3) \qquad h_i(t) = \gamma(t) * e^{X_{i,t}\beta}$$

where $\gamma(t)$ denotes the baseline hazard. We begin with a simple specification:

$$(4) \quad X_{i,t}\beta = \beta_1 * \text{GAIN}_{i,t-1}$$

$$+ \beta_2 * \text{GAIN}_{i,t-1} * December_{i,t}$$

$$+ \beta_3 * \text{LOSS}_{i,t-1}$$

$$+ \beta_4 * \text{LOSS}_{i,t-1} * December_{i,t}$$

$$+ \beta_5 * December_{i,t} + \varepsilon_{i,t}.$$

We estimate hazard functions for the full sample of stock purchases, but we focus most of our analysis on the subsample of purchases valued at $10,000 or more. Because GAIN is nonnegative and LOSS is nonpositive, the disposition effect predicts greater selling of stocks with accrued gains than with accrued losses, that is, $\beta_1 > 0$ and $\beta_3 > 0$. Tax-motivated trading predicts exactly the opposite. Households will hold stocks with accrued gains and sell stocks with accrued losses, that is, $\beta_1 < 0$ and $\beta_3 < 0$. Further, a year-end desire to postpone the realization of gains into the next tax year implies $\beta_2 < 0$, while a desire to capture tax losses in the current calendar year implies $\beta_4 < 0$. In sum, positive coefficients on GAIN and LOSS are consistent with the disposition effect dominating trading decisions, while negative coefficients suggest the domination of tax motivations.

We estimate hazard models for taxable accounts as well as models for all accounts with an indicator variable and interaction terms to test for statistical differences between behavior in taxable and tax-deferred accounts. In this case, the specification becomes:

$$(5) \quad X_{i,t}\beta = \beta_1 * \text{GAIN}_{i,t-1}$$

$$+ \beta_2 * \text{GAIN}_{i,t-1} * December_{i,t}$$

$$+ \beta_3 * \text{LOSS}_{i,t-1}$$

$$+ \beta_4 * \text{LOSS}_{i,t-1} * December_{i,t}$$

$$+ \beta_5 * December_{i,t} + \beta_6 * \text{GAIN}_{i,t-1} * \text{TAX}_i$$

$$+ \beta_7 * \text{GAIN}_{i,t-1} * December_{i,t} * \text{TAX}_i$$

$$+ \beta_8 * \text{LOSS}_{i,t-1} * \text{TAX}_i$$

$$+ \beta_9 * \text{LOSS}_{i,t-1} * December_{i,t} * \text{TAX}_i$$

$$+ \beta_{10} * December_{i,t} * \text{TAX}_i + \varepsilon_{i,t}$$

where TAX_i is an indicator variable for stock position i being held in a taxable account. We allow separate baseline hazard rates for taxable and tax-deferred accounts. In this specification, the disposition effect should affect β_1 through β_5, while the coefficients on the variables interacted with TAX will reflect the

TABLE 4—COX PROPORTIONAL HAZARDS MODEL OF STOCK SALES, BY SIZE OF PURCHASE

| | Full sample | | | Original purchase $0–4,999 | | |
| | All accounts | | | All accounts | | |
	Taxable accounts	Tax-deferred accounts	Interaction w/taxable accounts	Taxable accounts	Tax-deferred accounts	Interaction w/taxable accounts
GAIN	0.11***	0.09***	0.02*	0.14***	0.09***	0.05***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
GAIN * December	−0.02	0.07***	−0.09***	−0.01	0.07***	−0.08***
	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)
LOSS	1.03***	1.42***	−0.40***	1.01***	1.32***	−0.31***
	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.05)
LOSS * December	−2.23***	−0.26**	−1.97***	−2.11***	−0.31**	−1.80***
	(0.05)	(0.11)	(0.12)	(0.07)	(0.13)	(0.14)
December	0.12***	0.01	0.11***	0.09***	0.04*	0.05*
	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
# of Observations	3,449,531	5,997,368		1,942,611	3,599,068	

| | Original purchase $5,000–9,999 | | | Original purchase at least $10,000 | | |
| | All accounts | | | All accounts | | |
	Taxable accounts	Tax-deferred accounts	Interaction w/taxable accounts	Taxable accounts	Tax-deferred accounts	Interaction w/taxable accounts
GAIN	0.14***	0.25***	−0.12***	−0.03	0.06***	−0.09***
	(0.01)	(0.02)	(0.03)	(0.02)	(0.01)	(0.03)
GAIN * December	−0.05	−0.14**	0.10	−0.09	0.13***	−0.22***
	(0.06)	(0.06)	(0.09)	(0.08)	(0.04)	(0.09)
LOSS	0.91***	1.37	−0.47***	1.18***	1.65***	−0.46***
	(0.05)	(0.07)	(0.09)	(0.06)	(0.08)	(0.10)
LOSS * December	−2.28***	0.23	−2.51***	−2.72***	−0.45	−2.27***
	(0.11)	(0.27)	(0.29)	(0.12)	(0.29)	(0.32)
December	0.15***	0.05	0.11**	0.14***	−0.05	0.19***
	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.05)
# of Observations	829,498	1,395,918		677,422	1,002,382	

Notes: GAIN = max(percentage price change, 0) and LOSS = min(percentage price change, 0). The Cox proportional hazards model employs a nonparametric estimate of the baseline hazard, which is estimated separately for taxable and tax-deferred accounts in the model estimated using all accounts. Standard errors, which are shown in parentheses, allow for heteroskedasticity as well as correlation across observations of the same stock transaction over time. ***, **, * denote significance at the 1-percent, 5-percent, and 10-percent level, respectively.

importance of tax-motivated trading. Barber and Odean (2004) find that turnover is higher in taxable than in tax-deferred accounts, which may suggest differences in the way investors view these accounts. To the extent that the disposition effect might be more pronounced in taxable than in tax-deferred accounts, the interaction terms of TAX with GAIN and LOSS will understate the magnitude of tax-motivated trading.

Table 4 presents estimates of equations (4) and (5). The upper-left panel presents estimates for the full sample, while the other panels report results for subsamples based on the size of the initial purchase. The lower-right panel focuses on transactions with an initial purchase of at least $10,000. The findings for the full sample confirm the graphical results in Figure 1. In particular, the coefficient on LOSS for taxable accounts is positive, which implies that in most months a larger accrued loss leads to a lower probability of sale. The coefficient on the LOSS * *December* interaction term, however, is strongly negative, indicating that a loss is more likely to be realized in December than

in other months. The LOSS coefficient of 1.03 for the full sample implies that in non-December months the monthly hazard rate for a stock that has lost 25 percent of its value since the date of purchase is 23 percent lower than that for a stock with no price change: $e^{1.03*(-0.25)} - 1 = -0.23$. But, in December the stock with the accrued loss is 35 percent *more* likely to be sold than the stock with no price change: $e^{(1.03-2.23)*(-0.25)} - 1 = 0.35$. For the sample of all transactions, the coefficient on GAIN is positive, but only one-tenth as large as the LOSS coefficient.

The second and third columns of Table 4 compare hazard models for taxable and tax-deferred accounts. The data for the full sample show a slightly higher probability of realizing gains in taxable than in tax-deferred accounts, and a substantially attenuated probability of holding on to losses. The LOSS * *December* interaction is substantially smaller in tax-deferred accounts than in taxable accounts. This suggests that tax considerations are particularly important in explaining year-end trading patterns. Furthermore, by comparing realizations in taxable and tax-deferred accounts, we find evidence of tax-loss selling in all months, though the effect is strongest in December. In the full sample, for example, the difference between the coefficients on LOSS for taxable and tax-deferred accounts is −0.40, which implies, because LOSS is negative, that losses are more likely to be realized in taxable accounts than in tax-deferred accounts. A 25-percent loss is associated with an 11-percent-higher monthly hazard rate of stock sales in taxable accounts relative to tax-deferred accounts in non-December months: $e^{-0.40*(-0.25)} - 1 = 0.11$. This finding is consistent with a desire to realize a tax deduction. The comparable boost in December is 81 percent: $e^{(-0.40-1.97)*(-0.25)} - 1 = 0.81$. Controlling for returns, the trading rate in taxable accounts is higher in December than it is in other months.

The results in the subpanels of Table 4 describe the sensitivity of the hazard model coefficients to conditioning on stock purchases of different sizes. Two patterns stand out. First, the GAIN variable has a positive effect on sale probability for transactions of less than $10,000, yet a negative but statistically insignificant effect for transactions of more than $10,000. For gains in taxable accounts, the dis-

position effect seems to outweigh tax motivations for all transactions other than those in the greater-than-$10,000 category. We find evidence of a capital gains lock-in effect for purchases of more than $10,000. The GAIN coefficient estimate is −0.09 on the difference between taxable and tax-deferred accounts, and this effect is even stronger, −0.22, during the month of December. This implies that previous findings of a disposition effect may be driven by the behavior of small investors. Second, the LOSS coefficients are reasonably stable across positions of different sizes, but the LOSS * *December* effect is most pronounced for the transactions of more than $10,000. The coefficient on LOSS * *December* is −2.23 in taxable accounts for the full sample, and −2.72 for the sample of large transactions. This suggests that investors who make large stock transactions may be more sensitive to the value of realized losses than investors who make smaller investments.

B. *Investor- and Stock-Specific Heterogeneity*

To explore the sensitivity of our findings to heterogeneity in baseline hazard rates, we replace $\gamma(t)$ in specification (3) with investor-specific $\gamma_h(t)$ functions. The dataset we analyze contains sufficiently many repeated observations to make it possible to estimate investor-specific hazards. We can also estimate stock-specific baseline hazard rates. These replace the specification in (3) with

$$(3') \qquad h_{i,j}(t) = \gamma_j(t) * e^{X_{i,t}\beta}$$

where $h_{i,j}(t)$ denotes the hazard rate at holding period t for transaction i, which happens to be in stock j. The baseline hazard rate, $\gamma_j(t)$, is now stock-specific. It is even possible to allow for *investor-specific stock-specific* baselines that allow for both sources of heterogeneity:

$$(3'') \qquad h_{h,i,j}(t) = \gamma_{h,j}(t) * e^{X_{i,t}\beta}$$

where $h_{h,i,j}(t)$ represents the hazard rate for investor h's holding of transaction i, which is in stock j.

Table 5 presents our findings for different cases with regard to baseline heterogeneity, focusing on purchases of $10,000 or more. There are 8,146 investors who made purchases of

TABLE 5—COX PROPORTIONAL HAZARDS MODEL OF STOCK SALES, PURCHASES ≥ $10,000, WITH AND WITHOUT HETEROGENEITY IN BASELINE HAZARDS

	One baseline hazard rate			Investor-specific baselines		
	All accounts			All accounts		
	Taxable accounts	Tax-deferred accounts	Interaction w/taxable accounts	Taxable accounts	Tax-deferred accounts	Interaction w/taxable accounts
GAIN	−0.03	0.06***	−0.09***	0.11***	0.37***	−0.26***
	(0.02)	(0.01)	(0.03)	(0.03)	(0.05)	(0.06)
GAIN * December	−0.09	0.13***	−0.22***	−0.03	0.32*	−0.35*
	(0.08)	(0.04)	(0.09)	(0.08)	(0.18)	(0.20)
LOSS	1.18***	1.65***	−0.46***	1.98***	2.04***	−0.06
	(0.06)	(0.08)	(0.10)	(0.08)	(0.11)	(0.13)
LOSS * December	−2.72***	−0.45	−2.27***	−2.98***	−0.66*	−2.33***
	(0.12)	(0.29)	(0.32)	(0.16)	(0.37)	(0.40)
December	0.14***	−0.05	0.19***	0.11***	−0.13***	0.24***
	(0.03)	(0.04)	(0.05)	(0.03)	(0.05)	(0.06)

	Stock-specific baselines			Investor-stock-specific baselines		
	All accounts			All accounts		
	Taxable accounts	Tax-deferred accounts	Interaction w/taxable accounts	Taxable accounts	Tax-deferred accounts	Interaction w/taxable accounts
GAIN	−0.09***	0.27***	0.36***	0.19	1.16***	−0.96***
	(0.03)	(0.05)	(0.06)	(0.26)	(0.23)	(0.35)
GAIN * December	−0.05	0.00	−0.05	−0.29	0.68	−0.97
	(0.10)	(0.15)	(0.18)	(0.21)	(0.71)	(0.74)
LOSS	2.09***	2.48***	−0.39***	4.49***	5.67***	−1.17*
	(0.08)	(0.11)	(0.14)	(0.39)	(0.57)	(0.69)
LOSS * December	−3.03***	−0.21	−2.82***	−2.48***	1.40	−3.87***
	(0.17)	(0.33)	(0.37)	(0.80)	(1.37)	(1.59)
December	0.11***	0.00	0.11**	0.18**	−0.12	0.29**
	(0.03)	(0.05)	(0.06)	(0.08)	(0.12)	(0.15)

Notes: GAIN = max(percentage price change, 0) and LOSS = min(percentage price change, 0). Standard errors, which are shown in parentheses, allow for heteroskedasticity as well as correlation across observations of the same stock transaction over time. Sample consists of 677,422 monthly sale decisions in taxable accounts and 1,002,382 monthly sale decisions in all accounts. ***, **, * denote significance at the 1-percent, 5-percent, and 10-percent level, respectively.

$10,000 or more in taxable accounts. These purchases were in 5,043 distinct stocks. When we allow for investor-stock-specific baselines, there are 49,513 distinct investor-stock pairs, and the results are identified from repeat purchases in the same stock by the same investor. Because the results in Table 5 focus on the sale decisions for the sample of purchases of at least $10,000, the upper-left panel in Table 5, with homogeneous baseline hazards, corresponds to the bottom-right panel in Table 4. The upper-right panel in Table 5 presents results that allow for investor-specific baseline hazards. The one substantial difference in the results with heterogeneous baseline hazards is that the coefficient on GAIN is positive, as it was for the full sample but not for the subsample of large transactions when we assumed homogeneous baseline hazards. Allowing for investor-specific baselines weakens the evidence of lock-in if we analyze only taxable accounts.

When we focus on the *difference* between the GAIN effect in taxable and tax-deferred accounts, however, allowing for investor-specific baselines nearly triples the estimated effect, from −0.09 to −0.26. The evidence of lock-in due to tax-related factors becomes much stronger in this case. This pattern continues when we allow for stock-specific baselines, in the lower-left panel, and for stock- and investor-specific

baselines, in the lower-right panel. With both stock- and investor-specific baselines, the difference in the coefficients for taxable and tax-deferred accounts for LOSS and for the LOSS * December interaction are also much larger than they were in the homogeneous baseline hazard case.

The findings in Table 5 indicate that allowing for heterogeneity has an important effect on the estimates of how taxes affect investor behavior because the homogeneity assumption attenuates the evidence of tax effects. The results suggest that the estimated correlation between a stock's accrued return and its probability of sale is not simply an artifact of correlated cross-sectional differences in investor acumen and investor trading behavior.

C. Allowing for Holding Period Effects

The effect of accrued gains and accrued losses on realization probabilities may vary by holding period. For example, the GAIN effect might be positive shortly after purchase, as a large price increase induces a trader to sell and lock in gains in accordance with the disposition effect, while over the long-term, an investor may be reluctant to realize a sizable gain as a result of the associated tax penalty. Previous research on loss realizations, such as S. G. Badrinath and Wilbur G. Lewellen (1991), also suggests that whether losses are long term or short term can affect realization decisions. We allow for holding period effects by generalizing (4) as follows:

$$(6) \quad X_{i,t}\beta = \beta_1 * GAIN_{i,t-1}$$

$$+ \beta_2 * GAIN_{i,t-1} * (Month \leq 6)_{i,t}$$

$$+ \beta_3 * GAIN_{i,t-1} * (Month\ 7-12)_{i,t}$$

$$+ \beta_4 * GAIN_{i,t-1} * December_{i,t}$$

$$+ \beta_5 * GAIN_{i,t-1} * (Month \leq 6)_{i,t} * December_{i,t}$$

$$+ \beta_6 * GAIN_{i,t-1} * (Month\ 7-12)_{i,t} * December_{i,t}$$

$$+ \beta_7 * LOSS_{i,t-1} + \beta_8 * LOSS_{i,t-1} * (Month \leq 6)_{i,t}$$

$$+ \beta_9 * LOSS_{i,t-1} * (Month\ 7-12)_{i,t}$$

$$+ \beta_{10} * LOSS_{i,t-1} * December_{i,t}$$

$$+ \beta_{11} * LOSS_{i,t-1} * (Month \leq 6)_{i,t} * December_{i,t}$$

$$+ \beta_{12} * LOSS_{i,t-1} * (Month\ 7-12)_{i,t} * December_{i,t}$$

$$+ \beta_{13} * December_{i,t}$$

$$+ \beta_{14} * December_{i,t} * (Month \leq 6)_{i,t}$$

$$+ \beta_{15} * December_{i,t} * (Month\ 7-12)_{i,t} + \varepsilon_{i,t}.$$

In this specification, variables such as "Month 7–12" are indicator variables that describe a holding period of between 7 and 12 months. This specification permits us to study both the timing of sales relative to the turn of the year and the timing relative to the expiration of the twelfth month since purchase, the holding period that qualified for short-term tax status during our sample period.

Table 6 reports estimates of equation (6), as well as a variant of this equation with interaction effects between an indicator variable for taxable accounts and each explanatory variable. The holding period indicator variables reveal a rich pattern of trading behavior. The first column shows estimates for taxable accounts. For assets with accrued gains, larger gains result in higher sale probabilities in the first six months after acquisition of the asset. This effect is attenuated in the next six months and, after 12 months, larger gains exert a *negative* effect on sale probabilities. Thus, controlling for holding period suggests that the disposition effect is concentrated among short-term holdings, while the capital gains tax lock-in effect prevails at longer holding periods. The estimates imply that a capital gain of 25 percent is associated with a 22-percent increase in the monthly hazard rate of selling stock in a taxable account during the first six months after purchase; but, conditional on having held the stock for one year, a 25-percent capital gain is associated with a 6 percent *reduction* in the monthly sale probability. The differential impact of gains on realization behavior over different holding periods suggests that previous findings on disposition effects may have been driven by high-frequency traders with short-term horizons.

The second column of Table 6 reports the coefficients from estimating equation (6) on stock purchases in tax-deferred accounts, and the third column reports the *difference* in coefficients between taxable and tax-deferred accounts. Since

TABLE 6—COX PROPORTIONAL HAZARDS MODEL OF STOCK SALES WITH UNIFORM, INVESTOR-SPECIFIC, OR STOCK-SPECIFIC BASELINE HAZARDS, PURCHASES ≥ $10,000

	Common baseline			Investor-specific baselines		Stock-specific baselines	
	Taxable accounts	Tax-deferred accounts	Taxable relative to tax-deferred accounts	Taxable accounts	Taxable relative to tax-deferred accounts	Taxable accounts	Taxable relative to tax-deferred accounts
GAIN	−0.24***	−0.01	−0.23***	−0.09*	−0.10	−0.24***	−0.17*
	(0.04)	(0.03)	(0.05)	(0.05)	(0.07)	(0.06)	(0.10)
GAIN*(Month ≤ 6)	0.79***	0.99***	−0.20*	0.83***	−0.37***	0.48***	−0.31**
	(0.06)	(0.09)	(0.11)	(0.08)	(0.13)	(0.09)	(0.15)
GAIN*(Month 7–12)	0.29***	0.35***	−0.06	0.18**	−0.12	0.20**	−0.21
	(0.06)	(0.05)	(0.08)	(0.08)	(0.14)	(0.09)	(0.15)
GAIN*December	−0.08	0.10	−0.17	−0.03	−0.59*	0.05	−0.16
	(0.15)	(0.08)	(0.17)	(0.14)	(0.35)	(0.17)	(0.30)
GAIN*December*(Month ≤ 6)	0.34	−0.03	0.37	0.09	0.58	0.11	0.54
	(0.23)	(0.19)	(0.29)	(0.23)	(0.50)	(0.26)	(0.43)
GAIN*December*(Month 7–12)	−0.15	0.12	−0.27	−0.21	0.19	−0.28	−0.14
	(0.26)	(0.23)	(0.35)	(0.31)	(0.59)	(0.31)	(0.50)
LOSS	0.86***	1.09***	−0.23	1.08***	0.04	1.36***	−0.51**
	(0.10)	(0.12)	(0.16)	(0.14)	(0.22)	(0.16)	(0.26)
LOSS*(Month ≤ 6)	0.74***	0.60***	0.15	1.51***	0.25	1.28***	0.48
	(0.14)	(0.19)	(0.24)	(0.18)	(0.30)	(0.20)	(0.33)
LOSS*(Month 7–12)	0.03	0.63***	−0.60**	0.40**	−0.65**	0.16	−0.35
	(0.15)	(0.21)	(0.26)	(0.20)	(0.34)	(0.22)	(0.39)
LOSS*December	−2.59***	−1.03***	−1.55***	−2.45***	−0.91	−3.00***	−1.87***
	(0.20)	(0.35)	(0.40)	(0.29)	(0.68)	(0.30)	(0.57)
LOSS*December*(Month ≤ 6)	−0.23	1.59***	−1.82***	−0.40	−1.78**	−0.16	−2.18***
	(0.31)	(0.65)	(0.72)	(0.40)	(0.92)	(0.41)	(0.86)
LOSS*December*(Month 7–12)	−0.14	0.72	−0.86	−0.73*	−1.62	0.02	−1.03
	(0.30)	(0.73)	(0.79)	(0.42)	(1.04)	(0.45)	(0.09)
December	−0.00	−0.14	0.13	0.08	0.40**	−0.06	0.13
	(0.08)	(0.09)	(0.12)	(0.09)	(0.18)	(0.09)	(0.15)
December*(Month ≤ 6)	0.15*	0.19*	−0.04	0.07	−0.22	0.18*	−0.11
	(0.08)	(0.11)	(0.13)	(0.10)	(0.19)	(0.10)	(0.17)
December*(Month 7–12)	0.20**	−0.04	0.24	0.05	−0.02	0.24**	0.13
	(0.10)	(0.13)	(0.17)	(0.12)	(0.23)	(0.12)	(0.21)
Number of observations		1,002,382		1,002,382		1,002,382	

Notes: GAIN = max(percentage price change, 0) and LOSS = min(percentage price change, 0). The Cox proportional hazards model employs a nonparametric estimate of the baseline hazard. The third, fifth, and seventh columns present the coefficients obtained from the taxable account sample minus those obtained from the tax-deferred account sample. Standard errors, which are shown in parentheses, allow for heteroskedasticity as well as correlation across observations of the same stock transaction over time. ***, **, * denote significance at the 1-percent, 5-percent, and 10-percent level, respectively.

column 1 minus column 2 equals column 3, in the next two panels of the table, we report only information analogous to that in columns 1 and 3. The positive effect of GAIN on realization rates at short holding periods is more pronounced in tax-deferred than in taxable accounts. The difference between the coefficients for taxable and tax-deferred accounts, −0.20, is statistically significantly different from zero. At short horizons, the disposition effect seems to describe trading in both types of accounts, but the effect is somewhat attenuated in taxable accounts. The negative relation between accrued gains and realizations after a stock has been held for 12 months is statistically significantly different from zero for taxable accounts, but not for tax-deferred accounts. This finding suggests a long-term capital gains lock-in effect in taxable accounts, but not in tax-deferred accounts.

Larger losses reduce the probability of sale in both taxable and tax-deferred accounts, but, at least at short horizons, the reduction is larger for tax-deferred accounts. This reflects the lack of a tax benefit to realizing losses in these accounts.

The difference between the coefficient on LOSS * *December* in taxable and in tax-deferred accounts is larger for holding periods of fewer than six months, when the loss would qualify as a short-term loss, than for longer holding periods. Loss-realization effects in December are particularly strong in taxable accounts, although there is a statistically significant and substantively important effect for tax-deferred accounts as well, at least for stocks held more than one year. While it is less pronounced than the effect in taxable accounts, the December effect in tax-deferred accounts is still puzzling. It may reflect end-of-year portfolio evaluation and analysis.

Table 6 also reports results allowing for investor-specific or stock-specific baseline hazards. The results are similar to those in the first two columns of the table, suggesting that the key findings are not sensitive to our assumptions about the structure of baseline hazards.

D. *Tax Changes and Changes in the Incentive to Realize Losses*

In 1993, midway through the data sample that we analyze, the Omnibus Budget Reconciliation Act increased the maximum short-term capital gains tax rate from 31 percent to 39.6 percent. The long-term capital gains tax rate was capped at 28 percent throughout our sample period. This 1993 reform increased the incentive to realize losses short term and to defer gains until they are long term. Under the hypothesis that tax incentives affect investor behavior, this change should lead to different realization patterns before and after 1993. To test this possibility, we allow for separate pre-1993 and post-1993 coefficients on the variables defined by the interactions of LOSS and GAIN with an indicator variable for short-term holding period status. We focus on sales in December, which is the month when tax-loss trading is particularly important. The resulting estimates show a significant increase in the short-term loss-realization probability after the 1993 reform. The coefficient on the short-term loss variable is -1.25 (standard error $= 0.22$) prior to 1993, and -1.82 (standard error $= 0.18$) afterward. Specifically, while a stock held with a short-term loss of 20 percent has a 28-percent-higher probability of being sold relative to a stock with no price change ($e^{-1.25*(-0.20)} - 1 = 0.28$)

during December in the pre-1993 regime, it has a 44-percent-higher probability after the tax change ($e^{-1.82*(-0.20)} - 1 = 0.44$). The difference between these two coefficients is statistically significant at the 5-percent level.

There is no statistically significant difference in the selling probability for stocks with losses that have been held more than 12 months. Such stocks would qualify for the same long-term loss treatment before and after the reform. There is no statistically significant change in the probability of selling short-term gains before and after the reform, but, somewhat surprisingly, there is a statistically significant change in the coefficient on long-term gains. The long-term gain coefficient is 0.23 (standard error $= 0.22$) prior to the reform, and -0.45 (standard error $= 0.16$) afterward. This suggests a more pronounced lock-in effect for long-term gains after the 1993 tax reform; the explanation for this change is not clear.

E. *Loss Realizations and Investor "Need" for Losses*

One dimension along which investors differ, and which directly affects the tax cost of realizing gains and the tax benefit of realizing losses on a particular investment, is the amount of gains or losses realized elsewhere in their portfolio. No more than $3,000 in capital losses could have been used to offset other income during the sample period. Losses in excess of this amount must be carried forward to offset future gains or future ordinary income. Poterba (1987) found that relatively few investors faced this limit as a binding constraint in the early 1980s, although more recent work by Alan J. Auerbach et al. (2000) suggests that the number of affected investors has increased since then. For an individual investor who has realized net gains during the year, the incentive to realize losses is greater than that for an investor who has already realized net losses.

There is very little evidence on how gain or loss realizations early in the year affect investor behavior late in the tax year. Grinblatt and Matti Keloharju (2001, 2004) use a unique Finnish dataset on asset sales and investor tax liability to show that end-of-year tax-loss selling depends on whether investors have substantial losses or substantial gains from their trading activity earlier in the year. In the United States, Poterba and

Weisbenner (2001), Grinblatt and Moskowitz (2004), and several other studies find evidence consistent with this pattern, using the year-to-date return on the aggregate stock market as a proxy for the level of realized capital gains earlier in the year. Year-end loss realizations, and the magnitude of the December stock price decline and January price rebound for stocks with accrued losses, are positively related to the year-to-date market return.

The dataset we analyze permits a more direct test of how end-of-year loss trading responds to an investor's year-to-date portfolio realizations. We can evaluate the net gain or loss realizations in the investor's taxable account at this brokerage firm in the first 11 months of the year and then assess whether these realized gains or losses predict December realizations. This measure of gains and losses is imperfect because we are aware only of the investor's trades executed at the brokerage firm that provided the data and, moreover, we do not know the purchase price of stock positions that were purchased prior to the start of the sample in January 1991. Thus, we focus on the December trading activity of investors for whom we know the basis of stocks sold in the prior 11 months and hence can calculate the total realized capital gain or loss. Investors who expect to realize a large loss late in the year may realize gains earlier in the year, which makes the gains-in-year-to-date variable potentially endogenous. Because this is an imperfect measure, we also consider the variable used in earlier studies, the stock market return in the first 11 months of the year. This offers another, albeit also imperfect, measure of the investor's year-to-date gain realizations.

Table 7 reports our findings for the probability of selling stocks at year-end. The basic specification augments (6) to include two measures of "loss demand." The regressions in the left panel include net capital gains or losses realized in the tax year through the end of November. We interact this variable with an indicator variable for whether the stock has accrued gains or losses since the date of purchase. The regressions in the right panel include the year-to-date stock market return, again interacted with whether the stock price has gone up or down since purchase. The results offer mixed support for the importance of "loss demand" as a predictor of trading decisions. In taxable accounts, investors who have realized more gains to date

are more likely to sell stocks, but there are no statistically significant differences between stocks that have appreciated and those that have depreciated. This may reflect investor heterogeneity, because investors who are more likely to realize gains in previous months may also be more likely to realize gains in December.

In light of this potential concern, as well as the measurement error induced by not observing the investor's total portfolio, in the right-hand panel we, instead, focus on the overall market return as our proxy for "loss demand." In taxable accounts, the likelihood of selling a stock that has declined since purchase rises if the market return has been favorable during the first 11 months of the year. For example, a 25-percent market return is associated with a 16-percent-higher likelihood of a stock with a loss being realized in December: $e^{0.61*(0.25)} - 1 = 0.16$. On the other hand, there is a reduction in the chance of selling appreciated shares in years with strong market returns in the first 11 months, consistent with the notion that investors will have fewer tax incentives to realize gains if they cannot be shielded with losses elsewhere in the portfolio. There are no such effects in tax-deferred accounts, which is consistent with the view that investors consider their developing tax position in determining whether to realize gains and losses at the end of the year in their taxable account.

III. Evidence on Wash Sales and Restarting Tax Options

Our analysis so far has followed most of the literature on capital gains taxation in treating the time period over which the tax burden is measured as beginning with an asset's purchase, and ending with its sale. Yet optimal tax-trading strategies, such as those suggested by Constantinides (1984), suggest that a longer time horizon may be appropriate. If investors can sell a stock to realize a tax loss, and then repurchase the stock, and if transaction costs are low enough, they may choose to realize losses even when they are optimistic about the future returns on a security.

To prevent wholesale recognition of tax losses in this fashion, regulations known as "wash-sale rules" apply to loss realizations. The U.S. Treasury Department (2003) explains that capital losses associated with security sales can

TABLE 7—COX PROPORTIONAL HAZARDS MODEL OF STOCK SALES IN DECEMBER AS A FUNCTION OF PRIOR STOCK PERFORMANCE INTERACTED WITH HOUSEHOLD'S YEAR-TO-DATE CAPITAL GAIN/LOSS REALIZATIONS AND YEAR-TO-DATE MARKET PERFORMANCE, PURCHASES $\geq$ $10,000

		All accounts			All accounts	
	Taxable accts.	Tax-deferred	Interaction w/taxable	Taxable accts.	Tax-deferred	Interaction w/taxable
GAIN	−0.02	0.13	−0.15	−0.21	0.15*	−0.36**
	(0.14)	(0.09)	(0.17)	(0.14)	(0.08)	(0.16)
GAIN * (Month ≤ 6)	0.82*	1.52***	−0.70	1.07***	0.92***	0.15
	(0.46)	(0.30)	(0.55)	(0.21)	(0.17)	(0.27)
GAIN * (Month 7–12)	0.47**	0.30	0.17	0.17	0.49**	−0.32
	(0.21)	(0.35)	(0.41)	(0.22)	(0.23)	(0.32)
LOSS	−1.81***	0.07	−1.88***	−1.57***	0.06	−1.63***
	(0.26)	(0.42)	(0.50)	(0.18)	(0.34)	(0.39)
LOSS * (Month ≤ 6)	0.04	1.44*	−1.40	1.01***	2.36***	−1.35*
	(0.58)	(0.83)	(1.01)	(0.29)	(0.64)	(0.71)
LOSS * (Month 7–12)	0.10	1.20	−1.11	−0.09	1.41**	−1.50**
	(0.48)	(0.96)	(1.07)	(0.26)	(0.71)	(0.76)
Realized Gains * STOCK_UP	0.012**	−0.002	0.013			
	(0.005)	(0.020)	(0.020)			
Realized Gains * STOCK_DOWN	0.014***	−0.006	0.020			
	(0.004)	(0.028)	(0.028)			
MKT_RET * STOCK_UP				−0.69***	−0.46*	−0.23
				(0.21)	(0.27)	(0.34)
MKT_RET * STOCK_DN				0.61***	−0.16	0.77*
				(0.18)	(0.28)	(0.33)

Notes: GAIN = max(percentage price change, 0) and LOSS = min(percentage price change, 0). STOCK_UP and STOCK_DOWN are indicator variables for whether the stock price rose or fell from its purchase date through the end of November of the calendar year. *Realized gains* = net capital gain/loss realized via sales of stock in a taxable account from the start of the calendar year through the end of November, measured in thousands of dollars. MKT RET = value-weighted CRSP capital appreciation return from the start of the calendar year through the end of November. The Cox model employs a nonparametric estimate of the baseline hazard. Standard errors, which are shown in parentheses, allow for heteroskedasticity as well as correlation across observations of the same stock transaction over time. P-values for the test of the null hypothesis that *Realized Gains* * STOCK_UP and *Realized Gains* * STOCK_DOWN have the same coefficients are 0.66, 0.85, and 0.91 for columns one through three, respectively, and the p-values for the test of the null hypothesis that MKT_RET * STOCK_UP and MKT_RET * STOCK_DOWN have the same coefficients are 0.00, 0.41, and 0.02 for columns four through six, respectively. ***, **, * denote significance at the 1-percent, 5-percent, and 10-percent level, respectively.

be claimed for tax purposes only if the investor avoids repurchasing the same security within 30 days of the sale. There has been very little research on whether investors repurchase securities that they sell to claim losses or for other reasons, largely because of the limited number of datasets that provide longitudinal data on investor behavior. One notable exception is Grinblatt and Keloharju's (2004) analysis of investors in Finland, where there are no wash-sale restrictions and where investors who sell stocks at a loss in December are more likely to repurchase the stock immediately than are investors who realize losses in other months.

Table 8 presents information on the repurchase decisions of investors who sell stocks. It distinguishes sales with a gain from those with a loss, and considers the differences between sales in December and those in all other months. The first column focuses on sales with realized losses. For sales in taxable accounts in December, there is a 4.5-percent chance that the investor will repurchase the security in the taxable account within 30 days of the sale, thereby voiding the tax benefits associated with loss realization. The analogous probability for sales that occur in months other than December is 8.5 percent, with the differential probability of −4.0 percentage points being highly significant. This evidence suggests that tax considerations affect December loss realizations more than they affect loss realizations in other months.

The second column of Table 8 presents information on the probability of repurchasing the stock after realizing a gain, which is greater than the probability of repurchasing following a

TABLE 8—PROPENSITY TO REPURCHASE SAME STOCK IN TAXABLE ACCOUNT WITHIN ONE AND TWO MONTHS SINCE SALE IN TAXABLE ACCOUNTS, PURCHASES $\geq$ $10,000

Propensity to repurchase stock during first month since sale			Propensity to repurchase stock during second month since sale		
Sale with realized loss	Sale with realized gain	Difference	Sale with realized loss	Sale with realized gain	Difference
Sales in December			*Sales in December*		
4.5***	10.4***	−5.9***	4.0***	6.7***	−2.8***
(0.6)	(0.9)	(1.0)	(0.5)	(0.7)	(0.8)
Sales in non-December months			*Sales in non-December months*		
8.5***	12.1***	−3.6***	4.9***	7.0***	−2.2***
(0.4)	(0.5)	(0.4)	(0.3)	(0.3)	(0.3)
Difference (December − all other months)			*Difference (December − all other months)*		
−4.0***	−1.7*	−2.3**	−0.9	−0.3	−0.6
(0.6)	(0.9)	(1.0)	(0.5)	(0.7)	(0.9)

Notes: Sample consists of sales of stock from January 1991 to October 1996, originally purchased for at least $10,000. ***, **, * denote significance at the 1-percent, 5-percent, and 10-percent level, respectively.

tax-loss sale. For December sales in taxable accounts, there is a 10.4-percent chance that the gain-producing stock is repurchased in a taxable account within a month. The third column summarizes the difference between the probabilities of repurchasing a stock when the sale generated a loss and when it generated a gain. For sales in taxable accounts, the difference in the probability of repurchasing a share in a taxable account within 30 days when that share has been sold for a loss and when the share has been sold for a gain is −5.9 percentage points when the sale occurs in December and is −3.6 percentage points for sales in non-December months. The difference-in-differences, −2.3 percentage points, is statistically significantly different from zero.

The right panel of Table 8 presents estimates of the probability a stock that has been sold is repurchased in the second month following the sale. Unlike the repurchase activity in the first month after the sale, which is subject to wash-sale rules and is significantly lower for losses realized in December relative to other months, there is no differential in repurchase rates during the second month after sale (as might be expected if the wash-sale rules deterred repurchase in the first month).

We also examine, but do not report, the probability of purchasing a stock in a tax-deferred account after the stock has been sold in a taxable account, as well as the probability of purchasing in a tax-deferred account following a sale in that account. There is some ambiguity surrounding whether a purchase in a tax-

deferred account, following a sale in a taxable account, would trigger the wash-sale limitations. Because wash-sale rules do not apply to sales and repurchases in tax-deferred accounts, however, trading in these accounts alone may provide a baseline against which to judge the behavior in taxable accounts. For December loss realizations in a tax-deferred account, there is a 5.7-percent probability of repurchase within 30 days in the same account, compared with a 4.5 percent probability of repurchase for sales in a taxable account. There is a 0.9 percent chance of purchasing stock in a tax-deferred account within 30 days of selling it at a loss in a taxable account. The results suggest that offsetting transactions in taxable and tax-deferred accounts are rare.

These results suggest that trading to generate losses, and then repurchasing shares, is of limited importance in the dataset we analyze. While investors are less likely to repurchase a stock that they sell at a loss than they are to repurchase a stock that they sell for a gain, the baseline probability of repurchasing a stock that was sold at a loss, within two months, is less than 10 percent. This is consistent with the findings of Seyhun and Skinner's (1994) analysis of panel data on tax returns.

IV. Holding Periods and Effective Capital Gains Tax Burdens

One of the central goals of studies of capital gains taxation is to develop effective tax burden
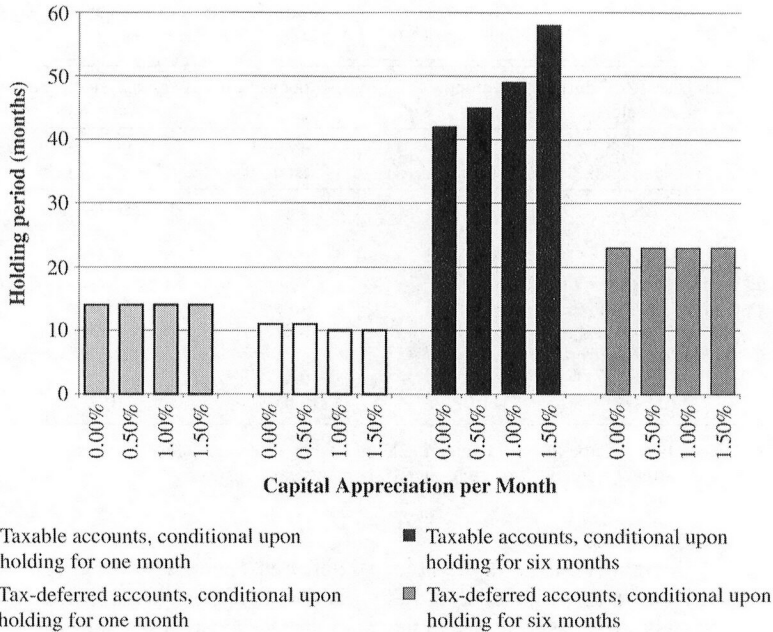
FIGURE 4. MEDIAN HOLDING PERIOD BY CAPITAL APPRECIATION OF STOCK

Notes: Estimates of median holding periods for stocks with hypothetical performance are provided by a proportional hazards Cox model based on a sample of purchases of stocks in taxable and tax-deferred accounts of at least $10,000 from 1991 to 1996. The model predicts the likelihood of sale given a stock's capital appreciation since purchase, allowing for a differential relation between sale and past performance by holding period.

measures. Such measures can be used to study the impact of the tax on investor behavior, and hence economic efficiency, and to evaluate the contribution of the capital gains tax to the tax burden on various types of capital income. Martin Feldstein and Lawrence Summers' (1979) analysis of the total tax burden on corporate capital income, for example, assumes an effective capital gains tax rate of 0.25 times the statutory rate. This assumption was justified by reference to Bailey (1969), who computed the effects of deferral and basis-step-up at death in reducing the effective tax rate relative to the statutory rate. Our estimates of holding period-specific asset sale probabilities can provide a much more refined estimate of the effective capital gains tax rate than earlier studies that assumed a constant rate of asset sales.

Figure 4 plots information on predicted median holding periods for stocks with different prospective rates of capital appreciation, and different current holding periods, in both taxable and tax-deferred accounts. The figure has four sets of four bars. The first four bars indicate the median holding periods for a stock that has already been held for one month in a taxable account, and that will experience monthly appreciation at a rate of 0, 0.5, 1.0, or 1.5 percent forever. Since we can begin to relate the likelihood of sale to accrued gains or losses only in the second month following purchase, we condition on the holding period of one month. Holding periods are calculated from our hazard model estimates.

The figure shows that the median holding period is insensitive to the assumed rate of capital appreciation for stocks that have been held for only one month, whether they are in a taxable or a tax-deferred account. The limited effect of the rate of capital appreciation is due to the high turnover rate in the few months immediately after a stock is purchased, regardless of whether the stock is held in a taxable or a tax-deferred account. The median holding period in a tax-deferred account is 10 or 11 months, compared with about 14 months in a taxable account.

The third and fourth sets of bars in Figure 4 correspond to stocks held for at least six

TABLE 9—EFFECTIVE CAPITAL GAINS TAX RATE FOR STOCK PURCHASES ≥ $10,000, VARIOUS HOLDING PERIOD
ASSUMPTIONS, BY CAPITAL APPRECIATION RATE OF STOCK

	Average effective capital gains tax rate (in percentage points)						
	Equally weighted across transactions			Weighted across transactions by capital gain ($)			
	Average tax rate assuming stock not sold after 5 years is sold & gain is taxed in year 5	Average tax rate assuming stock not sold after 5 years is sold in 20 years & gain is taxed in year 20	Average tax rate assuming stock not sold after 5 years is held until death (basis step-up)	Average tax rate assuming stock not sold after 5 years is sold & gain is taxed in year 5	Average tax rate assuming stock not sold after 5 years is sold in 20 years & gain is taxed in year 20	Average tax rate assuming stock not sold after 5 years is held until death (basis step-up)	
Assumed monthly return						Death 5 years after purchase	Death 20 years after purchase
0.5% per month	32	30	24	26	19	7	1.4
1.0% per month	31	28	24	24	13	6	0.6
1.5% per month	30	26	23	22	9	5	0.3

Notes: Estimates provided by the proportional hazards Cox model conditional on having held the stock for at least one month. The short-term capital gains tax rate (applied to stocks held 12 months or less) is assumed to be 40 percent and the long-term capital gains tax rate (applied to stocks held more than 12 months) is assumed to be 28 percent. The Cox model estimates are based on a sample of purchases of stocks in taxable accounts of at least $10,000 from 1991 to 1996. The model predicts the likelihood of sale given a stock's capital appreciation since purchase, allowing for a differential relation between sale and past performance by holding period.

months. They illustrate the lock-in effect. For a taxable account, the median holding period rises sharply with the assumed rate of appreciation. As this rises, the probability of sale declines. For example, for a stock that does not appreciate, the median holding period in a taxable account, conditional on being held for at least six months, is 42 months. This rises to 58 months if the appreciation rate is 1.5 percent per month. The pattern for a tax-deferred account is quite different, with very little effect of the rate of capital appreciation on the median holding period. These findings illustrate the substantive impact of our estimates of how unrealized capital gains on a stock affect the probability of sale.

The hazard functions estimated above can be used to compute the marginal effective tax rate (δ) suggested by Protopapadakis (1983). This is defined under the assumption that a stock yields certain gains that accrue at rate g and that the statutory tax rate on realized gains is τ_{cg}:

$$(7) \qquad e^{(1-\delta)gT} = e^{gT} - \tau_{cg} * (e^{gT} - 1).$$

In this expression, T is the holding period at which the stock is sold. This expression assumes that all gains are real. It does not consider the tax burden on inflation-induced asset price increases, which raise the total tax burden on accruing real capital gains. We calculate a weighted average marginal effective tax rate (METR) by evaluating this tax rate (δ) for each

holding period, and then using the distribution of holding periods generated by our hazard model to weight the different δ values. This tax rate measure should be distinguished from alternative measures of marginal capital gains tax rates, such as Yves Balcer and Kenneth L. Judd's (1987) measure of the tax burden associated with holding the asset for one more year.

Table 9 presents estimates of the effective accrual tax rate under the assumption that short-term capital gains are taxed at 40 percent and that long-term gains are taxed at 28 percent. These are approximately the tax parameters that prevailed during the second half of the sample period we analyze. The table presents two sets of findings, one weighting all transactions equally in computing the average marginal effective tax rate, and the other weighting each transaction by the size of the gain when sold. There are pronounced differences between the two calculations because most trades, which occur at short holding periods, involve relatively small gains, while the few trades at long holding periods involve large accrued gains.

The results show that, because most transactions involve the realization of short-term gains, the high turnover rate on newly purchased stock results in a high average METR when we weight all transactions equally. For a stock that has been held at least one month and that grows at the rate of 1.0 percent per month, the effective accrual tax rate, assuming that the stock

will be sold 60 months after it is purchased, if it has not been sold before that, is 31 percent. When we assume that stocks that have not been sold by five years from the date of purchase will never be sold, so that the gains will be eligible for basis step-up, the effective accrual tax rate falls to 24 percent. High turnover rates at short horizons imply a relatively low probability that the gain on any *transaction* will be held long enough to benefit substantially from the combined effects of tax deferral and basis step-up at death.

The last four columns in Table 9 present parallel calculations of effective capital gains tax rates, but transactions are now weighted by the size of the gain at the time of realization. Because we assume a constant monthly rate of appreciation, the absolute gain on a stock with a long holding period is much greater than that on a stock held for a short holding period, so a much higher share of gains than of transactions face the long-term capital gains tax rate. The weighted average METR, when we assume that any stock not sold within the first five years of purchase is sold at the five-year anniversary, assuming a 1.0 percent monthly appreciation rate, is 24 percent. If we assume that stocks not sold in the first five years are sold after 20 years, this value drops to 13 percent, less than half of the statutory long-term capital gains tax rate.

The weighted average METR is *much* lower when we assume that such gains are never realized and therefore qualify for basis step-up. For example, assuming the individual dies five years after purchase of the stock, and that basis step-up occurs at that point, the weighted average METR falls to 6 percent. It falls to below 1 percent if stocks not sold within five years are held until the investor's death, and if that death occurs 20 years after the stock was purchased. The explanation for such a low METR is that, with an assumed rate of appreciation such as 0.01 per month, a very high fraction of total realized gains accrues to assets that are held for 20 years and therefore qualify for basis step-up. With a 1-percent monthly appreciation rate, a stock with a purchase basis of one is worth 1.82 after five years and 10.89 after 20 years. The capital gain of 9.89 on the 20-year holding period is more than 12 times the gain of 0.82 when the stock is held for five years. Our hazard model estimates imply that roughly two-thirds of all stock purchases result in sales within the

first five years, and most sales occur within the first year. If, for illustrative purposes, we assume that two-thirds of all stock purchases result in a sale after one year, while one-third are held for 20 years, the share of gains accounted for by the 20-year holdings will be $0.975 = 9.89 * 0.33/(0.127 * 0.67 + 9.89 * 0.33)$. When we assume that all gains held for 20 years qualify for basis step-up, the gain-weighted METR is therefore a small fraction of the statutory rate.

The effective capital gains tax burdens reported in Table 9 are based on more precise information about the holding period distribution than previous analyses. They demonstrate that the gain-weighted average marginal effective tax rate on accruing capital gains may be much lower than the statutory long-term tax rate, even with a substantial amount of high-frequency trading, because a high fraction of aggregate realized gains are attributable to stocks that have been held for very long holding periods. The reduction in tax burden associated with deferral thus outweighs the substantial probability of short-term realizations in determining the effective tax burden.

V. Conclusion

This paper studies investors' capital gain and loss realization decisions in taxable and tax-deferred accounts. This comparison provides a means to identify the magnitude of tax-motivated trading. We find evidence of capital gains lock-in behavior in taxable accounts. This effect is more pronounced for larger stock purchases and is stronger for stocks that have been held for a long time. Investors are more likely to realize losses in taxable accounts than in tax-deferred accounts, not just in December, but throughout the calendar year. We estimate hazard functions that allow for realization rates to vary with a stock's holding period, and thereby disentangle the effect of holding period, calendar month, and accrued gain or loss on the probability that an investor sells a stock.

Our findings on the path-dependence of stock sale probabilities underscore the need to move beyond simple models in which the asset sale probability is a constant and to consider more realistic models. Economic analysis of the burden of the capital gains tax could be enriched by considering a wide range of potential stock

price paths, and determining the total tax burden associated with each. The challenge will be finding summary statistics for price histories that offer useful insights about capital gain realizations, but that nevertheless impose some structure on the price path.

Our analysis proceeds as though all investors are equally tax-sensitive, even though some investors are probability more tax-sensitive than others. It is not clear how to evaluate the fraction of investors in each category. In the dataset we analyze, 21 percent of all stock purchases of $10,000 or more resulted in a realized loss within one year, and 38 percent resulted in a realized gain within a year. Of the remaining stock purchases, 45 percent, or 18 percent of all purchases, had unrealized losses at the end of one year. Thus nearly one-half of the stock purchases that could have been used to generate a short-term loss were not liquidated in time to generate this loss. We cannot conclude with certainty that investors who did not realize short-term losses were foregoing substantial tax benefits because they might have been unable to use the tax losses to reduce their tax liability. Nevertheless, we suspect that many of these investors could have reduced their tax liability. Measuring the cost to investors of such tax-inefficient behavior is an avenue for future research.

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