

Tracking the U.S. Treasury: *Footprints from the Treasury's Debt Buy-Back Program*

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At the turn of the millennium, with its coffers flush from unexpectedly high tax receipts, the U.S. Treasury embarked upon a debt buy-back program, something not seen since 1930.¹ The buy-back program was a final response to operational debt management challenges arising from the sudden U.S. federal budget shift from persistent deficits to large surpluses in the late 1990s. True, the U.S. budget has subsequently returned to a position of large annual deficits; but at the time the large surpluses posed important challenges in a number of practical and conceptual dimensions for Treasury managers, bond market practitioners, and academics. To deal with the then-perceived stream of widening future surpluses, the Treasury reintroduced marketable Treasury security redemption operations.

This article analyzes the conduct and pricing impacts of the \$67.5 billion debt buy-back program that began in March 2000 and ended in April 2002. The buy-backs worked as reverse auctions. First, the Treasury announced a target par value debt repurchase of outstanding Treasury issues within a specific maturity range. Next, the designated primary dealers made competitive offerings of these securities according to specific procedures. Finally, the Treasury purchased specific amounts of these individual securities from particular dealers through operations managed by the Federal Reserve Bank of New York.² The first question is how well the Treas-

ury did versus its self-espoused goals of minimizing taxpayer financing costs while promoting efficient capital markets?³ Regarding security selection decisions, give the Treasury solid marks. It made no egregious errors (it avoided buying back the priciest issues) but could have done some additional fine-tuning (under one standard of value, it repurchased moderately rich issues as well as cheap ones). The second question is how well the Treasury conducted its business? Here, the good news is that its well-designed reverse auction procedures did not upset the markets for the bonds it actually touched. But the bad news is that the buy-backs produced unintended and unwanted reverberations in related markets (those for the single-payment Treasury STRIPS securities). Interestingly, adoption of Bennett, Garbade, and Kambhu's [2000] proposals for reforms of STRIPS market practices would have ameliorated exactly this type of disruption.

The remainder of this article is organized as follows. The next section describes the program's rules and procedures and summarizes the debt buy-back results. Then, the Treasury's issue acceptance decisions are analyzed, tests of program impacts on bond pricing are presented, and more direct program impacts on the STRIPS market are examined.

EXHIBIT 1

Results from the U.S. Treasury's First Debt Buy-Back Operation Held March 9, 2000

Eligible Issues		Pre-Auction Par Amounts			Auction Amounts		Accepted Auction Prices			Accepted Yields %		
Coupon Rate (%)	Maturity Date	Total Outstanding	Privately Held	In Stripped Form	Offered	Accepted	Highest	Average	Tail	Lowest	Average	Tail
11.250	02/15/15	12,668	11,012	4,962	772	160	144.796	144.779	0.017	6.511	6.513	-0.002
10.625	08/15/15	7,150	5,983	1,768	1,272	352	139.796	139.739	0.057	6.500	6.504	-0.004
9.875	11/15/15	6,900	5,958	3,427	559	125	132.906	132.893	0.013	6.496	6.497	-0.001
9.250	02/15/16	7,267	6,230	843	422	93	127.187	127.153	0.034	6.486	6.489	-0.003
7.250	05/15/16	18,824	17,726	161	549	0	N/A	N/A	N/A	N/A	N/A	N/A
7.500	11/15/16	18,864	17,486	1,005	509	0	N/A	N/A	N/A	N/A	N/A	N/A
8.750	05/15/17	18,194	15,677	7,592	670	148	123.515	123.501	0.014	6.462	6.463	-0.001
8.875	08/15/17	14,017	12,063	3,070	460	53	125.062	125.062	0.000	6.457	6.457	0.000
9.125	05/15/18	8,709	7,478	5,736	307	20	128.359	128.347	0.012	6.451	6.452	-0.001
9.000	11/15/18	9,033	8,494	5,488	660	25	127.500	127.500	0.000	6.445	6.445	0.000
8.875	02/15/19	19,251	17,566	7,576	794	25	126.398	126.398	0.000	6.441	6.441	0.000
8.125	08/15/19	20,214	18,373	733	868	0	N/A	N/A	N/A	N/A	N/A	N/A
8.500	02/15/20	10,229	8,868	2,011	785	0	N/A	N/A	N/A	N/A	N/A	N/A
	Totals	171,320	152,914	44,372	8,627	1,000		Average:	0.016		Average:	-0.001

Notes: Bond amounts in \$millions of par value as of March 3, 2000. All reported "Averages" are weighted averages using accepted par value weights.

U.S. TREASURY DEBT BUY-BACK PROGRAM RULES, PROCEDURES, AND RESULTS

Treasury security redemption operations began on March 9, 2000, and worked via reverse auctions. In May 2000, the Treasury began a regular schedule of two buy-backs per month in the third and fourth weeks of the month on one day's notice. However, plans to cut back reverse auction frequency were announced on October 31, 2001, after reversals in revenue and expenditure trends turned previous forecasts of future fiscal surpluses into forecasts of significant persistent deficits. The last operation took place on April 25, 2002. Thirty-six of the 45 operations involved 32 different eligible non-callable issues that accounted for \$58.5 billion in par value retired. The remaining 9 operations involved an identical set of 10 callable issues and accounted for \$8.75 billion in par value retired. TIPS issues were made eligible once and accounted for \$0.25 billion of the total program par value retired.

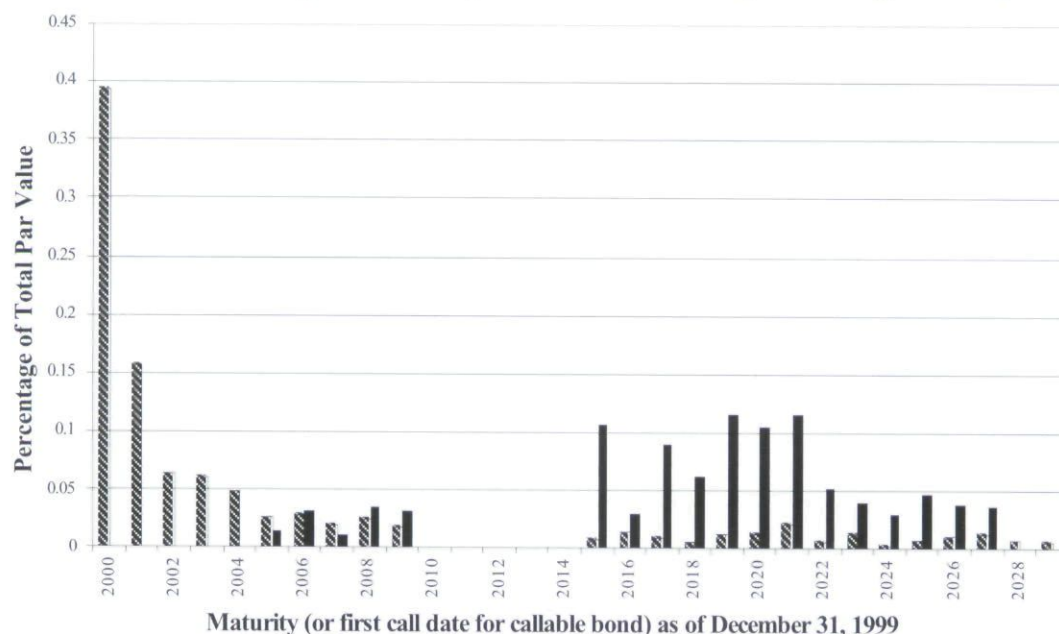
The specific rules and procedures for the buy-backs appear in the Federal Register ([2000], 31 Code of Federal Regulations Part 375). The Treasury listed four reasons supporting the program. Buy-backs would 1) enhance market liquidity by allowing continued regular issuance of new benchmark securities; 2) permit the Treasury to control the maturity structure of its outstanding debt; 3) provide additional cash management flexibility; and 4) permit reductions in the government's interest expense by replacing "off-the-run" debt with lower-yielding "on-the-run" debt (31 CFR Part 375).⁴ Thus, the projected

impacts of the buy-back program seemed to be consistent with the Treasury's stated goals for debt management. Public comment letters on an early version of the buy-back operation's rules drew attention to possible deleterious effects on the liquidity of redeemed issues.⁵ However, the Treasury's final rule did not focus on limiting such liquidity impacts and stated only that "[the Treasury] will determine the amount of any particular security to redeem during the redemption operation consistent with our debt management goals" (31 CFR Part 375).

On the announcement date, the Treasury scheduled the operation's trade date, the target total par redemption value, and the maturity range defining the set of eligible issues. The reverse auctions employed a multiple-price format under which dealers offered varying sizes of the specific eligible issues at specific prices. The same dealer might offer alternative quantities of the same issue at different prices. Only primary dealers could participate directly and only competitive offers could be applied. The Federal Reserve Bank of New York acted as the Treasury's agent. Exhibit 1 details the results for the buy-back program's initial March 9, 2000, operation. Primary dealers could submit offers of any of a set of 13 non-callable bonds maturing between February 15, 2015, and February 15, 2020, inclusive. For this auction, Exhibit 1 presents 1) a listing of the eligible issues; 2) 3 measures of issue size for these eligible issues (as reported the official reverse auction announcement): total par amount outstanding, total par amount held by the public, and the par amount of each eligible issue held in stripped form; 3)

EXHIBIT 2

Maturity Distribution: Outstanding U.S. Treasury Debt versus Total Buy-Back Program Acceptances



the par amounts of each eligible issue offered through primary dealers to the Treasury and the par amounts accepted by the Treasury; 4) the highest price paid by the Treasury on each accepted issue, the weighted average price paid, and the “tail” (defined as the difference between the high and the average prices); and 5) corresponding pricing results described in yield form. Dealers actually offered varying amounts of the 13 eligible issues totaling \$8.6 billion. The Treasury chose to purchase its entire targeted \$1 billion size using a combination of 9 of these 13 issues.

Exhibit 2 compares the maturity distribution of the Treasury’s buy-back program purchases with the initial distribution of outstanding Treasury debt. The lighter bars of Exhibit 2 summarize the percentage distribution of the total outstanding par value of non-indexed U.S. Treasury bill, note, and bond debt as of December 31, 1999 (viewed against the final calendar year maturities of the individual issues). The par value-weighted average maturity of these outstanding issues on December 31, 1999, was 5.9 years. However, Exhibit 2 reveals that Treasury debt maturities were not evenly distributed across the 30-year issuance horizon. Instead, maturities were skewed toward the short end of the spectrum. More than 55% of the debt would mature within 2 years (December 31, 2001) and approximately 75% of the debt would mature within 5 years.⁶ The darker bars of Exhibit 2 pre-

sent the corresponding maturity year distribution for buy-back operation acceptance shares, formed by aggregating the individual issue program acceptance shares by calendar year maturity. Compare these two distributions. Clearly, the Treasury’s debt repurchases under the buy-back program were strongly skewed toward one particular segment of its outstanding debt maturity structure.

BUY-BACK OPERATION ISSUE ACCEPTANCE DECISIONS AND DIRECT PRICING IMPACTS

The Treasury’s final rule on the buy-back operations *did not* specifically address eligibility criteria for each reverse auction or limits on the amount of any issue that might be repurchased under the program. Certain public statements suggest that the Treasury planned to use the buy-back program to help manage the average maturity of the public debt.⁷ However, buy-backs focused in the 15-25-year maturity sector were but one possible way to avoid a lengthening of the debt’s average maturity. For example, buy-back choices combining repurchases of 5-10-year maturity issues and 25-30-year maturity issues would also have worked.⁸ Nevertheless, here the initial eligibility decisions are taken as *given* in view of the *security selection* focus of this study.

EXHIBIT 3

Characteristics of Issues Accepted by the U.S. Treasury During the Debt Buy-Back Program

Coupon	Maturity	Pre-program amounts (2/29/2000)			Program totals by issue				Issue pricing data	
		Total Par Amount Outstanding	Held in Stripped Form	% Held Stripped	Number of times eligible	Par Amount Accepted	% of total accepted in program	% of noncallable issues	Market Price ^a	Average Richness ^b
8.875	02/15/19	17,611	7,562	39%	22	6,160	9.1%	10.5%	121.672	0.074
8.750	08/15/20	21,419	12,302	57%	15	4,359	6.5%	7.5%	121.109	0.038
7.625	11/15/22	10,700	6,886	64%	16	3,276	4.9%	5.6%	109.703	0.051
10.625	08/15/15	7,150	1,802	25%	12	3,126	4.6%	5.3%	136.063	0.059
8.875	08/15/17	14,017	3,070	22%	13	3,049	4.5%	5.2%	120.797	0.128
8.125	08/15/21	12,163	2,305	19%	14	2,657	3.9%	4.5%	114.672	0.028
8.750	05/15/17	18,194	7,592	42%	13	2,635	3.9%	4.5%	119.391	0.119
7.125	02/15/23	18,374	7,486	41%	17	2,592	3.8%	4.4%	104.141	0.095
8.750	05/15/20	10,159	6,710	66%	15	2,577	3.8%	4.4%	121.000	0.025
7.625	02/15/25	11,725	8,714	74%	11	2,216	3.3%	3.8%	110.766	0.055
8.000	11/15/21	32,798	19,085	58%	15	2,166	3.2%	3.7%	113.453	0.014
11.250	02/15/15	12,668	4,965	39%	12	2,147	3.2%	3.7%	141.281	0.044
6.750	08/15/26	10,894	2,668	24%	9	2,083	3.1%	3.6%	100.438	0.106
9.125	05/15/18	8,709	5,752	66%	14	1,991	2.9%	3.4%	123.891	0.071
8.125	05/15/21	11,959	4,983	42%	15	1,892	2.8%	3.2%	114.594	0.011
7.500	11/15/24	11,470	8,028	70%	11	1,866	2.8%	3.2%	109.109	0.041
9.000	11/15/18	9,033	5,549	61%	14	1,859	2.8%	3.2%	122.859	0.054
9.250	02/15/16	7,267	850	12%	12	1,835	2.7%	3.1%	123.484	0.116
6.375	08/15/27	10,736	1,379	13%	8	1,539	2.3%	2.6%	96.031	0.091
6.875	08/15/25	12,602	5,311	42%	11	1,415	2.1%	2.4%	101.766	0.044
9.875	11/15/15	6,900	3,454	50%	12	1,315	1.9%	2.2%	129.250	0.044
8.125	08/15/19	20,214	720	4%	22	1,273	1.9%	2.2%	113.938	0.091
7.875	02/15/21	11,113	1,099	10%	16	1,038	1.5%	1.8%	111.766	0.064
6.625	02/15/27	10,456	4,523	43%	8	934	1.4%	1.6%	99.063	0.135
8.500	02/15/20	10,229	2,025	20%	16	753	1.1%	1.3%	118.156	0.062
6.500	11/15/26	11,493	3,012	26%	9	633	0.9%	1.1%	97.469	0.088
6.125	11/15/27	22,519	5,344	24%	7	497	0.7%	0.8%	93.047	0.153
6.250	08/15/23	22,909	5,046	22%	14	250	0.4%	0.4%	94.328	0.232
7.250	08/15/22	10,353	1,282	12%	14	225	0.3%	0.4%	105.406	0.148
7.500	11/15/16	18,864	1,035	5%	12	77	0.1%	0.1%	106.938	0.200
6.000	02/15/26	12,905	1,394	11%	9	67	0.1%	0.1%	91.469	0.164
7.250	05/15/16	18,824	178	1%	12	0	0.0%	0.0%	104.500	0.224
Noncallable issue totals						58,500	86.7%	100.0%		

Coupon	First Call - Maturity	Total Par Amount Outstanding	Number of times eligible	Par Amount Accepted	% of total accepted in program	% of callables	Market Price ¹
12.000	08/15/08-13	14,755	9	2,838	4.2%	32.4%	133.547
13.875	05/15/06-11	4,609	9	1,064	1.6%	12.2%	136.688
11.750	11/15/09-14	6,006	9	990	1.5%	11.3%	135.188
10.375	11/15/07-12	11,032	9	905	1.3%	10.3%	121.578
14.000	11/15/06-11	4,901	9	852	1.3%	9.7%	139.516
12.500	08/15/09-14	5,128	9	740	1.1%	8.5%	139.703
12.750	11/15/05-10	4,736	9	655	1.0%	7.5%	128.891
13.250	05/15/09-14	5,007	9	527	0.8%	6.0%	144.109
11.750	02/15/05-10	2,494	9	179	0.3%	2.0%	121.453
10.000	05/15/05-10	2,987	9	0	0.0%	0.0%	114.547
Callable issue totals				8,750	13.0%	100.0%	

^aMarket price as of 12/31/1999.

^bAverage $V^i = P^i - C^i$ over program period.

Did the Treasury Favor Repurchasing Issues with Particular Characteristics?

Exhibit 3 summarizes the Treasury's buy-back program activities by breaking down the total program purchases of all eligible individual non-TIPS issues. This exhibit ranks the issues by their respective amounts purchased by the Treasury under the program. The exhibit reports the coupon rate and maturity date of each eligible bond as well as relevant issue characteristics related to size, STRIPS market significance, and "average richness" of the issue. The average richness is measured by the sample average of the difference between maturity-matched principal and coupon STRIPS prices over the program period (see later).⁹ A casual inspection reveals no detectable pattern relating program shares to either issue maturity dates or amounts outstanding. Among the issues in the top program share quartile, maturities range from August 2015 to February 2023. Similarly, the maturities in the bottom program share quartile range from May 2016 to November 2027. Thus, issue-specific program shares showed large variability not easily explained by the maturity structure. Furthermore, one might have expected the Treasury to repurchase more of the largest issues. However, the aggregated program data reveal no simple relation between, say, the amounts outstanding and ultimate individual issue program shares. For example, while the two most heavily repurchased issues are large, the issue with the fourth largest program share, the 10.625% 2015, is the second smallest of all 32 non-callables. In addition, the very large "double-issue" (i.e., reopened) 6.125% 2027 and 6.25% 2023 were virtually ignored by the Treasury (less than 1% program shares). Formal regressions (not reported here) of individual issue aggregate buy-back program shares on either of these maturity or issue size variables yield insignificant slope coefficients.

A Model-Free Measure of Issue-Specific Richness and Cheapness

Exhibit 3 also provides some insight into the impact of relative value on the Treasury's security selection decisions. To generate an issue-specific index of relative value, this article utilizes a direct model-free measure of the Treasury discount function: the prices observed in the Treasury coupon STRIPS securities market. Coupon STRIPS are particularly convenient for this purpose. Under the Treasury's STRIPS program, a market partic-

ipant with an account at the Federal Reserve Bank of New York may designate a qualified coupon-bearing Treasury issue to be held in stripped form.¹⁰ The assigned issue's remaining constituent coupon and principal cash flow payments may then be sold as separate individual single-payment securities. While stripped coupon and principal securities with identical maturities have the same cash flows, they are distinct securities with different CUSIP (Committee on Uniform Securities Identification Procedures) numbers. A significant difference between them concerns their roles in the reconstitution of coupon-bearing bonds. A coupon STRIPS created from stripping one particular Treasury issue can be used to reconstitute a different Treasury issue. Thus, stripped coupons are fungible. In contrast, principal STRIPS are not fungible. A principal STRIPS created through the stripping of one particular Treasury issue may be used only to reconstitute that same issue. Because of this difference, Jordan, Jorgensen, and Kuipers [2000] and Sack [2000] have recently emphasized that Treasury coupon STRIPS embody generic discount function qualities not found in the principal STRIPS. Conveniently, U.S. Treasury coupon STRIPS exist for a full range of final maturities at fixed three-month intervals.

Jordan, Jorgensen, and Kuipers [2000] also argue that the generic versus issue-specific dichotomy between stripped coupon and principal securities has an important pricing implication. They suggest a simple model-free measure of the i -th issue's relative value at time t as the deviation of P_t^i , the Treasury issue's principal STRIPS price, from C_t^i , the corresponding maturity-matched coupon STRIPS price:¹¹

$$V_t^i = P_t^i - C_t^i \quad (1)$$

Here, the issue-specific relative value variable V_t^i measures the issue's "richness" against the generic discount function comprised of coupon STRIPS prices. In turn, V_t^i forms a reasonable relative valuation context for benchmarking Treasury buy-back decisions.¹²

The Treasury Principal and Coupon Strip Price Data

The STRIPS pricing data set consists of Lehman Brothers' end-of-day closing bid-side marks for all mid-quarter maturity Treasury coupon STRIPS and corresponding marks for all principal STRIPS from all bonds ever made eligible for any buy-back operation.¹³ In addi-

tion, the data set also includes closing marks for the principal STRIPS of a few shorter-maturity, non-eligible bonds. Each price is expressed as a percentage of par value (an observed decimal price mark of 34.25 is interpreted as \$34.25 per \$100 of par). These data include 3.5 years of daily marks beginning in January 1999 and ending in June 2002. A “program period” subsample would begin only after the Treasury’s formal announcement of the program on January 13, 2000.¹⁴

Dealer price marks typically reflect reasonable indicative levels of market conditions. This is particularly true when such marks are used to indicate price or yield spreads among issues within a relatively transparent market such as that for U.S. Treasury securities. In this context, the Lehman marks provide a very good estimate of the basic STRIPS-based relative value measure for individual bonds. However, these marks provide no insight into the “depth” of offerings by dealers for specific issues in specific operations. Nevertheless, the Lehman marks should provide a good estimate of the relative terms under which the Treasury could have traded at least *some* amounts of all securities in each auction.

At first glance, the average richness variable appears to have little power to explain the observed Treasury repurchase behavior summarized in Exhibit 3. For example, the 8.875% 2019 was allocated the largest total program share (10.5% of all non-callable bond repurchases) yet is only a mid-ranked bond by the benchmark average richness measure (at +0.074, this is 17th cheapest of the 32 non-callable bonds). In contrast, the 8.125% 2021, the cheapest issue by the STRIPS-based measure (average richness value of +0.011) was allocated a mid-level 3.2% share of non-callables. Other bonds that were moderately rich such as the 8.875% 2017 (+0.128) and the 8.75% 2017 (+0.119) also were allocated higher than median program shares. However, a closer examination of program share totals versus the issue-specific average relative value measure (program period sample averages of $V_t = P_t - C_t$, as reported in the final column) reveals a special type of inverse relation.

In particular, focus on Exhibit 3’s bottom program share quartile of bonds. These 8 bonds have an average program sample period richness of +0.16 (0.16% of par value), but account for a mere 4.3% of the non-callable buy-back totals. The first, second, and third bond issue quartiles have average program sample period richness of +0.07, +0.05, and +0.08, while accounting for 47.6%, 29.0%, and 19.2% of buy-backs, respectively. The standard deviation of issue-specific richness across

these 32 issues is 0.06. Thus, as a group, this bottom program share quartile is more than “2 standard deviations rich” versus the generic (coupon STRIPS) discount function. On an individual issue basis, the “2 standard deviations rich” designation would apply to the 6 richest issues: the 6.25% 2023 (+0.232); the 7.25% 2016 (+0.224); the 7.50% 2016 (+0.200); the 6.00% 2026 (+0.164); the 6.125% 2027 (+0.153); and the 7.25% 2022 (+0.148).¹⁵ Each of these 6 issues had a non-callables program share of 0.8% or less, well below the median individual issue program share of 3.2%. In contrast, only 2 of the issues (the 8.125% 2021 and the 8.75% 2020) with the 8 highest acceptance shares were ranked among the 6 cheapest issues (i.e., among the 6 lowest in-sample average richness values in Exhibit 3).

Another Treasury issue-preference pattern emerges here: issues that are not heavily stripped are underrepresented. The 8 bonds comprising the bottom program quartile have an average initial issue strip percentage of 15%. The first, second, and third bond issue quartiles have average initial issue strip percentages of 39%, 55%, and 29% of par value. Thus, as a group, the bottom program issue quartile is “not heavily stripped.” Moreover, only 1 eligible issue was never repurchased in any amount: the 7.25% 2016. This issue was also the least-stripped (a mere 1%) of the 32 non-callable bonds that were made eligible under the program.

Other Factors

During the public comment period before the codification of the program’s final rules, the Bond Market Association had strongly urged the Treasury “to adopt a policy not to repurchase more than ten percent of the current amount outstanding of any particular issue at any given time.” In fact, the median acceptance/outstanding percentage over all 420 panel data points turned out to be just 0.8%. Indeed, the Treasury seriously violated the Bond Market Association’s recommendation only once. In the reverse auction of June 21, 2001, the Treasury repurchased \$670 million or 13.2% of a total outstanding amount of \$5.061 billion of the 10.625% 2015 issue. A year earlier, the Treasury stopped at the 10% guideline (by accepting \$662 million or 10.3% of a total outstanding amount of \$6.408 billion) on this same issue. Perhaps more significantly, this maximum percentage in all other auctions never breached 8%.¹⁶

EXHIBIT 4

Impact of Buy-Backs on Coupon STRIPS Operation Day Return

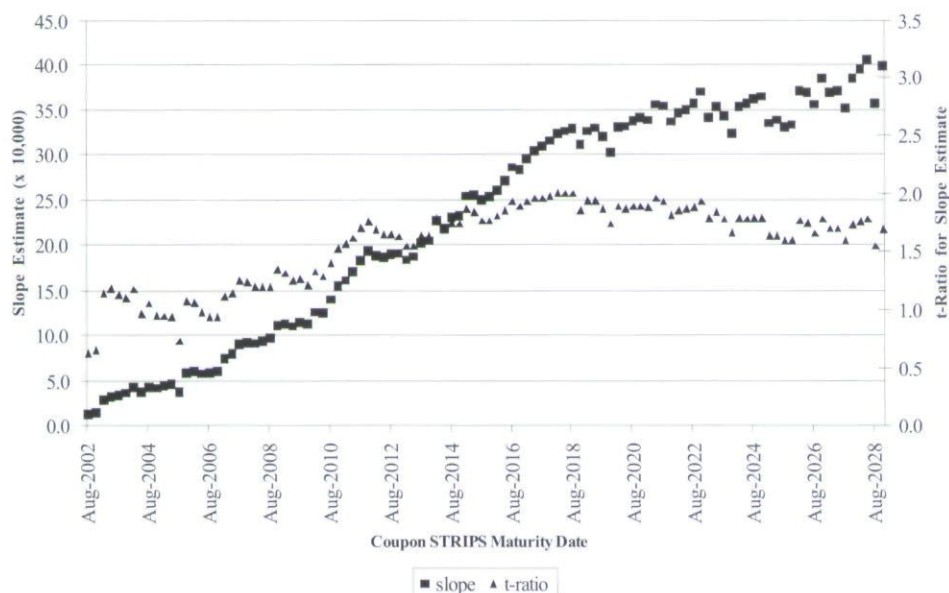


EXHIBIT 5

Impacts of Issue-Specific Reverse Auction Repurchases on Subsequent Change in Relative Value

Dependent variable		Intercept	A_k^i	R^2
$v_{k,t}^i - v_{k,t-1}^i$	Coefficient	-0.0019	0.0000137	0.012
	Std Error	0.0011	0.0000080	
	t-statistic	-1.69	1.71	
	p-value	0.099	0.096	
$v_{k,t+1}^i - v_{k,t-1}^i$	Coefficient	-0.0028	0.0000205	0.010
	Std Error	0.0016	0.0000110	
	t-statistic	-1.82	1.86	
	p-value	0.077	0.072	

(Number of observations = 420)

$v_{k,t}^i - v_{k,t-1}^i$ is the one-day change in the i -th issue's relative value and $v_{k,t+1}^i - v_{k,t-1}^i$ is the corresponding two-day change.

A_k^i is the size of the Treasury's repurchase of the i -th issue in the k -th reverse auction.

Regression equations of the form:

$$v_{k,t}^i - v_{k,t-1}^i = \delta_0 + \delta_1 A_k^i + u_k^i$$

$$v_{k,t+1}^i - v_{k,t-1}^i = \delta_0 + \delta_1 A_k^i + u_k^i$$

PRICING IMPACTS OF THE TREASURY'S REPURCHASES

Exhibit 4 presents tests of whether individual buy-back operations had important *general* impacts on Treasury returns by analyzing returns on coupon STRIPS

maturing between 2002 and 2028. Daily returns on Treasury coupon STRIPS for the full January 1999 to June 2002 sample period were constructed from the prices in the coupon STRIPS data set. Each return series was first adjusted by subtracting the implied daily accretion (calculated using the previous day's yield). This adjusted return series for the h -th coupon STRIPS (denoted R_t^h) was then regressed on a zero/one dummy variable indicating the date of the k -th buy-back operation ($D_{k,0}^d$) and on two additional zero/one dummy variables for the days immediately before ($D_{k,-1}^d$) and after ($D_{k,+1}^d$) an operation. The regressions take the form of Equation (2):

$$R_t^h = \rho_0 + \rho_1 D_{k,-1}^d + \rho_2 D_{k,0}^d + \rho_3 D_{k,+1}^d + e_t^i \quad (2)$$

The results reveal some evidence that the operations had positive contemporaneous impacts on Treasury coupon STRIPS returns. Specifically, the estimated ρ_1 coefficients (from the dummy variable for the day prior to each operation) are of mixed signs and always insignificant regardless of the maturity date of the individual coupon STRIPS. The ρ_2 coefficients (from the dummy variable for the day of each operation) are always positively signed, increase in magnitude

with maturity, and are sometimes significantly different from zero. Finally, the ρ_3 coefficients (from the dummy variable for the day after each operation) are always negatively signed but never significantly different from zero at the 5% level. Exhibit 4 plots the estimated ρ_2 slope coef-

ficients (contemporaneous operation day dummy variable) along with their associated t -ratios. Note that the estimated coefficients tend to rise with the maturity considered and that the highest t -statistics for these ρ_2 coefficients are associated with the 2017 to 2022 maturity sector favored by the Treasury. The estimated coefficients are consistent with impacts of approximately 9 cents per \$100 of par value for STRIPS in this maturity sector. Such an impact is a little larger than the typical 6–8 cent bid–ask spread and would not have been ignored by marketmakers.¹⁷ However, the magnitude of the net risk-adjusted profit opportunity for the typical fixed-income investor after taking transactions costs into account would not have been judged economically meaningful.¹⁸

Exhibit 5 presents tests for direct pricing impacts of the Treasury's *specific individual reverse auction repurchases*. In particular, Exhibit 5 reports estimates of the change in the i -th issue's *relative richness* (v_k^i) as a function of each million dollars of i -th issue par value accepted in the k -th buy-back operation (A_k^i).¹⁹ Explicit time subscripts appropriate for the k -th auction now appear. Both one-day and two-day changes in relative richness are studied as dependent variables. The variable $v_{k,t}^i - v_{k,t-1}^i$ refers to the pricing shift between market closes on date $t - 1$ and date t for a k -th auction occurring on date t . The variable $v_{k,t+1}^i - v_{k,t-1}^i$ refers to the pricing shift between market closes on date $t - 1$ and date $t + 1$ (the day *after* the k -th auction occurring on date t). The reported results are based upon regressions of the form

$$v_{k,t+f}^i - v_{k,t-1}^i = \delta_0 + \delta_1 A_k^i + u_k^i \text{ for all } k \text{ auctions and } i \text{ issues; } f = 0, 1 \quad (3)$$

Again, coefficient standard errors are corrected for contemporaneous cross-sectional correlations among the u_k^i residuals. The estimates in Exhibit 5 reveal no strong evidence that individual issue Treasury repurchases affected that same issue's relative pricing for either the auction-day or two-day horizons. Moreover, the point estimates of the average auction-day pricing impact—approximately 0.2 cents per \$100 million of par value accepted—are extraordinarily small relative to what one might have feared.²⁰ To provide some context for this estimated shift in (bid-to-bid) value, the bid–ask spread in the dealer market for a seasoned Treasury issue in the maturity sector under consideration for a \$10 million trade might be 6 cents. In sum, Exhibits 4 and 5 offer no strong evidence that the Treasury's buy-back program caused direct market congestion on operation days. The Treasury's procedures

for the reverse auctions appear to be quite consistent with its third self-imposed guideline to “promote efficient capital markets.”

INTERACTIONS BETWEEN BUY-BACKS AND THE TREASURY STRIPS MARKET

The Jordan, Jorgensen, and Kuipers [2000] study shows that a typical bond is more heavily stripped after its issuance than a typical note. Indeed, more than half of all bond observations in their sample have a higher proportion of total issue size held in stripped rather than in complete coupon-bearing form.²¹ The stripping of the typical bond begins after its auction-cycle price richness declines. Approximately half of the par value of a typical bond is stripped within two years of the bond's issue date.

Recall the individual percentages of par value initially held in stripped form for each of the 32 non-callable issues made eligible for the program as presented in Exhibit 3. As anticipated, many of these seasoned bonds have been heavily stripped. The median stripped percentage of these issues is 33%. However, a few issues remained substantially unstripped. In particular, the stripped percentages for the 7.25% May 2016 (1%) and the 7.5% November 2016 (5%) are remarkably low in the context of the patterns found by Jordan, Jorgensen, and Kuipers [2000]. Furthermore, these two issues went virtually untouched by the Treasury in the buy-back operations. The Treasury never accepted dealer offerings of the 7.25% May 2016, and the small amount of the 7.5% November 2016 purchased accounted for only 0.1% of the total program.

Given some thought, this relation is easy to understand. Lightly stripped issues clearly are different from heavily stripped issues. Heavily stripped issues are “cheap” issues. This relation makes economic sense since government bond dealers who need to create STRIPS to meet customer demand will naturally seek the lowest cost source for the product. Assuming a well-integrated STRIPS market, bonds with principal values trading close to (or even below) maturity-matched coupon values will be the cheapest sources of STRIPS supply.²² In contrast, bonds with principal value trading much higher than maturity date-matched coupon value will be expensive sources of supply. Given their high average principal minus matched-maturity coupon STRIPS price spreads, bonds such as the 7.25% May 2016 and the 7.5% November 2016 should remain lightly stripped by dealers.

EXHIBIT 6

Impact of Treasury Repurchases on Net Issue Amounts Reconstituted During the Program Period

	Intercept	A ⁱ	R ²
Coefficient	-3.26	0.360	0.048
Std Error	11.99	0.083	
t-statistic	-0.27	4.32	
p-value	0.789	0.000	

(Number of observations = 378)

Rec_m^i is the total par amount of the i -th issue reconstituted by dealers from the first operation date in the month until month-end.

A_m^i is the total par amount of the i -th issue repurchased by the Treasury during all operations in the same month.

$$Rec_m^i = \mu_0 + \mu_1 A_m^i + w_m^i$$

Treasury Repurchases and Dealer Bond Reconstitution Activities

Exhibit 6 looks for impacts of Treasury repurchases of specific issues on net issue reconstitutions by dealers. Data on net reconstitutions of individual issues can be derived from the month-end amounts held in stripped form. Exhibit 6 reports estimates of a regression equation of the form

$$Rec_m^i = \mu_0 + \mu_1 A_m^i + w_m^i \quad (4)$$

where Rec_m^i measures the net par amount of the i -th issue that was reconstituted between the first operation settlement date in a particular month and the end of the month and A_m^i measures the total par amount of the i -th issue repurchased by the Treasury during the same month. This regression tests whether Treasury repurchases affected the STRIPS market via bond reconstitution trading flows. Exhibit 6 reports the regression estimates for the available panel data (378 observations after the partial aggregation of any twice-monthly operations involving the same issues). The estimated slope coefficient (μ_1) is positively signed, large in magnitude, and statistically different from zero.²³

IMPACTS OF THE TREASURY BUY-BACK PROGRAM ON STRIP CURVE PRICING

Exhibit 6 shows a significant direct relation between Treasury buy-back program repurchases and bond reconstitution activity. This activity opens the possibility that buy-back program impacts extended beyond the particular 2015 to 2027 maturity sector of eligible issues because

coupon STRIPS maturing on each of a bond's coupon payment dates must have been acquired to reconstitute any particular bond. Thus, the program may have affected the coupon STRIPS market for maturities *shorter* than the program eligible bond maturities.

Exhibit 7 introduces $P-C_{ne}^I$, an equally weighted index of the principal-coupon price spreads (the "issue richness" measure previously used for program-eligible issues) for some *shorter-dated* issues maturing between August 2002 and August 2007 available in the Lehman data set. *None* of the issues in this August 2002 to August 2007 sector was ever made eligible for any Treasury reverse auction. Exhibit 7 reports results of two regressions. The first regression, based on Equation (5), tests for a significant shift in this index of non-eligible, short-maturity principal-coupon price spreads across pre-program and program periods. The regression uses D_{pp} , a dummy variable defined to be zero for the period up until January 12, 2000 (pre-program period), and +1 thereafter (program period), as the independent variable.

$$P-C_{ne}^I = \kappa_0 + \kappa_1 D_{pp} + u^I \quad (5)$$

The second regression is identical except that its dependent variable is $\Delta P-C_{ne,e}^I$, the *difference* between the index for non-eligible short-maturity principal-coupon price spreads ($P-C_{ne}^I$) and a corresponding equally weighted index for all program eligible non-callable issues ($P-C_e^I$).

$$\Delta P-C_{ne,e}^I = \kappa_0 + \kappa_1 D_{pp} + u^I \quad (6)$$

For both forms, the regressions reveal an economically and statistically significant decrease in the spread

EXHIBIT 7

Shifts in Principal-Coupon Strip Price Spreads Across Program Date Sample Splits

(1) Non-eligible, Short Maturity Issue P-Cⁱ Index used as dependent variable

$$P-C_{ne}^i = \kappa_0 + \kappa_1 D_{pp} + w^{\dagger}$$

	Intercept	D _{pp}	R ²
Coefficient	0.122	-0.309	0.593
Std Error	0.007	0.009	
t-statistic	16.80	-35.65	
p-value	0.000	0.000	

(2) Difference between Non-eligible and Eligible Issue P-Cⁱ Indexes used as dependent variable

$$\Delta P-C_{ne-e}^i = \kappa_0 + \kappa_1 D_{pp} + w^{\ddagger}$$

	Intercept	D _{pp}	R ²
Coefficient	-0.032	-0.2442	0.376
Std Error	0.009	0.0107	
t-statistic	-3.620	-22.90	
p-value	0.000	0.000	

Number of observations = 874. Regression of principal-coupon strip price spreads on pre-program/program period dummy variable.

Dependent variable for regression 1 is an index of principal-coupon strip price spreads of non-eligible, short-maturity issues.

Dependent variable for regression 2 is the *difference* between indexes of principal-coupon strip price spreads for indexes non-eligible, short-maturity and program-eligible issues.

[†]Non-eligible, short-maturity issue P-Cⁱ indexes.

[‡]Difference between non-eligible and eligible P-Cⁱ indexes.

between principal and maturity date-matched coupon STRIPS prices for the index of shorter-maturity issues that were not directly related to the buy-back program. The estimated slope coefficient on the dummy variable in each regression is large in magnitude and highly statistically significant. Exhibit 8 plots the daily principal less coupon price spread indexes for both the non-eligible short maturity issues ($P-C_{ne}^i$) and the program eligible bonds ($P-C_e^i$). The plot shows that principal-coupon price spreads for shorter-maturity issues turned negative after the program's announcement in mid-January and then fell steadily after the buy-back program's initial reverse auction in March 2000. By the end of June 2000, the average spread in the August 2002 to August 2007 maturity sector fell to nearly -0.60 (0.6% of par value).

These STRIPS market repricings provide a clear example of how trading flows can change relative pricing in the Treasury market. They also add further case-specific insight to Jordan, Jorgensen, and Kuipers' [2004] general empirical critique of Daves and Ehrhardt [1993]. The latter authors had hypothesized that principal STRIPS were *inherently* more valuable than maturity date-matched coupon STRIPS because of a principal's reconstitution

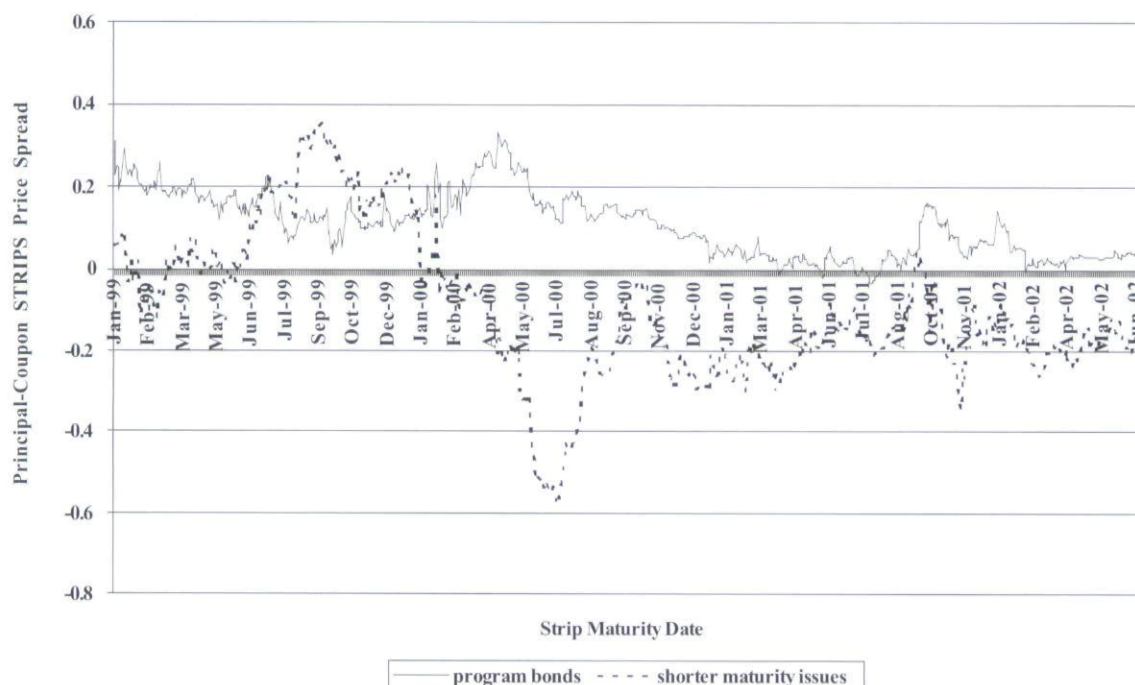
option. But the bond reconstitution flows associated with the Treasury's debt buy-back program generated only reconstitutions of issues in the February 2015 to November 2027 maturity sector. Yet, all of these program-related reconstitutions required dealers to repurchase long strings of coupon STRIPS. Importantly, principal STRIPS for (the shorter-dated) maturities that were not part of the buy-back program could play no direct role in these reconstitutions. Thus, in the current setting, the focus on issue reconstitution opportunity value is *reversed*. Indeed, the principal STRIPS could trade cheap to the maturity date-matched coupon STRIPS because only the coupon STRIPS had the *relevant* reconstitution value.

Exhibit 9 examines the buy-back program's impact on the pricing of coupon STRIPS from a different perspective involving just coupon STRIPS market data. Exhibit 9 plots the yield curves for coupon STRIPS for two dates: December 31, 1999 (pre-program), and June 30, 2000 (program). Indeed, consistent with standard empirical as well as theoretical term structure models, the yield curve for December 31, 1999, appears reasonably smooth along all maturity sectors. In contrast, by June 30, 2000, a little more than 3 months after the buy-back

EXHIBIT 8

Principal-Coupon STRIPS Price Spreads in Buy-Back Sector Versus Shorter Maturities

(sample period: January 1999 to June 2002)



program's first reverse auction, the coupon STRIPS yield curve appears to embody significant distortions. While the plot continues to appear well behaved for long-dated maturities (*including* buy-back program-eligible maturity dates), yields for some specific maturity points under 10 years exhibit trade "rich to the curve" by varying amounts.²⁴

The literature generally perceives the coupon STRIPS yield curve to embody "generic" yield curve qualities (Jordan, Jorgensen, and Kuipers [2000]; Sack [2000]). The surprising distortions observed during the buy-back program period call into question the routine use of the coupon STRIPS curve as a generic discount function, especially for short-dated maturities. These distortions direct attention to Bennett, Garbade, and Kam-bhu's [2000] suggestions to reform Treasury STRIPS market practices by 1) assigning an identical CUSIP number to all STRIPS maturing on a common date (making all matched-maturity STRIPS fungible regardless of origin) and 2) creating a facility to allow market participants to exchange (with Treasury) two outstanding STRIPS of very similar but not identical maturities for a newly issued STRIPS with an intermediate maturity

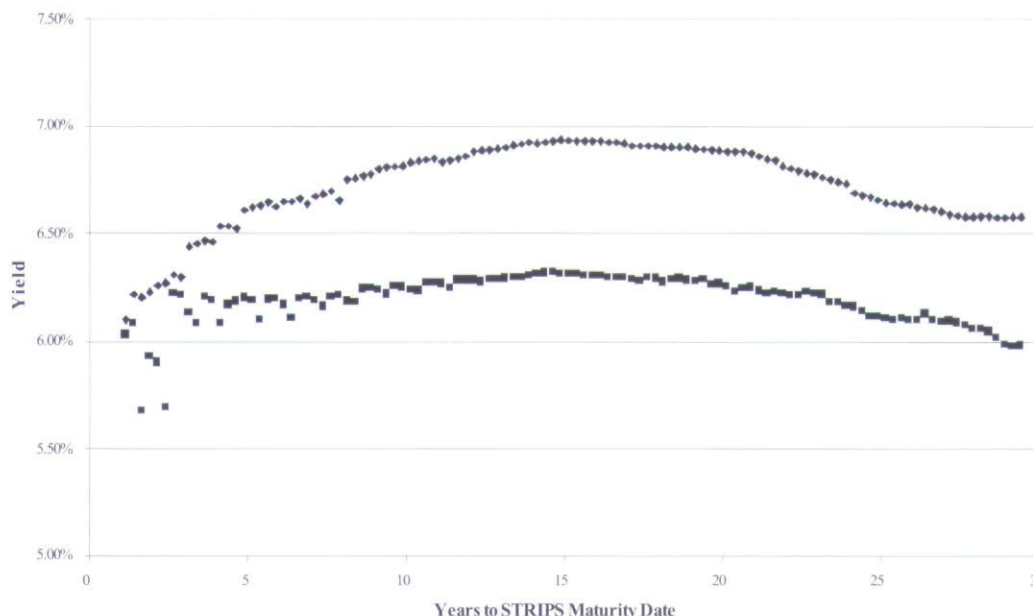
(essentially, a "butterfly" switch changing relative outstanding STRIPS quantities). Both reforms would alleviate the trade flow-induced STRIPS pricing pressures reported here.

SUMMARY AND INTERPRETATIONS

This article analyzes the U.S. debt buy-back program both to quantify the role that relative value played in determining Treasury repurchases and to investigate any resulting valuation impacts. The Treasury's auction eligibility decisions under the buy-back program were strongly skewed toward a particular segment of its outstanding debt maturity structure. In particular, the Treasury preferred repurchasing issues maturing between 2015 and 2023. The Treasury repurchased some 31 of the 32 non-callable bonds that, at one time or another, were made eligible under the program. Along relative value lines, the Treasury tended to avoid repurchasing the priciest issues, but under the featured STRIPS-based measure of relative value, it did not finely distinguish between cheap and moderately rich issues. Some evidence exists that the program generated general Treasury market pricing pres-

EXHIBIT 9

Two Treasury Coupon STRIPS Yield Curves: 06/30/2000 (lower plot) versus 12/31/1999 (upper plot)



tures during operation days. But the program's most important pricing distortions were for short-maturity coupon STRIPS linked to dealer reconstitutions of program-sector issues. No evidence could be found for issue-specific price impacts on accepted issues. Thus, the procedures adopted by the Treasury for the reverse auctions appear to be quite consistent with its self-imposed guideline to "promote efficient capital markets."

The analysis relating buy-back program repurchases and the Treasury STRIPS market yields some extremely interesting results. The specific par amounts of Treasury repurchases were positively contemporaneously correlated with specific issue reconstitutions via the STRIPS markets. This evidence provides a very clear insight into bond dealer use of the STRIPS market to access specific bond supply. Furthermore, economically and statistically significant shifts in the spread between principal and maturity date-matched coupon STRIPS prices occurred for shorter-maturity issues that were not directly related to the buy-back program. For these maturities, principals began trading below maturity date-matched coupons shortly after the start of the program and did so throughout the program sample. This shift in pricing relations for shorter-maturity issues was caused by the reconstitutions of longer-maturity bonds accepted under the buy-back program. These coupon STRIPS pricing distortions call into question the literature's routine use of the coupon

STRIPS curve as a generic yield curve and very possibly account for the disconnect between observed Treasury purchases and the STRIPS-based relative value measure. More importantly, the documented coupon STRIPS pricing distortions provide direct evidence in support of the case for reform of current STRIPS market practices.

Finally, the analysis of the Treasury's security selection choices has taken the initial issue eligibility decisions as given. Certain public statements suggest that the Treasury planned to use the buy-back program to help manage the average maturity of the public debt. For current purposes, this article has accepted these statements at face value. But buy-backs focused in the 2015 to 2023 maturity sector were but one possible way to avoid a lengthening of the debt's average maturity. As noted earlier, buy-back choices that combined repurchases of 5-10-year maturity issues with 25-30-year maturity issues would also have worked. Thus, an important remaining question is whether relative value played a role in defining the February 2015 to November 2027 sector that the Treasury made eligible. It is intriguing to note that the 2015 to 2023 maturity sector corresponds closely to what might naively be described as the "cheapest" (i.e., highest-yielding) part of the coupon STRIPS yield curve as depicted in Exhibit 3 for December 31, 1999 (just before the program's first operation in March 2000). Such sector-specific preferences lie outside of the current model-free

study of security selection. Nevertheless, the question as to whether a more generalized concept of relative value influenced the Treasury's sector choice remains open for future research.

ENDNOTES

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¹See Under-Secretary Gensler's remarks at the May 2000 quarterly refunding announcement (U.S. Treasury [2000b]).

²For simplicity, this article refers to all decisions under the program as being made by the Treasury even though certain reverse auction responsibilities were delegated to the Federal Reserve.

³The Treasury has three main goals in its debt management practices: 1) to provide sound cash management in order to ensure that adequate cash balances are available at all times; 2) to achieve the lowest-cost financing for the taxpayers; and 3) to promote efficient capital markets (see Sachs [1999]). Some observers might characterize the first as a "constraint" rather than a goal.

⁴"On-the-run" Treasuries are the most recently issued securities; "off-the-runs" are seasoned issues. See Babbel et al. [2004] for a recent study of off-the-run versus on-the-run Treasury pricing in the context of testing for short-run price pressure effects. Krishnamurthy [2002] analyzes the on-the-run bond/first off-the-run bond spread.

⁵Specifically, the Bond Market Association, a trade association representing securities firms and banks that underwrite, trade, and sell debt securities, "strongly urge[s] Treasury . . . to adopt a policy not to repurchase more than ten percent of the current amount outstanding of any particular issue at any given time."

⁶A corresponding graph constructed using market values (in place of par values) is quite similar.

⁷See Secretary Summers's August 4, 1999, statement: "buybacks enable us to prevent what would otherwise be a potentially costly and unjustified increase in the average maturity of our debt" (U.S. Department of the Treasury [1999]).

⁸Such a substitution would be in the spirit of a "butterfly" trade (Garbade [1996]).

⁹The average richness variable (the final column) clearly indicates that principal STRIPS tend to trade "rich" compared with coupon STRIPS: the average price spread is positive for all 32 bond principal STRIPS. The overall average richness for all bonds over the full sample is 9 cents. This finding is consistent with the general perception in the literature that the market pays

for a "reconstitution option," as in Daves and Ehrhardt [1993].

¹⁰STRIPS is an acronym for the "Separate Trading of Registered Interest and Principal of Securities" program.

¹¹A simple argument supports this interpretation. Let R be the semiannual coupon on the specific Treasury issue maturing at date T with M remaining coupons and let B_t^T be this issue's market value (price plus accrued). The price of the coupon-bearing bond must respect the no-arbitrage condition:

$$B_t^T = P_t^T + \sum_{z=1}^M RC_t^z$$

where P_t^T is price of the date T maturity bond's principal STRIPS and the C_t^z are coupon STRIPS prices for the bond's coupon payment dates. Define the issue's "richness" as the difference between the bond price and its cash flows discounted using the set of coupon STRIPS prices (i.e., using the "generic" discount factors). This measure of issue-specific relative value reduces to simply the difference between the principal and coupon STRIPS prices for the bond's maturity date:

$$V_t^i = B_t^i - \left[C_t^T + \sum_{z=1}^M RC_t^z \right] = P_t^T - C_t^T$$

¹²Indeed, Jordan, Jorgensen, and Kuipers report that the price differences for maturity-matched stripped principal-coupon pairs are strongly related to the relative richness or cheapness of the associated strippable bond or note as measured versus a standard spline-based term structure model.

¹³These STRIPS were created from 10-year notes and 20-year and 30-year bonds and mature on the 15th day of February, May, August, and November.

¹⁴This is before the March 7, 2000, announcement of the specifics of the first operation.

¹⁵If the standard for comparison is the deviation from the average richness of all program-eligible issues, three of these same six issues are more than two standard deviations richer than average and the others are one standard deviation richer than average.

¹⁶Furthermore, one additional public comment letter had suggested that the Treasury avoid repurchasing issues that were key deliverables against the Chicago Board of Trade Treasury futures contracts. Before the buy-back program period, the 11.25% 2015 issue had been the clear cheapest-to-deliver bond against the CBOT Treasury Bond futures contract (e.g., for the December 1999 maturity contract). The Treasury did repurchase this issue, but nevertheless limited its size to just 3.7% of all non-callables even though this bond was large in size, reasonably cheap on the basis of average program period richness (+.044) among the 32 non-callable bonds, and no longer deliverable against the bond futures contract beginning with the March 2000 contract cycle.

¹⁷Chakravarty and Sarkar [2003] estimate an average bid-ask spread for Treasury bonds of 8 cents.

¹⁸However, as might be expected, these dummy variables explain very little of the total variation in overall variation of coupon STRIPS returns (adjusted- R^2 of approximately 0.002).

¹⁹Denote the average of $V_{k,t-1}^A$ across all bonds eligible in that specific k -th auction as $V_{k,t-1}^A$. Then, define $v_{k,t-1}^i$ to be the difference between the issue-specific relative value measure for the i -th bond and the average for all n_k eligible bonds:

$$v_{k,t-1}^i = V_{k,t-1}^i - V_{k,t-1}^A$$

²⁰The average amount taken of the i -th issue in the k -th reverse auction was \$141 million in par value. The largest amount accepted within a given auction was \$1.014 billion (of the 8.875% 2019 in the August 23, 2001, operation). The predicted price response for this large purchase based on a slope of 0.00002 would be approximately +2.0 cents.

²¹This compares with just 0.6% of the monthly observations on Treasury notes.

²²This argument presumes no natural customer demand for a lower-yielding principal STRIPS given a higher-yielding maturity date-matched coupon strip alternative. Thus, dealers will have a harder time unwinding the principal piece after stripping a rich bond and may have to consume liquidity in the principal STRIPS market.

²³That the equation's adjusted R^2 of 0.048 is "low" suggests that the buy-back program was just one among a set of factors needed to explain issue-specific bond reconstitution flows over this period.

²⁴Such specific security richness would typically coincide with "specialness" in the repurchase agreement market for these same specific coupon strips (see Duffie [1996]; Jordan and Jordan [1997]).

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