PRICE DISCOVERY IN THE TREASURY FUTURES MARKET

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The paper conducts a regression analysis utilizing both futures and cash market prices and net orderflow to determine where price discovery takes place as well as the forces at play that influence the location. Specifically, given the strong theoretical linkage between the U.S. Treasury cash and futures markets, they compare how orderflow contributes to price discovery and analyze how and when information flows from one market to the other. How a number of environmental variables (trader type, financing rates, and liquidity) impact the information flows between these two markets is also considered. Their findings provide new evidence on the extent to which price discovery happens away from a primary market. © 2007 Wiley Periodicals, Inc. Jrl Fut Mark 27: 1021–1051, 2007

For helpful comments, we thank seminar participants at Babson College and the Texas Junior Finance Symposium as well as Michael Goldstein, Jim Hodder, Elizabeth Odders-White, Natalia Piqueira, and Mark Ready. In addition, we thank Brian Huber of Alpha Logic Technologies for providing and explaining their data. All remaining errors are our own.

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Received November 2006; Accepted February 2007

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The Journal of Futures Markets, Vol. 27, No. 11, 1021–1051 (2007)

Published online in Wiley Interscience (www.interscience.wiley.com).
DOI: 10:1002/fut.20275

INTRODUCTION

There are many ways that market participants can obtain exposure to the movement in riskless interest rates. One obvious way is through the cash market for U.S. Treasury securities. There has been a substantial literature that investigates the inner workings of this market, including Fleming and Remolona (1997, 1999), Brandt and Kavajecz (2004), and Green (2004). Another important avenue market participants use to gain exposure to riskless fixed income securities is through the trading of futures on U.S. Treasury securities. The sheer size of the Treasury futures market foreshadows its importance; for example, the 10-year Treasury futures contract traded on the Chicago Board of Trade (CBOT) has in excess of 100 billion dollars in notional volume traded every day. Financial theory suggests that these markets should be connected through the diligent and repeated application of arbitrage strategies as well as trades used to satisfy hedging demands. Yet despite the importance of the Treasury futures market, there have been only a handful of studies dealing with the potential linkages between the U.S. Treasury futures and cash markets (Simpson & Ireland, 1985).

The goal of this study is to better understand the movements of the term structure of interest rates through trading of both Treasury cash securities and Treasury futures contracts. Specifically, the following questions are of interest. First, are the mechanisms through which price discovery takes place the same in the U.S. Treasury futures and cash markets, i.e., does orderflow have the same impact in both markets? Second, does the primary location for price discovery switch between the cash and futures market? If so, when does that occur, and what environmental forces influence the transition?

This study fits in the intersection of three segments of the finance literature and thereby provides a synthesis of many of the ideas therein. First, there is mounting evidence that aggregate orderflow is the mechanism through which information is impounded into prices in numerous markets. Examples of work in this area include Glosten and Milgrom (1985) and Kyle (1985) in the equity markets, and more recently Evans and Lyons (2002a, 2002b) and Rosenberg and Traub (2006) in the foreign exchange market and Fleming and Remolona (1997, 1999) and Brandt and Kavajecz (2004) in the fixed income market. Second, there is a growing literature that investigates the connection between separate, but related markets. Examples include Simpson and Ireland (1985), Easley, O'Hara, and Srinivas (1998), Anderson, Bollerslev, Diebold, and Vega (2004) and Underwood (2006). This study stands at the intersection

of these two strands of the literature, in that whether the relation between orderflow and prices in the Treasury futures market is similar to, or different from, the analogous relation in the Treasury cash market is investigated.

Lastly, conditional on orderflow being the primary source for price discovery, it is natural to question what forces have an impact on the extent and direction of price discovery across markets. For example, some researchers have considered how orderflow from different trader types impacts the extent of price discovery, e.g., Keim and Madhavan (1995, 1997) and He (2005) consider institutional and retail orderflow, whereas Manaster and Mann (1996) compare the general public and exchange members. Other researchers have investigated the impact of liquidity on price discovery (see, for example, Brandt & Kavajecz, 2004). In the context of this analysis the impact of a number of environmental variables—including trader type, financing rates, and liquidity—on price discovery between the two markets is considered.

This article shares this intersection of the finance literature with two recent articles. Although these studies are similar to this investigation, the focus of each of these studies is distinct. Menkveld, Sarkar, and van der Wel (2006) focus on the informativeness of customer order flow in Treasury bond futures following macroeconomic announcements. Although they provide evidence on the time-varying importance of customer order flow in the futures market, they do not consider the interaction of futures and cash orderflow as is done here. Mizrach and Neely (2006) focus on the relative contributions of the Treasury cash and futures markets to intraday price discovery unconditionally. They show that the 5-year cash note and the 30-year futures contract contribute the most to price discovery in the Treasury market. Although the unconditional impact of orderflow on price discovery in the two markets is also investigated here, the differing roles played by the two markets depending on Repo financing rates and cash market liquidity is examined as well.

The analysis begins by comparing the direct impact that net orderflow has in the two markets. The results on the change in open interest reveals that traders in the futures market typically take a position on the slope of the yield curve, e.g., buy the 5-year contract and sell the 30-year contract. When futures net orderflow is disaggregated by trader type, trades originating from locals (i.e., market makers occupying the futures pits) were found to have almost no impact on daily returns, whereas trades originating from exchange members and retail customers contribute substantially to price discovery. That said, although exchange

members and retail trades have a permanent impact on prices, their impacts are in opposing directions. This study's results show that retail trades move prices in the direction of their trade (buy trades push prices up and sell trades push prices down), whereas prices move opposite the direction of exchange member trades. Given that much of the trading by exchange members is done to satisfy hedging demands, their trades are consistent with muted, and even opposing movements, in futures prices. Consistent with our intuition, net orderflow is also important to price discovery in the cash market. Of particular importance toward price movements in all maturities are the on-the-run trades of the 2- and 5-year notes. In contrast, trading in the 10- and 30-year securities are far less informative.

The paper conducts a regression analysis utilizing both futures and cash market prices and net orderflow to determine where price discovery takes place as well as the forces at play that influence the location. The results show that net orderflow in each market has a significant impact on the prices in both the Treasury cash and futures markets. The results using own market orderflow are shown to be robust to conditioning on orderflow variables from the cross market. Specifically, the 2- and 5-year cash market net orderflow is significantly positively related to both cash and futures price movements. The positive sign and strictly increasing size of the coefficients with respect to maturity suggests that cash purchases of the 2- and 5-year note shift up the price level along the entire curve and in addition, steepen the slope. In contrast, hedging-related trades conducted by futures exchange members on the long end of the curve (5-, 10-, and 30-year contracts) have a significant negative impact and are strictly decreasing with respect to maturity. Thus, these trades shift down prices along the entire curve and also flatten the slope. Retail futures trades have a positive and significant impact on both cash and futures prices. The price reaction to retail futures trades is to shift up and steepen prices along the yield curve similar to the reaction to short maturity (2- and 5-year) cash orderflow; however, the magnitude of the reaction is much more muted for retail orderflow. In addition to trader type, financing rates and the level of liquidity in a market are found to impact the extent and direction of price discovery. The results found here show that Repo specialness causes price discovery to occur relatively more in the futures market because transacting in the cash market is exceedingly expensive. Moreover, illiquidity in the cash market is associated with relatively more price discovery occurring in the cash market as informed traders are likely transacting in that market. Interestingly, the instrument of central importance to the above results is the 5-year

maturity in both the futures and cash market, largely to the exclusion of the other maturities.

PRELIMINARIES

Data Sources

The data used in this analysis are daily time-series of price and orderflow for both the futures and cash market over the period 1995 through 2000.[1] The futures data are obtained from two different sources. The futures transaction price and volume data are obtained from the Institute for Financial Markets (Washington, DC). Daily closing prices and daily volume information were used to construct a time-series of activity in each of the 2-, 5-, 10-, and 30-year Treasury futures contracts. The futures orderflow data are obtained from the Chicago Board of Trade's Liquidity Data Bank (hereafter LDB). These data provide net order flow (buy volume less sell volume) differentiated by trader type for all CBOT futures contracts at the daily frequency (beginning in 1995) as well as intraday (beginning in January 2003). Specifically, the LDB data assigns trades to one of four customer trade indicator (CTI) categories. The CBOT provides the following descriptions of the four categories: Category 1 consists of trades executed by individual CBOT members trading for their own accounts, Category 2 is made up of trades that are executed by CBOT clearing member firms trading for their house accounts, Category 3 comprises trades executed by CBOT members filling orders for other CBOT members, and Category 4 consists of trades filled for the public or any other type of "outside" customers. Daigler and Wiley (1999) provide a nice summary of the different categories and the likely type of traders that are included in each. They suggest that Category 1 is largely populated by market makers, "scalpers," or "locals," whose usual function is to provide liquidity and earn a small profit from the bid-ask spread. Category 2 appears to represent proprietary trading by clearing member firms, which may be conducted either for speculative or hedging purposes. The fact that Category 3 represents trades done on behalf of other CBOT members suggests that hedging is a likely motive. For example, a Category 3 trade might be a trade executed for a CBOT options trader wishing to hedge a position. Manaster and Mann (1996) and Ferguson and Mann (1999) also provide evidence on Categories 2 and 3 trading

[1]We end our sample in December 2000 because certain variables that allow us to calculate cash market order flow are missing from the GovPX dataset starting in early 2001.

for a variety of futures contracts that trade on the Chicago Mercantile Exchange. In general, they find that the bulk of Categories 2 and 3 volume is related to hedging as many trades are part of a delta-hedging strategy for options positions. Given the results of Manaster and Mann (1996) and in an effort to simplify this analysis, Categories 2 and 3 orderflow were combined into one category. Lastly, Category 4 is typically referred to as the *general public* or *retail* orderflow, although in some cases small institutional traders may fall into this category as well.

The Treasury cash data are obtained from GovPX (www.govpx.com), which consolidates quotes and transaction data from five of the six major interdealer Treasury securities brokers in the secondary U.S. Treasury cash market. Specifically, intraday U.S. Treasury security quotes and transactions were used for all Treasury issues. The GovPX dataset contains security identifier information, including the CUSIP (Committee on Uniform Security Identification Procedures, Standard & Poor's, New York, NY), coupon, maturity date, as well as an indicator of whether the security is trading when-issued, on-the-run, or off-the-run. The quote data contain the best bid and ask prices, associated yields, and respective bid and ask depths, all time-stamped to the nearest second. The transaction data include the time, initiator (i.e., signed trades), price and quantity. These data allow the calculation of the price, net orderflow, and liquidity measures for the Treasury cash market.

The basic futures and cash time-series data was supplemented with information regarding other pertinent aspects of the Treasury market, such as the timing of Treasury auctions, macroeconomic announcements and financing (Repo) rates. For macroeconomic announcements, a listing of the date and time of release, the market's expectation, and the announced statistic is obtained from Money Market Services (MMS). Data on announcements of the latest consumer price index (CPI), producer price index (PPI), housing starts, civilian unemployment, nonfarm payroll, retail sales, industrial production, consumer confidence, the NAPM (now Institute for Supply Management, Tempe, AZ) reports, as well as on all FOMC (Federal Open Market Committee, Federal Reserve Board, Washington, DC) meetings are used. Financing rates are also obtained from GovPX. Specifically, daily information on the overnight general collateral and on-the-run Repo rates for each of the specific maturities is used.

Aggregation, Timing, and Variable Definitions

Treasury futures end-of-day prices and daily net orderflow are taken from the nearby contract until the first delivery day, at which point the

series switches over to the second nearby contract. The trading activity in the delivery month is avoided because there may be some settlement-induced illiquidity as in Johnston, Kracaw, and McConnell (1991). Moreover, because the concentration of trading begins to naturally shift to the next nearby contract, trading in the delivery month becomes less and less representative of the overall market.

The Treasury cash securities are partitioned, and data aggregated, as in Brandt and Kavajecz (2004). Specifically, each Treasury security is categorized along two dimensions common in the literature, remaining time-to-maturity and seasonedness; *seasonedness* refers to how recently a security was auctioned. Securities are categorized into one of two groups: on-the-run and off-the-run. This partition will be important later when future delivery options are discussed. The daily Treasury cash price and orderflow series are constructed by aggregating data within nonoverlapping periods. Daily orderflow figures are computed using executed orders before 2:00 P.M. (Central time) on a given day and prices are averaged in the final hours of trading (from 2:00 P.M. to the close). This sampling technique is adopted because trading in the Treasury cash market tends to be concentrated in the morning and also to avoid any nonsynchronous measurement of orderflow and prices. The 2:00 P.M. Central time is chosen to line up with the close of trading in the futures market.

Any analysis of the connection between an exchange-traded future and its underlying asset hinges upon the delivery options set out by the exchange. The fact that traders have the ability to deliver any one of a well-defined set of securities to satisfy a futures contract suggests that they will naturally avail themselves of the cheapest-to-deliver security within the set of feasible and obtainable securities. Consequently, the set of securities that can be delivered against each futures contract each day is identified. Within that feasible set of deliverables, i.e., eligible securities that have the proper issuing maturity and remaining time-to-maturity, the securities are ordered by their implicit cost measured by the implied repo rate (IRR). Identifying the cheapest-to-deliver security involves a number of calculations. First, the current futures price is multiplied by a conversion factor, which converts the futures price to the comparable price at which that security would trade if it yielded 6% to first call.[2] Multiplying by the conversion factor puts all securities on a level playing field so that they may be compared. Second, the interest that has accrued since the last interest payment is calculated. This represents a reduction in the cost

[2]Note that prior to March 2000, the conversion factor was set to convert the price of the security to one yielding 8% to first call.

to delivering the security as the receiver of the bond must pay the deliverer for the interest that has accrued before taking ownership. Lastly, the percentage return is calculated on a 360-day basis until the first delivery day, i.e., the implied Repo rate, for each security in the feasible set of deliverables.[3] Because there are potentially many securities within the set of deliverables, for practicality, the two cheapest-to-deliver issues is tracked for each contract for each day. These two cheapest-to-deliver securities form the estimate of the price of the underlying security. As the futures contract is rolled over to the next nearby contract at the first delivery day, so too is the cheapest-to-deliver security rolled over at that time.

There are a number of facts about the cheapest-to-deliver securities that are worth highlighting given their relevance to the forthcoming analysis. First, the cheapest-to-deliver securities are rarely the on-the-run issues, in fact, they are always in the off-the-run category during the sample.[4] Second, despite the fact that these issues are cheapest-to-deliver, being off-the-run securities implies that these issues will be infrequently traded.

Summary Statistics

To appreciate the richness of the data used in this analysis, a number of summary tables is presented. Table I displays the average daily future returns, open interest and volume for each of the four futures contracts by year as well as the corresponding Treasury cash returns. Futures trading is concentrated in the long and middle part of the curve as seen through the elevated figures for open interest and volume in the 10- and 30-year contracts and the much lower figures for the 2-year contract.[5] No particular year stands out as an anomaly with both futures and cash returns averaging close to zero and open interest and volume trending upwards over the sample period.

Table II presents the change in open interest and the futures net orderflow broken out by CTI category for each year in the sample.[6] The

[3]For a more detailed explanation of the cheapest-to-deliver calculation see Burghardt, Belton, Lane, and Papa (1994).

[4]This is partly because the on-the-run security typically trades at a premium relative to similar maturity securities. In addition, typical interest rate environments tend to disadvantage new issues in terms of being cheapest to deliver. Burghardt et al. (1994) note that the regime of high, but falling, interest rates in the mid-1980s did lead to a role for the on-the-run securities as cheapest-to-deliver.

[5]It is worth noting, however, that the 2-year contract trades based on an underlying security with a face value of $200,000, whereas the 5-, 10-, and 30-year contracts trade on a $100,000 basis.

[6]Net orderflow broken out by category records both sides of a trade; thus the sum of the four categories must necessarily be 0.

TABLE I
Summary Statistics for U.S. Treasury Futures Contracts

	1995	*1996*	*1997*	*1998*	*1999*	*2000*	*Total*
2 Year							
Futures return	0.0192	−0.0034	0.0042	0.0054	−0.0083	0.0078	0.0000
Open interest	23.25	17.04	30.23	38.38	34.95	47.31	31.85
Volume	3.46	2.78	4.10	5.71	4.30	6.89	4.54
Cash return	0.0013	0.0075	0.0049	0.0025	−0.0064	0.0055	0.0000
5 Year							
Futures return	0.0398	−0.0116	0.0100	0.0138	−0.0196	0.0222	0.0001
Open interest	164.76	149.29	203.84	274.13	267.85	362.73	237.09
Volume	75.96	67.27	79.36	105.00	97.73	161.03	97.72
Cash return	0.0103	0.0016	−0.0023	−0.0001	−0.0313	0.0181	−0.0000
10 Year							
Futures return	0.0575	−0.0169	0.0170	0.0220	−0.0307	0.0357	0.0001
Open interest	235.09	256.25	318.31	435.77	502.13	527.72	379.23
Volume	127.13	123.12	137.82	191.26	198.10	348.02	187.60
Cash return	0.0587	−0.0095	0.0022	0.0060	−0.0501	0.0599	0.0001
30 Year							
Futures return	0.0842	−0.0292	0.0314	0.0298	−0.0492	0.0572	0.0002
Open interest	341.66	362.92	486.24	680.41	564.11	417.76	475.39
Volume	580.15	564.72	692.05	775.13	610.68	503.33	620.85
Cash return	0.0820	−0.0379	0.0308	0.0142	−0.0700	0.0571	0.0001

Note. This table provides the mean of daily values for the futures return, open interest and volume figures for the 2-, 5-, 10-, and 30-year Chicago Board of Trade Treasury futures contracts as well as the Treasury on-the-run cash return over the period 1995 through 2000. The futures and cash returns are quoted in percent and the open interest and volume figures are quoted in 1000s of contracts for the nearby future.

results generally reflect those shown in Table I: Trading becomes much more active the longer the maturity of the futures contract. In addition to reviewing the category averages, it is interesting to consider the correlation of activity across trader types. In untabulated results, the correlation between categories within a futures contract is relatively low, with the notable exception of Category 4, which is strongly negatively correlated with all other categories. The strong negative correlation with Category 1 is to be expected, given traders in that category are mainly providing liquidity via market making. However, Categories 2 and 3 net orderflow are also significantly negatively correlated with Category 4 orderflow, which suggests that these traders often take the opposite side of trades executed by Category 4 or retail traders. Moreover, very weak correlations are found across contracts within a category. Lastly, the change in open interest appears to be uncorrelated with any of the specific net orderflow categories, yet is highly positively correlated with the changes in open interest in other futures contracts.

TABLE II

Futures Contracts Net Orderflow

		1995	*1996*	*1997*	*1998*	*1999*	*2000*	*Total*
2 Year	Category 1	−13.84	−2.59	−17.75	16.01	−18.13	−4.38	−6.78
	2+3	−0.75	15.06	5.67	27.58	30.38	−32.86	7.51
	4	14.59	−12.47	12.08	−43.60	−12.25	37.24	−0.73
	Δ in open int.	−103.19	−61.17	−10.43	−271.83	−290.49	−149.10	−147.71
	Cash on-the-run	272.82	342.05	269.95	273.73	268.32	14.10	238.90
	Cash off-the-run	150.54	94.03	94.06	76.43	60.93	41.12	86.24
5 Year	Category 1	18.37	119.70	−46.80	180.60	−256.16	−424.73	−68.28
	2+3	0.85	63.35	−103.98	−81.98	372.12	−370.92	−19.96
	4	−19.22	−183.05	150.79	−98.82	−115.96	795.65	88.21
	Δ in open int.	82.62	−398.85	26.48	−1502.14	−1662.40	−2397.75	−976.70
	Cash on-the-run	413.83	344.53	362.94	234.95	83.21	29.54	245.78
	Cash off-the-run	68.79	18.97	13.87	41.88	22.21	14.15	29.99
10 Year	Category 1	18.64	17.40	81.33	11.90	−27.06	189.44	48.61
	2+3	−203.40	−70.95	−152.03	28.25	769.95	−797.31	−70.84
	4	184.76	53.56	70.70	−40.15	−742.92	607.87	22.22
	Δ in open int.	−62.27	−403.92	−103.57	−1154.48	−2996.62	−4116.92	−1475.29
	Cash on-the-run	162.28	227.57	168.48	123.95	56.39	13.69	125.57
	Cash off-the-run	5.98	0.92	2.34	0.27	0.34	0.34	1.47
30 Year	Category 1	−180.21	−185.40	−126.77	241.73	−158.69	−253.01	−110.62
	2+3	−111.21	−133.02	−158.99	1.90	282.06	−297.11	−69.40
	4	291.42	318.42	285.76	−243.62	−123.40	550.12	180.01
	Δ in open int.	−745.47	−1376.29	−999.59	−5624.05	−4412.46	−3634.17	−2799.79
	Cash on-the-run	10.17	38.38	4.32	21.95	7.64	6.79	15.53
	Cash off-the-run	0.29	3.18	−0.61	−0.05	−0.10	0.00	0.46

Note. This table provides the nearby contract net orderflow figures for the customer trade indicator (CTI) categories, change in open interest as well as net orderflow for the cash on- and off-the-run securities. Category 1 consists of trades executed by individual Chicago Board of Trade (CBOT) members trading for their own accounts, Category 2 is made up of trades that are executed by CBOT clearing member firms trading for their house accounts, Category 3 comprises trades executed by CBOT members filling orders for other CBOT members, and Category 4 consists of trades filled for the public or any other type of outside customers. Figures are averages of daily values over the respective year in contract units for futures and millions of dollars for the cash series. Note that the CTI figures are double counted in that each trade is recorded for both the buyer and the seller.

Table II also presents average net orderflow statistics for the cash Treasury market. The average net orderflow figures for the cash market display the usual pattern of a heavy concentration of trade in the on-the-run security with marked reductions in net orderflow in the off-the-run securities. Of note is the fact that GovPX net orderflow falls off substantially in 2000. Although this is potentially a result of a shift in trading venues, it also may result from the decreased issuance of Treasuries due to budget surpluses at that time.

In other untabulated results, the distribution of trading activity across the CTI categories is considered. The majority of futures trading is done through Categories 1 and 4, with the combined trading of Categories 2 and 3 accounting for, at most, 25% of traded volume. This result is consistent across contracts. Despite the prominence of Categories 1 and 4, their relative importance varies across the contracts. For the 2-year contract Categories 1 and 4 account for roughly equal proportions of average daily volume whereas for the 5-, 10-, and 30-year contracts, Category 1 makes up a much larger fraction of trading volume than does Category 4. Of all the contracts, the 5-year contact seems to exhibit the most trading in Categories 2 and 3. One possible explanation is that if a majority of fixed income portfolios have an average duration close to 5 years, the 5-year futures contract becomes the natural hedge instrument. The earlier description of the likely participants encompassing Categories 2 and 3 trades is consistent with this conjecture.

CASH AND FUTURES ORDERFLOW

In this section, the ability of orderflow to explain price movements in each of the respective markets is explored more directly. The daily return in the futures (cash) market is regressed on net orderflow variables from the different contracts (maturities). Owing to a strong seasonal "saw tooth" pattern within each of the net orderflow and open interest series, those series are detrended by regressing each on a constant and a time-to-delivery variable.[7] The variables used in the orderflow regressions represent the residuals from this detrending procedure. Lastly, after controlling for macroeconomic announcements, the impact of orderflow along the futures curve is estimated and is compared to the impact of orderflow in the cash market.

[7]In particular, net orderflow, volume, and open interest are highest immediately after the rollover to the next nearby contract and then slowly taper off until the first delivery day for the current contract.

TABLE III
Response of Futures Returns to Changes in Open Interest

		Change in open interest				
Futures return	*Intercept*	*2 Year*	*5 Year*	*10 Year*	*30 Year*	R^2
2 Year	0.0306	0.0742	**−0.2000**	−0.0425	**0.2093**	0.0230
	(1.1080)	(1.9431)	**(−3.8973)**	(−0.9966)	**(4.6562)**	
5 Year	0.0799	0.1101	**−0.4773**	−0.1573	**0.5646**	0.0292
	(1.2903)	(1.2851)	**(−4.1433)**	(−1.6429)	**(5.5951)**	
10 Year	0.1304	0.1392	**−0.6442**	**−0.3339**	**0.9103**	0.0339
	(1.4608)	(1.1266)	**(−3.8802)**	**(−2.4201)**	**(6.2600)**	
30 Year	0.1914	0.1472	**−0.8479**	**−0.5627**	**1.5938**	0.0372
	(1.3787)	(0.7659)	**(−3.2830)**	**(−2.6221)**	**(7.0456)**	

Note. This table presents the response of futures prices to changes in open interest separated by contract maturity. Each change in open interest series represents the residuals of a regression of the change in open interest regressed on a constant and a time-to-deliver variable. This adjustment accounts for the strong seasonal present in each open interest series. Coefficients are multiplied by 1,000 and *t*-statistics are shown in parentheses. Bold values represent significance at the 5% level.

Table III shows how changes in open interest impact futures prices. Recall that an increase in open interest simply means that additional futures contracts were created. Interestingly, the impact of changes in open interest in the center of the curve (5- and 10-year contracts) is opposite the impact at the curve's endpoints (2- and 30-year contacts). Moreover, the significance and uniform sign of the impact across returns of different maturities for the simple creation of a new contract suggest that market participants are likely to be executing strategies using multiple contract maturities. For example, a slope trade such as buying (selling) a 5-year contract and selling (buying) a 30-year contract would be a strategy consistent with these results.

Table IV presents the results based on the current and lagged net orderflow of the various CTI categories. The results are consistent with the description of each category given above. Category 1 trades appear to have little impact on the direction of prices as coefficients are typically insignificantly different from zero. This is consistent with the behavior of local market makers whose strategy is to temporarily supply liquidity in return for payment of the bid-ask spread. Anecdotally, these market makers do not take a position in the security, opting instead to "go home flat."[8]

[8]Manaster and Mann (1996) examine the behavior of Category 1 traders in a number of contracts trading on the Chicago Mercantile Exchange. They find that although Category 1 traders do take positions intraday, most of their positions are closed out by the end of the day.

TABLE IV

Response of Futures Returns to Current and Lagged Customer Trade Indicator (CTI) Category Orderflow

		Orderflow								
		2 Year		*5 Year*		*10 Year*		*30 Year*		
Futures return	*Intercept*	*Current*	*Lagged*	*Current*	*Lagged*	*Current*	*Lagged*	*Current*	*Lagged*	R^2
					Category 1					
2 Year	0.0416	0.0505	0.0095	−0.0059	0.0181	−0.0532	0.0406	−0.0627	−0.0307	0.0064
	(1.4757)	(1.6216)	(0.3069)	(−0.1494)	(0.4586)	(−1.3752)	(1.0481)	(−1.6388)	(−0.7871)	
5 Year	0.0883	**0.2900**	0.0542	−0.0282	0.0337	−0.1156	0.1019	−0.1528	−0.0751	0.0176
	(1.4180)	**(4.2175)**	(0.7909)	(−0.3232)	(0.3875)	(−1.3528)	(1.1897)	(−1.8087)	(−0.8703)	
10 Year	0.1440	**0.4559**	0.0689	0.0607	0.0574	−0.1052	0.1277	**−0.2693**	−0.1264	0.0203
	(1.6044)	**(4.5983)**	(0.6975)	(0.4823)	(0.4568)	(−0.8539)	(1.0345)	**(−2.2112)**	(−1.0163)	
30 Year	0.2150	**0.8076**	0.0429	−0.1093	0.0070	0.1326	0.1312	**−0.4683**	−0.2355	0.0255
	(1.5420)	**(5.2428)**	(0.2797)	(−0.5587)	(0.0358)	(0.6925)	(0.6839)	**(−2.4747)**	(−1.2181)	
					Category 2 + 3					
2 Year	0.0510	−0.0271	−0.0173	**−0.2236**	0.0408	**−0.2186**	−0.0289	**−0.2891**	−0.0197	0.1655
	(1.9736)	(−0.8295)	(−0.5254)	**(−5.5496)**	(1.0175)	**(−6.7579)**	(−0.9169)	**(−9.2884)**	(−0.6346)	
5 Year	**0.1135**	−0.0641	−0.0510	**−0.6251**	0.1057	**−0.5236**	−0.0684	**−0.7967**	−0.0744	0.2389
	(2.0880)	(−0.9311)	(−0.7355)	**(−7.3688)**	(1.2536)	**(−7.6887)**	(−1.0300)	**(−12.1586)**	(−1.1399)	
10 Year	**0.1700**	−0.1097	−0.0872	**−0.6645**	0.1092	**−0.8967**	−0.0948	**−1.2727**	−0.1560	0.2644
	(2.1996)	(−1.1198)	(−0.8852)	**(−5.5082)**	(0.9109)	**(−9.2584)**	(−1.0043)	**(−13.6563)**	(−1.6798)	
30 Year	**0.2467**	−0.1479	−0.0654	**−0.8106**	0.0961	**−1.2777**	−0.0430	**−2.5766**	−0.1985	0.3237
	(2.1320)	(−0.1097)	(−0.4432)	**(−4.4888)**	(0.5351)	**(−8.8131)**	(−0.3041)	**(−18.4696)**	(−1.4279)	

(Continued)

TABLE IV (*Continued*)

Response of Futures Returns to Current and Lagged Customer Trade Indicator (CTI) Category Orderflow

		Orderflow								
		2 Year		*5 Year*		*10 Year*		*30 Year*		
Futures return	*Intercept*	*Current*	*Lagged*	*Current*	*Lagged*	*Current*	*Lagged*	*Current*	*Lagged*	R^2
					Category 4					
2 Year	**0.0528**	0.0025	−0.0015	**0.1407**	−0.0192	**0.2470**	0.0156	**0.2954**	0.0343	0.1523
	(2.0485)	(0.0836)	(−0.0494)	**(3.5664)**	(−0.4881)	**(8.3340)**	(0.5356)	**(9.9655)**	(1.1569)	
5 Year	**0.1165**	−0.0836	−0.0027	**0.4260**	−0.0448	**0.6112**	0.0417	**0.8027**	0.0996	0.2214
	(2.1309)	(−1.3193)	(−0.0427)	**(5.0924)**	(−0.5361)	**(9.7278)**	(0.6767)	**(12.7751)**	(1.5829)	
10 Year	**0.1726**	−0.1226	0.0355	**0.4191**	−0.0634	**0.9409**	0.0708	**1.3125**	**0.2056**	0.2494
	(2.2170)	(−1.3595)	(0.3978)	**(3.5178)**	(−0.5332)	**(10.5155)**	(0.8074)	**(14.6677)**	**(2.2946)**	
30 Year	**0.2507**	−0.2334	0.0409	**0.6295**	−0.0375	**1.2551**	0.0719	**2.6073**	0.2572	0.3131
	(2.1550)	(−1.7326)	(0.3072)	**(3.5372)**	(−0.2107)	**(9.3896)**	(0.5489)	**(19.5037)**	(1.9211)	

Note. This table presents the response of futures prices to CTI orderflow separated by contract maturity. Each orderflow series represents the residuals of a regression of orderflow regressed on a constant and a time-to-delivery variable. This adjustment accounts for the strong seasonal present in each orderflow series. Coefficients are multiplied by 1,000 and *t*-statistics are shown in parentheses. Bold values represent significance at the 5% level.

In stark contrast stand Categories 2 and 3; for all but the 2-year contract the coefficients are significantly *negative*. This suggests that when Categories 2 and 3 traders buy, the futures prices actually *fall*. At first glance these results seem odd; however, they are consistent with these trades being part of a hedging strategy. Category 4, or retail trades, have a positive and significant impact on futures prices, especially for the 5-, 10-, and 30-year contracts. Furthermore, the fact that the current impact of orderflow is significant and permanent whereas the lagged impact is insignificantly different from zero suggests that Categories 2, 3, and 4 orderflow is not driven by inventory considerations; rather all three categories contribute meaningfully to price discovery in the futures market.[9]

The analogous results for the cash market are shown in Table V. The first panel, labeled "On-the-run," shows results for the most recently issued securities of each maturity. Net orderflow again plays a significant role in determining the movements in prices. The coefficients for the 2- and 5-year note are positive, significant, and strictly increasing with respect to maturity, for all the different maturities. In contrast, the 10- and 30-year contracts are far less informative. The weaker results for the 10- and 30-year maturities may owe, in part, to duration issues that are present when dealing with prices rather than yields. In addition, the scant coverage within GovPX for the 30-year Treasury is also likely a contributing factor here. Like the results for the futures market, movements induced by orderflow are permanent, as seen by the absence of a reversal in the price moves. Thus, the cash results are consistent with work by Brandt and Kavajecz (2004), which shows that movements in the cash yield curve are permanent even absent news announcements and are therefore indicative of price discovery rather than inventory considerations. The second panel further supports results documented in Brandt and Kavajecz (2004), namely that orderflow in on-the-run Treasuries plays a significant role in price discovery for off-the-run Treasuries. In these regressions, the dependent variable is the return on off-the-run Treasuries, whereas the independent variables are the orderflows for the on-the-run securities. Note that, once again, the 2-year on-the-run orderflow is positive and significant in all regressions. In this case, however, the 5-year orderflow is no longer significant.

The study results thus far suggest that locals in the pits (Category 1), in general, do not move prices, at least at the daily frequency, but instead provide short-term liquidity to the market. In contrast, movements

[9]Regressions were also done with up to five (daily) lags of orderflow, and consistent with the results of Table VIII, additional lags displayed little explanatory power over the current net orderflow.

TABLE V

Response of Treasury Cash Returns to Current and Lagged Orderflow

		Orderflow								
		2 Year		*5 Year*		*10 Year*		*30 Year*		
Futures return	*Intercept*	*Current*	*Lagged*	*Current*	*Lagged*	*Current*	*Lagged*	*Current*	*Lagged*	R^2
					On-the-Run					
2 Year	0.0425	**0.1405**	0.0194	**0.2516**	−0.0093	0.0050	0.0079	0.0455	0.0367	0.1317
	(1.5702)	**(5.0161)**	(0.6842)	**(8.8948)**	(−0.3303)	(0.1799)	(0.2807)	(1.5730)	(1.3121)	
5 Year	0.0800	**0.2967**	0.0452	**0.5066**	0.0029	0.0406	0.0174	0.0791	0.0656	0.1310
	(1.4315)	**(5.1231)**	(0.7701)	**(8.6627)**	(0.0501)	(0.7070)	(0.2982)	(1.3218)	(1.1329)	
10 Year	0.1652	**0.4973**	0.0849	**1.0608**	0.0510	0.0788	−0.0077	0.0919	0.0795	0.1507
	(1.6438)	**(4.7765)**	(0.8050)	**(10.0906)**	(0.4872)	(0.7632)	(−0.0738)	(0.8545)	(0.7637)	
30 Year	0.2571	**0.7075**	0.1671	**1.3753**	0.3007	0.2532	−0.0321	0.0363	0.0814	0.1219
	(1.6321)	**(4.3352)**	(1.0104)	**(8.3460)**	(1.8340)	(1.5642)	(−0.1956)	(0.2155)	(0.4990)	
					Off-the-Run					
2 Year	−0.1103	**0.1465**	−0.0171	0.0208	0.0433	0.1018	−0.0564	**0.0584**	0.0612	0.0809
	(−1.6816)	**(2.6695)**	(−0.2876)	(0.3649)	(0.7719)	(1.8055)	(−1.0879)	**(2.0405)**	(1.4350)	
5 Year	−0.2238	**0.3327**	−0.0319	0.0926	0.0911	0.2126	−0.1300	**0.1324**	0.0784	0.0925
	(−1.6706)	**(2.9690)**	(−0.2623)	(0.7962)	(0.7958)	(1.8476)	(−1.2286)	**(2.2667)**	(0.9001)	
10 Year	−0.2213	**0.4117**	0.3767	0.0338	0.0527	**0.4298**	−0.1568	0.1682	0.1692	0.0780
	(−0.9111)	**(2.0268)**	(1.7101)	(0.1601)	(0.2540)	**(2.0601)**	(−0.8176)	(1.5888)	(1.0711)	
30 Year	**−0.9347**	**0.8585**	0.3574	0.4369	0.0486	**0.6882**	**−0.6565**	−0.0252	0.3087	0.0919
	(−2.3050)	**(2.5306)**	(0.9717)	(1.2413)	(0.1402)	**(1.9756)**	**(−2.0499)**	(−0.1425)	(1.1705)	

Note. This table presents the response of Treasury cash returns to net orderflow in the cash market separated by contract maturity. Coefficients are multiplied by 1,000 and *t*-statistics are shown in parentheses. Bold values represent significance at the 5% level.

induced by Categories 2, 3, and 4 trades have a permanent impact on price suggesting that these trades all contribute to price discovery. Retail traders (Category 4) take positions such that prices move in the direction of their trades; thus, as a group they are the driving force behind movements in futures prices. Hedgers in Categories 2 and 3 attenuate movements in futures prices to the extent that they trade opportunistically against retail traders. As in past research, net orderflow is found to be the mechanism through which price discovery is accomplished in the Treasury cash market, with the 2- and 5-year net orderflow being particularly influential.

INTERACTION BETWEEN THE FUTURES AND CASH MARKET

In this section, the joint interaction is investigated between the futures market and the cash market. Although arbitrage dictates that the two markets must be linked, it is an empirical question in which market price discovery originates and how it is disseminated. Specifically, the return in the cash market is regressed on contemporaneous cash and futures orderflow and vice versa. The cash market return regressions are presented in Table VI. Although typically a market's own orderflow is more influential than cross-market orderflow in explaining a market's own return; that is not the case here. The results suggest that net orderflow in the futures market must contribute different information to price discovery in the cash market because the unconditional impact of cash market net orderflow is both quantitatively and qualitatively similar to the impact conditional on the cross market orderflow. Notice that like Table V, orderflow in the 2- and 5-year note are still significantly positively related to cash price movements. However, the futures orderflow is also significantly related to cash price movements for CTI categories 2, 3, and 4. Categories 2 and 3 orderflow is negatively related to cash prices throughout the curve, whereas Category 4 orderflow is positively related to cash prices. As is the case with the cash orderflow, the effect increases in magnitude as one goes toward the long end of the curve. The gain in explanatory power from adding futures orderflow to the cash return regressions is also notable; the adjusted R-squares nearly double with the addition of either Categories 2 and 3 or Category 4 orderflow. These results clearly indicate that trading activity in the futures market contributes significantly to price discovery in the cash market for U.S. Treasury securities.

The results in Table VII concerning the futures returns are also quite interesting with regard to the role of cross-market orderflow.

TABLE VI

Impact of Futures and Cash Net Orderflow on Treasury Cash Returns

		Orderflow								
		Futures net orderflow by CTI category				*Cash net orderflow by maturity*				
Cash return	*Intercept*	*2 Year*	*5 Year*	*10 Year*	*30 Year*	*2 Year*	*5 Year*	*10 Year*	*30 Year*	R^2
					Category 1					
2 Year	0.0312	−0.0046	0.0264	**−0.0737**	−0.0430	**0.1514**	**0.2294**	0.0056	**0.0587**	0.1346
	(1.2257)	(−0.1627)	(0.7369)	**(−2.1442)**	(−1.2841)	**(5.7614)**	**(8.6775)**	(0.2178)	**(2.2623)**	
5 Year	0.0541	0.0884	0.0799	−0.1300	−0.1225	**0.3119**	**0.4655**	0.0385	0.1023	0.1359
	(1.0303)	(1.5229)	(1.0820)	(−1.8352)	(−1.7730)	**(5.7566)**	**(8.5368)**	(0.7303)	(1.9112)	
10 Year	0.1211	**0.2285**	0.1483	−0.0869	**−0.3008**	**0.5267**	**0.9599**	0.0634	0.1368	0.1508
	(1.2795)	**(2.1824)**	(1.1126)	(−0.6795)	**(−2.4123)**	**(5.3875)**	**(9.7549)**	(0.6664)	(1.4158)	
30 Year	0.2230	0.2803	−0.0890	0.1613	−0.3104	**0.7374**	**1.2358**	0.1774	0.1277	0.1094
	(1.4811)	(1.6833)	(−0.4202)	(0.7932)	(−1.5655)	**(4.7432)**	**(7.8977)**	(1.1728)	(0.8309)	
					Category 2 + 3					
2 Year	0.0361	−0.0477	**−0.1649**	**−0.1113**	**−0.1872**	**0.1454**	**0.1702**	−0.0067	0.0458	0.2120
	(1.5004)	(−1.5326)	**(−4.0477)**	**(−3.6565)**	**(−6.3067)**	**(5.8022)**	**(6.5621)**	(−0.2760)	(1.8556)	
5 Year	0.0675	−0.1071	**−0.4419**	**−0.2548**	**−0.4593**	**0.2994**	**0.3233**	0.0120	0.0792	0.2470
	(1.3892)	(−1.7038)	**(−5.3711)**	**(−4.1449)**	**(−7.6640)**	**(5.9174)**	**(6.1716)**	(0.2465)	(1.5889)	
10 Year	0.1413	−0.2129	**−0.6955**	**−0.5835**	**−0.9513**	**0.4884**	**0.6766**	0.0234	0.0901	0.2797
	(1.6282)	(−1.8949)	**(−4.7301)**	**(−5.3121)**	**(−8.8822)**	**(5.4015)**	**(7.2275)**	(0.2685)	(1.0117)	
30 Year	0.2359	−0.1493	**−0.8305**	**−0.9249**	**−1.4388**	**0.6926**	**0.8189**	0.1397	0.0630	0.2247
	(1.6801)	(−0.8216)	**(−3.4914)**	**(−5.2046)**	**(−8.3047)**	**(4.7357)**	**(5.4079)**	(0.9901)	(0.4372)	

(Continued)

TABLE VI (*Continued*)

Impact of Futures and Cash Net Orderflow on Treasury Cash Returns

		Orderflow								
		Futures net orderflow by CTI category				*Cash net orderflow by maturity*				
Cash return	*Intercept*	*2 Year*	*5 Year*	*10 Year*	*30 Year*	*2 Year*	*5 Year*	*10 Year*	*30 Year*	R^2
					Category 4					
2 Year	0.0376	0.0470	**0.0776**	**0.1486**	**0.1859**	**0.1522**	**0.1769**	−0.0078	0.0427	0.2106
	(1.5634)	(1.6355)	**(2.0373)**	**(5.3417)**	**(6.5211)**	**(6.0710)**	**(6.8793)**	(−0.3238)	(1.7308)	
5 Year	0.0701	0.0494	**0.2153**	**0.3374**	**0.4658**	**0.3104**	**0.3369**	0.0137	0.0691	0.2373
	(1.4368)	(0.8458)	**(2.7858)**	**(5.9764)**	**(8.0555)**	**(6.1031)**	**(6.4555)**	(0.2790)	(1.3786)	
10 Year	0.1439	0.0541	**0.3539**	**0.6502**	**0.9909**	**0.5055**	**0.6972**	0.0274	0.0757	0.2695
	(1.6453)	(0.5180)	**(2.5554)**	**(6.4292)**	**(9.5652)**	**(5.5488)**	**(7.4575)**	(0.3122)	(0.8431)	
30 Year	0.2385	0.0690	**0.6810**	**0.7930**	**1.4485**	**0.7178**	**0.8620**	0.1398	0.0407	0.2127
	(1.6856)	(0.4078)	**(3.0397)**	**(4.8466)**	**(8.6429)**	**(4.8701)**	**(5.6990)**	(0.9856)	(0.2806)	

Note. This table presents the impact of futures and cash net orderflow on Treasury Cash returns separated by contract maturity. Coefficients are multiplied by 1,000 and *t*-statistics are shown in parentheses. Bold values represent significance at the 5% level. CTI = customer trade indicator.

TABLE VII

Impact of Futures and Cash Net Orderflow on Treasury Futures Returns

		Orderflow								
		Futures net orderflow by CTI category				*Cash net orderflow by maturity*				
Cash return	*Intercept*	*2 Year*	*5 Year*	*10 Year*	*30 Year*	*2 Year*	*5 Year*	*10 Year*	*30 Year*	R^2
					Category 1					
2 Year	**0.0624**	−0.0024	−0.0039	−0.0631	−0.0514	**0.1621**	**0.2398**	−0.0022	**0.0910**	0.1215
	(2.2511)	(−0.0778)	(−0.0986)	(−1.6822)	(−1.4179)	**(5.6664)**	**(8.2503)**	(−0.0788)	**(3.1701)**	
5 Year	**0.1297**	**0.1545**	0.0214	−0.1362	−0.1206	**0.3834**	**0.5830**	0.0407	**0.1213**	0.1485
	(2.1808)	**(2.3573)**	(0.2542)	(−1.6933)	(−1.5508)	**(6.2478)**	**(9.3505)**	(0.6754)	**(1.9707)**	
10 Year	**0.2194**	**0.2601**	0.1323	−0.1342	**−0.2248**	**0.5333**	**0.8557**	0.0810	0.1418	0.1541
	(2.5921)	**(2.7880)**	(1.1061)	(−1.1722)	**(−2.0303)**	**(6.1054)**	**(9.6402)**	(0.9450)	(1.6173)	
30 Year	**0.3325**	**0.5099**	0.0478	0.0350	**−0.4095**	**0.8065**	**1.4208**	0.1280	0.1691	0.1636
	(2.5167)	**(3.5015)**	(0.2560)	(0.1961)	**(−2.3696)**	**(5.9158)**	**(10.2565)**	(0.9567)	(1.2359)	
					Category 2 + 3					
2 Year	**0.0644**	−0.0614	**−0.1968**	**−0.1542**	**−0.2062**	**0.1529**	**0.1608**	−0.0124	**0.0864**	0.2097
	(2.4535)	(−1.8492)	**(−4.5209)**	**(−4.6219)**	**(−6.3723)**	**(5.6052)**	**(5.6194)**	(−0.4670)	**(3.1600)**	
5 Year	**0.1386**	**−0.1333**	**−0.5751**	**−0.3787**	**−0.6011**	**0.3664**	**0.3669**	0.0185	0.1060	0.2948
	(2.5870)	**(−1.9657)**	**(−6.4737)**	**(−5.5610)**	**(−9.0996)**	**(6.5811)**	**(6.2826)**	(0.3418)	(1.9003)	
10 Year	**0.2285**	**−0.1985**	**−0.6542**	**−0.7167**	**−0.9519**	**0.4986**	**0.5333**	0.0504	0.1077	0.3233
	(3.0415)	**(−2.0884)**	**(−5.2536)**	**(−7.5079)**	**(−10.2812)**	**(6.3903)**	**(6.5146)**	(0.6625)	(1.3772)	
30 Year	**0.3483**	−0.1882	**−0.8094**	**−1.0193**	**−2.1162**	**0.6933**	**0.8570**	0.0815	0.1110	0.3829
	(3.0835)	(−1.3171)	**(−4.3231)**	**(−7.1014)**	**(−15.2010)**	**(5.9094)**	**(6.9624)**	(0.7126)	(0.9442)	

(Continued)

TABLE VII (*Continued*)

Impact of Futures and Cash Net Orderflow on Treasury Futures Returns

		Orderflow								
		Futures net orderflow by CTI category				*Cash net orderflow by maturity*				
Cash return	*Intercept*	*2 Year*	*5 Year*	*10 Year*	*30 Year*	*2 Year*	*5 Year*	*10 Year*	*30 Year*	R^2
					Category 4					
2 Year	**0.0616**	0.0520	**0.1196**	**0.1849**	**0.2080**	**0.1642**	**0.1691**	−0.0097	**0.0816**	0.2106
	(2.3718)	(1.7117)	**(2.9324)**	**(6.0407)**	**(6.7873)**	**(6.0894)**	**(6.0328)**	(−0.3690)	**(3.0176)**	
5 Year	**0.1313**	0.0237	**0.3338**	**0.4804**	0.5956	**0.3909**	**0.3927**	0.0245	0.0959	0.2862
	(2.4495)	(0.3782)	**(3.9643)**	**(7.6021)**	(9.4135)	**(7.0181)**	**(6.7841)**	(0.4521)	(1.7169)	
10 Year	**0.2199**	0.0251	**0.3147**	**0.7952**	0.9775	**0.5258**	**0.5703**	0.0605	0.0981	0.3148
	(2.9192)	(0.2841)	**(2.6594)**	**(8.9555)**	(10.9952)	**(6.7186)**	**(7.0120)**	(0.7943)	(1.2494)	
30 Year	**0.3373**	−0.0751	**0.4363**	**1.0581**	**2.1352**	**0.7353**	**0.9007**	0.0905	0.1024	0.3769
	(2.9752)	(−0.5662)	**(2.4501)**	**(7.9182)**	**(15.9600)**	**(6.2436)**	**(7.3592)**	(0.7898)	(0.8670)	

Note. This table presents the impact of futures and cash net orderflow on Treasury Futures returns separated by contract maturity. Coefficients are multiplied by 1,000 and *t*-statistics are shown in parentheses. Bold values represent significance at the 5% level. CTI = customer trade indicator.

Trading by Categories 2 and 3, and Category 4 groups still explains a substantial amount of the variation in futures returns. However, as in the case of the cash returns, the cross-market orderflow variables also explain a great deal of the variation in returns for each of the futures contracts. Here the orderflow in the 2- and 5-year notes is significantly positively related to futures returns. The contribution to the *R*-squared values is again notable, especially in the case of the Category 1 regressions. But even in the Categories 2 and 3 and Category 4 regressions, adding cash orderflow to the futures return regressions increases the *R*-squared by around 6–7%. In short, the two sets of regressions shown in Tables VI and VII indicate that both the futures and cash markets for Treasury securities contribute substantially to price discovery in the market for riskless securities. The results suggest that futures may be more influential than cash in terms of cross-market effects, particularly for Categories 2, 3, and 4 orderflow.

As a final piece of evidence regarding the cross-market nature of price discovery in the Treasury market, further results are provided for off-the-run Treasuries. Recall that Table V showed that on-the-run orderflow explains a large part of the variation in off-the-run returns. These results are consistent with Brandt and Kavajecz (2004), and show that price discovery in the off-the-run portion of the curve largely occurs in on-the-run securities. Given the arbitrage relation that must hold between the cheapest-to-deliver security and the futures price, and given that the cheapest security is typically off-the-run, which market contributes more to off-the-run price discovery: the cash market or the futures market? Table VIII shows the results of adding futures market orderflow to the regressions run in the second panel of Table V. The results show that again, futures orderflow plays a substantial role. All of the CTI categories come in significant (including Category 1), and their addition increases *R*-squared values sharply. In the most extreme case of the 5-year returns, the *R*-squared increases from 9–35% with the addition of Category 4 orderflow. These results indicate that for off-the-run Treasuries, where the cheapest-to-deliver security typically resides, the futures market contributes more to the price discovery process than trading in on-the-run cash securities.

FORCES INFLUENCING THE CASH/FUTURES RELATION

In the previous section, the case for multidirectional price discovery between the Treasury futures and cash markets was established. In this

TABLE VIII

Impact of Futures and On-the-Run Cash Net Orderflow on Off-the-Run Treasury Cash Returns

		Orderflow								
		Futures net orderflow by CTI category				*Cash net orderflow by maturity*				
Cash return	*Intercept*	*2 Year*	*5 Year*	*10 Year*	*30 Year*	*2 Year*	*5 Year*	*10 Year*	*30 Year*	R^2
					Category 1					
2 Year	−0.0842	−0.0881	**0.2227**	**−0.2328**	0.0464	**0.1500**	**0.2619**	−0.0209	0.0798	0.2717
	(−1.5310)	(−1.2910)	**(2.5770)**	**(−2.4083)**	(0.5453)	**(2.7680)**	**(5.0990)**	(−0.4282)	(1.4853)	
5 Year	−0.1804	−0.1508	**0.4425**	**−0.4349**	0.0352	**0.3524**	**0.6089**	−0.0734	0.1763	0.3118
	(−1.6159)	(−1.0891)	**(2.5223)**	**(−2.2162)**	(0.2039)	**(3.2034)**	**(5.841)**	(−0.7403)	(1.6174)	
10 Year	−0.2542	−0.0651	**1.1098**	**−1.5625**	0.2695	0.2513	**1.0203**	−0.3846	0.0326	0.2233
	(−1.0782)	(−0.2225)	**(2.9953)**	**(−3.7698)**	(0.7385)	(1.0818)	**(4.6339)**	(−1.8357)	(0.1414)	
30 Year	**−0.9554**	−0.2106	0.7224	**−1.6484**	−0.8478	**1.0851**	**1.3897**	−0.4411	0.238	0.1807
	(−2.3843)	(−0.4235)	(1.1469)	**(−2.3397)**	(−1.3666)	**(2.7477)**	**(3.7133)**	(−1.2387)	(0.6081)	
					Category 2 + 3					
2 Year	−0.0382	−0.04	**−0.2489**	**−0.1736**	−0.0911	**0.1252**	**0.2103**	−0.0446	0.0791	0.2725
	(−0.6859)	(−0.4036)	**(−2.2268)**	**(−2.0832)**	(−1.4005)	**(2.2712)**	**(3.9445)**	(−0.9038)	(1.4759)	
5 Year	−0.0772	−0.0921	**−0.5716**	−0.3262	**−0.2714**	**0.2951**	**0.4873**	−0.123	0.1774	0.3313
	(−0.6928)	(−0.464)	**(−2.5546)**	(−1.9558)	**(−2.0854)**	**(2.6743)**	**(4.5663)**	(−1.2439)	(1.6542)	
10 Year	−0.0372	−0.0174	**−1.1282**	−0.5929	−0.3872	0.2169	**0.7887**	**−0.5267**	0.0609	0.1788
	(−0.1517)	(−0.0398)	**(−2.2883)**	(−1.6131)	(−1.3502)	(0.8921)	**(3.3543)**	**(−2.4178)**	(0.2579)	
30 Year	−0.6432	−0.2204	−1.4216	−0.709	**−1.0277**	**0.8683**	**1.0294**	−0.5464	0.1457	0.1856
	(−1.5903)	(−0.3058)	(−1.7495)	(−1.1705)	**(−2.1744)**	**(2.1672)**	**(2.6566)**	(−1.5221)	(0.3742)	

(Continued)

TABLE VIII (*Continued*)

Impact of Futures and On-the-Run Cash Net Orderflow on Off-the-Run Treasury Cash Returns

		Orderflow								
		Futures net orderflow by CTI category				*Cash net orderflow by maturity*				
Cash return	*Intercept*	*2 Year*	*5 Year*	*10 Year*	*30 Year*	*2 Year*	*5 Year*	*10 Year*	*30 Year*	R^2
					Category 4					
2 Year	−0.0438	**0.1946**	0.1101	**0.3336**	0.1121	**0.1164**	**0.2154**	−0.0365	0.0862	0.3036
	(−0.804)	**(2.3043)**	(0.9414)	**(4.2486)**	(1.7568)	**(2.1775)**	**(4.1227)**	(−0.7641)	(1.6417)	
5 Year	−0.0879	**0.3845**	0.2966	**0.6701**	**0.3197**	**0.2814**	**0.4953**	−0.1097	0.1945	0.3565
	(−0.8043)	**(2.2682)**	(1.2638)	**(4.2513)**	**(2.4965)**	**(2.6222)**	**(4.7232)**	(−1.1451)	(1.8444)	
10 Year	−0.0813	0.409	0.2834	**1.4523**	0.4258	0.1484	**0.8178**	**−0.488**	0.0415	0.2101
	(−0.3378)	(1.0953)	(0.5483)	**(4.1828)**	(1.5095)	(0.6279)	**(3.5403)**	**(−2.3134)**	(0.1788)	
30 Year	−0.6125	0.9305	1.3802	**2.0124**	**1.2984**	**0.7806**	**0.9756**	−0.5564	0.201	0.2271
	(−1.5544)	(1.5221)	(1.6311)	**(3.5403)**	**(2.8116)**	**(2.017)**	**(2.5798)**	(−1.611)	(0.5285)	

Note. This table presents the impact of futures and cash net orderflow on Treasury Cash returns separated by contract maturity. Coefficients are multiplied by 1,000 and *t*-statistics are shown in parentheses. Bold values represent significance at the 5% level. CTI = customer trade indicator.

section, we take a more comprehensive approach by investigating two outside forces that may influence the extent and/or direction of the cash/future relation. The costs of financing the purchase of fixed income securities as well as the liquidity environment in the cash market are conjectured to have a substantial impact on Treasury yield curve movements.

The rationale for considering these outside forces stems from the following background. First, due to Brandt and Kavajecz (2004), as well as results presented above, the on-the-run orderflow drives changes (price discovery) in the cash market. Second, has as shown above (and has been shown elsewhere), price discovery occurs in *both* the underlying and derivatives markets. Third, prices in the fixed income futures market apply *directly* to the cheapest-to-deliver issues, which are almost always off-the-run issues. Given these observations, it stands to reason that there is no *direct mechanism* (rather there is an indirect link due to the cheapest-to-deliver typically being off-the-run securities) by which the futures market is the primary location for price discovery and can move the cash curve. Said differently, even though price discovery occurs in the futures market, it has a *direct* impact on the off-the-run (CTD issues) securities, which has a muted impact on the current (on-the-run) curve. Thus, what alters the relative attractiveness of transacting between the futures and cash market?

We hypothesize that the cost of financing (Repo rates), as well as the liquidity of the Treasury cash market are key determinants of where price discovery takes place. If a trader is deciding between obtaining exposure to interest rate movements either through the cash market or the futures market, what is paramount is the relative cost of the required exposure in the two markets.

With regard to financing rates, a trader wishing to buy an on-the-run issue that is on special (i.e., the applicable repurchase agreement rate is lower than the analogous rate for general collateral), will pay relatively more than he would for an issue that is not on special because the issue on special is in high demand (or short supply). However, if the on-the-run issue is not on special, that same trader would be able to pay a lower price for the issue, albeit the applicable Repo rate would necessarily be higher. In addition, it may be more difficult to establish a short position in the cash market when the security is on special, as it would be more difficult to locate a security to deliver. Under this scenario, we hypothesize that specialness in a Treasury issue will induce price discovery to take place in the futures market, whereas more price discovery will take place in the cash market during periods when the issue can only be "Repoed" at the general collateral rate.

Finally, it is well understood that liquidity in a market, defined by the bid-ask spread and quoted depth, is a prime determinant of transaction costs. Financial theory suggests that liquidity is a function of the level of adverse selection risk within a market. In particular, when there is a high level of informed trading, spreads widen and depths fall, thereby reducing liquidity. Trading venues that have high levels of informed trading contribute relatively more to price discovery. Thus, we hypothesize that precisely when the Treasury cash market is less liquid is when informed traders are transacting in the cash market, which, in turn, leads to relatively more price discovery occurring in the cash market.

These hypotheses are tested by rerunning the orderflow regressions conditioning on measures for each of the variables described above. Specifically, a dummy variable is created for each maturity/contract that identifies periods of specialness (defined as a specialness being in the upper quintile of its distribution for the entire sample) and illiquidity (defined as the bid-ask spread being in the upper quintile of its distribution over the sample for that maturity). These dummy variables are multiplied by the net orderflow variables to form interaction terms, which allow us to measure the conditional impact of specialness and illiquidity on the price discovery relation.

Our hypothesis concerning financing rates suggests that specialness will shift price discovery to the futures market. Under this hypothesis, the impact of cash net orderflow would be muted and futures net orderflow would be accentuated during periods of specialness. Thus, interaction terms with cash net orderflow should be negative (muting the strong positive impact) and interaction terms with futures net orderflow positive for Category 4.[10] Tables IX and X present the results; for brevity only the interaction terms are shown, although all the unconditional variables (not shown) maintain their sign and significance from the previous analysis. Panel A shows results for the impact of futures orderflow on cash returns. Consistent with our hypothesis, the coefficients of the 5- and 30-year interaction terms take on the appropriate sign and are significant in three of the four cases, whereas the interaction terms for 2- and 10-year futures contracts are insignificantly different from zero. In addition, panel B shows that orderflow in the on-the-run 5-year note becomes relatively less important in explaining futures returns when the 5-year note is on special. In general, the results confirm our hypothesis that the futures market will become relatively more important during

[10]For brevity, we only display results for Category 4 orderflow. As expected, results for Categories 2 and 3 are similar in nature, but in the opposite direction.

TABLE IX
Cross-Market Orderflow Impact When Cash Treasury Is on Special

Panel A
Futures net orderflow interaction variable by maturity

Cash return	*2 Year*	*5 Year*	*10 Year*	*30 Year*
		Category 4		
2 Year	−0.0010	**0.2086**	0.0350	0.1164
	(−0.0136)	**(2.1375)**	(0.4692)	(1.6940)
5 Year	−0.0107	**0.4072**	0.1247	**0.3001**
	(−0.0675)	**(2.0601)**	(0.8255)	**(2.1596)**
10 Year	−0.0794	0.3037	0.3282	**0.5289**
	(−0.2778)	(0.8548)	(1.2106)	**(2.1201)**
30 Year	−0.2427	−0.9717	0.2154	**0.8500**
	(−0.5252)	(−1.6930)	(0.4911)	**(2.1070)**

Panel B
Cash net orderflow interaction variable by maturity

Futures return	*2 Year*	*5 Year*	*10 Year*	*30 Year*
		Category 4		
2 Year	0.0587	**−0.1656**	−0.0070	−0.0871
	(0.8277)	**(−2.4711)**	(−0.1100)	(−1.2482)
5 Year	0.1151	**−0.2762**	−0.0081	−0.0374
	(0.7929)	**(−2.0107)**	(−0.0618)	(−0.2620)
10 Year	0.1682	−0.3337	−0.0063	0.0276
	(0.8290)	(−1.7378)	(−0.0344)	(0.1380)
30 Year	−0.1461	−0.3724	−0.0753	0.2469
	(−0.4795)	(−1.2904)	(−0.2747)	(0.8232)

Note. This table presents the impact of futures net orderflow on cash Treasury returns when the given on-the-run Treasury is trading on special in the repo market. Futures net orderflow is interacted with a dummy that is equal to 1 when the given maturity Treasury is trading in the upper quintile of specialness over the entire sample. In panel A, each estimate shown represents the interaction term added to the regressions shown in Table VII for CTI4 orderflow. In panel B, each estimate shown represents the interaction term added to the regressions shown in Table VI for CTI4 orderflow. Only the coefficient estimates and *t*-statistics (shown in parentheses) for the interaction variables are shown. Bold values represent significance at the 5% level.

periods where specialness in the on-the-run Treasury is high, with the 5- and 30-year maturities most affected.

Our hypothesis concerning liquidity implies that illiquidity in the cash market is a manifestation of the presence of informed traders, thus a primary location for price discovery. Under our hypothesis, cash market

TABLE X
Cross-Market Orderflow Impact When Cash Treasury Is Illiquid

Panel A
Futures net orderflow interaction variable by maturity

Cash return	*2 Year*	*5 Year*	*10 Year*	*30 Year*
		Category 4		
2 Year	−0.0499	−0.1408	−0.1033	**0.1649**
	(−0.6568)	(−1.4947)	(−1.5971)	**(2.3392)**
5 Year	−0.2494	−0.1420	−0.1914	**0.4583**
	(−1.6236)	(−0.7437)	(−1.4614)	**(3.2183)**
10 Year	−0.4711	−0.4206	**−0.5021**	0.4308
	(−1.7087)	(−1.2277)	**(−2.1382)**	(1.6795)
30 Year	−0.4091	−1.0675	**−1.9090**	−0.3448
	(−0.9168)	(−1.9289)	**(−5.0758)**	(−0.8306)

Panel B
Cash net orderflow interaction variable by maturity

Futures return	*2 Year*	*5 Year*	*10 Year*	*30 Year*
2 Year	0.0017	**0.2678**	−0.0836	0.1571
	(0.0210)	**(2.7616)**	(−0.7976)	(1.6523)
5 Year	0.1985	**0.6529**	−0.1515	0.3169
	(1.1850)	**(3.2927)**	(−0.7060)	(1.6271)
10 Year	0.3575	**1.2263**	−0.0208	0.3948
	(1.5277)	**(4.4436)**	(−0.0695)	(1.4504)
30 Year	**0.7556**	**1.9897**	0.2976	0.5054
	(2.1518)	**(4.8073)**	(0.6607)	(1.2358)

Note. This table presents the impact of futures net orderflow on cash Treasury returns when the given on-the-run Treasury is less liquid in the cash market. Futures net orderflow is interacted with a dummy that is equal to 1 when the given maturity Treasury exhibits a bid-ask spread in the upper quintile of its distribution over the entire sample. In panel A, each estimate shown represents the interaction term added to the regressions shown in Table VII for CTI4 orderflow. In panel B, each estimate shown represents the interaction term added to the regressions shown in Table VI for CTI4 orderflow. Only the coefficient estimates and *t*-statistics (shown in parentheses) for the interaction variables are shown. Bold values represent significance at the 5% level.

interaction terms should reinforce the positive impact that cash market orderflow has on Treasury prices. The results (shown in Table X) are generally consistent with our hypothesis, with the exception of trading in the 30-year futures contract. Panel A shows that Category 4 orderflow in the 10-year futures contract becomes less important in explaining cash returns when the 10-year cash Treasury is illiquid. Orderflow in the

30-year contract, however, actually becomes more useful in terms of its ability to explain 2- and 5-year cash returns when the 30-year Treasury is relatively illiquid. Panel B shows that trading activity in both the 2- and 5-year notes takes on increased importance in explaining futures returns when the cash market is relatively illiquid. This is also consistent with our hypothesis concerning contributions to price discovery when the cash market is illiquid.

In general, the results in this section suggest that where price discovery takes place depends on two important environmental variables: financing (Repo) rates and liquidity. Moreover, the impact on prices of orderflow in the 5-year maturity appears to be a focal point for these effects as it is especially influenced by these factors.

CONCLUSION

The goal of this study is to understand the forces that shape movements in the Treasury yield curve. Orderflow within the cash market for U.S. Treasuries has been shown to be an important conduit through which price discovery takes place; nevertheless, the trading of fixed income futures is another important facet of this market that needs to be understood if a complete picture of yield curve movements is to be painted.

How prices respond to information flows in the fixed income futures market were analyzed. As in the cash market, the results reinforce the notion that orderflow drives movements in the futures prices. In particular, the type of trader executing the trade has an impact, with retail traders moving futures prices significantly in the direction of their trades, exchange members moving futures prices significantly against their trades likely owing to hedging demands, and local market makers who supply short-term liquidity, having little long term impact on futures prices. In the Treasury cash market, trading in the 2- and 5-year notes play significant roles in price discovery as they have significant effects on prices along the entire yield curve.

When the joint interaction of orderflow between the cash and futures markets is considered, both markets contribute to price discovery as net orderflow in each market has explanatory power in explaining price changes in both the Treasury cash and futures market contemporaneously. As such, the results suggest that futures and cash net orderflow contain information that is different from the information contained in trading activity in the other market. Specifically, net orderflow in the 2- and 5-year Treasury cash market has significant explanatory power

over price movements in both markets, as do futures net orderflow from both exchange members and retail traders. On the one hand, net orderflow originating on the short end of the cash market (2- and 5-year maturities) and retail trades on the long end of the futures market push up prices and steepen the entire yield curve. On the other hand, net orderflow originating from exchange members in the futures market depresses prices and flattens the entire yield curve. In addition, trading in the futures market has a substantial impact on price discovery within off-the-run Treasury securities.

The above analysis reveals the unconditional relation between price discovery in the two markets. The direction and extent of price discovery is influenced by environmental variables such as Repo financing rates and liquidity. Consistent with our hypothesis, specialness causes price discovery to occur relatively more in the futures market because transacting in the cash market when the issue is on special is exceedingly expensive. Moreover, illiquidity, measured by wide bid-ask spreads, in the cash market is associated with relatively more price discovery occurring in the cash market as asymmetric information is high and therefore, informed traders are likely transacting in that market. Interestingly, the instrument of central importance to the above results is the 5-year maturity in both the futures and cash market, largely to the exclusion of the other maturities.

In conclusion, this analysis highlights the importance of considering the relation between separate, but related markets, and not simply analyzing the behavior of a market in isolation. As market participants are always comparing the costs and benefits of transacting in related markets, so too should our models of the fixed income market. Failure to account for cross-market effects, at best, paints an incomplete picture, and at worst may lead to inaccurate conclusions.

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