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Strategic trading behavior and price distortion in a manipulated market: anatomy of a squeeze ☆

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Abstract

This paper investigates an attempted delivery squeeze in a bond futures contract traded in London. Using cash and futures trades of dealers and customers, we analyze their strategic trading behavior, price distortion, and learning in a market manipulation setting. We argue that marked differences in settlement failure penalties in the cash and futures markets create conditions that favor squeezes. We recommend that regulators require special flagging of forward term repurchase agreements on the key deliverables that span futures contract maturity dates, and that exchanges mark-to-market

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their contract specifications more frequently, or consider a cash-settled contract on a basket of bonds.

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1. Introduction

History is filled with instances of individuals and corporations manipulating securities markets and attempting to generate high private returns from acquiring and exercising market power in securities trading. Well-publicized major manipulation episodes have occurred in bond markets,[1] in commodity markets and their futures contracts,[2] and also in equity markets.[3] Manipulative grabs for pricing power are neither uncommon, nor even have the appearance of impropriety, in self-regulated over-the-counter markets such as the government bond markets of the United Kingdom and the United States. For example, a U.K. or U.S. bond dealing firm might acquire a large position in a particular issue and then partially restrict its availability in the market. Such an action could turn the issue "special" so that the firm could generate trading profits on its bond inventory and/or obtain disproportionately good financing rates using the bond as collateral.[4]

Even though there have been innumerable cases of often serious market manipulations reported in securities markets worldwide, surprisingly little is documented about the trading behavior of major players in manipulated markets. Early empirical research on market manipulation is largely confined to the study of

[1]Examples include the Eurex BOBL squeeze in March 2001, the London International Financial Futures and Options Exchange's (LIFFE's) Italian Government Bond futures contract squeeze in September 1997, the Tokyo Stock Exchange September 1996 Japanese Government Bond futures squeeze, the squeeze pressures in the Chicago Board of Trade's Treasury bond futures contract through 1993 and 1994, the Salomon Brothers U.S. Treasury note squeeze in May 1991, and the alleged cornering of the 2016 U.S. Treasury bond issue by Japanese investors in the February 1986 auction.

[2]There have been innumerable alleged attempts to corner commodities markets, for example, episodes in the oil (Exxon, 1996), tin (1980 to 1981 and 1984 to 1985), silver (the Hunt family, 1979 to 1980), and soybean (the Hunts again, 1977) markets, to name a few. See Pirrong (1995) for numerous episodes of market manipulation at the Chicago Board of Trade and other U.S. and international exchanges, and the shortcomings of self-regulation by the exchanges.

[3]Jarrow (1992) relates a collection of early references on attempted corners in individual common stocks. Lefebrve's (1994) lively *Reminiscences of a Stock Operator* contains several discussions of manipulations. A casual web search also yields a large number of press reports of market manipulation in equity markets. In particular, in the U.S. in battles involving corporate insiders, it is not uncommon for these insiders to collude with shareholders to engineer short squeezes, i.e., situations in which short-sellers are forced to cover their short position due to their not being able to borrow shares because these shares have been withdrawn from the share lending market.

[4]Duffie (1996) and Chatterjee and Jarrow (1998) discuss causes of repo specialness. See Jordan and Jordan (1998) for an empirical analysis of bond pricing effects of repo specialness.

the May 1991 Salomon squeeze (Jegadeesh, 1993; Jordan and Jordan, 1996) and the price distortion of the 30-year U.S. Treasury bond in 1986 (Cornell and Shapiro, 1989). Our paper is the first to investigate both the price distortions as well as the trading positions of market participants during a major market manipulation episode. We analyze the six-month period of an attempted delivery squeeze in the March 1998 long-term U.K. government bond futures contract traded on the London International Financial Futures and Options Exchange (LIFFE).

A classic manipulative delivery squeeze in a bond futures contract takes place when a manipulator acquires a substantial long position in the futures contract and a sizeable fraction of its cheapest deliverable bond issue. The squeezer attempts to profit by restricting the supply of the cheapest deliverable issue. This action increases the price of the original cheapest-to-deliver issue and simultaneously forces holders of short futures contract positions to either deliver more highly valued bond issues or else buy back their futures contract positions at inflated prices.

Futures market participants, futures exchanges, and futures markets regulators are all very concerned about delivery squeeze attempts since they distort prices, hamper price discovery, and create deadweight losses (see Pirrong, 1993). In particular, squeeze-generated sustained price distortions erode the beneficial economic role of futures markets by significantly reducing the effectiveness of the contract for hedging (see, e.g., Figlewski, 1984; Merrick, 1988). Moreover, because of the high volume of futures trading, a much larger market population feels the adverse impact of delivery squeezes relative to a cash market squeeze in any particular issue. Importantly, since the scale of futures trading can be a large multiple of trading in any individual cash market issue, bond futures contracts provide a feasible way to acquire more than 100% of the cheapest deliverable issue's supply. The judicious choice of different execution brokers and clearing accounts can help cloak the manipulator's accumulation of a major position.[5] Unfortunately, while extensively acknowledged, there has been no investigation of strategic trading behavior of market manipulators during delivery squeezes.[6]

[5]Such accumulation is perfectly legal. In contrast, in the May 1991 Treasury squeeze, Salomon Brothers accumulated a sizeable fraction of the target issue via illegal bidding activity in a Treasury auction. For a discussion of squeeze-related issues in the context of auctions, see Nyborg and Sundaresan (1996), Nyborg et al. (2001), and Nyborg and Strebulaev (2001, 2004). Although important, this literature has limited implications for squeezes that arise during the course of trading of a futures contract (see Section 6.8). In the popular press, hedge funds have often been accused of market manipulation. For academic investigation of this allegation and hedge funds' risk exposures, see Brown et al. (1998), Fung and Hsieh (2000), Fung et al. (2000), and Agarwal and Naik (2004).

[6]The only research that relates, albeit indirectly, to delivery squeezes is that of Jordan and Kuipers (1997), which traces the appearance of negative option value in a callable U.S. Treasury bond to its cheapest-to-deliver status against the CBOT Treasury bond futures contract. Academic attention on the distorting influences of futures trading on pricing in the cash markets has focused on volatility effects (e.g., see Figlewski, 1981).

Our joint examination of price distortions and inventory positions of market participants is based on a rich dataset consisting of the cash and futures trades reported by individual bond dealers and the Exchange to the U.K. Financial Services Authority (FSA), the chief government regulator. First, we document the extent of price distortions, i.e., the deviations of the cheapest deliverable bond's price from its discounted cash flow value derived from the prevailing term structure. Following Kyle's (1984) model of a squeeze, we also compare the price of the futures contract to its full-squeeze and no-squeeze values (derived from the discounted cash flow values of the first-and the second-cheapest deliverable bonds) and estimate the risk-neutral squeeze probability implied by the futures price. Following industry practice, we also compute butterfly yield spreads where the "center" is the cheapest deliverable issue and the "wings" are two other bond issues with adjacent maturities. Using these metrics, we identify different phases of the squeeze.

Second, we track the positions of all dealers and their customers across the different phases of the squeeze. From these inventory positions, we identify two dominant and opposing trading styles among the market participants active in the squeeze, styles that correspond to "squeezers" and "contrarians", where squeezers are market players who initiate the squeeze and those who reinforce the squeeze, and contrarians are market players who aggressively speculate that the squeeze attempt will not succeed.

Third, we identify three main ways squeezers build up their long positions in the cash market: purchase of the cheapest deliverable issue, purchase of bond futures contracts, and utilization of forward repurchase agreements. These last agreements involve a simultaneous forward purchase of the cheapest deliverable issue for settlement prior to, and a companion forward sale for settlement after, the futures delivery date. Because forward repurchase trades provide control of the cheapest deliverable issue across the futures contract delivery date, they are extremely important from the perspective of the squeeze.

Fourth, since strategic traders try to manipulate market prices in order to profit from the manipulation, we compute both the raw profits and the abnormal profits (i.e., raw profits less the contribution from market-wide changes in the term structure of interest rates) of strategic traders (i.e., squeezing and contrarian customers and dealers) over the different phases of the squeeze. We also measure the profits of the remaining market participants that did not actively participate in the squeeze in a major way.

Fifth, in the context of market microstructure literature, we examine whether market depth is adversely affected by the strategic trading behavior of market participants. In this regard, we shed light on how the price of the squeezed bond relates to trading flows of market participants. In the context of the information content of the order flow, we document the relation between the proprietary trades of individual dealers and their customers; specifically we find evidence of learning and concerted action. We also show how information about a potential squeeze was disseminated to the market-at-large.

Finally—and, importantly, from a regulatory perspective—we show how squeeze attempts are facilitated by the marked differences that exist in conventions among the cash bond market, the bond repurchase agreements (repo) market, and the futures market regarding settlement nonperformance. Futures exchanges, for instance, levy heavy fines on contract shorts that fail to deliver against an outstanding short position. No such penalty exists for traders who fail to perform on their obligations in the cash bond and bond repurchase agreement markets. We show that this has important implications for the cross-market cash-futures arbitrage pricing relation, since arbitrageurs cannot use repos to fund their cash positions in the presence of a squeeze. Consistent with this expectation, and contrary to what one would expect from the "specialness" of the cheapest deliverable issue, we show that LIBOR replaces the general collateral rate as the marginal implied funding rate as the risk of strategic failure to perform on the obligations increases. In this context, we also show how a narrowly targeted temporary change in repo market policy announced by the Bank of England successfully ended the squeeze analyzed in this paper.

This investigation of price distortions and trading positions of participants is of significant interest to both academics and market regulators. From an academic perspective, this paper provides empirical evidence on the strategic trading behavior of major market participants (both dealers and customers) in a market manipulation setting, and illustrates how learning takes place in the market place. From a regulatory perspective, this paper offers several messages. First, regulators and exchanges need to be very concerned about ensuring that squeezes do not take place, since they are accompanied by severe price distortions, and erosion of market depth, which randomly penalizes hedgers. Second, regulatory reporting should require flagging of trades such as forward term repos that provide control of key deliverable issues against the futures contracts—these trades can go unnoticed under current reporting systems, and may also slip through the internal controls of dealers as they do not change net duration risk exposures of individual traders. Third, regulators and exchanges should take notice of the fact that the marked asymmetry in penalties for settlement failures between cash and futures markets creates conditions that engender squeezes. Finally, futures exchanges should remove the sources of opportunities for squeezes in the first place. Towards this end, the exchanges should mark-to-market the specifications of their bond contracts much more frequently than they do at present, so that the prevailing market conditions do not differ dramatically from those assumed in the calculation of conversion factors. Moreover, futures exchanges should also consider requiring that their bond futures contracts be cash-settled on a basket of traded bonds, rather than requiring physical delivery against a contract specified on a bond with a notional coupon and maturity.

The remainder of this paper is organized as follows. Section 2 analyzes the theoretical and institutional framework relevant to delivery squeezes. Section 3 describes the data. Section 4 describes the conditions that generated the opportunity for the squeeze we investigate in this paper. Section 5 examines different metrics of price distortions to identify the different phases of the squeeze. Section 6 investigates trading flows and trader behavior during the squeeze. Section 7 analyzes the impact on squeezes of settlement nonperformance conventions in the cash and futures markets. Section 8 offers concluding remarks.

2. Theoretical and institutional framework

2.1. Delivery convergence for conversion factor-based bond futures contracts

Bond futures contracts typically allow shorts to deliver any one of a predetermined basket of deliverable issues during the contract delivery month.[7] By basing the contract on a basket of potentially deliverable issues, rather than on a single issue, the exchanges aim to reduce the incidence of market manipulation. Since the market values of the alternative deliverable bonds differ, exchanges apply conversion factors in an attempt to make the different bonds equivalent in value for delivery purposes. The LIFFE, like the CBOT, calculates the conversion factor for each bond by discounting the individual bond's remaining cash flows using the assumption that the spot yield curve is flat at the level of the notional coupon defined in the futures contract. Clearly, if the level of the spot yield is significantly different from the defined notional coupon, or, if the slope of the yield curve differs significantly from zero, the conversion factors defined by the exchange will not equate the net delivery costs of all eligible deliverable issues.[8] In particular, one bond issue will become the cheapest deliverable issue (hereafter, *cdi*1). The presence of arbitrageurs implies that the futures contract will be priced off the price of *cdi*1. This also means that buyers of futures contracts can effectively acquire a position in *cdi*1 that is greater than the issue size of that bond.

Let P_i be the delivery date price of the ith deliverable issue, cf_i be the conversion factor for the ith issue, and F^{ns} be the last futures price prior to delivery under normal market conditions (i.e., under a no-squeeze scenario). The basis, which equals the short's loss-on-delivery of the ith issue, is defined as

$$\text{Basis}_i = P_i - cf_i F^{\text{ns}} = \text{Loss on delivery}_i. \tag{1}$$

The variable *cdi*1 denotes the bond that minimizes the difference between the market price and the invoice price of the delivered bond at the time of delivery. The futures price at contract maturity under a no-squeeze scenario is given by

[7]On the CBOT, the T-bond futures contract makes all issues with maturity or date-to-first-call greater than 15 years eligible for delivery. On the LIFFE, for the March 1998 Long Gilt contract, eligible gilts include those issues with between 10 to 15 years-to-maturity. The short decides which bond to deliver (the quality option), and also when to deliver during the delivery month (the timing option). There exists an extensive literature on these quality and timing options. See, for example, Kane and Marcus (1986), Boyle (1989), Hemler (1990) and Barnhill (1990). Chance and Hemler (1993) provide a review. From the perspective of this paper, however it is important to note that the quality option is unlikely to be important at the time of a squeeze, since squeezes typically take place only if there is a significant difference between the cheapest-to-deliver bond and the next-cheapest-to-deliver bond. Also while the timing option can continue to be important in a squeeze setting, Boyle's (1989) simulations show that the value of the timing option is much smaller than the value of the quality option.

[8]See Kilkollin (1982) for biases that conversion factor systems of this type introduce into the delivery mathematics. See Garbade and Silber (1983) for a more general discussion of penalty-versus-equivalence systems for quality adjustments on contracts with multiple varieties.

the zero profit condition

$$F^{\text{ns}} = P_{cdi1}/cf_{cdi1} = \operatorname*{Min}_{i}(P_i/cf_i). \tag{2}$$

The no-squeeze cash market price for the ith issue with n_i periods to maturity equals the present value of its cash flows $C_{i,t}$ using the default-free discount factors, h_t:

$$P_i^{\text{ns}} = \sum_{t=1}^{n_i} C_{i,t}h_t. \tag{3}$$

2.2. Pricing during a squeeze

Cash and futures contract market pricing can be distorted by the actions of a strategic investor (or group of investors). For instance, the strategic investor can acquire a large long position in the futures contract, in *cdi*1, and in repo agreements on *cdi*1 written over the futures delivery date. This futures-cash-repo strategy increases the quantity of contracts that must settle through physical delivery and reduces the supply of *cdi*1 available for delivery.

Consider the case in which the strategic investor accumulates a large long futures position at a fair price (i.e., a price consistent with the no-squeeze scenario given in Equations (2) and (3)). The objective of the manipulative short squeeze strategy is to force at least some fraction of the outstanding futures contract shorts to acquire and deliver what would normally be the second-cheapest deliverable issue, i.e., *cdi*2. Let P_{cdi2} denote the delivery date price of *cdi*2. Under a squeeze scenario, cash and futures prices increase. In the case of a full squeeze, both *cdi*1 and *cdi*2 become equally cheap to deliver, and the futures price rises to the converted price of *cdi*2

$$F^{\text{s}} = P_{cdi2}/cf_{cdi2} = \operatorname*{Min}_{i \neq cdi1}(P_i/cf_i). \tag{4}$$

The futures price reflects the marginal cost of making delivery on *cdi*2. A competitive short is willing to pay up to F^{s} to liquidate the short futures position.[9] Consequently, the price of *cdi*1 rises until the following condition is satisfied:

$$F^{\text{s}} = P_{cdi2}/cf_{cdi2} = P^{\text{s}}_{cdi1}/cf_{cdi1}, \tag{5}$$

where P^{s}_{cdi1} denotes the price of *cdi*1 under a full-squeeze scenario.[10] The price of the squeezed issue, P^{s}_{cdi1}, no longer conforms to the level consistent with pure discounted cash flow valuation, P^{ns}_{cdi1}. That is,

$$P^{\text{s}}_{cdi1} = (cf_{cdi1}/cf_{cdi2})\sum_{t=1}^{n_2} C_{2,t}h_t > \sum_{t=1}^{n_1} C_{1,t}h_t = P^{\text{ns}}_{cdi1}. \tag{6}$$

[9] As in Kyle (1984), the final futures price rises to make the second issue equal in delivery value with the first issue even if only a fraction of deliveries take place with the second issue. See Salant (1984) for a comment on Kyle's (1984) stylized model of a squeeze.

[10] If only one issue has been squeezed, the cash price of the *cdi*2 issue remains at its normal discounted cash flow value. If the manipulator's positions are large enough relative to the sizes of *cdi*1 and *cdi*2, then even the third- or fourth-cheapest-to-deliver issues can also get "squeezed in."

In trades for post-delivery settlement, the cash price of *cdi*1 reverts to its normal discounted cash flow value. Clearly, one useful measure of the squeeze potential is given by

$$\textit{Squeeze Potential} = F^{\mathrm{s}} - F^{\mathrm{ns}}. \tag{7}$$

In the spirit of Kyle (1984), one can relate the futures price F with F^{s} and F^{ns}, and infer an implied risk-neutral probability π of the success of the squeeze,

$$\pi = \frac{F - F^{\mathrm{ns}}}{F^{\mathrm{s}} - F^{\mathrm{ns}}}. \tag{8}$$

3. Data and salient features of U.K. government bond market

Trading in U.K. government bonds (known as "gilts") takes place in a competitive over-the-counter dealership environment where roughly 15–20 dealers compete with each other to execute the order flow.[11] These dealers are typically major investment houses, or their subsidiaries or affiliates (see Table 1 for an illustrative list of dealers during 1997 through 1998). Each dealer is required to report all trades in each bond issue and in all futures contracts to the Financial Services Authority, the chief financial markets government regulator in the U.K. These reports (running from September 1997 through March 1998) form one major source of the data used in this study.

Our data include all trades of each dealer and their affiliates in the March 98 Long Gilt futures contracts and the key 9% 2008 deliverable issue. We analyze the transactions of 17 dealers and their customers in the cheapest deliverable issue and in the March 98 futures contract. Our data includes 100% of the trading volume in the key deliverable issue and about 70% of the volume in the March 98 futures contract.[12] The data provide the name of the security, the identities of buyer and seller, the transaction price and quantity, the date and time of the transaction, the trade settlement date, the direction of trade (buy or sell), the dealing capacity of buyer and seller (principal or agent), and any special conditions. These data enable us to calculate, for each dealer and each customer, the running inventory positions (par value of bonds, and, whether long or short) in the deliverable issue, and the number of contracts (long or short) in the March 98 futures contract.

We also use data from two other sources. First, we use Lehman Brothers' proprietary daily cash gilt bid-side prices marked at the close of futures trading to

[11] See Proudman (1995), Vitale (1998), and Hansch and Saporta (1999) for microstructure details of the U.K. government bond market, and Naik and Yadav (2003a) for microstructure details of the U.K. equity market.

[12] This percentage is estimated by comparing trades executed by the dealers on their own account as well as on the behalf of their customers in March 98 Long Gilt futures contract with all trades reported in the LIFFE dataset. The remaining 28% can be attributed to market participants who trade in the futures contract but do not involve the dealers in our cash issue sample.

Table 1
This table provides an illustrative list of dealer firms in the U.K. government bond market during the 1997–1998 sample period

Barclays
Credit Suisse First Boston
Daiwa Securities
Deutsche Bank
Dresdner Kleinwort Benson
Goldman Sachs
HSBC
J P Morgan
Lehman Brothers
Merrill Lynch
Morgan Stanley
National Westminster Bank
Nikko Securities
Salomon Brothers
SG Warburg
Union Bank of Switzerland
Winterflood Securities

analyze basis-trading opportunities. Second, to calculate the discounted cash flow value of the different cash bonds, we use daily gilt market discount factors based upon the Bank of England's closing spot rates (see Anderson and Sleath, 2001 for a description of the specific term structure model used to estimate the spot rates).

4. Initial conditions and the squeeze potential

4.1. Notional coupon of the bond futures contract and the level of yield curve

Fig. 1a plots the 15-year zero-coupon bond yield relative to the 9% flat yield curve assumed by LIFFE in the calculation of conversion factors. As can be seen, until early 1997, the long-term yields were relatively close to 9%. However, they thereafter decreased steadily to about 7% by September 1997, and to about 6% by March 1998. Under such conditions, the lowest-duration deliverable bond becomes the cheapest deliverable issue (see Kilkollin, 1982).

Table 2 illustrates the potential profitability of a squeeze for the special case of a 6% flat zero-coupon yield curve with the conversion factors used by LIFFE. There are five issues eligible for delivery. In view of the short's timing option, the last delivery date is the last day of the month except for the 9% 2008 issue, for which the last delivery date is March 9, 1998. LIFFE does not permit deliveries of bonds during their 'special ex-dividend period'—a period of 21 calendar days prior to the ex-coupon date. Given the three-business-days delivery invoicing process, the price

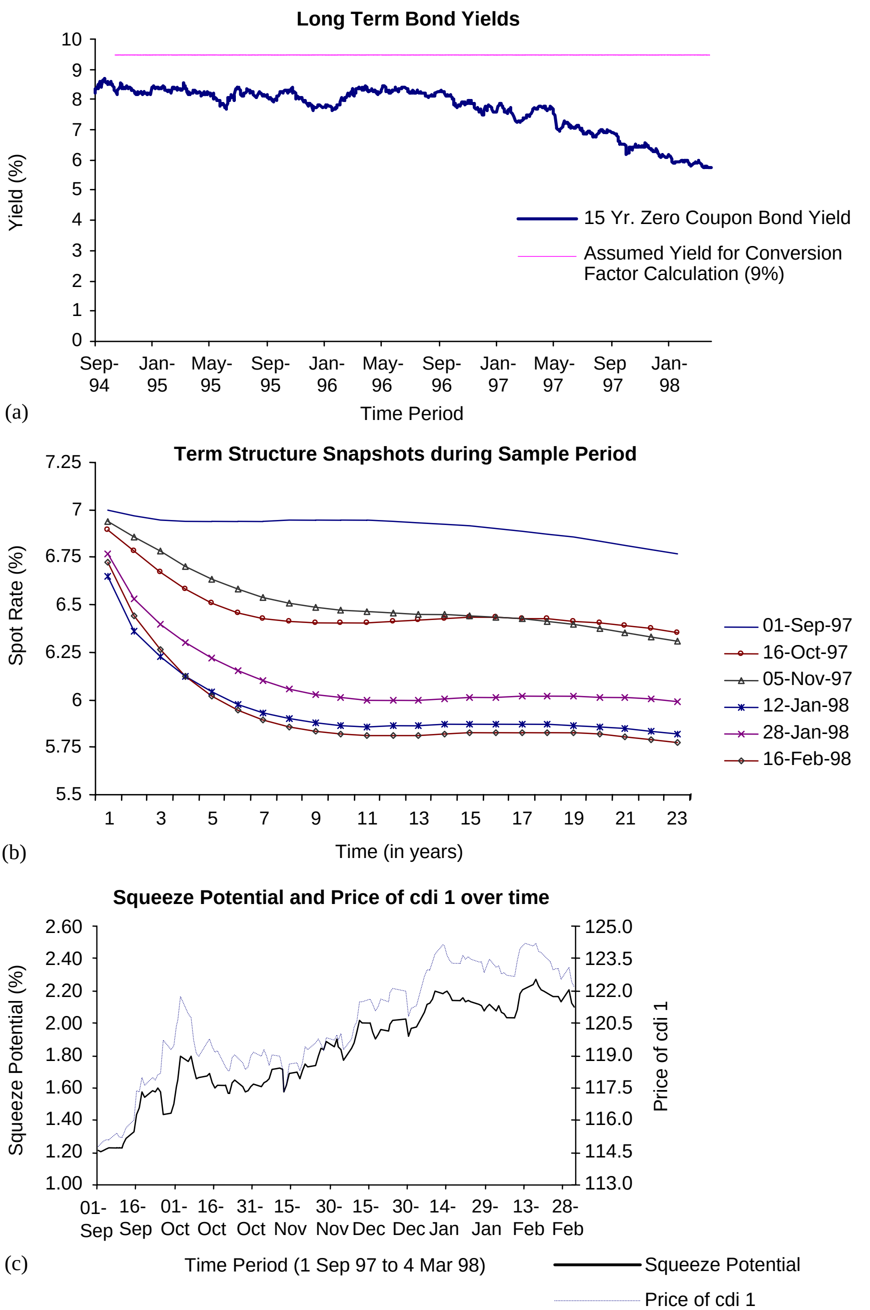


Fig. 1. (a) plots the long-term bond yields from September 1994 to March 1998. (b) provides snapshots of the term structure of interest rates during the sample period. (c) displays the market price of cheapest-to-deliver bond issue (9% October 2008, or, *ctd*1) and squeeze values over the sample period (September 1, 1997 to March 4, 1998).

Table 2
This table describes the impact of a squeeze on the pricing of 9% 2008 and March 1998 Long Gilt futures contracts under a flat 6% spot rate term structure

Deliverable issues coupon (%)	Maturity	Conversion factor	Modified duration	Assumed yield (%)	Delivery date	Issue price	Forward price	Converted forward price	Net basis	
Panel A: no-squeeze scenario										
9.00	10/13/2008	0.9999442	7.02	6.00	03/09/1998	123.28	123.27	123.27	0.00	CDI
8.00	09/25/2009	0.9291579	7.59	6.00	03/31/1998	116.50	116.40	125.28	1.86	
6.25	11/25/2010	0.7941347	8.60	6.00	03/31/1998	102.19	102.19	128.68	4.29	
9.00	07/12/2011	1.0001748	8.33	6.00	03/31/1998	127.29	127.20	127.17	3.90	
9.00	08/06/2012	1.0002554	8.78	6.00	03/31/1998	128.68	128.59	128.56	5.29	
						Minimum $(P/cf) = 123.27 =$ Futures price				
Panel B: full-squeeze scenario										
9.00	10/13/2008	0.9999442	7.02	5.777	03/09/1998	125.28	125.27	125.28	0.00	co-CDI
8.00	09/25/2009	0.9291579	7.59	6.00	03/31/1998	116.50	116.40	125.28	0.00	co-CDI
6.25	11/25/2010	0.7941347	8.60	6.00	03/31/1998	102.19	102.19	128.68	2.70	
9.00	07/12/2011	1.0001748	8.33	6.00	03/31/1998	127.29	127.20	127.17	1.90	
9.00	08/06/2012	1.0002554	8.78	6.00	03/31/1998	128.68	128.59	128.56	3.28	
						Minimum$(P/cf) = 125.28 =$ Futures price				

The table analyzes two scenarios: no-squeeze and full-squeeze. In view of LIFFE's three business days delivery invoicing process, the last date on which the 9% 2008 bond can be delivered is March 4, 1998, which corresponds to a cash settlement date of March 5, 1998. All issues are priced on March 4th for regular settlement on March 5th. The 9% 2008 issue is financed for four days until March 9th. The other issues are financed for 26 days until the March 31st delivery date. The assumed financing rate is the then prevailing average yield of 6%. The delivery cheapness measure is the "net basis", defined as the basis less the issue's "carry" (coupon accrual less financing cost) over the financing period.

for March 9th delivery is based upon the closing price on March 4, 1998. The upper panel of Table 2 illustrates our calculations. The 9% 2008 issue is clearly the *cdi*1. The 8% 2009 issue is the relatively unattractive second choice, *cdi*2. A delivering short would lose nearly 2% of par value (2 full price points) by delivering *cdi*2 instead of *cdi*1.

The lower panel of Table 2 describes a manipulator's trading target. Under a two-issue full-squeeze scenario, the contract shorts would be forced to deliver *cdi*2. The price of *cdi*1 and the March 98 futures would then rise. The *cdi*1 could gain 2% of par value (2 full price points), increasing from 123.28 to 125.28. The March 98 futures contract would also gain by a similar amount. The squeezer would generate mark-to-market paper profits. The realized profits, however, would depend on the weighted average price at which the squeezer manages to unwind the positions.

4.2. Changes in squeeze potential over the sample period

Fig. 1b shows how the spot yield curve changed over the sample period from September 1, 1997 (the first trading day in the March 98 futures contract) to March 4, 1998. March 4, 1998 is the last day to purchase a cash gilt issue for regular settlement in time for a March 9th futures delivery given the futures exchange's three-business-days delivery invoicing process. Although the short-term yield remained at about 7%, long-term yields fell from 7% in early September 1997 to a little under 6% in mid-February 1998. Fig. 1c shows how, given the changes in the term structure, the price of the contract's key deliverable issue rose during our sample period. Fig. 1c also plots the squeeze potential measured as the difference between F^{s} and F^{ns} over the life of the March 98 futures contract. F^{s} and F^{ns} are the converted forward delivery date prices of *cdi*2 and *cdi*1, respectively, where the forward prices are based upon the bond's discounted cash flow value under the Bank of England's daily discount factor series and net financing costs.

As can be seen, the March 98 contract's squeeze potential increased substantially over the sample period, peaking at 2.35% of par value (2.35 price points) in February 1998. This increase reflects the fall in the level of yields as well as an inversion of the yield curve during the period. Both of these factors exacerbated the contract's conversion factor bias and increased the potential profitability of a successful squeeze.[13]

[13]LIFFE responded ex post to the market distortions generated by the March 98 contract squeeze by lowering, for the first time since 1982, the notional coupon of its June 98 bond futures contract, from 9% to 7%. This change dramatically reduced future squeeze potential for contracts maturing June 98 and beyond. It also reduced part of the abnormal value that the 9% 2008 bond—the *cdi*1 for both March 98 and June 98 contracts—would have in forward trading after March 1998. However, since the March 98 contract was already trading, its terms remained fixed.

5. Price distortions during the squeeze

5.1. Mispricing of the cheapest-to-deliver issue relative to fundamental value

The difference between the market value of the bond and its discounted cash flow value, as per Equation (3), on any particular date can be interpreted as an issue-specific price distortion or mispricing. Transient issue-specific effects can be due to liquidity trading or can potentially be "noise", but consistent differences between the market price and the discounted cash flow value for *cdi*1 arguably reflects squeeze-related price distortions. Fig. 2a plots the difference between the market value of *cdi*1 and its discounted cash flow value from September 1, 1997 to March 4, 1998. Based on this mispricing, we identify six different phases of the squeeze:

- Phase I, September 1st to October 15th. During this phase, the average mispricing (i.e., price distortion of *cdi*1) held firm at about 0.075% of par value.
- Phase II, October 16th to November 4th. During the early part of this phase, i.e., up to October 29th, the mispricing rose steadily to 0.24%; from October 30th to November 4th, it rose sharply to 0.77%.
- Phase III, November 5th to January 9th. During this phase, the mispricing was largely steady at an average level of about 0.67%.
- Phase IV, January 12th to January 27th. During this phase, the mispricing jumped sharply to its maximum level of 1% of par value.
- Phase V, January 28th to February 13th, the last business day before the Bank of England's repo policy announcement. During this phase, the mispricing fell steadily to about 0.67%.
- Phase VI, February 16th to March 4th, the last day of delivery of *cdi*1. During this phase, the mispricing fell to about 0.24%.

5.2. Cash-market butterfly spreads and futures-market calendar spreads

Practitioners often use butterfly trades—position switches from one "center" issue into a combination position of two "wing" positions in issues of longer and shorter duration—as a repositioning strategy among three securities See Garbade (1996, Chapter 14), for an analysis of cash market bond butterfly trades. The butterfly yield spread is the basis point pick up that a switch from *cdil* into a combination of the 7.25% 2007 and the 8% 2009 would generate. Although the average yield differential of this type does not index true relative value as precisely as the discounted cash flow approach, practitioners track such spreads closely because the bond triplet position implicit in such spreads provides a low-risk trading strategy to exploit relative value mispricings. Note that this particular butterfly is reasonably symmetric, since the modified duration differences between the center issue and each wing are approximately equal (about 0.5 years in each case, as computed in November 1997). Fig. 2b plots the butterfly yield spread, i.e., the difference between the average of the yields-to-maturity of the 7.25% 2007 and the 8% 2009 (the wings), and the

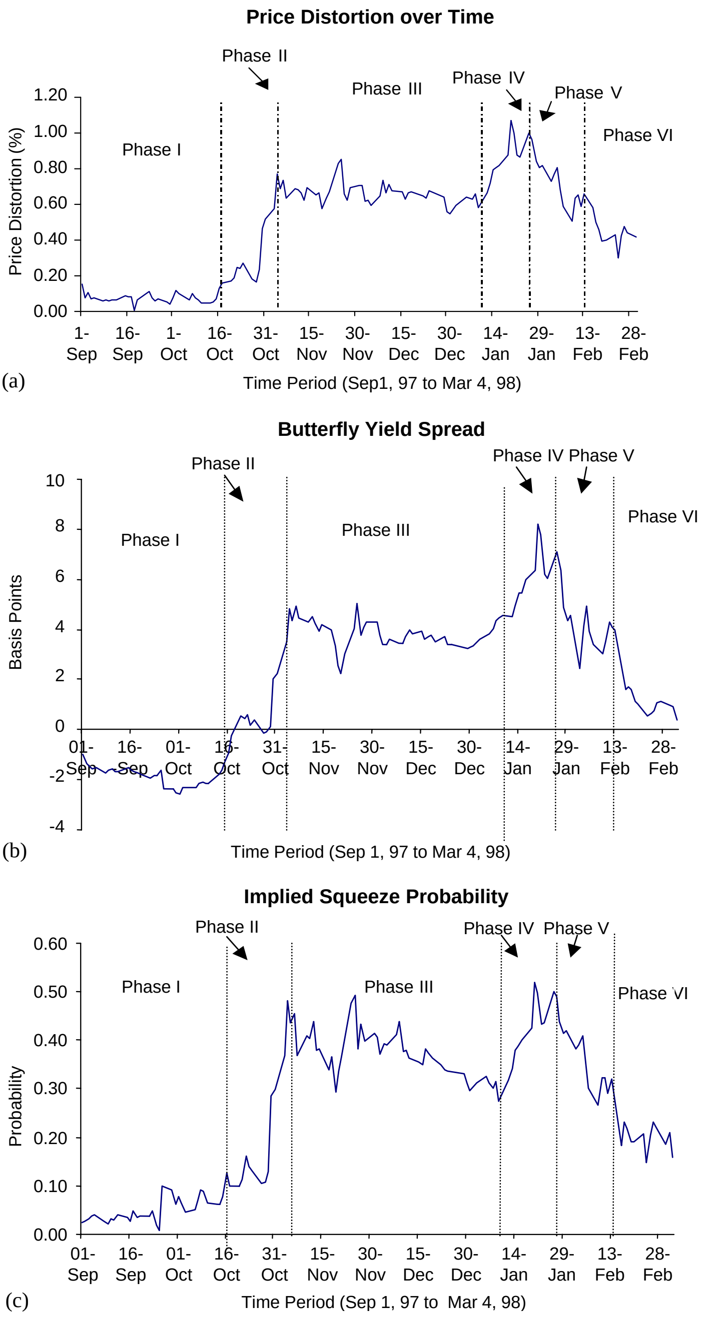


Fig. 2. (a) plots the percentage price distortion of key deliverable bond, vis-à-vis its fundamental value during the sample period. (b) plots the butterfly yield spread with *cdi*1 as the center and two bonds with adjacent maturity as the wings. (c) plots the implied probability that the attempted squeeze will be successful.

yield-to-maturity of the 9% 2008 (the center). This butterfly yield spread metric portrays the *cdi*1'*s* mispricing as qualitatively very similar to that identified using the discounted cash flow approach.

Practitioners also use futures contract calendar spreads to measure changes in pricing relations over the trading life of the contracts. When we examine the calendar spreads between the December 97 and March 98 contracts and also those between the March 98 and June 98 contracts, we find spread changes that mimick the price distortion of *cdi*1 that is reported in Figs. 2a and b. In particular, we find that the March–December spread increased sharply from a discount of $\frac{1}{32}$nd to a premium of $\frac{6}{32}$nds by October 30, 1997. This spread widened further to $\frac{12}{32}$nds by November 3rd, $\frac{18}{32}$nds the following day, and peaked at $\frac{27}{32}$nds on November 25th before contracting and stabilizing for most of December at about $\frac{16}{32}$nds. Similarly, the March–June spread appreciated by $\frac{12}{32}$nds from phase III to phase IV, slipped back in phase V, and returned to more normal levels by the end of February 1998. Since neither the cash market butterfly nor the futures market calendar spread analysis requires sophisticated analytical tools, the shift in the pricing of *cdi*1 would have been observable to all bond market participants around mid-October 1997.

5.3. Implied squeeze probability

Fig. 2c plots π, the implied squeeze probability calculated from Equation (8). The identifiable phases in Fig. 2c are virtually identical to the phases found in Fig. 2a. Fig. 2c reveals that virtually no thoughts of a squeeze were priced into the market until mid-October 1997. After this time, the implied squeeze probability rose sharply, averaging about 35% in November and December 1997, and 40% in January 1998. In the first half of February 1998, the implied squeeze probability fell back to an average of 30%. The change in the implied probability of the squeeze on February 16, 1998 stands out. On this date, the Bank of England announced a change in its repo market policy and the implied probability fell sharply from 27% to 14%. During the second half of February, the implied squeeze probability continued to fall.

5.4. Open interest and delivery experience

Table 3 summarizes the open interest and delivery history of the LIFFE Long Gilt futures contract for maturities from March 1995 through March 1998 (source: LIFFE and Bloomberg). For Long Gilt futures contracts maturing from March 1997 to March 1998, the peak open interest is about one-and-a-half to two times the par value size of the associated *cdi*1. However, the size of the delivery for the March 98 contract—nearly double the size of the largest reported prior delivery and about six times the average delivery amount for March 95 to December 97 contracts—stands out. This delivery also represents 82.4% of the total outstanding par amount of the *cdi*1 versus an average of only 11.3% for March 95 to December 97 contract deliveries. The March 98 delivery is also 47.7% of the contract's peak open interest, as against an earlier average of 8.7%.

Table 3
This table provides the details of the most-delivered bond issue for each long gilt futures contract maturing between March 1995 and March 1998: issue size in £millions, issue size in terms of equivalent number of futures contracts, the peak open interest in terms of number of contracts, actual delivery size in terms of number of contracts, actual delivery size (contract equivalent) versus peak open interest, and actual delivery as a percentage of issue size

Contract expiry date	Most delivered bond issue (coupon rate and maturity date)			Issue size (£millions)	Issue size: equivalent no. of futures contracts	Peak open interest: no. of contracts	Actual delivery: no. of contracts	Actual delivery versus peak open interest (%)	Actual delivery as a % of issue size
March-98	9.00%	October 13	2008	5,621	112,420	194,223	92,401**	47.7	82.2
December-97	7.25%	December 07	2007	5,000	100,000	197,528	20,559	10.4	20.6
September-97	9.00%	October 13	2008	5,621	112,420	184,449	27,335	14.8	24.3
June-97	8.50%	July 16	2007	7,397	147,940	229,943	49,042*	21.3	33.1
March-97	8.50%	July 16	2007	7,397	147,940	203,199	15,424	7.6	10.4
December-96	7.50%	December 07	2006	11,700	234,000	168,602	4,230	2.5	1.8
September-96	7.75%	September 08	2006	4,000	80,000	152,796	8,031	5.3	10.0
June-96	9.00%	October 13	2008	5,621	112,420	127,654	6,650	5.2	5.9
March-96	8.50%	July 16	2007	7,397	147,940	148,013	2,359	1.6	1.6
December-95	7.50%	December 07	2006	11,700	234,000	114,353	13,115	11.5	5.6
September-95	7.75%	September 08	2006	4,000	80,000	110,623	6,171	5.6	7.7
June-95	7.50%	December 07	2006	11,700	234,000	107,544	11,529	10.7	4.9
March-95	9.50%	April 18	2005	4,842	96,840	111,098	9,302	8.4	9.6
Average (March 1995 through December 1997)					143,958	154,650	14,479	8.7	11.3

**(*) indicates that the number of contracts against which a bond was delivered is significantly different from the average of March 1995 to December 1997 at 1% (5%) level. *Source*: London International Financial Futures Exchange (LIFFE).

6. Squeeze-related trading flows

In this section, we examine the positions and trading behavior of seventeen dealers (and dealer affiliates) and their customers during the life of the March 98 futures contract. In particular, we compute the sum of their end-of-day positions (in par value) in the *cdi*1 and the March 98 futures contract. We construct the inventory positions by adding the net value of trades over a day to the position at the end of the previous day. We assume that the participants start with a zero inventory on September 1, 1997, about eight weeks before the first signs of the abnormal price distortions became evident (see Fig. 2a). This assumption is innocuous since we know that dealers' positions in individual U.K. government bonds typically exhibit half-lives of less than a week (see Naik and Yadav, 2003b). We investigate the inventory positions of any market participant (dealer or customer) with an overnight net position in excess of £300 million (roughly $0.5 billion) on any date. We find that there are twenty such market participants (nine dealers and eleven customers); we examine the individual inventory series of these participants more closely.

6.1. Can any of the market participants be characterized as "squeezers"?

We find that 10 market participants (six customers and four dealers) had large long positions consistent with those of a squeezer, and we hereafter address them as squeezers. We label the squeezing customers from SC1 to SC6 and the squeezing dealers from SD1 to SD4, where the numbering generally reflects the order in which each participant took up its position. Figs. 3 and 4 report the positions.

Fig. 3a shows that the first players in this squeeze were clearly customers SC1 and SC2. SC1 rapidly built up a large position in *cdi*1 in phase I, the second week of September 1997. The size of the position of SC1 and SC2 was about £1.5 billion through phase I (amounting to 27% of the outstanding size of *cdi*1). Customers SC1 and SC2 realized some profits in phase II (reducing their position to about £0.9 billion), and subsequently retained a position of about £1.1 billion through the rest of the sample period. Interestingly, even though the initial trades of SC1 and SC2 were intermediated by several dealers, this build-up of positions seems to have either gone unnoticed or been ignored—it entailed no price impact. Squeeze-related price distortions started only in phase II, about 30 days after these positions were built up. Customers SC3 and SC4 became squeezers towards the end of phase I and accumulated a total position of about £0.5 billion by the end of phase II (see Fig. 3b). Customers SC5 and SC6 started building up their long positions only in middle of phase III, with positions totaling about £1.2 billion by the end of December 1997 (see Fig. 3c).

Among the dealers, SD1 (who initially had a short position due to trades with SC1 and SC2) started building up a long position in late September 1997 (see Fig. 4a). Dealer SD1 is the only dealer who seemed to have "learned" from trading with the squeezing customers. This dealer built up a significant long position of about £0.8 billion towards the beginning of phase II, just as the price distortions began (see Fig. 2a), then engaged in early profit-taking, closing out three-fourth of the peak

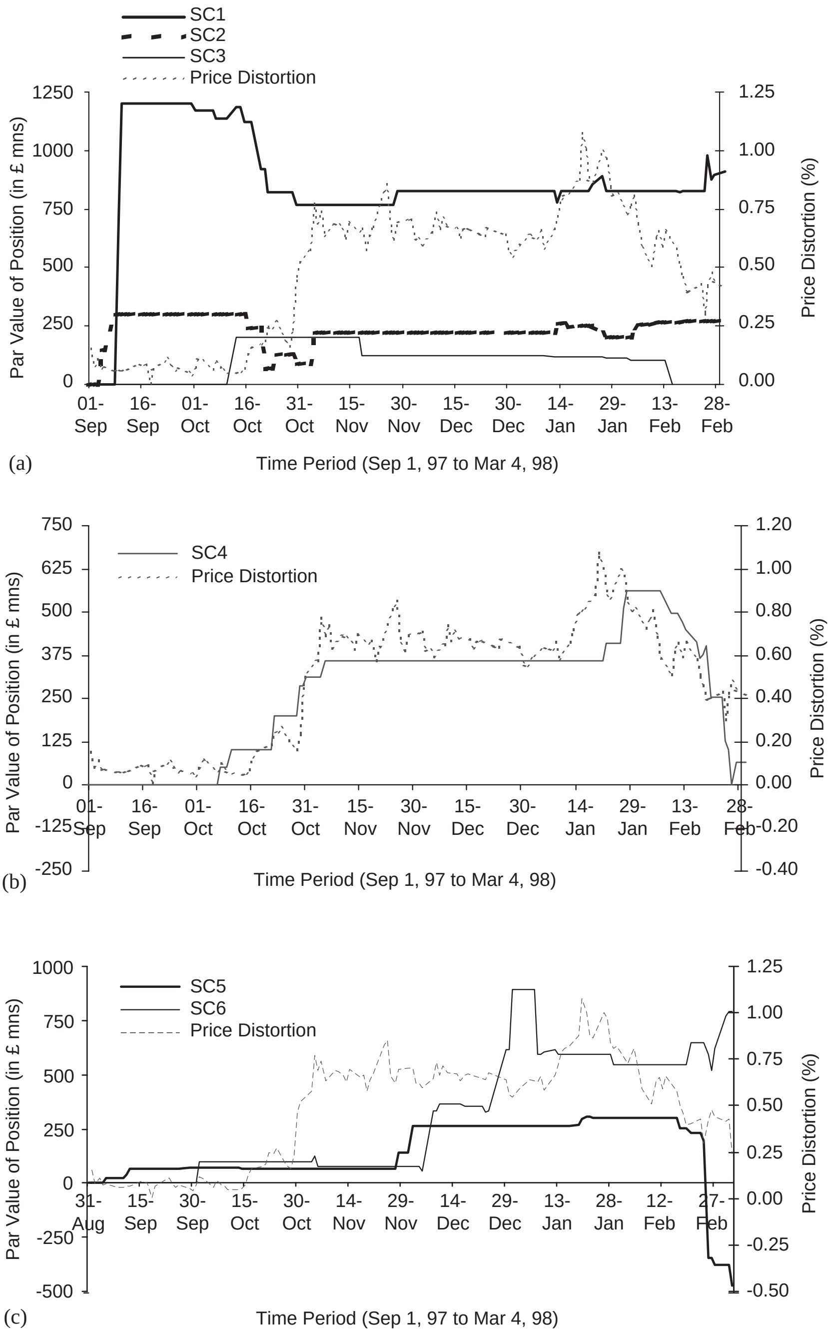


Fig. 3. This figure plots the par value position of the six squeezing customers (in £ millions) in the context of the price distortion (in %) during the sample period (from September 1, 1997 to March 4, 1998). (a) inventories of first three squeezing customers. (b) Inventory of squeezing customer (active trader). (c) Inventories of squeezing customers (late entrants).

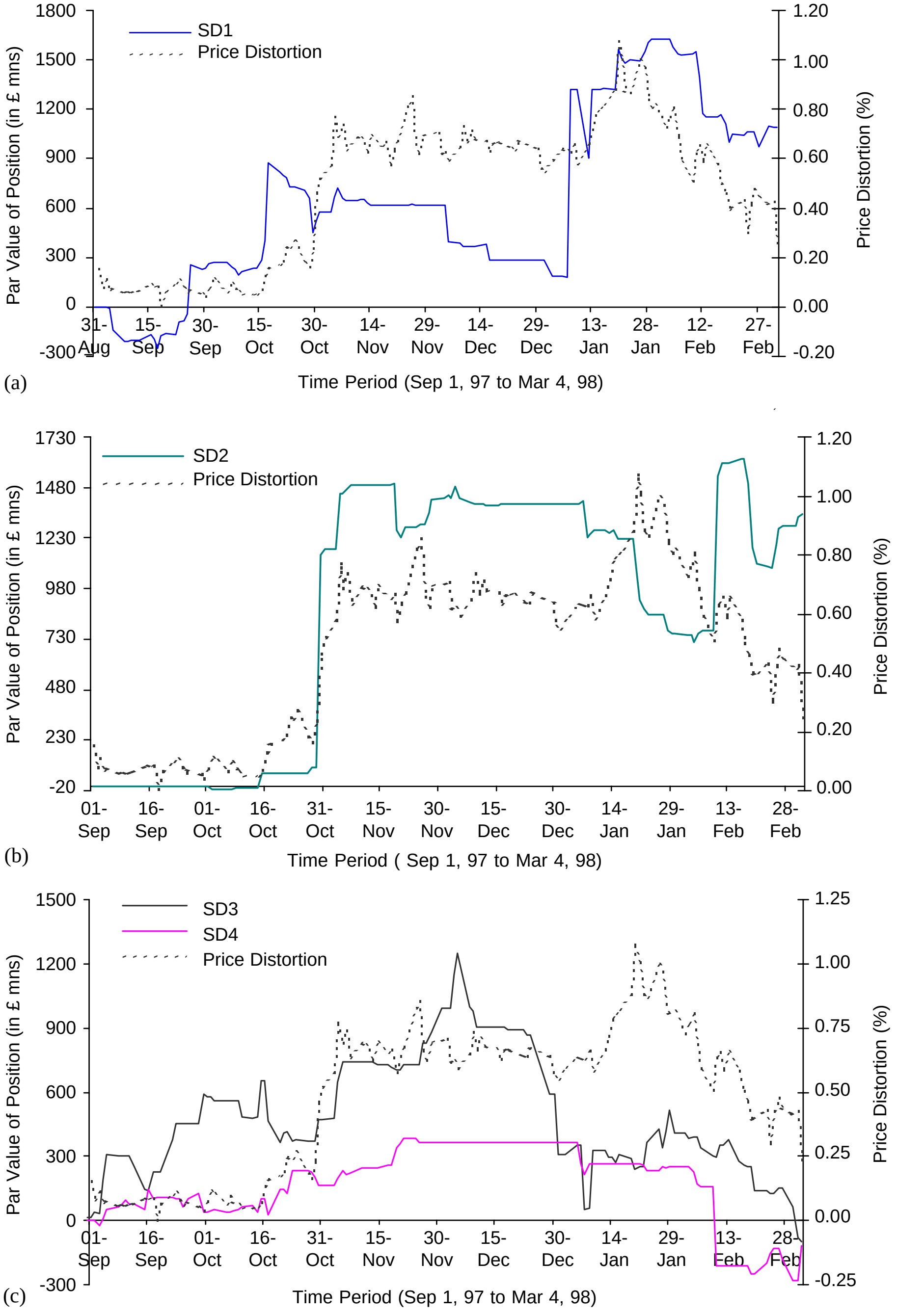


Fig. 4. This figure plots the par value position of the four squeezing dealers (in £ millions) in the context of the price distortion (in %) during the sample period (from September 1, 1997 to March 4, 1998). (a) Inventory of squeezing dealer 1. (b) Inventory of squeezing dealer 2. (c) Inventories of squeezing dealers (profit takers).

position by the beginning of January 1998. Dealer SD2 built up a long position of about £1.5 billion towards the end of phase II and the start of phase III, after the squeeze became evident from price distortions (see Fig. 4b). However, as we shall see in the next section, SD2 also built up massive forward-term repo positions from the start of Phase II. Except for some reduction in January 1998, SD2 maintained that position throughout the sample period. Dealer SD3 built up a long position of about £0.65 billion by the end of phase I, engaged in limited profit-taking in late October 1997, and then aggressively built up a long position in early December 1997 that peaked at about £1.2 billion (see Fig. 4c). In early January, SD3 again took profits by reducing the position to less than £0.1 billion. Dealer SD4, a relatively small player who reached a maximum position of about £0.35 billion in mid-November 1997, was a late entrant.

We cannot say whether these ten squeezers acted in concert. In fact, dealer SD3's decision to repeatedly book profits indicates a perception of ultimate squeeze success that differed significantly from those of the other squeezing dealers. Clearly, the trading activities of these dealers were less than perfectly coordinated. See Fig. 8a for the total position of the squeezing dealers and squeezing customers over time during the sample period.

6.2. Are there trades with unusual settlement configuration targeted at gaining possession of cdi1 around the futures delivery date?

A large number of trades in our sample belong to one of two categories: cash market gilt trades and short-term repo trades. Cash market gilt trades typically settle in the regular way, on the next business day. In contrast, short-term repo trades are booked as paired cash trades in which one participant sells to (buys from) another participant for a near settlement date while simultaneously agreeing to buy back (sell) that same security for some later settlement date. For example, the near date could be the next business day and the deferred date could be between one day and two weeks later. Interestingly, we also observe a number of extremely unusual repo trades towards the end of phase I, and all through phase II. All of these trades are forward-term repo (FTR) trades in *cdi*1 in which one trader/dealer buys from another trader/dealer for forward delivery on February 20, 1998 (i.e., some two weeks before the last delivery date of *cdi*1 against the March 98 contract), while simultaneously agreeing to sell that same security on or soon after March 20, 1998.

Fig. 5 shows that the first FTR trade took place on October 7, 1997 when SC4 took up a £0.25 billion long position in *cdi*1 (i.e., SC4 bought £0.25 billion of *cdi*1 for delivery on February 20, 1998 and simultaneously sold that lot for delivery on March 20, 1998). Customer SC4 rapidly increased the position in these FTRs on October 10, 1997 to £0.8 billion. Around the same time, on October 10, 1997, SC3 also built up a long FTR position of £0.5 billion. The FTR trades of SC3 and SC4 were intermediated by several different dealers, and one of these dealers, SD2, learned about the squeeze from these trades and started trading in the FTRs. Dealer SD2 built up a large long position in these FTRs on October 15th, starting with a position of £0.5 billion, and increasing quickly to a maximum of £2 billion by the end

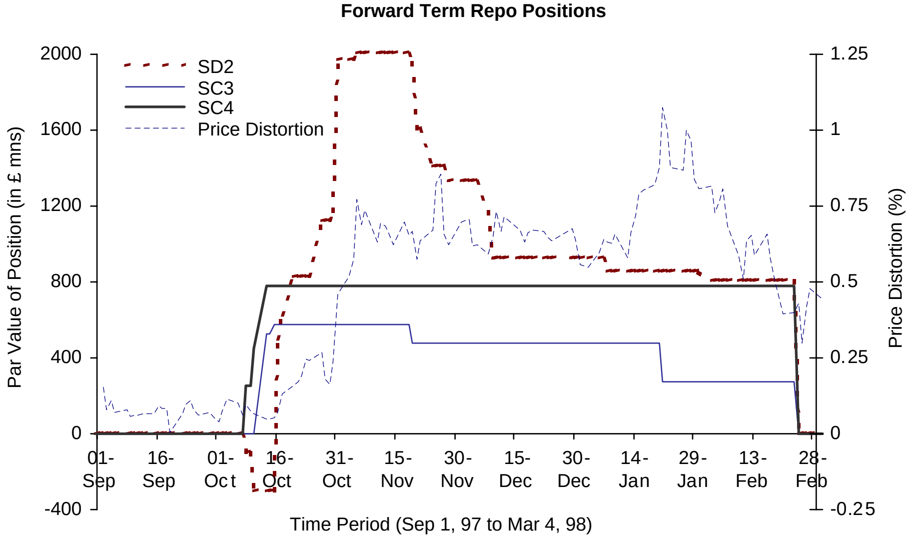


Fig. 5. This figure plots the par value position of the forward-term repo positions of two squeezing customers and one squeezing dealer (in £ millions) in the context of the price distortion (in %) during the sample period (from September 1, 1997 to March 4, 1998).

of phase II. Dealer SD2 subsequently settled down in steps to reach a final position of about £0.9 billion. Interestingly, SD2 also took direct exposure in the squeezable bond and the associated futures contract, but did so only after building a large position in the FTRs. Over the period October 10–29, 1997, in addition to customers SC3 and SC4, several other customers also took up positions in FTRs, albeit on a smaller scale. In fact, the trading records show that dealer SD2 also did brisk business as a market-maker in these FTRs after October 10, 1997.

As mentioned earlier, the direct accumulation of *cdi*1 positions by SC1 and SC2 in September went largely unnoticed. In contrast, these unusual FTR trades appear to have tipped the market-at-large off about the possible squeeze attempt. The price distortion started in the second week of October 1997, after the first few FTR trades. The price distortion increased from about 0.05 price points on October 10, 1997 to about 0.25 price points on October 29, 1997. Over this period, squeeze-related trading activity was mainly in FTR trades rather than direct purchases of *cdi*1.

FTR trades generate little interest rate risk exposure because they are offsetting forward calendar spreads. However, these FTR trades are very important from the perspective of a squeeze since they provide temporary control of the deliverable supply of *cdi*1 just prior to the futures delivery date. These FTR trades are relatively invisible to governmental regulators because the actual settlements are scheduled to take place several weeks/months in the future. FTRs may also escape close internal scrutiny within a dealer firm, as they do not affect the net duration-based position risk limits of individual traders.

6.3. Can any of the market participants be characterized as "contrarians"?

By the first week of November 1997, all market participants would have observed the changes in butterfly yield spreads and calendar spreads and therefore would have become aware of the distortion in the prices of *cdi*1 and the March 98 futures contract. So, market participants taking large short positions after the price had become abnormally high should be characterized as "contrarians", where a contrarian is a market participant whose short position is consistent with the view that the squeeze attempt would ultimately be unsuccessful. A squeeze attempt can collapse either because some members of the squeezing coalition take profits and run, or because external intervention by regulators or the exchange effects a collapse. We find that five dealers and five customers had short positions that were consistent with those of a contrarian. We label these participants as CD1 to CD5 and CC1 to CC5, respectively. Figs. 6 and 7 report their positions.

Dealer CD1 initially acquired a short position when the first squeezing customers SC1 and SC2 made their trades, whereas CD2 initially acquired a short position in the wake of the first wave of buying in phase II. Both CD1 and CD2 later decided to bet aggressively against the squeeze with positions in excess of £1.0 billion each (see Fig. 6a). In addition, three other dealers (CD3, CD4, and CD5) wagered aggressively against the squeeze from the middle of phase III (after *cdi*1 had become significantly overpriced) with positions of at least £0.5 billion each (see Figs. 6b and c).

Among the contrarian customers, CC1, CC2, and CC3 had an aggregate short position of about £0.9 billion around the start of phase II, which they more or less maintained during the course of the squeeze (see Figs. 7a and b). Customer CC4 built a short position of about £0.9 billion during phase III. Customer CC5 started betting against the squeeze towards the end of phase III and reached a maximum short position of about £0.3 billion in early February 1998 (see Fig. 7c). Fig. 8b reports total positions of contrarian dealers and customers during the sample period.

6.4. Are there any other identifiable trading styles?

We do not discern any other identifiable trading styles that are relevant to the squeeze. We do find one dealer who was a classic cash-futures basis arbitrageur. This dealer took short positions in the March 98 contract paired with corresponding long positions in *cdi*1. However, this dealer did not take any active role in the squeeze. There were seven other dealers and numerous customers with individual positions that were too small to indicate a conscious speculation in favor of or against the squeeze (see Fig. 8c for their aggregate inventory position).

6.5. Summary of the squeeze

Table 4 presents a schematic summary of the actions of the major market participants involved in the squeeze. In early September, two customers started the ball rolling by building a position of 27% of the outstanding issue size of *cdi*1. Though these trades were intermediated by several dealers, the market largely

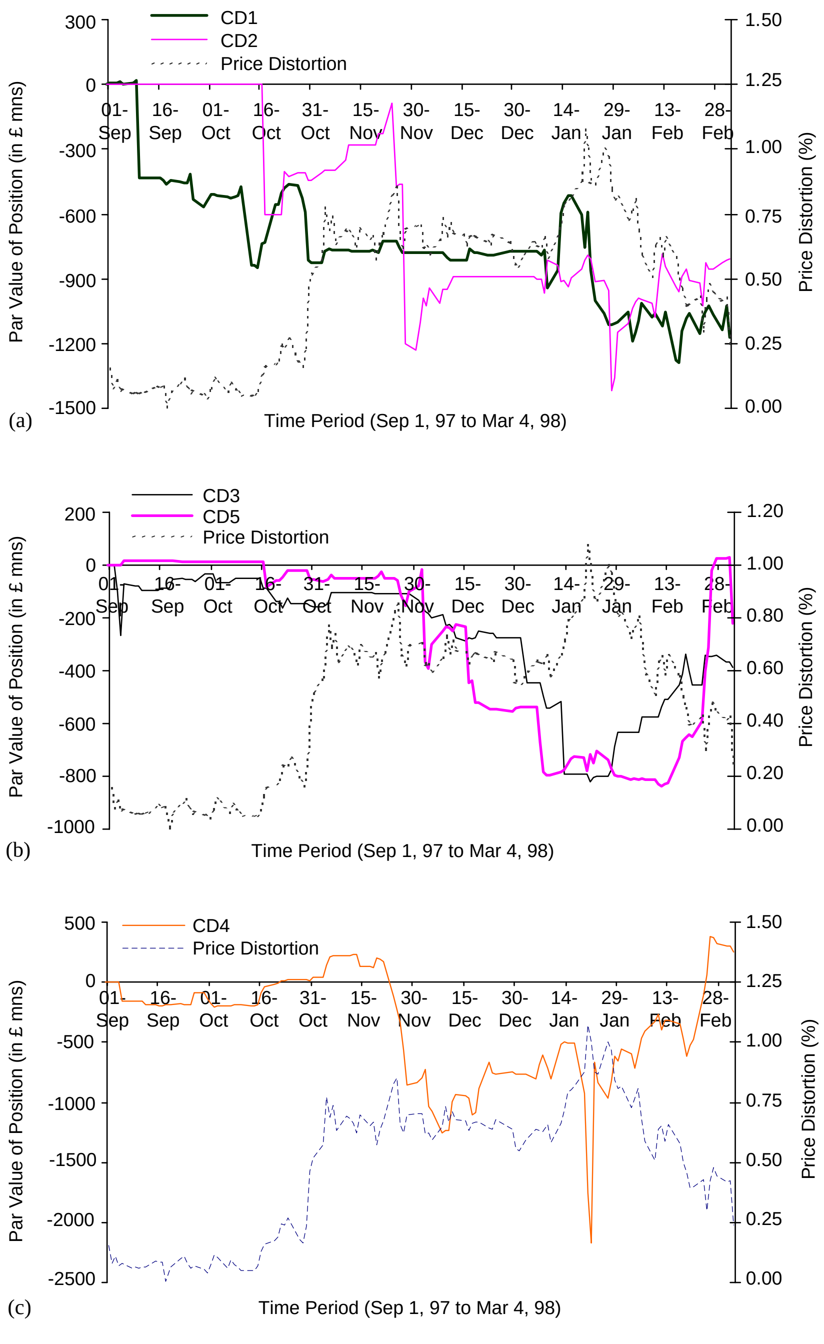


Fig. 6. This figure plots the par value position of the five contrarian dealers (in £ millions) in the context of the price distortion (in %) during the sample period (from September 1, 1997 to March 4, 1998). (a) Inventories of first two contrarian dealers. (b) Inventories of contrarian dealers (late entrants). (c) Inventories of contrarian dealer 4.

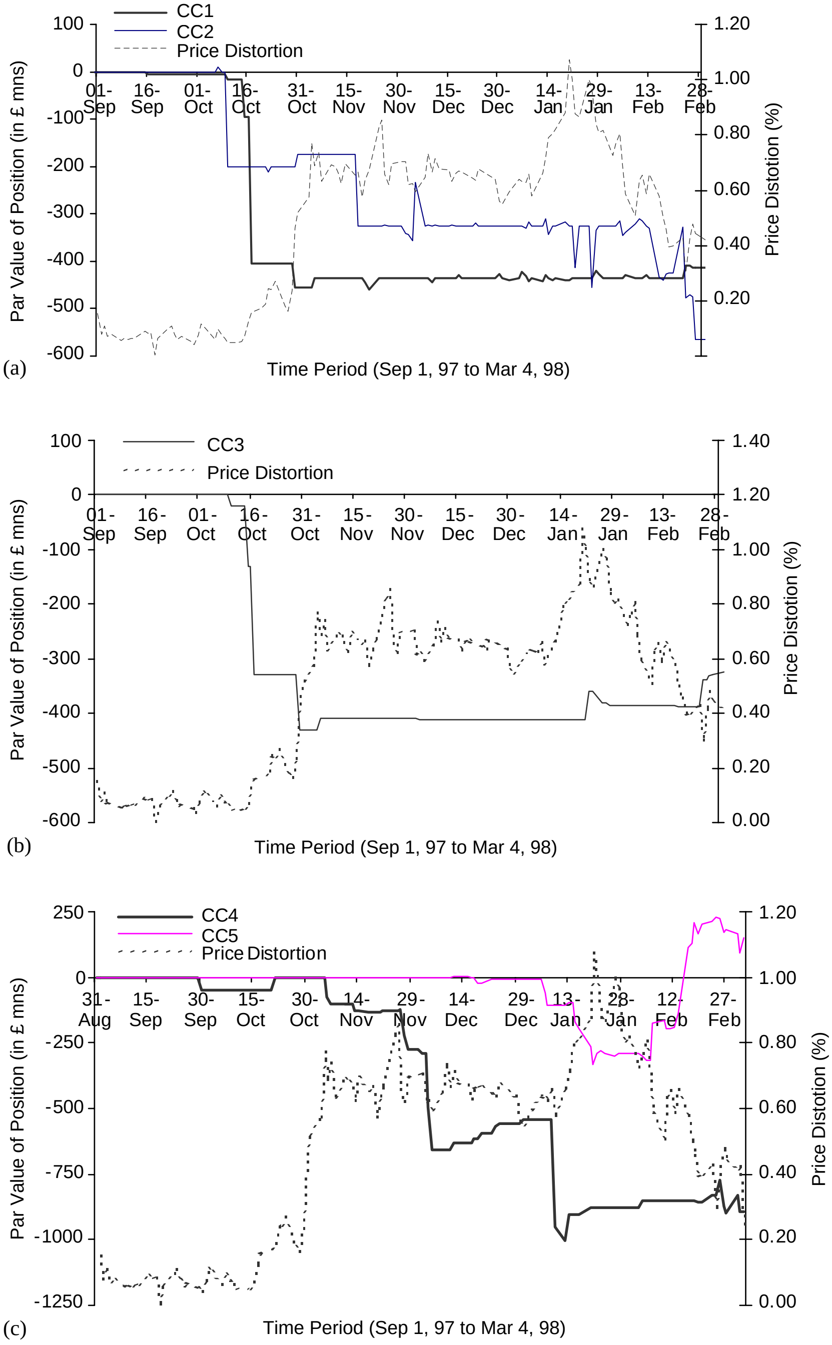


Fig. 7. This figure plots the par value position of the five contrarian customers (in £ millions) in the context of the price distortion (in %) during the sample period (from September 1, 1997 to March 4, 1998). (a) Inventories of the first two contrarian customers. (b) Inventory of contrarian customer 3. (c) Inventories of contrarian customers (late entrants).

Table 4
This table reports the trading activity of individual squeezing and contrarian dealers and customers in the key deliverable issue 9% October 2008 from September 1, 1997 to March 4, 1998

Dates	Market participant activity in 9% 2008 bond	Price distortion
Phase I: September 1, 1997 to October 15, 1997		
Sep. 9–10th	SC1 and SC2 built up a long position of ~£1.5 billion.	No price impact
Sep. 26th	SD1 took a long position of ~£0.25 billion.	No price impact
Sep. 16–Oct. 15th	SD3 gradually built a long position of ~£0.65 billion.	No price impact
Oct. 7–10th	SC3 and SC4 built up long FTR positions to ~£1.3 billion.	Initiation of price distortion
Oct. 15th	CD4 built up short position to ~£0.8 billion.	
Phase II: October 16, 1997 to November 4, 1997		
Oct. 17th	SD1 built up a position of ~£0.9 billion.	Widening of price distortion
Oct. 16–23rd	Limited profit taking by SD3; long position down to ~£0.4 billion.	
Oct. 16–30th	SD2 built a long position in FTRs of up to ~£2.0 billion.	Price distortion increased to 0.25%
Oct. 30–Nov. 4th	SD2 built a significant long position of ~£1.4 billion in a very short time.	Sharp jump in price distortion up to 0.70%
Phase III: November 5, 1997 to January 9, 1998		
Nov. 28–Dec. 4th	CD2 and CD4, contrarian dealers, built short positions of over £1.0 billion each.	Price distortion remained in a band of ~0.60–0.70%
Dec. 2–10th	SC5 and SC6, late entrants, took long positions of ~£1.2 billion.	
Dec. 4–5th	CC4, a contrarian, built a short position of ~£1.3 billion, increasing further to ~£2.0 billion by early January 1998.	
Dec. 29–31st	SC6, a late entrant, built a long position of ~£0.9 billion.	
Dec. 29–30th	SD3 booked profits by partly unwinding its long position.	
Jan. 7th	SD1 rapidly built up a long position of ~£1.3 billion after limited profit taking over the entire Phase III.	
Phase IV: January 12, 1998 to January 27, 1998		
Jan. 12–27th	Squeezers maintain an aggregate long position at around £5.5 billion. SD2 booked partial profits during this period.	Price distortion increased to ~1.00%
Jan. 12–27th	Contrarians increased their aggregate short position to ~£7.0 billion (reaching a max. of £7.6 billion on January 21st).	
Phase V: January 28, 1998 to February 13, 1998		
Jan. 28–Feb. 13th	Contrarians continued to maintain a significantly bigger short position (~£6.5 billion) as opposed to the long position held by squeezers (~£5.5 billion).	Price distortion declined to ~0.70%

Table 4 (*continued*)

Dates	Market participant activity in 9% 2008 bond	Price distortion
Phase VI: February 16, 1998 to March 4, 1998		
Feb. 16th	Bank of England announced a change in its repo policy.	Price distortion declined to 0.20% by March 4th

This trading activity is graphed in Figs. 3–8. SDs and SCs represent squeezing dealers and squeezing customers while CDs and CCs denote contrarian dealers and contrarian customers.

remained unaware of a potential short-squeeze, and these trades were executed with little price impact. One dealer "learned" from intermediating these trades and became a squeezer. Another dealer, caught short when the price distortions began, became a contrarian. "Learning" in the market-at-large about the possibility of a squeeze began with the building of forward term repo positions in mid-October 1997. Although these FTR trades were intermediated by several dealers, the price impact became evident only when one of these dealers started building up a substantial proprietary position in the FTR contracts.

By early November 1997, the possibility of a squeeze became evident to all market participants. The price distortion jumped from 0.24% to 0.70% between October 30, 1997 and November 4, 1997. In December 1997, a few more customers joined the squeezers, and the total positions of the squeezers reached about £2.1 billion in FTRs and over £5.0 billion in *cdi*1 (see Figs. 5 and 8). During December 1997 and January 1998, another group of players, the contrarians, became active, wagering aggressively against the squeeze with short positions averaging about £5.5 billion. The price distortion remained in the range of 0.70% to 1.00% up to late January 1998. On February 16, 1998, the Bank of England announced a narrowly targeted repo policy in *cdi*1 that effectively ended the squeeze. Price distortion fell from its high of 1.00% in late January 1998 to about 0.20% by early March.

6.6. Squeeze-related profits

The primary motivation of strategic traders in trying to manipulate a market is to profit from the price distortion. The ex ante squeeze potential (shown in Fig. 1c and based on the converted price difference between *cdi*1 and *cdi*2) was about 1.20% of par value in early September 1997, 1.60% towards the end of October 1997, and 2.20% by mid-January 1998. With an average long par position of about £5 billion in *cdi*1 from early November 1997 onwards (see Fig. 8c), the potential value of the squeezers' collective positions (as of early November 1997) was about 1.6% of £5 billion or £80 million. Clearly, this potential paper profit was of an economically significant amount.[14] In this section, we examine the profits made by the different

[14]Jarrow (1992) distinguishes between "paper wealth" and "real wealth" from the viewpoint of a large trader manipulating prices. The trader's paper wealth is the marked-to-market value of that trader's securities positions in the midst of the manipulation. In contrast, real wealth is the realized change in

strategic market participants (i.e., the individual squeezers and contrarians), and, for the sake of completeness, the profits of all remaining dealers and all remaining customers who traded in the *cdi*1 issue during the squeeze period. We define the raw (or unhedged) profit of a market participant at the end of day t as the mark-to-market value (based on the end of day t price of *cdi*1) of the total inventory position at the end of day t minus the cost incurred in acquiring that inventory position. For example, assume that market participant k has executed S_T^K transactions in *cdi*1 or equivalent units of the futures contracts, from the beginning of the sample period until the end of day T. Each transaction s^k (s^k=1, 2,…,S_T^K) involves either a purchase or a sale of q_s^k units ($q_s^k>0$ for a purchase of *cdi*1and $q_s^k<0$ for a sale of *cdi*1) at a transaction price of x or $P_{cdi1,s}$. Then, the raw profit at the end of day T equals

$$\text{Raw Profit}_T^k = \sum_{s^k=1}^{S_T^k} q_s^k (P_{cdi1,T} - P_{cdi1,s}), \tag{9}$$

where $P_{cdi1,T}$ equals the price of *cdi*1 at the end of day T.

We report raw profits in Table 5. These raw profit figures are large, and somewhat counterintuitive in the sense that, in spite of the collapse of the squeeze in February 1998, the squeezers seemed to have collectively made a profit of £235 million while the contrarians incurred a loss of £174 million. The reason for this is that interest rates were generally falling over the course of our sample period (see Fig. 1b), which resulted in a substantial increase in the price of *cdi*1 over the period. Specifically the price of *cdi*1 rose from 114.8 on September 1, 1997 to 122.2 on March 4, 1998 (see Fig. 1c). Hence, market participants that generally held long positions (i.e., squeezers) made profits, while those that held short positions (i.e., contrarians) made losses.

In the context of a squeeze, strategic traders enter positions designed to profit from squeeze-related price distortions, not from market directional interest rate risk exposure. Such strategic traders should be fully hedged with respect to general shifts in market yields. Therefore, we decompose the raw profits into two components, one that arises from changes in the term structure of interest rates that affect all bond prices across the market, and another, which we call "abnormal profit", that arises from changes in the price distortion, or, the mispricing of *cdi*1. The abnormal profit is the amount a market participant would make by fully hedging the risk arising from changes in the term structure of interest rates. The abnormal profit component depends on the difference between the level of mispricing of *cdi*1 at the time it was bought and the time it was sold. For example, consider a hypothetical trader who bought £1.0 billion of *cdi*1 on October 1, 1997 and sold it on January 21, 1998. From Fig. 2a, we know that the mispricing (or price distortion) was 0.07 price points on October 1, 1997, while it was 1.07 price points on January 21, 1998. Therefore, the trader's abnormal profit (i.e., profit arising purely from price distortion without any

(*footnote continued*)
position value at the prices that would be attained in a position-unwinding liquidation. This distinction between paper and real wealth focuses attention on the large trader's endgame strategy. See Section 7.

Table 5
This table reports raw (or unhedged) profits of squeezing customers (SC), squeezing dealers (SD), contrarian customers (CC), contrarian dealers (CD), other dealers (OD), and other customers (OC) arising from their trading from the beginning of the sample up to the end of the six phases of the squeeze

Cumulative profits up to	End of phase I (10-15-1997)	End of phase II (11-04-1997)	End of phase III (01-09-1998)	End of phase IV (01-27-1998)	End of phase V (02-13-1998)	End of phase VI (03-04-1998)
SC1	48.17	44.77	86.59	76.29	86.15	69.83
SC2	11.74	9.78	21.18	18.21	21.32	16.18
SC3	−0.92	−1.22	4.65	3.16	4.43	10.79
SC4	−0.72	0.22	18.67	13.25	19.09	15.06
SC5	2.49	2.39	14.09	10.50	14.10	14.76
SC6	−1.46	−1.68	24.60	17.04	23.71	11.16
SC total	59.29	54.27	169.79	138.46	168.80	137.78
SD1	−7.92	−11.77	15.05	−3.08	15.27	−5.77
SD2	−0.13	−0.82	67.60	54.50	68.71	44.73
SD3	11.09	9.85	38.91	34.94	38.85	36.90
SD4	2.75	3.02	20.65	17.41	16.94	21.50
SD total	5.79	0.29	142.20	103.78	139.77	97.36
CC1	−3.13	−2.92	−14.23	−11.41	−14.07	−9.84

CC2	−0.41	−0.24	−17.32	−12.45	−16.19	−8.02
CC3	0.28	0.88	−20.15	−15.22	−19.83	−12.98
CC4	0.16	0.60	−28.86	−17.48	−27.75	−11.74
CC5	0.00	0.00	−1.40	0.89	−1.15	−4.24
CC total	−3.10	−1.68	−81.96	−55.67	−78.99	−46.82
CD1	−14.62	−13.06	−53.66	−42.59	−55.18	−33.95
CD2	0.00	1.43	−39.32	−27.49	−41.56	−25.02
CD3	−2.94	−3.23	−20.66	−10.92	−17.93	−10.30
CD4	−7.15	−7.05	−48.70	−41.70	−45.09	−43.73
CD5	0.64	1.04	−20.89	−11.08	−20.90	−14.42
CD total	−24.07	−20.87	−183.23	−133.76	−180.65	−127.42
OD total	−16.90	−13.29	−44.52	−38.44	−41.17	−39.45
OC total	−21.01	−18.72	−2.29	−14.36	−7.76	−21.45

These are mark-to-market raw profits of different market participants and are computed under the assumption that participants can liquidate their position at the market price prevailing at the end of different phases. All figures are in £ millions.

contribution from the changes in the term structure) from this transaction would equal 1.07−0.07 = 1.00 price point (1%) of £1.0 billion, or, £10 million.

We define the abnormal profit of market participant k at the end of day T as

$$\text{Abnormal Profit}_T^k = \sum_{s^k=1}^{S_T^k} q_s^k (X_{cdi1,T} - X_{cdi1,s}), \tag{10}$$

where $X_{cdi1,\tau}$ equals the mispricing of *cdi*1 at time τ and equals $P_{cdi1,\tau} - P^{\text{ns}}_{cdi1,\tau}$, i.e., the difference between the market price of *cdi*1 and its fundamental price, based upon its discounted cash flow, as per Equation (3), at time τ.

Table 6 reports the abnormal profits of the squeezers, contrarians, and other participants. By the end of phase IV, the abnormal paper profit of the squeezing customers and dealers was about £28 million (about £14 million to each group). However, the mispricing of *cdi*1 subsequently contracted and the squeezers' abnormal profits fell by about one-half to £13 million by February 13, 1998, presumably on the news that the Bank of England was investigating the squeeze. By the end of our sample, the abnormal profit of the squeezers had become a small loss of £1.1 million. In contrast, by the end of phase IV, the abnormal loss of the contrarian dealers and customers was about £18 million, and by the end of our sample, it had turned into a profit of about £13.4 million. The abnormal losses of the other non-player dealers were small. Other customers collectively made a substantial cumulative abnormal loss of £11.6 million. As Fig. 8c shows, they were the net sellers in phase II when *cdi*1 became overpriced, and they became net long in phases III and IV when *cdi*1 mispricing was at its highest. This latter positioning resulted in losses in phases V and VI when the mispricing began to reverse itself.

The results with the abnormal profits are intuitive. Since the squeeze collapsed before most of the squeezers could unwind their positions, squeezers generally lost money. The early entrant squeezers, those who put on their positions before the *cdi*1 appreciated, saw their paper profits burn as the squeeze collapsed but did not suffer overall net losses. Dealers who took profits early, e.g., SD3 and SD4 (see Fig. 4c), enjoyed some abnormal profit. In contrast, late-entrant squeezers, e.g., SC4 and SC6, those who bought after the price of *cdi*1 had increased and who held their positions, suffered abnormal losses. The contrarians, however, correctly predicted that the squeeze would not succeed and thus they realized abnormal profits. The contrarians had short positions when the overpricing of the *cdi*1 fell from its maximum of 1.00 price point in January to its end-of-sample period value of 0.24 price points.

The Bank of England's repo policy announcement came on February 16, 1998. However, a press release (quoted in Section 7.3) indicates that the Bank had been monitoring squeeze developments for some time. Recall from Fig. 2a that *cdi*1 mispricing peaked around the end of January 1998. After this time, the market seemed to have started incorporating a higher probability of intervention by the Bank of England, as the mispricing fell from 0.84 price points to 0.66 price points over phase V until the Bank of England announcement. Following the announcement, the mispricing fell by a further 0.42 price points in phase VI. As a result,

Table 6

This table reports abnormal or fully hedged profits of squeezing customers (SC), squeezing dealers (SD), contrarian customers (CC), contrarian dealers (CD), other dealers (OD), and other customers (OC) arising from their trading from the beginning of the sample up to the end of the six phases of the squeeze

Cumulative profits up to	End of phase I (10-15-1997)	End of phase II (11-04-1997)	End of phase III (01-09-1998)	End of phase IV (01-27-1998)	End of phase V (02-13-1998)	End of phase VI (03-04-1998)
SC1	0.79	5.46	5.25	6.69	4.54	1.60
SC2	0.20	0.74	0.68	1.19	0.55	−0.37
SC3	0.16	1.28	1.23	1.45	1.17	2.55
SC4	0.06	1.49	1.40	1.89	0.40	−0.88
SC5	0.04	0.42	0.33	0.72	−0.07	0.14
SC6	0.01	0.55	0.84	1.90	0.47	−1.79
SC total	1.26	9.94	9.73	13.83	7.07	1.26
SD1	0.21	3.14	3.15	4.73	0.81	−2.97
SD2	0.04	2.76	2.06	4.94	2.54	−2.58
SD3	0.33	2.62	2.21	2.83	1.74	1.42
SD4	0.04	0.96	0.96	1.41	1.08	1.97
SD total	0.63	9.48	8.38	13.92	6.17	−2.17
CC1	−0.06	−1.00	−0.96	−1.35	−0.77	−0.01
CC2	−0.16	−1.24	−1.12	−1.50	−0.63	0.75
CC3	−0.08	−2.09	−1.99	−2.70	−1.70	−0.44
CC4	−0.04	−0.07	−0.59	−2.24	−0.01	3.05

Table 6 (*continued*)

Cumulative profits up to	End of phase I (10-15-1997)	End of phase II (11-04-1997)	End of phase III (01-09-1998)	End of phase IV (01-27-1998)	End of phase V (02-13-1998)	End of phase VI (03-04-1998)
CC5	0.00	0.00	−0.03	−0.12	0.66	0.32
CC total	−0.35	−4.41	−4.69	−7.91	−2.44	3.66
CD1	−0.62	−4.58	−4.55	−5.29	−2.46	1.49
CD2	0.00	−2.35	−1.42	−3.06	−0.38	2.48
CD3	0.01	−0.81	−0.88	−2.12	−0.54	0.89
CD4	−0.10	−0.09	0.30	1.70	3.14	3.50
CD5	0.01	−0.23	−0.49	−1.73	0.38	1.47
CD total	−0.70	−8.05	−7.04	−10.50	0.13	9.83
OD total	−0.48	−1.11	−0.45	−2.61	−2.00	−1.03
OC total	−0.35	−5.85	−5.93	−6.72	−8.92	−11.55

These are mark-to-market abnormal profits of different market participants and are computed under the assumption that participants can liquidate their position at the market price prevailing at the end of different phases. All figures are in £ millions.

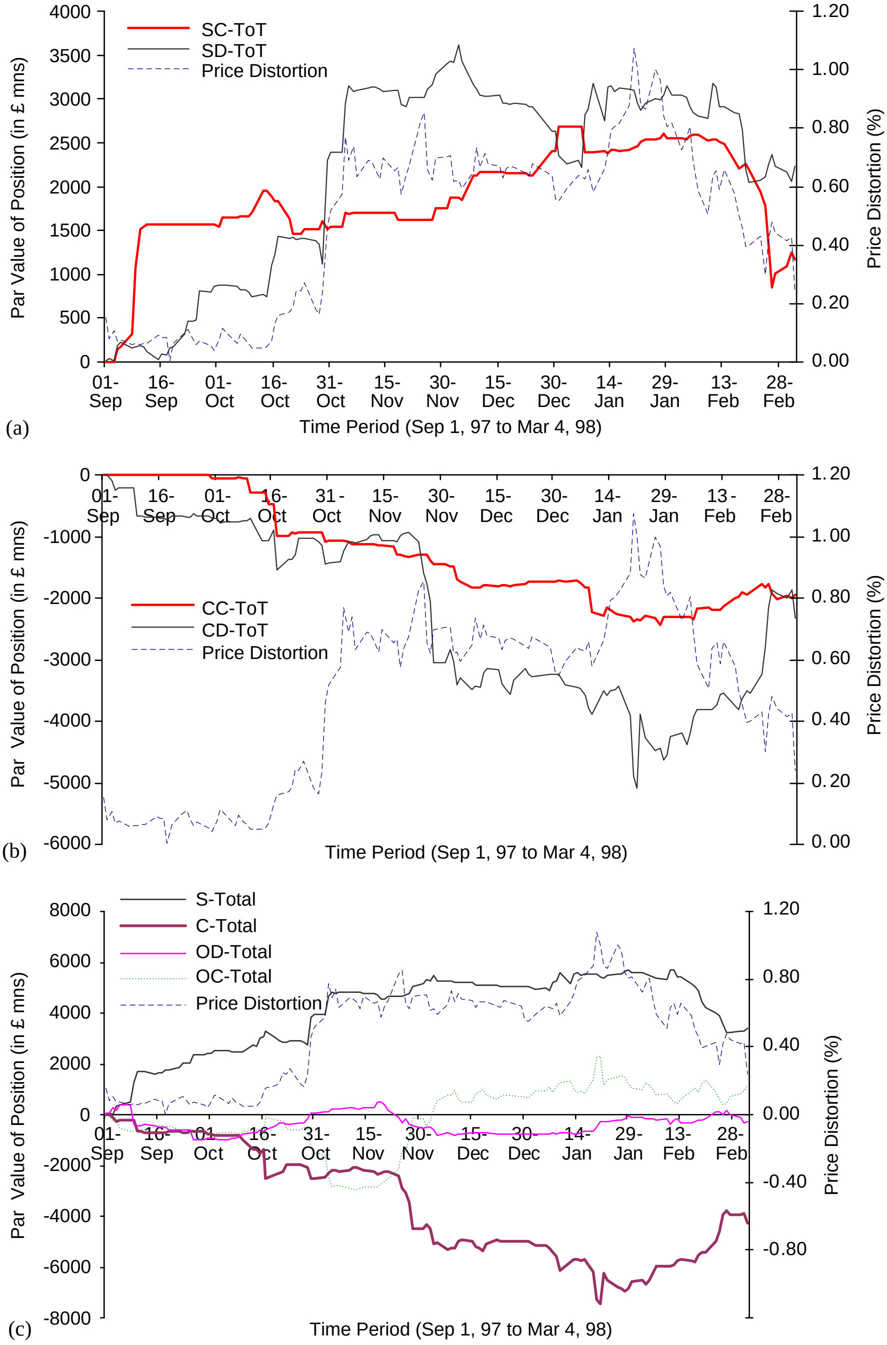


Fig. 8. The figure plots the par value position of squeezers, contrarians, and other dealers and customers (in £ millions) in the context of the price distortion (in %) from September 1, 1997 to March 4, 1998. (a) Inventories of squeezing customer and dealers. (b) Inventories of contrarian customers and dealers. (c) Inventories of different players.

contrarians collectively observed abnormal profits of £16.1 million in phase V and £15.8 million in phase VI. In contrast, squeezers recorded abnormal losses of £14.5 million in phase V and £14.1 million in phase VI.

6.7. Squeeze and market depth

Pirrong (1995, p. 146) argues that delivery squeezes erode market depth and randomly penalize traders who consume liquidity (e.g., hedgers). In this context, we examine the impact of the squeeze on market depth as measured by the relation between price changes and customer order imbalances. Our specification is similar to that in Coval and Shumway (2001) and Manaster and Mann (1996). However, following Naik and Yadav (2003b), we also control for daily price changes arising from day-to-day changes in the term structure of interest rates. This control is necessary because daily bond price changes are largely driven by one common factor. Existing studies show that the impact of customer order flow per se on price changes, even when statistically significant, is typically small. This can be easily swamped by potentially much larger variation due to other systematic influences. The necessity for such controls is much less pronounced in studies with high frequency minute-by-minute data (where the interval is so small that the variation in economic driving factors is typically much smaller than the impact of micro-structural frictions); or for other assets such as equities or commodities for which systematic common factors explain only a small proportion of the variation. However, as shown by Chaumeton et al. (1996), over 90% of the daily variation in bond prices can be explained by just one factor. We control for term structure effects by using the change in the discounted cash flow value of *cdi*1 based on the estimated daily cash gilt term structure as an additional explanatory variable.

Naik and Yadav's (2003b) findings are of particular interest. They examine data on all U.K. government bonds during the August 1994 to December 1995 period and find that the bond market in London is typically very deep. Indeed, Naik and Yadav show that this depth is affected only in certain special circumstances, e.g., when dealers are collectively at extreme inventory levels and their inventory is changing in a direction that exacerbates the effect of capital adequacy constraints. Hence, within the above framework of depth estimation, we also incorporate the impact of other context-relevant factors and special circumstances.[15] First, we test whether overall activity or net order flow in the futures market is related to the market depth of the key deliverable issue in the cash market. Since publicly available LIFFE transactions data does not distinguish between customer order flow and market intermediary order flow, we proxy activity or net futures market order flow by the change in futures open interest. Our cash market dealer firms, when they report to the regulator, do distinguish between whether a LIFFE trade has been done by them on their own account or on behalf of a client, and we do have this information.

[15]Examination of extreme net dealer inventory levels as in Naik and Yadav (2003b) is not relevant in the current context because what we have here are two groups of dealers with diametrically opposite extreme inventory levels, rather than an overall net extreme inventory level.

However, this constitutes only about 70% of the total trading volume. Second, we distinguish between days on which there are net customer buys and days on which there are net customer sells. If squeezers have cornered the supply, customers may experience more difficulty executing their buy orders relative to their sell orders. Third, because the behavior of strategic traders is very different in time periods before, during, and after the squeeze, our analysis allows for differences in market depth across different phases of the squeeze.

In particular, we run the following two regression specifications:

$$\Delta P_{cdi1,t} = \alpha_0 + \beta_0 \Delta P^{\mathrm{ns}}_{cdi1,t} + \lambda_0 \Delta I_{cdi1,t} + \gamma_0 \Delta OI_{\mathrm{fut},t} + e_t$$

$$\Delta P_{cdi1,t} = \sum_{i=1}^{6} D_{i,t}\alpha_i + \beta_1 \Delta P^{\mathrm{ns}}_{cdi1,t} + \sum_{i=1}^{6}\sum_{d=1,2} \lambda_{i,d} D_{i,t} D_{d,t} \Delta I_{cdi1,t} + \gamma_1 \Delta OI_{\mathrm{fut},t} + e'_t, \tag{11}$$

where $P_{cdi1,t}$ and $P^{\mathrm{ns}}_{cdi1,t}$, respectively, denote the market price and the fundamental discounted cash flow price of *cdi*1, as per Equation (3), at end of day t; $\Delta P_{cdi1,t}$ is the change in the market or fundamental price of *cdi*1 from the end of day $t-1$ to the end of day t; $\Delta I_{cdi1,t}$ is the change in inventory of all dealers taken together as a group from the end of day $t-1$ to the end of day t; $\Delta OI_{\mathrm{fut},t}$ is the change in open interest in the March 98 Long Gilt futures contract from the end of day $t-1$ to the end of day t; $D_{i,t}$ is a dummy variable for phase i ($i = I, II, \ldots, VI$), that captures the average change in market price due to the squeeze factor in different phases; $D_{d,t}$ is a dummy variable for the direction of order imbalance d ($d = 1$ for net customer buys and $d = 2$ for net customer sells); λ is the degree of market depth (similar to Kyle's (1985) lambda); and, e_t is the error term.

The motivation behind running the regression in Equation (11) in two ways is as follows. The first specification tells us the extent of the variation in the market price of *cdi*1 that is related to market-wide changes in the term structure of interest rates, the change in inventory, and the change in futures open interest. The second is a more general specification that permits the market depth in cash *cdi*1 trading to vary across the different phases of the squeeze and to also differ for net customer buys versus net customer sells. We report the results of the regressions in Equation (11) in Table 7.

The results from Model 1 indicate that most of the variation in day-to-day price changes of *cdi*1 is explained by market-wide term structure changes. Furthermore, on average, λ is not significantly different from zero for this bond issue. However, specifying the coefficient λ, the metric of market depth, to be constant fails to capture the interesting way in which depth is related to trading during the different phases of the squeeze. Both these findings are consistent with those of Naik and Yadav (2003b).

In particular, we find that λ is not significantly different from zero in phase I, neither for net buys nor for net sells, suggesting that the market was generally unaware of the potential of a squeeze. The coefficient λ continues to be indistinguishable from zero for net customer buys in phase II, when the squeezers

Table 7
This table reports the results from the regression of the daily change in the market price of the key deliverable issue (9% October 2008) on the change in the fundamental discounted cash flow value (due to term structure changes), the change in inventory of dealers (in £billions), and the change in open interest in March 98 Long Gilt futures contracts (in 100,000 contracts)

Slope coefficient on	Model 1	Model 2
Constant	−0.00	
	(0.96)	
Change in fundamental price of *cdi*1 ($\Delta P^{ns}_{cdi1,t}$)	1.017***	1.016***
	(0.000)	(0.000)
Change in dealer inventory of *cdi*1 ($\Delta I_{cdi1,t}$)	0.84	
	(0.69)	
Change in open interest of futures contract ($\Delta OI_{fut,t}$)	−0.00	−0.22**
	(0.83)	(0.03)
Customer sells Ph I		−0.06
		(0.58)
Customer sells Ph II		−0.21***
		(0.000)
Customer sells Ph III		0.02
		(0.79)
Customer sells Ph IV		0.013
		(0.28)
Customer sells Ph V		−0.28
		(0.22)
Customer sells Ph VI		0.07
		(0.46)
Customer buys Ph I		0.02
		(0.77)
Customer buys Ph II		0.14
		(0.39)
Customer buys Ph III		0.12**
		(0.03)
Customer buys Ph IV		0.14**
		(0.05)
Customer buys Ph V		0.45*
		(0.07)
Customer buys Ph VI		−0.04
		(0.12)
Constant for phase I		−0.009
		(0.49)
Constant for phase II		0.004
		(0.85)
Constant for phase III		−0.013
		(0.32)
Constant for phase IV		0.029
		(0.15)
Constant for phase V		−0.07**
		(0.03)
Constant for phase VI		0.015
		(0.70)
Adjusted R^2	95.5%	98.2%

***, **, and * indicate that the slope coefficients are significant at the 1%, 5% and 10% level. Model 2 allows for the intercept and slope coefficient to be different for the six different phases of the squeeze; *p*-values are in parentheses.

were building up their long positions. Yet, for customer sells, λ is negative and highly significant, suggesting that customer selling activity during this period reduced the price change of *cdi*1. The situation is different, however, between phase III and phase V; here, λ is significantly positive for net customer buys in phases III, IV, and V, with p-values of 0.03, 0.05 and 0.07 respectively, suggesting that these customer-buy trades were moving the price against the buyers. Note that λ is significantly positive also for customer buys in phase IV, when both squeezers and contrarians were equally active. In phase VI, after the Bank of England's announcement, λ is indistinguishable from zero for both customer sells and customer buys.

Given that term structure changes explain about 95% of the variation in market price, one may think that the economic significance of the reduction in depth is small. Indeed, the depth-related variables add only another 3% or so to the explained variance. However, most studies about changes in depth (as defined through the dependence of the price change on signed volume) typically make strong inferences with smaller improvements in R^2. For example, Coval and Shumway (2001) infer the significance of impact of sound level on depth on the basis of an incremental R^2 of 0.5% using about 17,000 observations. In contrast, we find an incremental R^2 of 3% with 130 observations. In this light, the changes in market depths documented above are noteworthy distortions caused by the squeeze.

Overall, our findings offer support for Pirrong's (1995) contention that delivery squeezes erode market depth and randomly penalize traders who consume liquidity. Even though most of the variation in the market price of *cdi*1 is explained by the changes in the term structure of interest rates, these regression results indicate that the squeeze not only caused price distortions, but also led to erosion of market depth particularly for public buys. A public trader attempting to buy *cdi*1 would have faced significantly higher market impact costs from early November 1997 to mid-February 1998.

From an economic perspective, while we do find erosion of depth in some phases, we do not think that depth erosion is the most important manifestation of the negative impacts of market manipulation. Instead, the major cost is that traders and investors who would otherwise trade in *cdi*1 and use the futures market for hedging would most likely curtail their routine use of these markets because of the period of sustained mispricing and, more importantly, the uncertainty about when this mispricing would revert to normal. A short-term hedger using a short (long) position in the futures market would face the "peso problem" of a loss due to a large sudden change in price relations if and when the squeeze succeeded (collapsed). Thus, it is likely that hedgers curtailed their use of gilt futures during this period for fear of large sudden contract price changes that would be unrelated to term structure fundamentals.

6.8. Implications of theoretical models

In this section, we use the trading activity of our squeezers and contrarians to test selected implications of the theoretical literature relating to trading in markets in general and episodes of market manipulation, such as short squeezes, in particular.

6.8.1. Trading and heterogeneity of beliefs

The extent of trading in financial markets has received considerable attention in the literature. The no-trade result of Milgrom and Stokey (1982) stands at one extreme. However, a number of papers argue that differences in prior beliefs (or, in revisions of beliefs) or in interpretations of public information across market participants generate trading in the financial markets (see, e.g., Varian 1985; Karpoff 1986, 1987; Kim and Verrechhia 1991a, b; Shalen, 1993; Harris and Raviv, 1994; Wang, 1994; He and Wang, 1995). While the hypothesis that differences of opinion generate trading is of central importance in the microstructure literature, as of yet it has not been tested directly. Moreover, a number of theoretical models of trading volume (see, e.g., Epps, 1975; Copeland, 1976; Jennings et al., 1981) rely on the presence and behavioral distinctions of "bulls" vs. "bears" (or, optimists vs. pessimists). In the present context, the squeezers are the bulls who believe that the squeeze will succeed and that the price of *cdi*1 will rise even further to P^{s}_{cdi1}. In contrast, the contrarians are the bears who believe that the squeeze will not succeed and that the price of *cdi*1 will fall to P^{ns}_{cdi1}. Given this divergence of beliefs, so long as the market price of *cdi*1 lies between P^{s}_{cdi1} and P^{ns}_{cdi1}, the squeezers would be buyers of *cdi*1 and the contrarians would be sellers of *cdi*1.

We measure the fraction of total trading that takes place between squeezers and contrarians, among different squeezers, and among different contrarians during our sample period. We find that on average, about 89% of the trading takes place between the squeezers and the contrarians, about 10% among the squeezers, and less than 1% among the contrarians. The trading between squeezing dealers and squeezing customers takes place mainly during phases III to VI when some squeezers unwind their positions and take profits. In contrast, the trading among contrarians is virtually zero as most of them maintained their short position throughout the squeeze period. Overall, the proportion of trading between squeezers and contrarians is statistically highly significant, substantially higher than one would expect if trading were randomly distributed across different market participants, which clearly supports those theoretical models that argue that differences in opinion generate trading.

6.8.2. Do "small" players free-ride on "large" players?

The theoretical literature on short-squeezers considers, in particular, the extent to which "small" participants with a long position are able to free-ride on a short squeeze by a "large" long participant. The ability of small participants to free-ride on the squeeze is similar to the ability of small shareholders to free-ride on the monitoring effects of a large shareholder (see, e.g., Shliefer and Vishny, 1986) and is related to the notion that when there are externalities, smaller participants can do better, on a per unit basis, than larger ones. Also, see Dunn and Spatt (1984) for a model of a short squeeze without free-riding. For example, Kyle (1984) argues that the small long participants will be able to unwind their entire position well above the competitive price before the large squeezer will be able to sell any of its units. Cooper and Donaldson (1998) formalize this notion and consider a case in which all players are strategic. Nyborg and Strebulaev (2004) present a generalized short squeezing model in the context of auctions. One important implication of their model is that some market participants do free-ride on the efforts of large squeezers, and earn more than the large squeezers. In our context, this theoretical implication is clearly supported by the trading of customer SC3 and dealer SD4 (see Figs. 3 and 4 and Table 7): these traders build up their long position after the initiation of squeeze, but due to their early profit taking, make more money than the larger squeezers such as dealers SD1 and SD2 who do not manage to fully unwind their long position. Nyborg and Strebulaev's (2004) model also implies that the volatility after a squeeze will be higher relative to a no-squeeze scenario. If we think of the volatility of *cdi*1 as caused by market-wide changes in the term structure, and of changes in price distortion as arising from the squeeze factor, then clearly the price distortion (plotted in Fig. 2a) contributed to an increase in the volatility of *cdi*1 during phases II to VI of our sample period.

7. Settlement nonperformance penalties and squeeze incentives

7.1. Settlement nonperformance penalties in cash and futures markets

Pirrong (1993) emphasizes the role of economic frictions such as transportation and transactions costs in the delivery squeeze of physical commodities. Although neither of these costs is important for financial securities, settlement-related frictions can potentially play an important role in a squeeze of financial securities. For example, not all trades settle smoothly through an orderly transfer of money and title on the contractual settlement date, i.e., a small number of trades "fail". Ultimately, fails are "cleaned-up" by a good settlement at a subsequent date. In the U.K. and U.S. cash bond markets, a fail by the seller does not alter the contractual cash flows of the originally agreed upon transaction. A failed-to buyer is still the recognized owner of the undelivered securities in question and is responsible for paying the originally agreed upon invoice amount when the securities are ultimately delivered. The failing seller is still obligated to make delivery of the securities, but receives only the originally agreed upon invoice amount, not the interest between the original settlement date and the actual delivery date. Hence, the failing seller is effectively penalized by implicitly lending at 0% over the fail period.

The right to fail provides an important release valve for pressures caused by trade processing problems, and also limits the damage a potential squeezer can cause. In a market without fails, individual traders caught with short positions in a manipulated issue would be compelled to either buy back the issue in the cash market at the squeeze-inflated price or borrow the security in the repo market, to make good on the settlement of the shorted security. In a no-fail system, the repo rate on a borrowing of the affected issue would not be floored at 0%. Indeed, the repo rate could be negative, since traders would compete to avoid being bought-in at the (temporarily) squeeze-inflated cash market price in order to make good settlement. The trader who chooses to fail prefers to lend at 0% than to pay the squeeze-inflated cash market price. The fail system obviates the need for a "buy-in" aimed to ensure a smooth securities transfer on the original settlement date. However, if the failed-to buyer were set up to receive the bond to then make delivery against a short bond futures contract position, these bonds would not be available for use in a timely futures delivery, and the buyer would consequently fail in the futures market.

Settlement date nonperformance is much more of an issue for bond futures markets than for the respective cash markets because bond futures exchanges in the U.S. and U.K. also impose substantial fines on contract shorts that fail. For example, the CBOT can fine the nonperforming member up to $25,000 for each violation, and an additional $25,000 for "conduct detrimental to the exchange". The exchange is perceived to be free to interpret this per-violation standard as applying on a per contract basis, which makes the base $25,000 fine alone equivalent to 25% of the bond contract's par value. Clearly, fails in these futures markets are so costly that they are virtually not an available option. The existence of such draconian nonperformance penalties dramatically alters the futures manipulator's endgame. In particular, most futures shorts cannot wait for a potential last-minute supply releasing pre-delivery collapse of the squeeze. The exchange imposes penalties on the failing clearing member regardless of whether the failed deliveries reflect the clearing member's proprietary positions or that member's customer accounts. Not surprisingly, clearing members typically identify those customers with short positions in the delivery month and require such customers to position the correct quantity of deliverable bonds in their clearing accounts three-to-seven days ahead of the last trading day. If these customers do not have the correct quantity of bonds in their account by this deadline, the clearing member offsets the relevant short futures positions by buying contracts back in the market. In essence, the clearing member performs a preemptive "buy-in" to avoid the penalties for a settlement fail. In a delivery squeeze showdown between a credible squeezer and contract shorts, the contract shorts blink first.

7.2. Settlement nonperformance penalties and cash-futures arbitrage

The arbitrage-based price of a bond futures contract F_τ at time τ is given by

$$F_\tau = \frac{1}{cf_{cdi1}}[(P_{cdi1,\tau} + A_{cdi1,\tau})(1 + r\kappa) - A_{cdi1,T} - C_{cdi1} - DOV_{cdi1}], \tag{12}$$

where cf_{cdi1} is the conversion factor for the planned deliverable *cdi*1; $P_{cdi1,\tau}$ is the price of *cdi*1 at time τ; $A_{cdi1,\tau}$ is the accrued interest on *cdi*1 on settlement date τ; r is the financing rate; κ is the fraction of a year between dates τ and T; C_{cdi1} is the value of coupons received (if any) between dates τ and T, adjusted for any riskless reinvestment income until date T; and, DOV_{cdi1} is the total value of the short's delivery options expressed as the net basis for *cdi*1. These options reflect the delivering short's flexibilities regarding ultimate delivery grade quality and precise delivery timing. The quality option, QO_{cdi1}, reflects the short's right to substitute an alternative issue for the one originally planned. The timing option, TO_{cdi1}, relates to the delivering short's flexibility to choose the exact date within the delivery month to deliver. Finally, $DOV_{cdi1} = TO_{cdi1} + QO_{cdi1}$.

Gay and Manaster (1986) thoroughly discuss the timing options of the CBOT's U.S. Treasury bond futures contract in the context of "accrued interest", "wild card", and "end-of-month" (or, "Royal Flush") components. The analysis of these components in the case of the LIFFE's March 98 Long Gilt futures contract is straightforward. First, the accrued interest option implies that, ceteris paribus, deliveries should be made at the end rather than the beginning of the delivery period. In the case of *cdi*1, this means that deliveries should be made on March 9, 1998, the last eligible delivery date. Analysis of the wild card and end-of-month components of delivery options relevant for *cdi*1 simplifies dramatically in the case of Long Gilt futures. Except for the last notice day, the Long Gilt contract requires that shorts identify the issue to be delivered during the morning of the notice day. Thus, the CBOT-style daily wild card option does not exist. A small end-of-month option does exist, however. The final trading day for the Long Gilt contract is the third-to-last business day of the delivery month; the final notice day is the second-to-last business day. The short can wait until 10:00 AM on this final notice day to give notice and identify the issue to be delivered the next day at the invoice price that was determined on the previous day. Note that this fixed-price window starts on the third-to-last business day for the Long Gilt contract. In the CBOT Treasury bond and note contracts, the end-of-month window starts on the eighth-to-last business day. Thus, the Long Gilt contract's end-of-month option is considerably less valuable because of its shorter (just one business day) time to expiration. Furthermore, Gay and Manaster (1986) relate the payoffs to exercising both the wild card and end-of-month components to the issue's conversion factor "tail" = 1 − cf_{cdi1}. Coincidentally, for the March 98 Long Gilt futures contract, the conversion factor for the 9% 2008 gilt equals 0.9999442, implying a *cdi*1 conversion factor tail = 1 − 0.99994420 = 0. Thus, the contract's end-of-month option is worthless: $TO_{cdi1} = 0$.

The value of the quality option, denoted QO_{cdi1}, depends upon the probability that the identity of the cheapest-to-deliver issue will change prior to the chosen delivery date. In the case of a contract with two deliverable issues, Margrabe (1978) solves a switching option model that can be applied to determine the value of the quality option (see Gay and Manaster (1984), Garbade and Silber (1983) and Hemler (1990) for discussions and applications of Margrabe's model to futures pricing). Let $CFP_{\text{cdi1}} = FP_{\text{cdi1}}/cf_{\text{cdi1}}$ and $CFP_{\text{cdi2}} = FP_{\text{cdi2}}/cf_{\text{cdi2}}$ denote the converted forward delivery date prices of *cdi*1 and *cdi*2, respectively. Under Margrabe's model, futures pricing can be summarized as

$$F_\tau = CFP_{cdi1} - QO_{cdi1}/cf_{cdi1} \tag{13}$$

and the date-T forward value of the quality option is worth

$$QO_{cdi1} = [CFP_{cdi1}N(d_1) - CFP_{cdi2}N(d_2)](1 + r\kappa), \tag{14}$$

where $N(.)$ is the cumulative normal distribution function such that $d_1 = [\ln(CFP_{cdi1}/CFP_{cdi2}) + 1/2\sigma^2\kappa]/\sigma\kappa^{1/2}$, $d_2 = d_1 - \sigma\kappa^{1/2}$, and $\sigma =$ the standard deviation of the difference between the returns on *cdi*1 and *cdi*2.

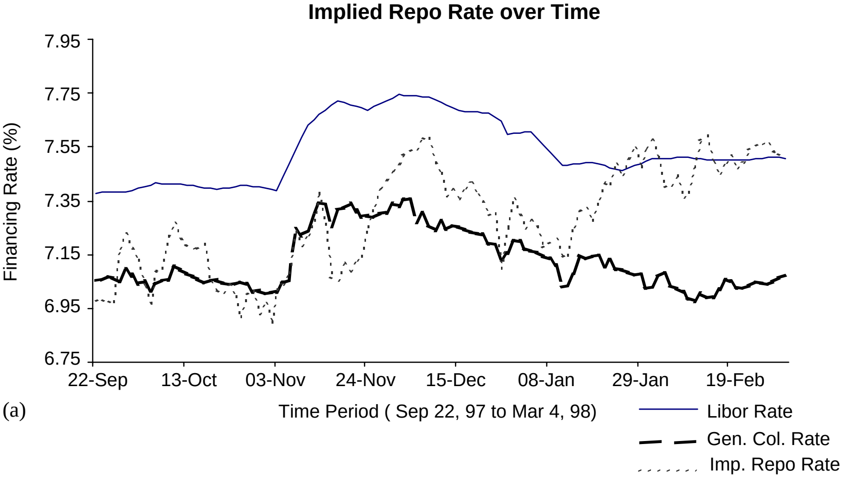
The impact of the quality option on the futures price depends upon both the initial gap between the converted forward prices of *cdi*1 and *cdi*2 and the volatility of the difference of the rates of return on these two issues. In the case of the March 98 Long Gilt futures contract, consider pricing the contract on September 1, 1997, i.e., just slightly more than six months prior to the planned delivery date of March 9, 1998 ($\kappa = 0.518$). Importantly, this pricing example takes place before any squeeze pressures were revealed in October. On September 1, $CFP_{cdi1} = 123.27$, $CFP_{cdi2} = 125.28$, and $r = 0.07$. Using an estimate of the annualized volatility of the difference in the returns on the two issues derived from daily data between January 1, 1997 and August 31, 1997, $\sigma = 0.0054$. Over this time period, no squeeze occurred and thus the observed sample standard deviations of daily returns on the two issues as well as their return correlation—the determinants of σ—reflect the equilibrium pricing condition (3) applied to each bond. For this case, the calculated value of Margrabe's (1978) model yields $QO_{cdi1} = 0.0004$ and the quality option is essentially worthless: the initial gap of 1.22 between the two converted forward prices (see Fig. 1c) is too large to be overcome given the low volatility of the difference between the two bond returns. The same gap indicating that squeeze potential exists for the March 98 contract implies that the value of the quality option in a no-squeeze equilibrium is trivial, i.e., $QO_{cdi1} = 0$.

Evaluation of quality option value under the manipulated full-squeeze equilibrium differs in a subtle, but fundamental, way. Under the full-squeeze condition (5), the converted price *cdi*1 rises to meet its upper bound (in forward terms, this would imply $CFP_{cdi1} = CFP_{cdi2}$). However, under this full-squeeze equilibrium, the terminal prices for *cdi*1 and *cdi*2 would be perfectly correlated (so that in Margrabe's (1978) model, $\sigma = 0$). This condition implies that the option to sell *cdi*1 and then buy and deliver *cdi*2 is worthless in a full-squeeze. In sum, for the case of the March 98 Long Gilt futures contract, the no-arbitrage futures-cash pricing Equation (12) effectively simplifies to pure cash-and-carry pricing ($DOV_{cdi1} = 0$) for both no-squeeze and full-squeeze outcomes. Analysis of arbitrage pricing during this interesting episode should focus directly on the financing component of the pricing relationship.

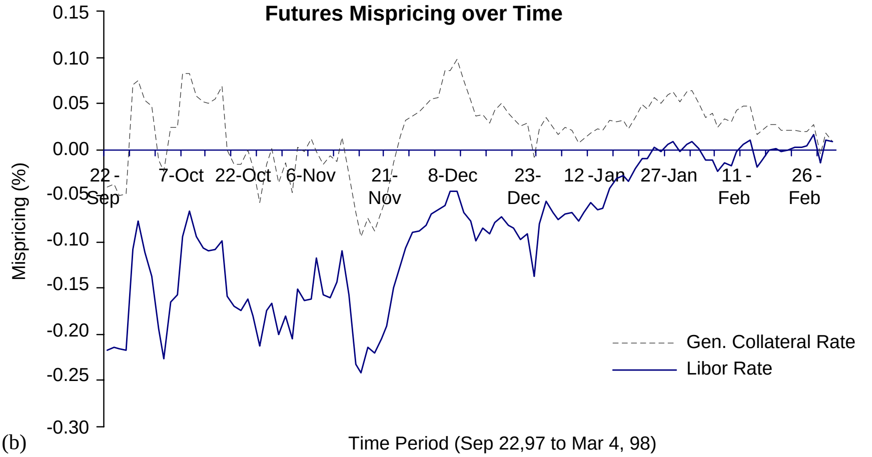
Duffie (1996) and Jordan and Jordan (1998) discuss the importance of repo/reverse repo agreements in the financing of bond positions. For highly leveraged traders such as bond dealers and cash-futures arbitrageurs, the financing cost savings of accessing the preferential rates associated with collateralized lending via the repo market can be very significant. Particularly large savings occur when a specific bond turns "special" and can be financed at rates even lower than the prevailing general collateral rates. Such a special financing rate directly affects the futures price via Equation (12). Ceteris paribus, the futures price on a contract whose *cdi*1 turns special will be lower than if the issue were traded in the repo market at the general collateral term repo rate (because the financing cost to delivery shrinks).

However, this argument is not likely to hold during a squeeze in the presence of draconian futures market nonperformance penalties. During a squeeze, an arbitrageur with a long-cash/short-futures position cannot feel confident using a standard repo agreement to finance the cash market position because the repo counterparty may fail on the timely return of the collateral bond. Thus, when the probability of a squeeze increases, repo-dependent cross-market arbitrage traders begin to leave the market in favor of traders such as commercial bank trading desks with access to uncollateralized sources of funds. In such circumstances, LIBOR should become the marginal financing rate in Equation (10). Since LIBOR is higher than the repo rate, the futures price should increase (rather than decrease) relative to that of the *cdi*1 during periods when squeeze concerns arise. Thus, evidence that LIBOR replaces repo as the relevant marginal financing rate during the squeeze episode provides a direct test of the valuation significance of the asymmetric penalties for failed settlements between cash and futures markets.

Fig. 9a plots three interest rate series: the general collateral repo rate, LIBOR, and the implied repo rate (i.e., the break-even financing rate implied by the relative prices



(a)



(b)

Fig. 9. (a) plots the LIBOR rate, the general collateral rate, and the implied repo rate (in %) during the sample period (from September 1, 1997 to March 4, 1998). (b) plots the mispricing of futures contract under two scenarios: first, when the financing rate is the general collateral rate, and second, when the financing rate is LIBOR.

of the *cdi*1 and March 98 futures). Up until January 20, 1998, the difference between the implied repo rate and LIBOR has a mean of −0.34% (*t*-statistic: 26.1). The difference between the implied repo rate and the general collateral rate has a mean of −0.05% (*t*-statistic: 4.06). After January 20, 1998, these mean differences equal −0.006 (*t*-statistic:−0.47) and 0.45 (*t*-statistic 30.4), respectively. Thus, up until January 20, 1998, the implied financing rate was slightly smaller than but significantly closer to the general collateral rate than LIBOR. Thereafter, instead of decreasing (as if the *cdi*1 had turned special due to futures-delivery related high demand), the implied financing rate increased and became statistically indistinguishable from LIBOR. This result clearly reveals that during the latter part of the squeeze, the marginal arbitrageurs financed their cash market position using an uncollateralized source of funding rather than the repo market.

Fig. 9b sheds more light on this issue by plotting two measures of futures mispricing based upon two alternative financing rates. The first measure assumes that the financing rate is the general collateral rate; the second measure uses LIBOR. After January 20, 1998, the March 98 futures contract appears overpriced relative to the repo-based funding calculations, while it seems to be fairly priced relative to the LIBOR-based funding calculation. The average daily overpricing with repo-based calculation equals 0.035% (*t*-statistic: 11.5) while that with LIBOR equals −0.002% (*t*-statistic: −1.35). These findings provide strong evidence of the importance of settlement nonperformance penalties in determining the behavior of arbitrageurs and market prices.

7.3. Squeeze-ending action by the Bank of England

Interestingly, the specific action taken by the Bank of England to end the squeeze also illustrates the importance of the differences in settlement nonperformance penalties between cash and futures markets in squeeze facilitation. Concerned about the distortions generated by the squeeze attempt, the Bank of England introduced an innovative noninvasive policy response via a temporary change in its repo policy. On February 16, 1998, the Bank of England released a press notice concerning "market developments in 9% Treasury Loan 2008 and the long gilt future contract on LIFFE". The following is an excerpt from that press notice:

> *The Bank of England continues to monitor market developments in 9% Treasury Loan 2008 and the long gilt future contract on LIFFE. It recognizes that there is concern that some market participants may fail to be delivered stock due for repurchase under repo agreements and intended for delivery into the long gilt future.*
>
> *In order to forestall any market disruption resulting from significant failed trades or returns, the Bank of England is prepared to make supplies of the stock available from 23 February, on overnight repo only, to any gilt-edged market maker (GEMM) who has been subject to a failed return or delivery of stock, or has a customer who has been subject to a failed return or delivery of stock. HM Treasury will issue further amounts of this stock for this purpose.... The repo rate applying to any stock made available through this facility will be 0%.*

Note the ingenuity of the Bank of England's offer. The fact that the repo rate on the newly available quantities of gilts was set at 0% did not change the profit or loss or other incentives for any dealer or customer versus the alternative of failing in cash market settlement. The incremental supply of bonds would simply replace any quantity cornered by the squeezers through strategic repo fails. Thus, the Bank of England's action was targeted narrowly at addressing the asymmetries between settlement nonperformance penalties in the cash and futures markets. As Fig. 2 shows, the price distortion, the butterfly yield spread, and the implied squeeze probability all fell towards their "normal" values after the Bank's announcement. The squeezers were relying on the exceptionally high costs of failing in the futures market to force shorts to capitulate as the delivery date approached. The Bank's narrow action removed futures delivery fail risk, eliminated the fear of the additional LIFFE delivery fail penalties, and ended the squeeze.

One puzzle does remain. While the 9% 2008 cash issue re-priced back towards normal no-squeeze equilibrium levels after the Bank of England's policy change, March 98 futures remained slightly overpriced relative to cash on the basis of the cash-and-carry arbitrage relationship. In Fig. 9b, the deviation of the futures price from its repo-generated cash-and-carry arbitrage value remained about +0.02% of par value. We interpret this as a premium that the market was willing to pay for an option on "irrational" March 9th delivery behavior. Recall that the 9% 2008 was no longer eligible for delivery after the March 9th delivery date. Once the 9% 2008's eligibility ended, the price of the March 98 futures would jump 2% to reflect the new deliverable: the 8% 2009. Apparently, some market participants were willing to overpay for March 98 futures even after the squeeze threat vanished in the hope that some contract shorts would "forget" to deliver on March 9, 1998. Speculators on delivery irrationality were willing to pay +0.01% to +0.02% of par value on a lottery ticket that had a potential payoff of +2.00% of par value. However, in the end, rational delivery behavior reigned. Indeed, 92,401 contract deliveries were made using the *cdi*1 prior to the close of its eligibility window. These deliveries absorbed an amazing 82.4% of the outstanding par value of *cdi*1. No cash market gilt fails occurred and the Bank of England's special repo facility was never used.

8. Concluding remarks

This paper examines the strategic trading behavior of major market participants during an attempted delivery squeeze in a bond futures contract traded on the LIFFE. Our study investigates both the price distortions and trading positions of major market participants involved in the market-manipulation episode and identifies the particular institutional features that give an important endgame advantage to squeezers in futures markets. We present empirical evidence on the strategic trading behavior of major market participants (both dealers and customers), and demonstrate how learning takes place in a market-manipulation setting. We document how market prices and market depth were distorted and estimate the profits of strategic traders during different phases of the squeeze.

Finally, we present evidence in support of implications of certain models of trading volume and short squeezes.

From a regulatory perspective, this paper has several messages. First, regulators and exchanges need to be concerned about ensuring that manipulative squeezes do not take place. Squeezes entail severe price distortions and also some erosion of market depth, both of which randomly penalize hedgers. Second, regulatory reporting should require flagging of trades such as the forward term repo trades on the key deliverable issues underlying the futures contracts. Under current reporting systems, these trades can go undetected. Third, exchanges and regulators should be concerned about the fact that the marked differences in the penalties for settlement failures in the cash and futures markets create conditions that engender squeezes. Finally, futures exchanges should remove the sources of opportunities for engineering squeezes. Towards this end, the exchanges should mark-to-market the specifications of their bond contracts much more frequently than they do at present, so that the prevailing market conditions do not differ dramatically from those assumed in the calculation of conversion factors. Moreover, the futures exchanges should explore the possibility of redefining their bond futures contract to be cash-settled on a basket of traded bonds, rather than requiring physical delivery against a contract specified on a bond with a notional coupon and maturity.

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