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Risk Management with Derivatives by Dealers and Market Quality in Government Bond Markets

NARAYAN Y. NAIK and PRADEEP K. YADAV*

ABSTRACT

This paper investigates how bond dealers manage core business risk with interest rate futures and the extent to which market quality is affected by their selective risk taking. We observe that dealers use futures to take directional bets and hedge changes in their spot exposure. We find that, cross-sectionally, a dealer with longer (shorter) risk exposure sells (buys) a larger amount of exposure the next day. However, this risk control takes place via the futures market and not the spot market. Finally, we find strong support for the price effects of capital constraints emphasized by Froot and Stein (1998).

RISK MANAGEMENT PRACTICES OF CORPORATIONS have received wide attention in recent years largely due to some well-publicized cases of losses incurred by firms as a result of trading in derivatives.¹ The theoretical literature provides several motivations for why corporations should use derivatives to manage their risk.² From

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¹Metallgesellschaft, Orange County, and Proctor and Gamble reported large losses as a result of trading in derivatives while Daimler Benz reported large losses for not using derivatives to hedge its dollar receivables.

²See for example, Holthausen (1979), Anderson and Danthine (1981), Stulz (1984, 1996), Smith and Stulz (1985), Froot, Scharfstein, and Stein (1993), DeMarzo and Duffie (1995), May (1995), Breeden and Viswanathan (1998), and Mello and Parsons (2000) for risk management by firms or managers of firms.

an empirical perspective, our understanding of corporate risk management practices has improved significantly in recent years, thanks to Wharton/CIBC surveys, to changes in the public disclosure requirements that have enabled extensive empirical research, and to case studies that describe the risk management practices of specific firms and industries.³

In contrast, there is very limited research on the overall risk management practices of market intermediaries. Theoretical modeling of the risk management problem faced by market intermediaries has been very recent (Froot and Stein, 1998). On the empirical side, microstructure researchers have shown how intermediaries charge a bid-ask spread to protect themselves against adverse selection risk and individual asset inventory risk, and how dealers manage the specific risk implicit in their individual asset inventories. However, we know relatively little about how intermediaries manage the *hedgeable* market risk component of their core business risk, and the role that derivatives contracts play in this risk management.⁴ In this paper, we undertake a comprehensive investigation of this for market intermediaries in bond markets.

Using a comprehensive data set from the Bank of England that provides daily close-of-business positions (long or short) of individual U.K. government bond dealers in every U.K. government bond issue and in related interest rate futures contracts, we address four questions of interest to regulators, academics, and market participants. First, we analyze the extent of selective market (i.e., interest rate) risk taking by government bond dealers and the way they use interest rate futures contracts to manage their spot risk on a day-to-day basis. In this context, we also investigate the factors that govern the time-series variation in hedging with futures. Second, in view of the potential informational advantage enjoyed by dealers, we examine whether the magnitude and profitability of selective market risk taking is related to the dealer's market share; here we also investigate the extent to which the profits from selective market risk taking are significant. Third, we test, for the first time, the central implication of Ho and Stoll's (1983) model which applies at the overall portfolio level, namely, it is the dealers with extreme long (short) total risk exposure who sell (buy) relatively greater exposure in the next period. We also examine, in this context, the effect of the availability of a well-functioning futures market. Finally, we investigate the relation between the selective market risk-taking activity of dealers and market quality in the context of the price effects of capital constraints as argued by Froot and Stein (1998).

³ See Tufano and Serbin (1993) and Tufano and Headley (1994a, 1994b) for case studies on risk management. For empirical research on risk management by corporations and banks, see, for example, Block and Gallagher (1986), Nance, Smith, and Smithson (1993), Dolde (1995), Mian (1996), Tufano (1996), Geczy, Minton, and Schrand (1997, 1999), Schrand and Unal (1998), Koski-Lynch and Pontiff (1999), Graham and Smith (1999), Graham and Rogers (2000), Brown, Crabb, and Haushalter (2001), and Guay and Kothari (2001). See Barnes (2002) for a comprehensive survey.

⁴ There exists literature on hedging with futures contracts in the U.S. government bond market (see, e.g., Kane and Marcus (1986), Hemler (1990), and Barnhill (1990)). However, the focus of our work is very different.

The extent to which market intermediaries actually hedge the (hedgeable) market risk component of their core business risk, and the profitability of their selective market risk-taking activity, is of considerable interest because there exist two different views in the literature in this regard. Froot and Stein (1998) assume that intermediaries do not enjoy any informational advantages over other market participants and thus they argue that financial intermediaries should fully hedge their exposure to any efficiently tradable risk. In contrast, Stulz (1996) contends that some firms may have a comparative advantage in bearing certain risks, and that such firms should exploit this advantage by engaging in selective risk taking. If the order flow in the bond market is informative (as has been found in the equity and foreign exchange markets),⁵ then one would expect bond dealers to try to exploit this information through selective market risk taking by following a duration-targeting policy. One would also expect larger dealers to carry a relatively greater amount of risk on their books, to hedge less, and to profit more from their informational advantage compared to the smaller dealers. Finally, one would expect the extent to which dealers hedge risk to vary across time depending on relevant economic factors including the level of uncertainty in the market place, the cost of hedging, and the pressures of capital constraints arising from external regulatory capital requirements and/or internal risk-budgeting controls.

We find that dealers engage extensively in selective market risk taking through duration targeting. The size of their futures positions is comparable in magnitude to their spot positions and their futures positions usually reinforce the risk of their spot positions. However, we also find that dealers use futures contracts to offset or hedge changes in their spot positions. This offset is partial in most cases, suggesting that dealers engage in selective risk taking as argued by Stulz (1996). In terms of time-series variation in hedging, we find that dealers offset the changes in their spot risk to a greater extent when the cost of hedging is lower, when the pressures of capital constraints are greater, and when economic uncertainty is greater.

We also find that larger dealers (dealers with higher market share) engage in a greater amount of selective market risk taking and hedge changes in their spot exposure to a lesser extent compared with smaller dealers. This behavior supports Stulz (1996). However, we do not find that larger dealers earn more profits from their selective risk-taking activity than the smaller dealers. In fact, on average, most of the dealers do not make significant profits from their overnight risk exposure. These results indicate that bond markets are efficient, and that the order-flow-related informational advantage of bond dealers is more perceived than real.⁶

⁵ See, for example, Easley and O'Hara (1987), Barclay and Warner (1993), Lyons (1995), Keim and Madhavan (1996) and Hansch, Naik and Viswanathan (1999).

⁶ In a recent paper, Brown et al. (2001) examine time-series variation in hedging and profitability of selective risk taking of firms from gold, milk, and durable-manufacturing industries. Like us, they find considerable time-series variation in hedge ratios. They also find that some firms have a statistically significant ability to selectively hedge, and that the average economic significance of the gains is small.

Theoretical models of competitive dealership markets, like Ho and Stoll (1983), imply that dealers with relatively long (short) total exposure in one period sell (buy) a larger amount of exposure in the following time period. This cross-sectional implication applies at a dealer's overall portfolio level, where the portfolio includes derivatives positions. In view of data constraints, this implication has not been tested in the extant literature.⁷ When we test this implication, we find strong support for it: Dealers with extreme levels of high (low) total risk exposure sell (buy) a greater amount of total risk. However, important from the perspective of regulators and extant models, we find that this is achieved almost entirely by trading in the futures market and not by trading in the spot market. This is particularly important for bond markets, because in contrast to individual stocks, a large fraction of the risk of individual bonds is hedgeable with bond futures.⁸

Finally, we investigate whether selective market risk-taking policies of dealers affect their ability to provide liquidity to investors and therefore affect market quality in the context of price effects of capital constraints as argued for by Froot and Stein (1998). This issue is of significant interest to academics and regulators. If dealers follow a duration-targeting policy, then a part of their limited capital gets allocated to bearing hedgeable risk, risk that could be laid off via futures markets. This effectively reduces the amount of capital available for providing liquidity to public investors, which, according to Froot and Stein, should affect the prices at which dealers will be ready to execute trades. Using the Bank of England's capital adequacy directive guidelines, we compute the amount of capital required by the dealers for carrying the hedgeable market risk exposure. We examine price effects on days when the capital requirement is very high and find that on these days trades that worsen (relax) dealers' capital constraints experience significantly worse (better) prices. This finding offers strong support for Froot and Stein's argument about the price effects of capital constraints. Regulators interested in market quality should be concerned about these asymmetric, adverse price effects of the selective market risk taking of dealers, especially where the risks can be efficiently offloaded through the futures market.

In the context of the four issues discussed above, it is important to note that we analyze the risk management practices of a homogenous group of sophisticated market professionals who, compared to managers of traditional firms, are in a better position to understand and manage their risk. This is because government bond dealers are exposed to a single source of risk (namely, interest rate risk) that can be estimated precisely and hedged efficiently through futures markets.

The rest of the paper is organized as follows. Section I describes the salient features of the U.K. government bond market and the data analyzed in this paper. Section II outlines the measures used for analyzing the risk exposure of spot and

⁷ It has been possible to do only limited tests at an individual stock-by-stock (instead of portfolio) level, and without consideration of derivatives. See, for example, Hansch, Naik, and Viswanathan (1998) and Naik and Yadav (2001), both of whom examine individual equities.

⁸ For example, a regression of individual stock returns on stock index futures returns provides an *R*-square of about 30 percent while a regression of individual bond returns on bond futures returns provides an *R*-square of 80 percent.

derivative positions. Section III provides a descriptive analysis of risk exposures of different bond dealers. Section IV investigates how dealers manage spot risk with derivatives while Section V examines intertemporal variation in hedging behavior. Section VI compares the extent of selective risk taking and hedging by larger dealers relative to smaller dealers, and the profitability of selective risk taking. Section VII tests cross-sectional portfolio-level implications of theoretical models of competitive dealership markets and the role played by futures markets in this regard. Section VIII examines price effects of capital constraints and the relation between dealers' selective risk taking and market quality. Section IX offers concluding remarks.

I. The Data and the Salient Features of the U.K. Government Bond Market

Our sample period runs from August 1, 1994, to December 30, 1995 (358 business days). In August 1994, there were 90 different U.K. government bond issues with a nominal outstanding value of £205 billion. Trading in these bonds is organized on the London Stock Exchange in a competitive dealership environment with several dealer firms competing with each other to execute the public order flow.⁹ During the sample period, the dealer firms were required to be independent legal entities separately capitalized from the parent firm. They also had to register themselves with the Bank of England, the supervising regulatory authority, and were required to report to the Bank every day their close-of-business inventory position in each government bond issue and in related derivatives contracts. Our data consists of the daily close-of-business reports filed by the dealer firms and provides individual dealer inventory positions in each bond issue (number of bonds and whether long or short) and in related futures contracts (number of futures contracts and whether long or short). We analyze the close-of-business reports of 15 dealer firms, who are separately capitalized subsidiaries of well-known banking houses such as Barclays, CSFB, Deutsche Bank, Goldman Sachs, Lehman Brothers, Natwest, HSBC, JP Morgan, Merrill Lynch, Nomura, Salomon Brothers, UBS, and others. Among our 15 dealers, 5 dealers report positions in 70 or more bonds, 6 dealers report positions in 50 to 70 bonds, and the remaining 4 dealers report positions in less than 50 bonds. All dealers report positions in long-term bond futures contracts (called the Long Gilt futures contracts) traded on the London International Financial Futures Exchange (LIFFE). These positions are typically in the nearest maturity contract, rolled forward to the next maturity contract in the expiry month. Occasionally, some dealers report small positions in the three-month LIBOR interest rate futures contract. However,

⁹ See Hansch and Saporta (1999) for microstructural details of the U.K. government bond market. The London Stock Exchange Quarterly reports that in 1994, the total turnover in U.K. government bonds was £1,545 billion in about 700,000 trades, corresponding to an average trade size of £2.2 million. However, the median trade size was much smaller, less than £0.1 million.

more than 99 percent of their futures risk exposure comes from positions in the long-gilt futures contracts.¹⁰

II. Measures of Systematic Risk Exposure

We compute the systematic risk exposure of a dealer's portfolio using both a theoretical measure, modified Macaulay duration,¹¹ and an empirical measure, the number of futures contracts one needs to trade in order to hedge a bond.

A. Theoretical Measure of Risk Exposure

We compute the modified Macaulay duration (henceforth, simply referred to as duration) $D_{i,t}$ at time t of bond i ($i = 1, \dots, 90$ in our sample) maturing at time T as

$$D_{i,t} = \frac{1}{P_{i,t}} \sum_{s=1}^T \frac{sC_{i,t+s}}{(1+y_{i,t})^{s+1}}, \quad (1)$$

where $P_{i,t}$ is the market price of bond i at time t , $C_{i,t+s}$ is the cash flow received from bond i s periods after time t , and $y_{i,t}$ is the yield to maturity on bond i at time t . We measure the theoretical (duration-based) spot exposures $S_{k,t}$ of dealer k at the end of day t as

$$S_{k,t} = \sum_{i=1}^{90} \frac{V_{i,t}^k D_{i,t}}{100}, \quad (2)$$

where $V_{i,t}^k$ is the Pound Sterling value of the position (duly signed) of dealer k in bond i at the end of day t , and $D_{i,t}$ is the duration of bond i as defined in equation (1) above. Similarly, we measure theoretical (duration-based) futures exposure $F_{k,t}$ of dealer k at the end of day t as

$$F_{k,t} = \sum_{fut=1}^2 \frac{W_{fut,t}^k D_{fut,t}}{100}, \quad (3)$$

¹⁰ No dealer reports any positions in options on interest rate futures contracts. The annual reports of the dealer firms also do not report any options' positions. This may be because during our sample period, the options market in London was relatively illiquid and not very deep. In particular, the average net exposure corresponding to the total open interest in option contracts on long gilt futures was of the order of two percent to three percent of the average net exposure corresponding to the total open interest in long gilt futures contracts. During our sample period, there was no Strips market or Repo market in the U.K. government bonds either. These developments took place in 1996–1997.

¹¹ Arguably, there exist systematic risk factors other than duration in the bond markets. Chaumeton, Conner and Curds (1996) examine the relative explanatory power of different risk factors in the U.K. government bond market. They find that (see their Table 3) the second factor adds an extra 3.4% explanatory power over the 86.4% provided by duration (i.e., Shift). Therefore, we select duration as our proxy for the systematic risk factor in our analyses.

where $W_{fut,t}^k$ is the Pound Sterling value of the position (duly signed) of dealer k in futures contract at the end of day t , and $D_{fut,t}$ is the duration of the futures contract (based on the cheapest-to-deliver bond) at the end of day t .¹²

B. Empirical Measure of Risk Exposure

Our empirical measure of the systematic risk of a bond is based on the number of long-gilt futures contracts one needs to trade to hedge the systematic (or hedgeable) risk of a bond position. We estimate the beta of each bond vis-à-vis the long-gilt futures contract (β_i) by regressing the daily bond return on the daily return on the long-gilt futures contract, as follows:

$$R_{i,t} = a_i + \beta_i R_{fut,t} + \eta_{i,t}, \quad (4)$$

where $R_{i,t}$ is the return on bond i from day $t-1$ to day t , $R_{fut,t}$ is the return on the long-gilt futures contract from day $t-1$ to day t , and β_i is the slope coefficient or the beta of the given bond vis-à-vis the long-gilt futures contract.

We estimate the systematic or hedgeable risk of bond i on day t ($\beta_{i,t}$) on a rolling basis using price data over the previous three-month period. We define our empirical (beta-based) spot exposure $S_{k,t}^E$ of dealer k at the end of day t as

$$S_{k,t}^E = \sum_{i=1}^{90} \frac{V_{i,t}^k \beta_{i,t} D_{fut,t}}{100}, \quad (5)$$

where $V_{i,t}^k$ is the Pound Sterling value of the position (duly signed) of dealer k in bond i at the end of day t , $\beta_{i,t}$ is the systematic risk of bond i on date t , and $D_{fut,t}$ is the duration of the futures contract (based on the cheapest-to-deliver bond) at the end of day t .

Note that since a futures contract has a beta of one with respect to itself, the empirical futures exposure measure equals the theoretical measure defined in equation (3). However, this is not the case for spot exposure measure. In a frictionless world in which duration captures all term-structure risk, the two would be identical. However, if the factors representing changes in the slope and curvature of the yield curve are important, or if some bonds are illiquid, then the beta of the bonds would be different from the ratio of their durations. Figure 1 plots the beta versus duration of each bond. As can be seen, most of the bonds fall on a straight line, with beta values corresponding approximately to the values that we would expect on the basis of duration.¹³ We find the average correlation between the theoretical and empirical measures of risk exposures of the 15 dealers to be 0.92 for spot exposure and 0.85 for spot-plus-futures exposure.

¹² Since dealers only use the nearest maturity and next to nearest maturity futures contracts, the futures exposure is measured by summing over these two futures contracts.

¹³ About seven bonds—all of them at the short end—are above the line, while about four times that number are below the line. Most of the bonds below the line are long maturity bonds, which are relatively illiquid. As a result, our empirical measure turns out to be somewhat less in magnitude relative to our theoretical measure.

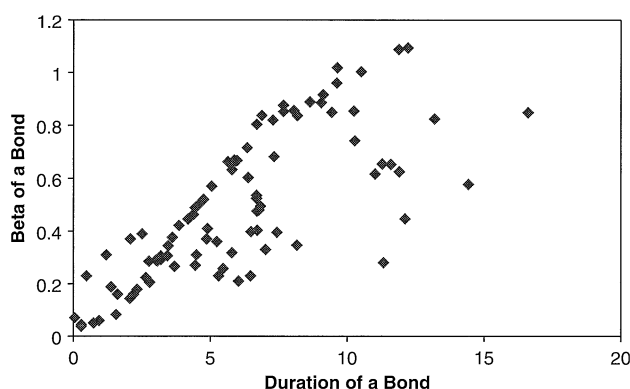


Figure 1. Beta versus duration of individual bonds.

III. Descriptive Analyses of Spot and Futures Risk Exposure

A. Total (i.e., Spot-plus-Futures) Risk Exposure

The first row of Table I describes the average total (i.e., spot-plus-futures) risk exposure carried by the dealers overnight, using both theoretical and empirical measures. The “Overall” column reports information for the dealers as a group (arrived at by aggregating the signed positions of each dealer in every bond issue and in every futures contract). As can be seen, the mean total risk exposures are negative and there is considerable variation across the 15 dealers’ average total risk exposures.¹⁴ The total risk exposures of individual dealers exhibit significant mean reversion with half-lives (see second row of Table I) ranging from 3 days to 36 days (2 days to 28 days) using the theoretical (empirical) measure.¹⁵ Furthermore, the overall total risk exposure mean reverts around a sample average that is negative and statistically significant, suggesting that dealers engage in duration targeting and actively control the variance of the total exposure around their targets. Figure 2, which plots the evolution of overall spot and futures exposures, clearly highlights this fact.

B. Spot Risk Exposure versus Futures Risk Exposure

The third and fourth rows of Table I describe the variation in the average spot and futures exposures across 15 dealers. We find that the average futures and spot

¹⁴ Changes in interest rates on normal days are typically of the order of few basis points. The numbers appear high because they correspond to a one percent change in interest rates. These risk exposures can also be expressed in terms of the value-at-risk (VAR), using average daily volatility of the long-gilt futures contract price of about 0.5%. The average empirical exposures correspond to a one-day one percent level VAR of about £6 million for the biggest dealer and about £0.2 million for the smallest dealer.

¹⁵ The half-life of a dealer’s daily total risk exposure series is given by $-\ln 2 / \ln(1 - b)$ where b is the mean reversion coefficient of the dealer’s daily total risk exposure series and is obtained by regressing the change in dealer’s total risk exposure during day t on the level of her total risk exposure at the end of day $t - 1$.

Table I
Salient Features of the Data

This table reports across 15 dealers the mean, median, minimum, and maximum of total (spot-plus-futures) risk exposure, half-life (in days) of end-of-day total risk exposure, average signed spot risk exposure (*S*), average signed futures risk exposure (*F*), magnitude of futures exposure as a percentage of gross exposure, mean offset by futures exposure of spot exposure, mean offset by demeaned futures exposure of demeaned spot exposure and percentage of days when demeaned futures exposure is of the opposite sign of the spot exposure using theoretical (duration-based) risk measure as well as empirical (regression beta-based) risk measure. It also reports the overall figures arrived at by aggregating duly signed positions of individual dealers in each bond and in each futures contract.

Sample Statistics across the 15 U.K. Government Bond Dealers	With Theoretical Risk Measure				With Empirical Risk Measure					
	Mean	Median	Minim.	Maxim.	Overall	Mean	Median	Minim.	Maxim.	Overall
Total risk exposure, £ m	-11	-9	-32	-0	-161	-9	-5	-0	-26	-134
Half-life of signed total risk exposure, days*	14	11	3	36	7	10	6	2	28	5
Signed spot risk exposure, £ m	-6	-3	-28	11	-87	-4	-3	-22	7	-61
Signed futures risk exposure, £ m	-5	-3	-20	0	-73	-5	-3	-20	0	-73
Magnitude of futures exposure as percentage of magnitude of total (spot + futures) exposure	36	33	16	60	47	42	43	20	63	53
Mean offset by futures of spot exposure, %	27	19	2	67	3	30	27	3	65	5
Mean offset by demeaned <i>F</i> of demeaned <i>S</i> , %	40	36	16	75	50	44	44	8	72	58
Days when demeaned <i>F</i> and <i>S</i> offset, %	68	69	44	93	72	71	76	37	91	79

*The half-life of a dealer's daily total risk exposure series is given by $-\ln 2/\ln(1 - b)$, where *b* is the mean-reversion coefficient of the dealer's daily total risk exposure series and is obtained by regressing the change in dealer's total risk exposure during day *t*.

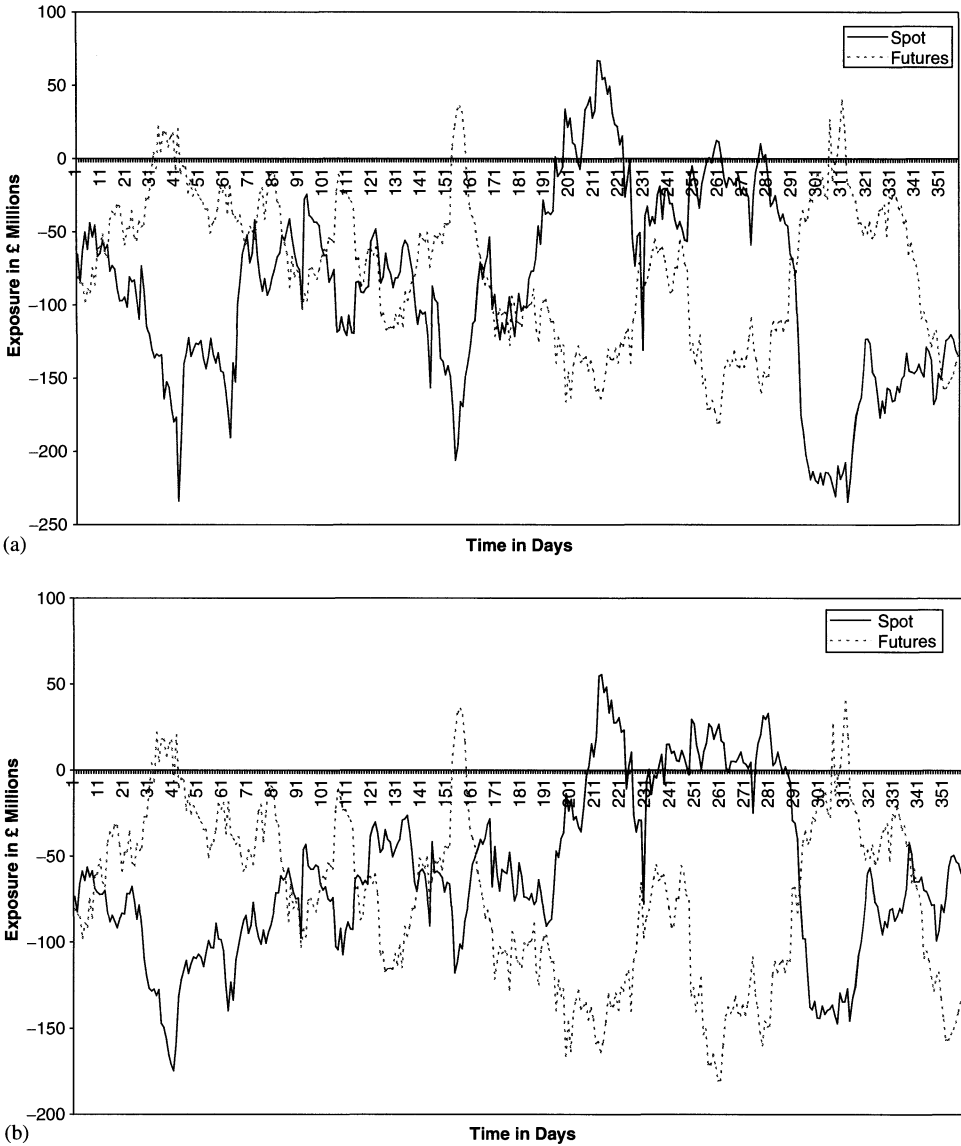


Figure 2. Aggregate spot and futures exposure of all dealers. A: Evolution of the theoretical measure of spot and futures exposure over time for the 15 dealers as a group; B: Evolution of the empirical measure of spot and futures exposure over time for the 15 dealers as a group.

exposures are of the same sign, and the magnitude of the futures exposure is similar to the magnitude of the spot exposure (see fifth row of Table I), suggesting that dealers rely on the spot market and the futures markets more or less equally to achieve their target exposures. When we compute the spot-futures-offset ratio (defined as one minus the ratio of dealer's net exposure to her gross exposure), we find that (see sixth row of Table I) a great majority of the offset ratios are closer to

0 than to 100 percent.¹⁶ This indicates that dealers achieve their target exposures by taking futures positions that are often in the same direction as their spot positions.

In this context, Figure 2 plots the evolution of the theoretical and empirical measures of the aggregate spot and futures exposures of the 15 dealers as a group. As can be seen, the futures exposure varies in a direction opposite to that of the spot exposure. We examine the relation between the deviation (from the mean) of a dealer's spot exposure and her futures exposure by computing the demeaned spot-futures-offset ratio (see seventh row of Table I). We also examine percentage of days when the demeaned spot and futures exposures are of opposite sign (see the last row of Table I). The results indicate that, in general, when a dealer's spot exposure is above its sample mean, her futures exposure is below its sample mean and vice versa.

The results of this section highlight three important features. First, dealers engage extensively in duration targeting. Second, they achieve their duration target by taking a futures position that is of similar order of magnitude and often in the same direction as their spot position. Finally, they actively control the variation around their duration target. During our sample period, the duration target of the 15 dealers as a group was negative. This may be because, during the six-month period immediately prior to the beginning of our sample, the term structure had shifted upwards (almost in a parallel manner) by about two percent. Since short positions benefit when interest rates rise, the negative duration target suggests that the dealers expected the interest rates to increase during the sample period. In Section VI on profitability of selective risk taking, we examine whether these expectations materialized or not.

IV. Risk Management with Futures

Theoretical models of dealer behavior like Amihud and Mendelson (1980) show that when dealers are risk averse or face inventory carrying costs, they will actively control their inventory risk exposure. Our U.K. government bond dealers can affect this by offering competitive prices in the spot market to induce movements towards the desired risk levels or by trading (laying off or acquiring) in highly liquid bond futures markets. In this section, we investigate the extent to which dealers use futures markets to control their spot risk exposure. In particular, we examine whether they hedge the changes in their spot exposure and if they do, whether they hedge selectively (as predicted by Stulz (1996)) or whether they engage in full-cover hedging (as shown by Froot and Stein (1998) in Proposition II). Towards that end, we regress the daily changes in a dealer's futures risk exposure on the contemporaneous and lagged daily changes in her spot exposure

¹⁶ For example, suppose a dealer's spot exposure and future exposures at the end of a day equal £4 million and -£2 million, respectively. Then, her net total exposure is £2 million, her gross total exposure is £6 million, and her spot-futures offsetting equals $1 - \{|2|/|6|\} = 0.667$ or 66.7 percent. When futures position exposure reinforces (offsets) the spot position, then this ratio approaches 0 (100) percent.

as follows:

$$\Delta F_{k,t} = \alpha_k + h_k \Delta S_{k,t} + h_{k,l} \Delta S_{k,t-1} + e_{k,t}, \quad (6)$$

where $\Delta F_{k,t}$ is the change in futures exposure of dealer k from end of day t to end of day $t + 1$, $\Delta S_{k,t}$ is the change in spot exposure of dealer k from end of day t to end of day $t + 1$, $\Delta S_{k,t-1}$ is lagged change in spot exposure of dealer k (from end of day $t - 1$ to end of day t), h_k and $h_{k,l}$ are contemporaneous and lagged hedge ratios, respectively, α_k ($k = 1, 2, \dots, 15$) are dealer-specific intercepts, and $e_{k,t}$ is the error term.¹⁷ It is important to note that our use of the term “hedge” ratio is not just for simplicity of exposition. Given the fact that interest rate risk represents a dealer’s core business risk, and the fact that dealers engage extensively in selective risk taking, the economic consequences of hedging are measured by the extent to which the dealers offset the changes in their spot exposures by actively changing their futures exposures.

We report the results in Table II. The results indicate two features. First, the contemporaneous hedge ratio is negative and significant for each and every dealer, and varies from -0.20 to -0.80 (-0.23 to -1.06) using the theoretical (empirical) measure. The lagged hedge ratio is also negative and significant in the case of seven (five) of the dealers. This confirms that dealers actively use the futures markets to hedge the changes in their spot exposures. The active control of risk exposure is consistent with the predictions of dealer behavior in Amihud and Mendelson’s (1980) model. Second, in an overwhelming majority of the cases, the hedge ratios are significantly different from negative one. This indicates that the extent of hedging is partial. Partial or selective hedging by an overwhelming majority of dealers supports the predictions of Stulz (1996).

V. Intertemporal Variation in Hedge Ratios

The analysis in the previous section measures the average amount of hedging by dealers. Arguably, there exist market conditions under which dealers hedge more or hedge less than the average. First, as argued by Stulz (1984), costs should play an important role in a dealer’s decision to use futures markets. A major cost faced by the users of futures markets is the predictable change in futures mispricing over time.¹⁸ Short hedges established with underpriced futures and long hedges established with overpriced futures are relatively costly, and vice versa. Clearly, dealers will have a lesser (greater) incentive to use futures markets to

¹⁷ We include lagged changes in the spot exposure for several reasons. The dealer may trade with the public or other dealers towards the end of the day or after the futures market has closed. The dealer’s risk management actions would then only be observed on the next day. Also, when a dealer receives an order flow, it consists of a liquidity-based component and an information-based component. Since, the dealer is not able to distinguish these two components, she may decide to wait before deciding how much of the change in spot exposure needs to be hedged through the futures market.

¹⁸ See Merrick (1988). Mispricing is defined as the difference between the actual futures price and its fair value calculated from the cost-of-carry model. LIFFE data provides both these numbers, details of the cheapest-to-deliver bond, and so on.

Table II

Changes in the Futures Exposure and Changes in the Spot Exposure

This table shows the coefficients of the following regression for each of the 15 bond dealers using theoretical and empirical measures of risk exposures:

$$\Delta F_{k,t} = \alpha_k + h_k \Delta S_{k,t} + h_{k,l} \Delta S_{k,t-1} + \varepsilon_{k,t},$$

where k indicates the dealer ($k = 1, 2, \dots, 15$), $\Delta F_{k,t}$ is the change in futures exposure of dealer k from the end of day $t - 1$ to the end of day t , $\Delta S_{k,t}$ is the change in spot exposure of dealer k from the end of day $t - 1$ to the end of day t , $\Delta S_{k,t-1}$ is lagged change in spot exposure of dealer k , h_k and $h_{k,l}$ are contemporaneous and lagged hedge ratios, and α_k and $\varepsilon_{k,t}$ are the intercept and error terms, respectively. The table reports the slope coefficients (the t -statistics are reported in parentheses). Figures in bold face indicate significance at the five percent level. Hedge ratios indistinguishable from -1.0 at the five percent level are denoted with an asterisk.

Dealer K	With Theoretical Measure of Risk Exposure			With Empirical Measure of Risk Exposure		
	Hedge Ratio h_k	Lagged Hedge Ratio, $h_{k,l}$	Adjusted R -square	Hedge Ratio h_k	Lagged Hedge Ratio, $h_{k,l}$	Adjusted R -square
1	-0.37 (-8.69)	-0.09 (-2.13)	22.9%	-0.47 (-8.80)	-0.12 (-2.39)	23.1%
2	-0.42 (-8.13)	-0.10 (-1.97)	20.5%	-0.36 (-6.00)	-0.16 (-2.02)	13.0%
3	-0.39 (-11.93)	0.06 (1.63)	34.2%	-0.51 (-11.57)	0.03 (0.74)	33.0%
4	-0.42 (-7.70)	-0.02 (-0.53)	22.7%	-0.52 (-7.94)	0.01 (0.23)	23.7%
5	-0.76 (-20.88)	-0.02 (-0.78)	62.1%	-0.99* (-23.17)	-0.03 (-0.67)	64.9%
6	-0.27 (-6.02)	-0.08 (-2.00)	11.8%	-0.33 (-5.95)	-0.11 (-1.98)	11.7%
7	-0.20 (-3.50)	0.03 (0.50)	4.3%	-0.23 (-3.07)	0.05 (0.65)	3.1%
8	-0.66 (-14.50)	-0.09 (-2.09)	43%	-0.85 (-15.83)	-0.06 (-0.97)	47%
9	-0.47 (-8.02)	-0.10 (-1.76)	18.4%	-0.63 (-7.60)	-0.17 (-2.23)	17.5%
10	-0.59 (-12.15)	0.01 (0.28)	35%	-0.68 (-11.74)	-0.03 (-0.55)	35.2%
11	-0.67 (-17.14)	-0.07 (-1.97)	49.9%	-1.00* (-20.47)	-0.04 (-0.82)	59.6%
12	-0.80* (-6.63)	0.01 (0.06)	50.7%	-0.94* (-5.76)	0.01 (0.05)	45.1%
13	-0.44 (-9.21)	0.11 (1.43)	25.3%	-0.43 (-7.68)	0.05 (0.86)	19.3%
14	-0.55 (-15.13)	-0.13 (-3.58)	50.5%	-1.06* (-25.84)	-0.12 (-3.15)	73.8%
15	-0.68 (-10.97)	-0.13 (-2.27)	44%	-0.67 (-7.69)	-0.26 (-1.05)	12.6%

hedge in time periods when hedging is costlier (cheaper). Second, since dealers are risk averse, we should observe that the dealers hedge to a greater extent when the volatility of the bond market is higher. Third, the pressures of capital requirements (whether arising externally through regulatory capital requirements or internally because of in-house risk budgeting) are greater when the magnitude of spot exposure is relatively high and when the change in spot exposure is in a direction that increases the magnitude of this exposure. Therefore, we should observe a higher hedge ratio on such days. Finally, there exist several macroeconomic variables (such as measures of money supply and retail price indices) that potentially affect the prices of government bonds. These macroeconomic variables are announced on a monthly basis, and the date and time of the announcements are well known.¹⁹ One would expect that the perceived information asymmetry would be relatively high (low) before (after) these announcements, and therefore, we expect the dealers to hedge more (less) during periods of high (low) perceived information asymmetry.

In view of these arguments, in this section we examine whether dealers hedge the changes in their spot exposures relatively more (a) when hedging requires buying (selling) underpriced (overpriced) futures, (b) when the bond market volatility is greater, (c) when the magnitude of spot exposure is higher and increasing, and (d) around important macroeconomic announcements.²⁰ In particular, we run the following regression:

$$\begin{aligned} \Delta F_{k,t} = & \gamma_0 + \sum_{k=1}^{15} D_{k,t} [(h_k \Delta S_{k,t} + h_{k,l} \Delta S_{k,t-1}) \\ & + (\gamma_1 Vol_t + \gamma_2 S_{k,t-1}^{Std} + \gamma_3 \Delta S_{k,t-1}^{Std} + \gamma_4 D_t^{Misp} + \gamma_5 D_t^{Ann} \\ & + \gamma_6 D_t^{dbAnn}) \Delta S_{k,t}] + \omega_{k,t} \end{aligned} \quad (7)$$

where $\Delta F_{k,t}$, $\Delta S_{k,t}$, $\Delta S_{k,t-1}$, h_k , and $h_{k,l}$ are the same as in equation (6), $D_{k,t}$ is a dummy variable which takes the value 1 for observations corresponding to dealer k , Vol_t is the standardized absolute value of the open-to-close price change of the near-maturity long-gilt futures contract, $S_{k,t-1}^{Std}$ ($\Delta S_{k,t-1}^{Std}$) is the standardized level (change in level) of dealer k 's spot exposure at the end of day $t-1$, D_t^{Misp} is a dummy variable which takes the value 1 when hedging requires buying (selling) underpriced (overpriced) futures and the value -1 when hedging requires selling (buying) underpriced (overpriced) futures, D_t^{Ann} (D_t^{dbAnn}) is a dummy variable indicating whether day t is an announcement day (a day before an announcement

¹⁹ For example, during the sample period, the Bank of England announced the provisional money supply estimates of M_0 three working days after the final Wednesday in the month while it announced the provisional estimates of M_4 on the 14th working day after the last day of the month.

²⁰ We consider M_0 , M_4 , and retail price index (RPI) announcements. Three announcements per month for 17 months give us a total of 51 announcements. These announcements, like most major announcements in the United Kingdom, are made at 09:30 hours. Almost all the trading on the day of announcements takes place after the announcement is made. This is captured by our day-of-announcement dummy.

day), γ_0 and $\omega_{k,t}$ are the intercept and error terms, respectively, and γ_i , $i = 1, 2, \dots, 6$ are slope coefficients on the respective explanatory variables.

Table III reports the results. We find that with both measures, the “normal” contemporaneous hedge ratios for dealers (the $h_{k,t}$ s) continue to be negative and of the same order of magnitude as in Table II, and statistically highly significant in the case of 14 of the 15 dealers (Dealer 12 being the exception). The lagged hedge ratios are negative, although for some dealers they lose their statistical significance. The slope coefficients on the volatility, the lagged level of and the lagged change in exposure, and the futures’ mispricing variables (γ_1 to γ_4) are each negative and statistically significant at the five percent level with the theoretical measure. The results with the empirical measure are similar, with the exception that the slope coefficient on the volatility variable, γ_1 , is negative but not significant. With both measures we find the coefficient on the day of announcement dummy, γ_5 , is positive and significant while that on the day before announcement day dummy, γ_6 , is negative and significant.

These results confirm that dealers hedge to a greater extent when the cost of hedging is lower and when capital requirements are higher. The results also confirm that dealers hedge relatively more in periods when the perceived information asymmetry is high, such as on days before major macroeconomic announcements. Once the announcement is made, perceived information asymmetry is reduced and dealers hedge relatively less. Finally, the dependence of the hedge ratio on bond market volatility is in the expected direction, but is significant only with the theoretical measure. The results relating to the cost of hedging are consistent with predictions of Stulz (1984), and the results pertaining to selective hedging are supportive of the implications of Stulz (1996).

VI. Information in Order Flow, Selective Risk Taking, and Profitability

Froot and Stein (1998) argue that financial intermediaries should fully hedge their exposure to any efficiently tradable risk. In contrast, Stulz (1996) contends that some firms may have a comparative advantage in bearing certain risks, and that these firms should exploit this advantage by engaging in selective risk taking. If the order flow in the government bond market is informative, then dealers with a higher turnover would enjoy a comparative informational advantage over dealers with a smaller turnover. If this is the case, then, according to Stulz (1996), we should find that dealers with higher market share (a) engage in selective interest rate risk taking to a greater extent, (b) hedge the changes in their spot exposures to a lesser extent, and (c) profit more from their duration-targeting activity as compared to dealers with lower market share.²¹ Furthermore, all dealers who selectively take on (potentially hedgeable) market risk would do so in the expected

²¹ To obtain the market share of dealers, we use transactions audit trail data from the London Stock Exchange. The data identifies buy and sell trades executed by each dealer on his own account and therefore tell us the change in inventory of each dealer in each bond on each day. By matching the changes in inventory from these two data sets, we obtain the turnover and market share of each of our 15 dealers.

Table III
Hedge Ratios in Different Market Conditions

This table examines the determinants of the time-series variation in the hedge ratios and reports the results from the following regression:

$$\Delta F_{k,t} = \gamma_0 + \Sigma D_{k,t}(h_k \Delta S_{k,t} + h_{k,l} \Delta S_{k,t-1}) + \left(\gamma_1 Vol_t + \gamma_2 S_{k,t-1}^{Std} + \gamma_3 \Delta S_{k,t-1}^{Std} + \gamma_4 D_t^{Misp} + \gamma_5 D_t^{Ann} + \gamma_6 D_t^{dbAnn} \right) \Delta S_{k,t} + \omega_{k,t},$$

where k indicates the dealer ($k = 1, 2, \dots, 15$), $\Delta F_{k,t}$ is the change in futures exposure of dealer k from the end of day $t - 1$ to the end of day t , $\Delta S_{k,t}$ is the change in spot exposure of dealer k from the end of day $t - 1$ to the end of day t , $\Delta S_{k,t-1}$ is lagged change in spot exposure of dealer k , h_k and $h_{k,l}$ are contemporaneous and lagged hedge ratios, $D_{k,t}$ is a dummy variable which takes the value 1 for observations corresponding to dealer k , Vol_t is the standardized absolute value of the open-to-close price change of the near-maturity long-gilt futures contract, $S_{k,t-1}^{Std}$ ($\Delta S_{k,t-1}^{Std}$) is the standardized level (change in level) of dealer k 's spot exposure at the end of day $t - 1$, D_t^{Misp} is a dummy variable which takes the value 1 when hedging requires buying (selling) underpriced (overpriced) futures and the value -1 when hedging requires selling (buying) underpriced (overpriced) futures, D_t^{Ann} (D_t^{dbAnn}) is a dummy variable indicating whether day t is an announcement day (a day before an announcement day), γ_0 and $\omega_{k,t}$ are the intercept and error terms, and γ_1 to γ_6 are slope coefficients on the respective explanatory variables. Figures in bold face indicate significance at the five percent level. Hedge ratios indistinguishable from -1.0 at the five percent level are denoted with an asterisk.

Dealer K	Theoretical Measure of Risk Exposure			Empirical Measure of Risk Exposure		
	h_k	$h_{k,l}$	Slope Coefficients	h_k	$h_{k,l}$	Slope Coefficients
1	-0.33 (-5.59)	-0.09 (-2.03)		-0.39 (-5.26)	-0.12 (-2.17)	
2	-0.43 (-8.37)	-0.11 (-2.61)		-0.38 (-6.33)	-0.18 (-3.11)	
3	-0.40 (-6.87)	0.06 (1.32)		-0.49 (-6.31)	0.02 (0.24)	
4	-0.41 (-5.14)	-0.06 (-0.80)		-0.47 (-4.66)	-0.03 (-0.35)	
5	-0.80 (-13.54)	-0.01 (-0.38)		-1.03* (-14.26)	-0.02 (-0.35)	
6	-0.26 (-3.68)	-0.09 (-1.51)		-0.32 (-3.35)	-0.09 (-1.07)	
7	-0.38 (-8.46)	0.04 (1.44)		-0.40 (-7.16)	0.07 (1.58)	
8	-0.66 (-15.39)	-0.08 (-3.10)		-0.82 (-15.18)	-0.04 (-1.40)	
9	-0.51 (-6.96)	-0.06 (-1.01)		-0.67 (-6.28)	-0.12 (-1.35)	
10	-0.63 (-4.75)	-0.00 (-0.00)		-0.72* (-4.33)	-0.05 (-0.27)	
11	-0.69 (-3.17)	-0.07 (-0.34)		-1.03* (-3.22)	-0.02 (-0.06)	
12	-0.91 (-1.21)	0.01 (0.01)		-1.15 (-1.19)	-0.01 (-0.01)	
13	-0.46 (-3.13)	0.10 (0.73)		-0.39 (-2.35)	0.02 (0.10)	

Table III— *Continued*

Dealer K	Theoretical Measure of Risk Exposure			Empirical Measure of Risk Exposure		
	h_k	$h_{k,l}$	Slope Coefficients	h_k	$h_{k,l}$	Slope Coefficients
14	-0.54 (-3.44)	-0.11 (-0.68)		-0.97* (-3.74)	-0.11 (-0.44)	
15	-0.72 (-4.26)	-0.13 (-0.88)		-0.63 (-2.92)	-0.24 (-1.22)	
Volatility			-0.03 (-2.01)			-0.03 (-0.64)
Lagged exposure			-0.08 (-5.89)			-0.10 (-6.26)
Mispricing			-0.07 (-5.82)			-0.06 (-3.53)
Lagged change in exposure			-0.10 (-3.88)			-0.14 (-4.25)
Announcement day dummy			0.11 (2.84)			0.22 (4.58)
Day before announc. dummy			-0.14 (-3.19)			-0.14 (-2.84)
Adj. R -square			32.2%			30.7%

tation of earning economic profits; this should be reflected in their actual profits. In this section, we investigate these implications.

We measure dealer profits from selective risk taking as follows. We express each dealer's end-of-day total empirical risk exposure in terms of the number of futures contracts, and multiply this exposure measure by the change in the price of the futures contract from the close of that day to the open of the next day. This product represents the daily profit from a dealer's overnight risk-taking activity.

We examine the relation between a dealer's informational advantage (as proxied by market share) and the extent of her selective risk taking, hedging, and profitability as follows. We regress on a dealer's market share, her average scaled overnight risk exposure, her hedge ratios (h_k s reported in Table II), and her average daily scaled profits. Since dealers with larger turnover are also likely to have larger risk exposure, we scale the dealer's average overnight risk exposure by the natural logarithm of her turnover.²² In particular, we run the following cross-sec-

²² A dealer's order flow consists of buy and sell orders from the public. Some of these buy and sell orders would offset each other and therefore one would not expect a dealer's net risk exposure to increase linearly with turnover. Hence, while controlling for differences in size of dealers, we scale their duration risk exposure by the logarithm of their turnover. Our results are robust to scaling by other concave functions of turnover such as the square root of turnover.

Table IV
Relation between a Dealer’s Market Share and Her Risk Exposure, Her Hedge Ratio, and Her Profits from Selective Risk Taking

This table reports the findings when the risk exposure (scaled by turnover), hedge ratio, and profitability of dealers are regressed on their market share according to the following cross-sectional regressions ($k = 1, 2, \dots, 15$):

$$\begin{aligned} Scaled Exposure_k &= c_0 + c_1 Market Share_k + f_k \\ Hedge Ratio_k &= d_0 + d_1 Market Share_k + g_k, \\ Scaled Profit_k &= e_0 + e_1 Market Share_k + n_k \end{aligned}$$

where c_0 , d_0 , and e_0 are intercepts, and c_1 , d_1 , and e_1 are slope coefficients and f_k , g_k , and n_k are error terms respectively. The t -statistics are reported in parentheses. Figures in bold face indicate significance at the five percent level.

Risk Measure Used	Intercept	Slope Coefficient	Adjusted R-square
Panel A: Duration (Scaled Exposure) Regression			
Theoretical	0.15 (1.16)	0.04 (2.57)	28.5%
Empirical	0.09 (0.86)	0.04 (2.79)	32.7%
Panel B: Hedge Ratio Regression			
Theoretical	− 0.67 (− 9.34)	0.03 (2.58)	28.8%
Empirical	− 0.88 (− 8.08)	0.04 (2.55)	28.2%
Panel C: (Scaled) Profit Regression			
Profit per unit turnover (bp)	0.20 (0.87)	− 0.03 (− 1.05)	0.8%
Fraction of correctly predicted market moves	0.51 (47.56)	− 0.002 (− 1.30)	4.6%

tional regressions across our 15 dealers ($k = 1, 2, \dots, 15$):

$$\begin{aligned} Scaled Exposure_k &= c_0 + c_1 Market Share_k + f_k \\ Hedge Ratio_k &= d_0 + d_1 Market Share_k + g_k \\ Scaled Profit_k &= e_0 + e_1 Market Share_k + n_k \end{aligned} \tag{8}$$

We report the results in Table IV. When we regress the dealers’ average risk exposures on their market shares, we find the slope coefficient to be positive and statistically significant (Table IV, Panel A) suggesting that the greater the market share of a dealer, the greater is the amount of selective risk taking. When we regress the dealers’ hedge ratios on their market shares, we find the slope coefficient to be positive and statistically significant (Table IV, Panel B). Since hedge ratios are negative, the positive and significant slope coefficient suggests that the greater the market share of a dealer, the lower is the extent of hedging. Both

these results are consistent with larger dealers perceiving themselves as having a comparative informational advantage over smaller dealers, and therefore taking on market risk taking to a greater extent and hedging the changes in their spot exposures to a lesser extent.

However, when we regress the dealers' scaled profits on their market shares, we do not find any systematic relation (Table IV, Panel C), that is, we do not find that larger dealers earn significantly greater profits from their duration-targeting activity compared to smaller dealers.²³ When we regress the percentage of time the dealers made a profit from their overnight risk-taking activity on their market share, once again we fail to find any systematic relation.

Since dealers who selectively take on (potentially hedgeable) interest rate risk do so in the expectation of earning economic profits, we examine their average overnight profits and average scaled (by turnover) overnight profits. We find (see Table V) that the average overnight profit (average scaled overnight profit) across the 15 dealers has a mean of only - £2,600 (- 0.03 basis points). For 12 of the 15 dealers, the average overnight profit is indistinguishable from zero. For 1 dealer it is positive and significant, while for 2 dealers, it is negative and significant.²⁴ When we compute the proportion of days when dealers make a profit (as opposed to a loss) from their overnight risk-taking activity, we find that the proportion varies from 46 percent to 54 percent, and is statistically indistinguishable from 50 percent for all dealers. Whichever way one looks at it, dealers in general do not appear to earn significant profits from their overnight risk-taking activity.

Overall, these findings support Stulz's (1996) argument that dealer firms engage in selective risk taking based on their perceived comparative informational advantage, though in this particular case, the comparative advantage is more perceived than real. The lack of significant profits, and the absence of a significant relation between market share and profitability, suggest that the U.K. government bond market is reasonably efficient. These observations are also consistent with the fact that the nature of information in the government bond market is macroeconomic and public, and to this all market participants argu-

²³ Our finding is robust to measuring the profitability of risk taking in different ways. For example, instead of using close-to-open (of next day) price change in the futures contract as the measure of profit from overnight risk-taking activity, if we measure the price change as close to close, or close to the best price next day (i.e., buying at the lowest price and selling at the highest price), once again we fail to find any systematic relationship.

²⁴ Note that these profits are from overnight risk taking. The dealers also earn a bid-offer spread from trading in bonds (see Hansch and Saporta (1999) for dealers' profits from market making). It is important to note that the parent firms of the dealers may have motives other than profits to create these subsidiaries. These dealer firms can provide useful services to the proprietary trading arm of the parent firm. For example, the dealer firms can execute large trades for the parent without leaving much of a footprint that can enable other market participants to infer the information contained in the trade. Second, the dealer firms can borrow stock and engage in short-selling, otherwise difficult in the United Kingdom even for institutions. Third, dealer firms are exempt from paying stamp duty for its own trades, which can be useful in the context of short-term arbitrage trading strategies. Finally, dealer firms have preferential access to new government bond issues.

ably have equal access. Therefore, observing order flow does not impart dealers a significant comparative advantage.

VII. Derivatives and Control of Extreme Risk Exposures

Theoretical models of competitive dealership markets, like Ho and Stoll (1983), provide an important *cross-sectional* implication that holds at a dealer's overall *portfolio* level at each point in time: Dealers with relatively extreme long (short) total exposure (relative to their duration target) in one period sell (buy) a larger amount of exposure in the following time period. Due to the unavailability of portfolio-level data, this implication has not been tested in the literature. Importantly, the dealer's portfolio has to include derivatives positions, and the critical role played by a well-functioning derivatives market has not been examined in this context. In this section, we investigate whether dealers with larger total exposure sell a larger quantity than dealers with smaller exposure, and vice versa. And we also examine the important role of the futures market (compared to the spot market) in the management of risk exposure.

Our investigation proceeds as follows. At the end of each day we measure the total (i.e., spot-plus-futures) exposure of each dealer, $S_{k,t} + F_{k,t}$, and standardize it to make it comparable across dealers.²⁵ We assign the dealer with largest (smallest) total exposure an exposure-level rank of 1 (15). Next, we compute $\Delta(S_{k,t+1} + F_{k,t+1})$ —the change in the spot-plus-futures exposure of each dealer over the next day—and assign a change-in-exposure rank of 1 (15) to the dealer who sells the most (least) exposure. We repeat this exercise for each day in the sample and compute the average change-in-exposure rank corresponding to each exposure-level rank from 1 to 15. Note that in this procedure, different dealers get assigned an exposure-level rank of 1 on different days depending on whether they had the longest risk exposure or not. Also, different dealers get assigned a change-in-exposure rank of 1 depending on whether they sold the most exposure during the next day or not. The same logic holds for all ranks from 1 to 15. We compute these ranks each day, and then pool these cross-sectional rankings to compute the average change in exposure rank corresponding to each exposure-level rank.

We report the results of our investigation in Table VI and Figure 3. As far as change in total exposure is concerned (Table VI, first row and Figure 3A), our findings strongly support the portfolio-level cross-sectional implications of Ho and Stoll's (1983) model. Dealers with the top five (bottom five) exposure levels show a change in exposure that is statistically significantly greater (smaller) than the median dealer. The same holds vis-à-vis change-in-futures exposure

²⁵ Standardization involves subtracting the mean and dividing by the standard deviation. The former adjusts for differences in duration targets while the latter makes the measure comparable across firms if it is assumed that different dealers perceive risk in a similar way when their exposure is measured in terms of the distance in standard deviations from the duration targets. Hansch et al. (1998) and Naik and Yadav (2001) use a similar procedure while examining the trading behavior of dealers in the equity market. For expositional convenience, we hereafter drop the descriptor standardized.

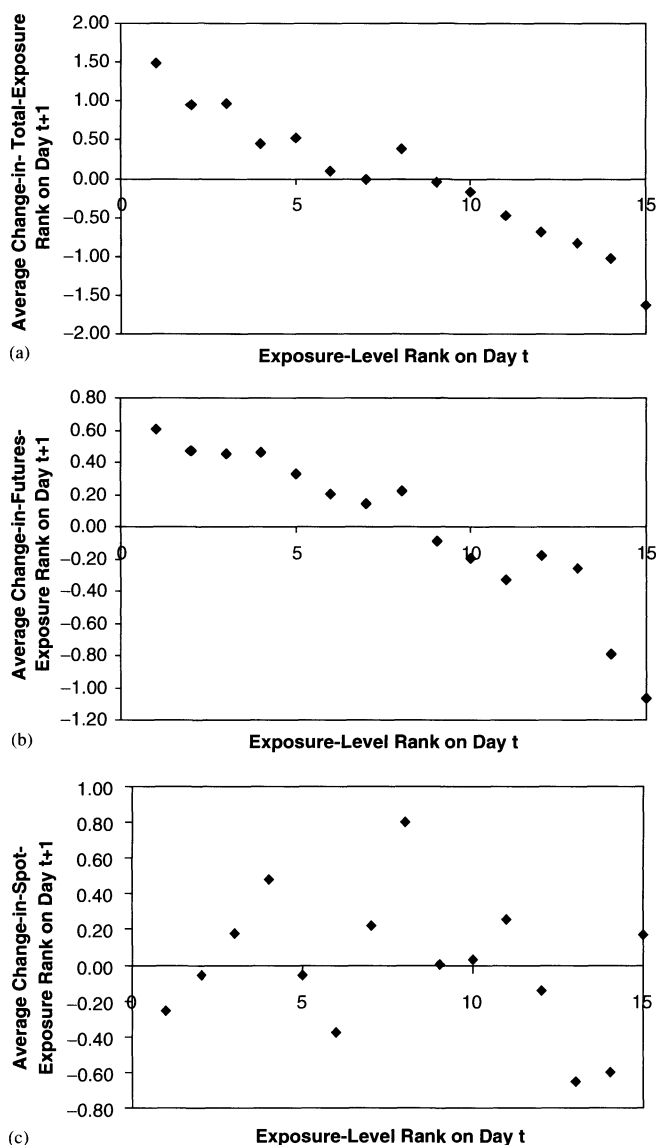


Figure 3. Change-in-exposure rank versus exposure-level rank. A: Average change in total (spot-plus-futures) exposure rank. B: Average change in futures exposure rank. C: Average change in spot exposure rank.

(Table VI, middle row and Figure 3B); namely, dealers with relatively long total exposure sell a greater amount of exposure in the futures market the next day, and vice versa. However, interestingly, we do not find a systematic relation when we use the change-in-spot exposure as the dependent variable (Table VI, bottom row and Figure 3C). In particular, we do not find that dealers with relatively long exposure sell greater exposure in the spot market the next day, and vice-versa.

Table V
Profitability of Selective Risk Taking

This table shows the average overnight profits (in £'000), average overnight profits scaled by turnover (in basis points), and proportion of days when the overnight profits is positive (percent). The *t*-statistic of the test that the average overnight profits and average scaled overnight profits are significantly different from zero is reported in parentheses in columns 2 and 3. The *z*-statistic that the proportion of times the overnight profit is positive is reported in parentheses in column 4. Figures in bold indicate that the statistic is significantly different from zero at the five percent level.

Dealer	Average Overnight Profits, in £'000	Average Scaled Overnight Profits, in Basis Points	Proportion of Days the Profit is Positive, %
1	15.7 (0.29)	0.40 (0.29)	48.5% (-0.51)
2	-34.9 (-0.75)	-0.57 (-0.75)	48.0% (-0.69)
3	40.3 (2.17)	0.59 (2.17)	54.2% (1.48)
4	-9.6 (-0.27)	-0.13 (-0.27)	46.4% (-1.10)
5	19.5 (0.81)	0.45 (0.81)	51.6% (0.56)
6	-2.4 (-0.09)	-0.04 (-0.09)	51.0% (0.35)
7	-3.8 (-0.10)	-0.05 (-0.10)	46.9% (-1.12)
8	- 53.6 (-2.26)	- 0.68 (-2.26)	48.8% (-0.45)
9	-27.9 (-1.43)	-0.81 (-1.43)	46.8% (-1.14)
10	8.7 (0.63)	0.56 (0.63)	50.7% (0.23)
11	- 2.5 (-2.07)	- 0.37 (-2.07)	47.0% (-1.06)
12	15.6 (0.08)	0.64 (0.08)	50.0% (0.00)
13	-4.9 (-0.80)	-0.23 (-0.80)	48.9% (-0.40)
14	4.2 (0.75)	0.36 (0.75)	50.5% (0.17)
15	-3.7 (-0.88)	-0.16 (-0.88)	51.5% (0.39)

These findings show that dealers actively control their total risk exposure at a portfolio level as predicted by Ho and Stoll's (1983) model. The more extreme the risk exposure of a dealer relative to her own duration target and relative to the extremeness of other dealer positions, the greater is the amount of exposure the dealer trades in the direction predicted by the model. However, dealers seem to achieve this entirely via the futures market rather than the spot market. This overwhelming preference for the futures market for risk management is reasonable in view of its lower costs and greater depth. Our findings, on the one hand,

Table VI
Relation between Dealers' Total Risk Exposure Level at the End of a Day and the Change in Exposure on the Next Day

This table reports the relation between a dealer's end-of-day total-exposure-level rank and her average change-in-exposure rank on the next day. The average change-in-exposure rank is reported as deviation from the median rank of eight; the *t*-statistic is in parentheses. Figures in bold face indicate the average change-in-exposure ranks that are significantly different from the median rank at the five percent level.

Exposure Level Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Change-in-total-exp. rank	1.49 (6.06)	0.95 (3.97)	0.97 (4.30)	0.45 (1.99)	0.52 (2.29)	0.09 (0.39)	-0.02 (-0.08)	0.38 (1.72)	-0.04 (-0.17)	-0.16 (-0.72)	-0.47 (-2.27)	-0.69 (-3.16)	-0.82 (-3.68)	-1.03 (-4.48)	-1.63 (-7.04)
Change-in-futures-exp. rank	0.61 (2.51)	0.47 (2.00)	0.46 (1.97)	0.46 (2.02)	0.33 (1.37)	0.20 (0.92)	0.15 (0.66)	0.22 (1.06)	-0.09 (-0.39)	-0.20 (-0.89)	-0.32 (-1.55)	-0.18 (-0.82)	-0.25 (-1.16)	-0.79 (-3.32)	-1.07 (-4.54)
Change-in-spot-exp. rank	-0.26 (-1.15)	-0.05 (-0.25)	0.18 (0.76)	0.48 (2.15)	-0.06 (-0.26)	-0.37 (-1.57)	0.22 (0.94)	0.80 (3.39)	0.01 (0.04)	0.03 (0.12)	0.26 (1.09)	-0.14 (-0.63)	-0.66 (-2.98)	-0.60 (-2.87)	0.17 (0.73)

indicate that futures markets play a healthy role that can potentially improve spot market quality by enabling the efficient management of the hedgeable component of spot risk. On the other hand, our findings also indicate that, in the presence of an efficient futures market, dealers would care primarily about the unhedgeable (and not the hedgeable) component of their spot risk, as emphasized by Froot and Stein (1998). The extent to which these effects manifest in practice requires detailed market microstructure investigation, and is beyond the scope of this paper.

VIII. Price Effects of Capital Constraints

The central tenet of Froot and Stein's (1998) model is that an intermediary's capital position affects her pricing of risks. They argue that in the presence of capital constraints intermediaries will offer worse (better) prices to trades that increase (reduce) the demand on their limited capital. We investigate this issue in this section. We note that the government bond dealers in the United Kingdom are separately capitalized from their parent company and their equity capital is fixed, at least in the short run. The firms are also likely to have position limits due to internal risk budgeting. When bond dealers follow a duration-targeting policy, a part of their capital gets allocated to bearing hedgeable risk, risk that could be laid off in the futures markets. Thus, duration targeting effectively reduces the amount of free capital available with the dealers for providing liquidity to investors. One expects this to have significant price effects when dealers carry a large amount of hedgeable risk on their books and therefore when the capital required to support the risk is high. We investigate these price effects by examining the relation between the change in prices of bonds with a given change in inventory on days when dealers have relatively less free capital available to provide liquidity to investors.

The prices of bonds change from day to day due to three factors. First, there are term-structure-related effects. We capture these through the differences in durations of different bonds. Second, there are capital constraints as emphasized by Froot and Stein (1998). To estimate these, we use the Bank of England's capital adequacy directives (the salient features of which are documented in the Appendix) and compute the regulatory capital required to support each dealer's position in the 90 bonds and futures contracts.²⁶ Third, there are inventory control considerations. These play an important role when the risk exposure deviates substantially in either direction from the duration target (sample mean). An important difference between the second and the third factors is that inventory control considerations are symmetric around the sample mean, while capital constraints (whether imposed externally or internally) are symmetric around zero, as the latter relate to the magnitude of the risk exposure. We use this key difference to isolate the price effects arising from capital constraints.

²⁶ The regulatory capital required is very highly correlated with the *magnitude* of dealers' total risk exposure. The correlation is 0.997 by one measure and 0.97 by another. In particular, the days on which the overall total risk exposure belongs to the bottom decile are also the days when the capital required belongs to the highest decile and vice versa.

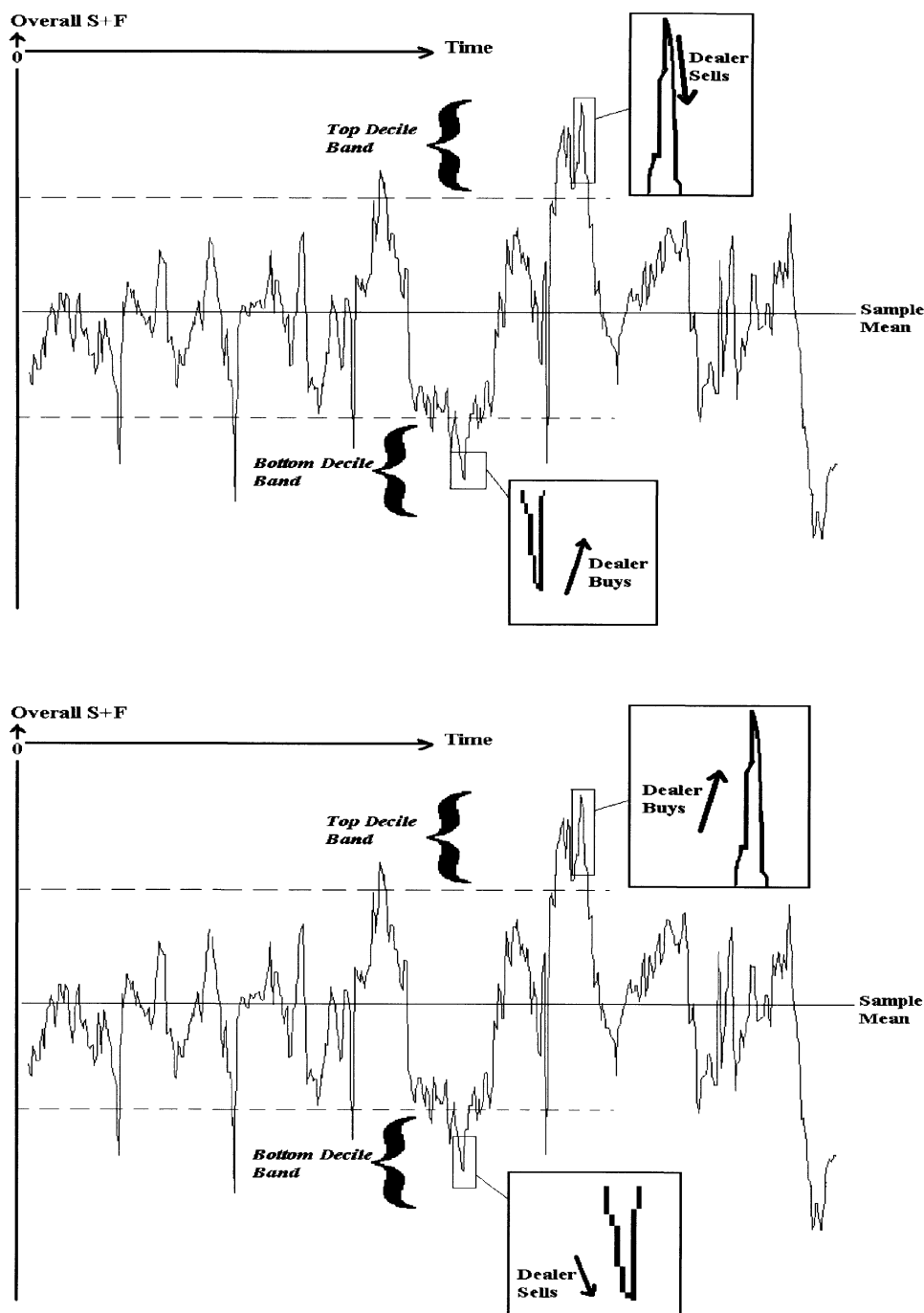


Figure 4. Evolution of the empirical measure of total (spot-plus-futures) exposure over time for the 15 dealers as a group. The top panel highlights the fact that when dealers sell exposure on days when total exposure belongs to the top decile or when they buy exposure on days when the total exposure belongs to the bottom decile, the distance between their exposure and the sample mean is qualitatively of similar order. The bottom panel shows that the same holds when dealers buy exposure on top-decile days or when they sell exposure on bottom-decile days.

Figure 4 illustrates the essence of our investigation. It shows the evolution of the dealers' total risk exposure over our sample period. As can be seen, the total risk exposure is negative throughout and is mean-reverting around the sample mean, that is, their duration target.²⁷ Now consider the two boxes highlighted in the top panel of Figure 4. The top box highlights the days when dealers are selling bonds and the total risk exposure is in the top decile (above the top dashed line) while the bottom box shows the days when dealers are buying bonds and the total risk exposure is in the bottom decile (below the bottom dashed line). Notice that in both these cases, the deviation of the risk exposure from the sample mean is of comparable order of magnitude and the change in exposure is in a direction that takes the dealers towards the sample mean. Since empirical evidence in the market microstructure literature shows that the intensity of mean reversion is symmetric around the mean (see Hansch et al. (1998, Table V), Naik and Yadav (2001, Table II)), we expect the price effects arising from inventory control considerations to be of similar order of magnitude in these two cases.

However, this is not the case as far as capital-constraint-related price effects are concerned. When the total risk exposure belongs to the top decile (i.e., when the risk exposure lies above the top dashed line in Figure 4), the magnitude of the risk exposure is small (it is near zero) and therefore the amount of capital required is small (in fact, it belongs to the lowest decile of capital required). In contrast, capital considerations are of great importance when the total risk exposure belongs to the bottom decile (i.e., when the risk exposure lies below the bottom dashed line in Figure 4). This is because on these days, the magnitude of the risk exposure is high (it is far away from zero) and therefore the capital required to support this is also high (in fact, it belongs to the highest decile of capital required). Therefore, on these days, dealers arguably perceive their capital to be constrained. If this indeed is the case, then according to Froot and Stein (1998), we should expect the dealers to bid a significantly higher price while buying bonds, as these trades reduce the short position and help alleviate the capital constraints.

The bottom panel of Figure 4 shows the mirror image of the above in the sense that instead of the risk exposure reverting to the mean, it is diverging away from the mean. In this case, for reasons described above, we expect the inventory-related price effects on top-decile and bottom-decile days to be of similar order of magnitude, but the capital-constraint-related price effects to be important only for days when the total risk exposure belongs to the bottom decile. Specifically, on bottom-decile days, we expect the dealers to ask a significantly higher price while selling bonds, as these trades increase the magnitude of their exposure and therefore make additional demands on their limited capital.

We investigate the price effects of perceived capital constraints by running the following regression:

$$\Delta P_{i,t} = \sum_{t=1}^T D_{i,t} D_t + \lambda \Delta I_{i,t} + \psi D_{hd} \Delta I_{i,t} + \xi_{i,t}, \quad (9)$$

²⁷ The second row of Table I shows that the half-life of overall total risk exposure is seven (five) days with theoretical (empirical) measure, indicating significant mean reversion.

where $\Delta P_{i,t}$ is the percentage change in the price of bond i on day t , $D_{i,t}$ is the duration of bond i on day t , D_t is a dummy representing the day of the sample period ($t=1,2,\dots,T$), D_{hd} is a dummy that takes the value of 1 if the capital required is in the highest decile on day t , $\Delta I_{i,t}$ is the change in inventory risk exposure of all dealers on day t , λ is the regression coefficient that captures inventory effects, and ψ captures the incremental effect due to changes in capital constraints.²⁸ Note that the term $\sum_{t=1}^T D_{i,t} D_t$ controls for the changes in bond prices due to changes in the term structure of interest rates while λ and ψ , respectively, capture the inventory- and capital-constraint-related price effects.

When dealers buy (sell) bonds from the public, the change in their inventory is positive (negative). The price effect of this change in inventory depends on whether the change in inventory is moving a dealer's risk exposure away from the target or towards the target. If trading takes the exposure away from the target, then the dealer will offer worse prices, making λ negative and vice versa. However, our focus is on ψ —the economic effects of capital constraints. When dealers buy bonds on days when the total exposure belongs to the bottom decile, these trades alleviate capital constraints. If the price effects of capital constraints as emphasized by Froot and Stein (1998) are important, then we expect the dealers to pay a higher price for these trades, thereby making ψ positive. Similarly, when dealers sell bonds on days when the total exposure belongs to the bottom decile, these trades exacerbate capital constraints. Therefore, we expect the dealers to ask a higher price for it, thereby making ψ negative.

We implement the regression in equation (9) in the following way. We measure the inventory risk exposure (i.e., the inventory value of the bond multiplied by its duration) of all dealers in each bond at the end of each day and standardize the measure to make it comparable across bonds. We compute the capital required (according to the Bank of England's duration-based capital adequacy directive) to support the overall total exposure at the end of each day. We run the regression on days when the capital required lies in the highest decile and in the lowest decile. Note that these correspond to days when the overall total risk exposure belongs to the bottom decile and the top decile, respectively.

We report our findings in Table VII. Panel A reports the findings for the scenario shown in the top panel of Figure 4. For the extreme-decile-based analysis (first row of Panel A), we find that ψ is positive, large in magnitude compared to λ , and statistically significant at the five percent level.²⁹ This is consistent with dealers' buying activity alleviating capital constraints on days when the capital required is in the highest decile, and therefore the dealers offering significantly higher prices in order to execute these trades. When we consider the mirror image sce-

²⁸ Since we have 357 days in the sample for which change in price is observed, the top- and bottom-decile analysis covers 35 days each (70 days in total, so $T=70$) while the top- and bottom-quartile analysis covers 89 days each (so $T=178$). The number of observations included in the regression equals 90 bond issues times the number of days (70 for decile-based analysis and 178 for quartile-based analysis).

²⁹ We note that three out of four estimates of λ reported in Table VII are positive and therefore are of the opposite sign of that predicted by theory. However, none of these three estimates are statistically significant.

Table VII
Price Effects of Capital Constraints

This table reports the findings from the following regression for days when the capital requirement as per the Bank of England's Capital Adequacy Directive belongs to the top-decile and bottom-decile, and top- and bottom-quartile:

$$\Delta P_{i,t} = \sum_{t=1}^T D_{i,t} D_t + \lambda \Delta I_{i,t} + \psi D_{bd} \Delta I_{i,t} + \xi_{i,t},$$

where $\Delta P_{i,t}$ is the percentage change in the price of bond i on day t , $D_{i,t}$ is the duration of bond i on day t , D_t is a dummy representing the day of the sample period ($t = 1, 2, \dots, T$), D_{bd} is a dummy that takes the value of 1 if the total exposure is in the lower extreme (i.e., bottom-decile or bottom-quartile) on day t , $\Delta I_{i,t}$ is the change in inventory risk exposure of all dealers on day t , λ is the regression coefficient that captures inventory effects and ψ captures the incremental effect due to the degree of tightness of capital constraints, and $\xi_{i,t}$ is the error term. The t -statistics are reported in parentheses. Figures in bold face (italics) indicate significance at the five (ten) percent level.

Panel A: Top Sells and Bottom Buys by Dealers (see Figure 4, Top Panel)			
Days Selected	λ	ψ	Adj. R-square
Decile-based analysis	- 0.62 (- 0.30)	5.86 (2.06)	57%
Quartile-based analysis	0.14 (0.12)	<i>2.69</i> <i>(1.62)</i>	66%
Panel B: Top Buys and Bottom Sells by Dealers (see Figure 4, Bottom Panel)			
Days Selected	λ	ψ	Adj. R-square
Decile-based analysis	0.30 (1.29)	- 5.27 <i>(1.78)</i>	67%
Quartile-based analysis	0.90 (0.68)	- 2.77 <i>(1.58)</i>	78%

nario (Figure 4, bottom panel), we find ψ to be negative, large in magnitude, and statistically significant at the 10 percent level (first row of Panel B). This is consistent with the dealers' selling activity exacerbating the capital constraints on these days and the dealers offering significantly worse prices in order to execute these trades.

We examine how the relative importance of capital constraints varies as the capital required moves away from the extreme by running the regression in equation (10) for days when the capital required belongs to the top quartile and the bottom quartile. Once again, we find results that are consistent with the price effects of capital constraints (see the bottom rows of Table VII, Panels A and B). The magnitude of ψ is smaller compared to the decile-based analysis; however, it is of the correct sign and is significant at the 10 percent level. This is to be expected as quartile-based results also include days where the capital constraints are not as binding as on the extreme-decile days.

Overall, our findings strongly support the price effects of capital constraints as argued by Froot and Stein (1998). These effects are strongest when the con-

straints are perceived to be most binding, that is, when dealers are carrying a large amount of hedgeable risk on their books, risk that could be laid off in the futures markets. These findings of the adverse, asymmetric price effects of the selective risk-taking activity of dealers is clearly of interest to regulators concerned about market quality.

IX. Concluding Remarks

In this paper, we employ a comprehensive data set from the Bank of England containing the close-of-business spot and futures positions of 15 U.K. government bond dealers to provide empirical evidence relating to how market intermediaries manage the hedgeable component of their core business risk and the relationship of this risk with market quality in the context of perceived capital constraints. We find that dealers engage extensively in selective market (i.e., interest rate) risk taking through a duration-targeting policy, and during our sample period, their duration target is consistently negative. The size of their futures positions is comparable in magnitude to their spot positions and the futures positions usually reinforce the risk of their spot positions. However, the dealers actively use futures contracts to partially and selectively hedge the changes in their spot positions. We find that dealers use futures markets to a greater extent when the cost of hedging is lower, when the pressures of capital constraints (either due to regulatory requirements or due to internal controls) are greater, and during periods of greater economic uncertainty.

We also find that larger dealers carry a greater amount of risk on their books and hedge the changes in their spot risk less compared to smaller dealers. This behavior is consistent with the predictions of Stulz (1996). However, larger dealers do not earn significantly greater profits than smaller dealers as a result of their selective risk-taking policy. In fact, the profits from selective risk taking are statistically insignificant for most dealers. This suggests that the government bond markets are efficient and the informational advantage of dealers as a result of observing and executing order flow is more perceived than real.

We test a central cross-sectional implication of Ho and Stoll's (1983) model at the portfolio level (including derivatives positions), and find strong support for it. In particular, we find that the dealers with extreme long (short) risk exposures sell (buy) a relatively larger amount of exposure in the subsequent period. However, this is undertaken entirely through the futures market and not the spot market. This finding indicates that futures markets play a healthy role that can potentially improve spot market quality by enabling efficient management of the hedgeable component of spot risk. However, it also indicates that, in the presence of an efficient futures market, dealers care primarily about the unhedgeable (and not the hedgeable) component of their spot risk, as emphasized by Froot and Stein (1998). Assessing these effects further requires a comprehensive microstructural investigation, and is left for subsequent research.

Finally, we examine price effects of capital constraints as argued by Froot and Stein (1998), and find strong support for such price effects. We find that trades that

worsen (relax) dealers' capital constraints receive significantly worse (better) prices. We believe that regulators interested in market quality should be concerned about this adverse effect of the selective risk taking (duration-targeting) activity of dealers.

Although this paper analyzes the U.K. government bond market, we believe that most of our findings are relevant for intermediaries operating in a wide range of other spot markets; in particular, the U.S. Treasury bond market, the foreign exchange market, and numerous over-the-counter markets. The intermediaries in these markets face conditions and incentives that are not dissimilar to those faced by our bond dealers. These other spot markets also have a decentralized semitransparent dealer market structure, and the assets traded are also macroeconomic variables associated with largely public information. Furthermore, there exist liquid futures markets that enable efficient hedging of market risk. Finally, the dealers competing for business in these markets also face capital constraints which may be either explicitly imposed by regulators or implicitly imposed through the risk budgeting process within these dealer firms. Therefore, we believe that our findings are likely to characterize, to a significant extent, the behavior of intermediaries in these other markets as well.

Appendix: Salient Features of the Bank of England's Capital Adequacy Directive

To compute the capital requirement according to the Bank of England's capital adequacy directive, first, one categorizes the bonds into different bands depending on their modified Macauley duration: short (less than 1 year in duration), medium (between 1 and 3.6 years' duration), and long (over 3.6 years' duration). Then one multiplies the duration of short-duration bonds by a factor of 1.0 (i.e., no scaling), that of medium-duration bonds by a factor of 0.85, and that of long-duration bonds by a factor of 0.7. Subsequently one computes long and short exposures within each duration band and measures the extent of offsetting (i.e., matching) of risk exposure within each band. One then calculates the extent of offsetting of unmatched risk exposures across different bands. According to the Bank of England's capital adequacy directive, the capital required equals 2 percent of gross risk exposure plus 100 percent of net risk exposure plus 40 percent of unmatched offsetting risk exposure across adjacent bands (i.e., short-medium and medium-long) plus 150 percent of any remaining unmatched offsetting risk exposure across nonadjacent bands (i.e., short-long).

Using this method, we compute the capital required each day to support the overnight risk position of all 15 dealers and find that it varies between 71 percent and 78 percent of the magnitude of their overall total risk exposure. We find the correlation between the magnitude of overall total exposure and capital required to be 0.997. The Bank also allows the capital to be computed by assigning a coupon and maturity-based weight to each bond, where the weights are closely linked to the modified duration of the bond. When we compute the capital required by this alternate method, we find the correlation between the magnitude

of overall total risk exposure and the capital required to be 0.97. In general, we find that the days during which the overall total risk exposure belongs to the bottom decile are days when the capital requirement belongs to the highest decile and vice versa. This is to be expected given the fact that the overall total risk exposure is always negative during our sample period and the capital required is nearly perfectly correlated with the magnitude of overall total risk exposure.

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