Foreign Central Bank Activities in US Futures Markets

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We analyze the daily positions of 31 foreign Central Banks in US interest rate futures markets between 2003 and 2011 for targeted hedging or informed profit-making decisions. Central Bank positions before the financial crisis of 2007–2009 are consistent with hedging some underlying balance sheet exposure. During and after the crisis, the pattern suggests an attempt to enhance returns. In particular, Central Banks held and profited from directional positions in 5- and 10-year T-Note futures in a manner indicative of a non-hedging strategy. We also examine whether Central Bank position changes are synchronized in the sense that they tend to occur simultaneously. We identify differences before and after the onset of the financial crisis: Euro-linked Central Banks become more synchronized, whereas non-European Central Banks show no significant change during the crisis. We document that Central Bank positions generally account for a small fraction of the overall size of the futures markets, so it is unlikely that these institutions' goal is to influence US interest rates. Jrl Fut Mark 36:3–29, 2016

1. INTRODUCTION

Most Central Banks disclose little information about their activities in derivatives markets. When there is public disclosure, it usually occurs in annual reports, is limited in scope, and

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JEL Classification: E58; G01; G11

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Received August 2014; Accepted October 2014

The Journal of Futures Markets, Vol. 36, No. 1, 3–29 (2016)

Published online 28 November 2014 in Wiley Online Library (wileyonlinelibrary.com).
DOI: 10.1002/fut.21705

often claims hedging as a motive for derivatives positions. Only a few Central Banks admit that they seek to enhance returns with such positions. We investigate these claims by testing whether Central Banks' *actual* positions in US interest-rate futures markets are consistent with targeted hedging or, alternatively, speculative activities. We pay special attention to trading during the financial crisis of 2007–2009 because low interest rates and macroeconomic uncertainty in that period may have caused greater risk taking, perhaps due to reserve managers' incentive schemes[1] or the need to fund government treasuries.[2]

We also ask whether the 2007–2009 financial crises brought about greater synchronization of Central Banks' futures trading. Although several papers investigate how Central Banks changed their reserve holdings after the onset of the crisis, our interest is in whether the financial crisis influenced their incentive to use derivatives, leading to more synchronized behavior in futures markets.[3] Importantly, while a single Central Bank's futures trades may have a benign effect on prices, if a set of those institutions react in similar ways to exogenous shocks, then the combined effects may be of consequence to other market participants and to market regulators.

To investigate Central Bank futures trading, we create a comprehensive, trader-level dataset of the daily positions of all 31 foreign Central Banks that held reportable positions in US interest rate futures markets for the years 2003–2011. These unique, non-public data are from the US Commodity Futures Trading Commission (CFTC), which keeps records on the end-of-day positions of all large traders in futures markets. This information is confidential, so we present our analysis in a way consistent with the CFTC's privacy rules.

We also analyze the publicly available data on foreign reserves and the notional or market values of derivatives holdings for Central Banks. This public information comes from surveys by the International Monetary Fund (IMF) and individual Central Banks' own annual reports. Of more than 70 Central Banks that voluntarily provided foreign reserves data for dissemination by the IMF in 2011, only 22 reported derivatives use. Of the 31 Central Banks in our CFTC sample, more than 10 are absent from the IMF dataset, which suggests significant under-reporting in the IMF data. While helpful, the IMF database does not provide information on notional values, breakdowns between over-the-counter (OTC) vs. exchange-traded positions, or on underlying assets. By itself, it is inadequate to assess a Central Bank's purpose for trading derivatives.

To supplement the IMF data, we examine the annual reports of 70 Central Banks between 2005 and 2010. Some Central Banks reveal extensive facts about their derivatives positions, including notional and market values, the types of derivative instruments used (forwards, futures, options, swaps, etc.), and periodic gains and losses. The least transparent Central Banks do not mention derivatives at all, even though it is understood by market participants that they use such instruments in reserve management. The remaining Banks do not offer any rationale for why they hold derivative positions. In all cases, the annual reports

[1]For example, Scalia and Sahel (2012, p. 1) document "the existence of risk-shifting behavior by (European Central Bank or ECB-linked) reserve managers related to their year-to-date ranking: interim losers increase relative risk in the second half of the year, in the same way as mutual fund managers." These authors show that those managers' risk-taking incentives are magnified by the annual frequency of reports to the ECB Governing Council and, consequently, the nature of the managers' reputational reward structure. More generally, Remolona and Schrijvers (2004, p. 97) argue that, in an environment "of historically low yields on highly-rated government securities, Central Bank reserves managers seek instruments with higher yields in an effort to enhance returns."

[2]Usually, Central Banks return net surpluses to their own governments' treasury, which may encourage profit-making to reduce political pressure on bank managers. Dominguez, Hashimoto and Ito (2012, p. 389) argue that the Bank of Japan (and possibly the People's Bank of China) engage(s) in carry trades for a profit-making motive.

[3]See, for example, Dominguez (2012), Steiner (2013), and references cited therein.

are accounting statements and show only stocks at a certain time or aggregate flows over a year.

To gain additional insight into Central Bank motives, we use the CFTC-sourced dataset on daily positions in the four interest rate futures markets most used by the Central Banks in our sample: Eurodollars as well as 2-, 5-, and 10-year Treasury notes. The daily magnitude of Central Banks' US futures positions, while large individually, is generally small compared to the overall market, which suggests no intention to affect US interest rates. Accordingly, we investigate alternative reasons for Central Banks' use of these markets.

We argue that pure hedgers might adjust their futures positions in response to volatility changes but would not adjust them consistently in response to changes in the price level. Using this argument as the basis of a test, we find mixed evidence that Central Bank positions are consistent with hedging some underlying balance sheet exposure. Before the crisis, a hedging motive has support, but during and after the 2007–2009 financial crisis, our results suggest an attempt to enhance returns on foreign reserve assets. The latter result is most prominent for 5- and 10-year T-Note futures, in which Central Banks changed positions in the same direction as prices during and after the crisis. The results that challenge the hedging motive are even stronger for Euro-linked Central Banks, whose interest rate futures positions were more profitable than other Central Banks' during the crisis period. We address possible reasons why our test could falsely reject hedging (e.g., if Banks experienced repeated unexpected balance sheet changes), but we argue that these reasons are not sufficient to explain our results.

We also find differences in the degree of co-movement or synchronization of Central Bank positions before and after the onset of the 2007–2009 financial crises. Only Euro-linked Central Banks became more synchronized in their trading during the crisis period—consistent with the notion that they were affected by common shocks or, perhaps, coordinated their policy actions.

Overall, our results clarify the claims made in public documents about Central Banks' hedging motives. We establish that the hedging motive is present, but during the crisis profit-linked actions and common reactions to shocks also explain individual Banks' futures positions.

The remainder of the paper is structured as follows. Section 2 outlines the related literature. Section 3 analyzes the information contained in public documents. Section 4 discusses our empirical methodology. Section 5 describes the trader-level information from the CFTC and the data used in our analyses. Section 6 presents the results and Section 7 offers our conclusions.

2. RELATED LITERATURE

The present paper contributes to the literature on Central Bank policy as well as the research on hedging balance sheet risk. Dominguez, Hashimoto, and Ito (2012, p. 395) note that "researchers would like data on the types of securities (by currency, maturity, and risk-class) and types of deposits (by currency, type of financial institution taking deposits, and domestic or foreign) held in Forex (reserves) in order to analyze portfolio management of foreign currency reserves and intervention policy. However, in most countries, this kind of detailed information is not made public." Our analysis is partly a response to this observation. We focus on specific derivative markets in which we know the contractual details and can follow the actual holdings of Central Banks. Therefore, while we make inferences from only one part of the Banks' balance sheets, it is a part that explicitly reveals their risk exposure.

Our paper is closely connected to the 20 case studies published by the International Monetary Fund (IMF, 2003a, 2003b) and to Blejer and Schumacher (2000). These case studies shed light on official reserves management practices in IMF member countries but offer a limited analysis of derivatives data. Blejer and Schumacher (2000) focus on derivative use "as *policy tools*, i.e., operations designed to influence variables such as the exchange rate or the interest rate (p. 4)." These authors' portfolio analysis is hypothetical, however, due to data limitations.

This paper is part of a growing body of research on foreign reserve management. Generally, it is argued that Central Banks do not try to influence asset prices in that context. Dominguez *et al*. (2012), Scalia and Sahel (2012), and Dominguez, Fatum and Vacek (2013) are recent advances. The extant papers, in contrast to ours, generally abstract from the use of derivatives by Central Banks. Indeed, a lack of data has meant that investigations of derivative use have been limited to theoretical analyses, such as those of Caballero and Panageas (2005) or Claessens and Kreuser (2007), or analyses of how derivatives may help improve reserve risk management.

Our analysis is also connected to the finance literature on hedging by banks and corporations. Booth, Smith and Stolz (1984) provide an early survey of the literature on derivatives trading by financial institutions. Purnanandam (2007) argues that most such trading is tied to hedging. He analyzes "the effects of bank characteristics and macroeconomic shocks on interest rate risk management behavior of commercial banks" (p. 1769). Financial distress is a key issue in this context, but is not directly relevant to the hedging motives of Central Banks.

At non-financial firms, there is considerable survey evidence that managers' market views affect their risk management decisions.[4] Econometric studies by Brown (2001), Adam and Fernando (2006), Brown, Crabb and Haushalter (2006), Chernenko and Faulkender (2011), and Beber and Fabbri (2012) find evidence of "selective hedging" (Stulz, 1996) or outright speculative behavior by corporate managers. Using uniquely detailed information to calculate profits and losses from derivative positions, we document both hedging and speculative interest-rate futures trading by Central Banks.

Finally, our study contributes to the finance literature that asks whether some traders' derivative positions contain valuable information. Fishe and Smith (2012) find evidence that only a small fraction of futures traders are informed for short horizons and document that these informed traders are not typically the more fundamental traders (such as manufacturers or producers). A longer-term view is provided by Fernando and Raman (2010), who document that Canadian gold producers' stock price reactions to changes in hedging are "consistent with the market believing that (these) firms have credible private information about future gold prices (p. 2)." Our analysis complements the above studies by providing evidence that some Central Banks' interest rate futures trading is profitable, especially during the financial crisis. We further contribute by showing that Euro-linked Central Banks' trading actions during the Great Recession are consistent with similar market views or similar underlying hedging demands.

3. PUBLIC INFORMATION ON CENTRAL BANK ACTIVITIES IN DERIVATIVES MARKETS

Public information on Central Bank derivative activities is collected by the IMF and also revealed in annual reports. Although limited and low-frequency, this information is helpful

[4]See Dolde (1993) or Bodnar, Hayt, and Marston (1998) for US firms, or Glaum (2002) for German firms.

because it reveals to market participants the reality of Banks' involvement in derivatives markets and provides an occasional explanation for the objectives behind their positions.

3.1. IMF Survey of Central Bank Practices and Motives for Trading Derivatives

In an investigation of Central Bank practices in its member countries, the IMF found derivatives trading at 16 out of 20 institutions it surveyed (IMF 2003a, p. 32). Detailed country case studies (IMF, 2003b) reveal that those Central Banks traded interest rate futures, forwards, and swaps, "though the nature of derivatives allowed varies from country to country (IMF 2003a, p. vi)." Central Banks reported using interest rate-linked derivatives for three purposes: to manage risk, synthetically replicate portfolio positions with more liquid instruments, or improve the risk-return profile of the Central Bank's existing reserves portfolios.

While informative, the IMF survey does not provide cardinal measures of the magnitude of the derivatives positions held by Central Banks. To fill this void, the IMF developed a monthly dataset on foreign exchange reserves and financial derivative holdings (Section 3.2), which we supplement using Central Banks' own annual reports (Section 3.3).

3.2. IMF Database of Official Reserves and Derivatives Positions

As Pihlman and van der Hoorn (2010, p. 11) remark, "[the] most extensive and consistent dataset available on reserve levels and composition is collected by the IMF. This dataset consists of reserve data from countries that voluntarily subscribe to the Special Data Dissemination Standard (SDDS) and report the data according to a common template."[5] Two features of the IMF's SDDS dataset make it informative for this study.[6] First, amounts are all expressed in US dollars, allowing for meaningful cross-country comparisons. Second, the reporting template provides information on the market values of derivatives positions.

Figure 1 shows that the number of Central Banks reporting foreign reserves information in the IMF's public database (blue line) has increased substantially since 2000. As of the end of 2011, information was available for 72 foreign Central Banks (vs. fewer than 40 at the end of 2000), including almost all of the largest institutions. Figure 1 (green line), however, shows that less than one-third of Central Banks reported derivatives positions with non-zero market values in each year in the last decade.

A more detailed analysis of the SDDS dataset shows that 53 of these 72 Central Banks either did not provide complete information or did not use financial derivatives. Of the 19 banks that did provide complete information, only 10 report exposure in any year exceeding (plus or minus) 1% of foreign currency reserves (with extremes ranging from −9.93%–17.57%). These data suggest that not many Central Banks are involved in derivative markets. Yet, the fact that we found 31 Central Banks in our CFTC sample (including some institutions absent from the public SDDS data) suggests a substantial reporting bias in the IMF database.

Overall, the public SDDS database highlights that selected Central Banks use derivatives in their operations. To examine which derivatives they use, how much, and possibly why, we turn next to Central Banks' annual reports.

[5]See International Monetary Fund, "Dissemination Standards Bulletin Board: Special Data Dissemination Standards," available online at http://dsbb.imf.org/Pages/SDDS/Home.aspx

[6]The SDDS dataset has one major disadvantage for our goals because it excludes any breakdown of Central Bank positions by underlying asset or market (exchange-traded vs. OTC). This missing information rules out identifying the underlying purposes of Central Banks' derivatives trading.

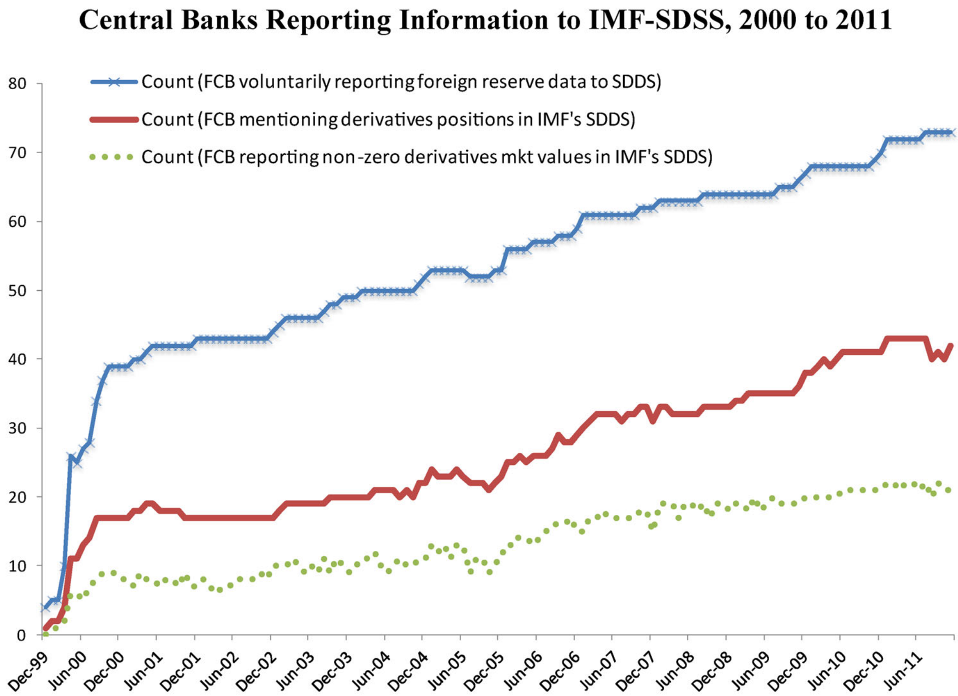

FIGURE 1

The top line plots the number of foreign Central Banks that voluntarily report foreign reserves information for monthly publication by the International Monetary Fund's (IMF) Special Data Dissemination Standard (SDDS) database. The middle curve (solid line) displays how many of those Banks that include some information on their derivatives use. The bottom curve (dashed line) shows that less than a third of the total report non-zero derivatives positions. (Source: IMF). [**Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.**]

3.3. Derivatives Information in Central Bank Annual Reports

We collect the annual reports of all non-US Central Banks listed in the IMF's SDDS dataset for fiscal years 2005–2010 and add two large Central Banks not in that dataset: the People's Republic of China and Taiwan-ROC ("SDDS + 2").[7] After eliminating reports that could not be obtained in English, our sample size ranges from 67 (2005) to 70 (2010) institutions.

The *qualitative* information we collect is whether the annual report discusses any derivatives activities and whether, in the affirmative, the institution provides one or more purposes for trading. Our approach is to search each annual report for derivatives-related terms such as (i) "derivative," "futures," "option," "forward," "swap," and "CFD"; (ii) "exchange-traded," "over-the-counter," and "OTC"; (iii) "hedging," "foreign (exchange) reserves" and "risk management," (iv) "risk-return," "speculation," "trade-offs" and "opportunistic". For each hit, we read and interpret the material before and after the search term's occurrence.

The *quantitative* information collected includes the notional and fair values of Central Bank derivatives positions, separated by instrument and market when provided. To find these data, we peruse the financial statements for evidence of derivatives trading, income, or notional positions. Table I provides counts of the information extracted from these annual

[7]Most Central Banks provide these annual reports on their websites. When this information was not available electronically, we obtained hard copies from Central Banks' public relation offices.

TABLE I
Derivative Use from Central Banks' Annual Reports

		Annual Report Provides Information			*Motives for trading…Interest Rate Derivatives*		*Motives for trading…Foreign Exchange Derivatives*	
Annual Report Year	*Sample Size*	*No Derivatives*	*CB Holds Derivatives*	*Annual Report is Silent*	*Hedging*	*Speculation*	*Hedging*	*Speculation*
Panel A: Overview								
2005	67	3	46	18	17	2	20	2
2006	68	3	47	18	16	1	22	1
2007	69	2	48	19	17	1	21	2
2008	69	2	50	17	16	2	23	2
2009	70	3	55	12	17	1	24	3
2010	70	1	55	14	17	2	25	2

	Unspecified Underlying Asset(s)…Mentions		*Mentions Interest Rate Derivatives…*			*Mentions Foreign Exchange Derivatives…*		
Annual Report Year	*Instrument*	*Purpose*	*Instrument*	*Purpose*	*Amounts*	*Instrument*	*Purpose*	*Amounts*
Panel B: Underlying Instruments								
2005	3	1	30	18	19	44	22	33
2006	3	1	30	17	20	45	27	33
2007	1	1	31	19	22	46	26	36
2008	3	1	28	18	20	51	37	38
2009	1	1	31	19	22	53	36	39
2010	2	1	30	18	22	51	33	36

This table summarizes information contained in the annual reports published by Central Banks from 2005 to 2010, regarding derivatives activities. The sample comprises those Central Banks reporting financial information to the International Monetary Fund (IMF) for public dissemination as part of the Fund's online SDDS database and two major Central Banks not included in that database. We exclude Central Banks whose annual reports could not be obtained in English. Panel A shows the sample size, the count of banks that report derivative holdings or no holdings, the number of banks providing no derivatives information, and the reported motives for derivatives positions if available. Panel B uses the Central Banks that report derivative holdings to show the types derivatives they trade. The first two columns focus on the three Central Banks that report using derivatives without specifying the contract markets in which they hold positions. The next six columns show the kind of information provided by these reports for interest-rate and foreign-currency derivatives.

reports. Table II examines the type of derivatives held and the stated purposes for trading, using 2009 as the reference year.

Blinder, Ehrmann, Fratzscher, and de Haan (2008) state that Central Banks have "become remarkably more transparent in the last ten to fifteen years and are placing much greater weight on their communications" (p. 911). Consistent with this idea, we find that discussions of Central Banks' derivatives positions in their annual reports have become more detailed over time. In Table I, the left half of Panel A shows that a shrinking number of Banks say nothing about their derivatives activities.[8] Approximately 75–80% of these Banks do mention trading derivatives—a figure consistent with the proportion of Banks reporting

[8]In 2009, for example, the annual reports of China and Mexico make no mention of using derivatives.

TABLE II
Derivatives Held by Central Banks, Use and Purpose by Country in 2009

	Report Mentions		*Derivative Instrument(s) Mentioned*		*Purpose(s) Stated*	
Country	*Usage*	*Amounts*	*Interest Rate*	*Foreign Exchange*	*Interest Rate*	*Foreign Exchange*
Panel A: Euro-Related Countries						
Austria	Yes	Yes	SW	SW, FW		L
Belgium	Yes	Yes	FT	SW, FW	H	L
Cyprus	Yes	Yes		FW, SW		H
Denmark	Yes	Yes	SW	FW, SW, FT		H, L
Estonia	Yes	Yes	SW, FT	FW, SW	H	H
European Central Bank	Yes	Yes	FT, SW	SW, FW	H	H, L
Finland	Yes	Yes	SW	FT, FW, SW		
France	Yes	Yes	FT, SW	FW, OP, SW	C	H, L
Germany	*(a)*	No				
Greece	Yes	No		FW, SW		L
Ireland	Yes	Yes		FW		
Italy	Yes	Yes	FT	FW, SW		
Latvia	Yes	Yes	FT	FW, SW, FT	H	H
Lithuania	Yes	Yes	FT	FW, SW	H	H
Luxembourg	Yes	Yes	FT		H	
Malta	Yes	Yes	FT	FW, SW	H	H, L
Netherlands	Yes	Yes	SW	FW, SW	L	H, L
Portugal	Yes	Yes	FT, SW	FW, SW	H	H
Slovakia	Yes	Yes	FT	SW		
Slovenia	Yes	Yes		SW		L
Spain	Yes	Yes	FT	FW, SW		L
Panel B: Other OECD and Advanced Economies						
Australia	Yes	Yes	FT	SW	H	L, H
Canada	No					
Czech Republic	Yes	Yes	FT, SW	FW, SW		L
Hungary	Yes	Yes	SW, FT	OP, SW	H	
Iceland	Yes	Yes		FW, SW		
Israel	Yes	Yes	FT	SW, OP, FT, FW		
Japan	Yes	No		SW		L
Korea	No					
Mexico	No					
New Zealand	Yes	Yes	FT, SW	FW, SW	S, H	H, L
Norway	Yes	Yes	FT, SW	SW, FT	H, L	H, L
Singapore	*(a)*	No			L	
Sweden	Yes	Yes		FW, SW		
Switzerland	Yes	Yes	FT, SW, FW	FW, OP, SW	H	H, S, L
United Kingdom	Yes	Yes	SW, Bond FT	SW, FW	H	H, L
Panel C: Emerging Markets						
Armenia	Yes	Yes	SW	FT		
Belarus	Yes	Yes		FW, SW		

continued

TABLE II
(Continued)

	Report Mentions		*Derivative Instrument(s) Mentioned*		*Purpose(s) Stated*	
Country	*Usage*	*Amounts*	*Interest Rate*	*Foreign Exchange*	*Interest Rate*	*Foreign Exchange*
Brazil	Yes	Yes	FT, SW	FW, SW		H, L, S
Bulgaria	Yes	Yes	FT	FW		
Chile	Yes	Yes		SW, FW		H, L
China	No					
Croatia	*None*	*0*				
Eastern Caribbean	Yes	Yes		FW		H
Egypt	No					
Georgia	Yes	Yes		FW		
India	Yes	Yes		FW, SW		L
Indonesia	Yes	No		SW, Other Derivatives		L, H
Jordan	*None*	*0*				
Kazakhstan	No					
Kuwait	No					
Kyrgyz	*None*	*0*				
Malaysia	Yes	No		SW		L
Moldova	No					
Morocco	Yes	Yes		SW		
Pakistan	Yes	Yes		FW, SW, FT		H
Peru	Yes	Yes		FW, SW		L
Philippines	Yes	Yes				L
Poland	Yes	Yes	FW	SW, FW		
Romania	Yes	No		FW, SW		
Russia	Yes	Yes		FW, SW		L
Saudi Arabia	No					
Seychelles	No					
South Africa	Yes	Yes		FW		
Taiwan	No					
Thailand	Yes	Yes	FT	SW, FW	H, S	L, H
Trinidad	No					
Tunisia	Yes	Yes		SW, FW		
Turkey	Yes	No		FW, SW	H	H
Ukraine	Yes	Yes	FT, SW		H, L	

This table reports information about the usage of derivative contracts based on annual reports in 2009 by 70 Central banks in the Euro-related countries, other OECD member and advanced countries, and countries in emerging markets. Note that Chile and Estonia did not become members of the OECD until 2010, and hence are not listed among OECD countries. Israel and Singapore, though not members of the OECD in 2009, are nevertheless listed among other "advanced economies" as per the MSCI listings for that year. The first column shows whether a report provides any information about whether a Central Bank uses derivatives ("Yes"), does not use them ("No"), or provides no information ("None"). For the 55 Central Banks that report using derivatives, the second column shows whether the report provides information about the amounts involved (either notional or fair values). For both interest rate and foreign exchange derivatives, the next four columns show whether the report states that it uses forwards (FW), futures (FT), swaps (SW) or options (OP), and whether its purposes are for hedging (H), liquidity (L) or speculation (S). The (a) entries mean that derivatives are referenced in general terms but there is no affirmative statement of their use.

affirmatively in the IMF survey (IMF, 2003b). Only three Central Banks state explicitly that they do not trade any derivatives at all.

The most transparent Central Banks' provide annual snapshots of substantial positions in interest rate and foreign exchange-based instruments with some data on duration of the underlying asset class. In most other cases, the annual reports provide limited information about the magnitudes of such positions. Still, Panel B in Table I shows that, in any given year, at most three Central Banks that report using derivatives fail to specify the underlying asset. All the other Central Banks in our "SDDS + 2" sample specify an underlying instrument: approximately 45% say that they trade interest rate derivatives and 60% report trading foreign exchange derivatives.

The annual reports of over 60% of all Central Banks either are silent or make only vague statements about a reason for using derivatives. As Table I shows, when a purpose is expressed, the vast majority claim to trade for risk management or hedging purposes.[9] Whether they trade interest rate derivatives or foreign exchange derivatives, only a handful of Banks acknowledge seeking to enhance returns or to synthetically replicate non-derivative financial instruments.[10]

To further understand how derivatives usage varies among Central Banks, Table II summarizes the textual information in the annual reports for fiscal year 2009. The sample is the same as in Table I ("SDDS + 2"), but Table II splits the data between "Euro-linked" (Panel A: Eurozone national Banks, European Central Bank, and Central Banks whose countries belong to the European Exchange Rate Mechanism but have not adopted the Euro); "Other OECD Members and Advanced Economies" (Panel B); and "Emerging Markets" (Panel C). We use a similar partitioning in the analyses of CFTC daily position data in Sections–6.

Table II shows that advanced economies' Central Banks provide more information about derivatives use. Only two Banks from "Other OECD" countries make no reference to derivatives (Korea, Mexico)—although two others (Germany, Singapore) refer to derivatives in only the most general terms as part of a discussion of accounting valuation principles.[11] In contrast, Panel C in Table II shows that almost 30% of emerging markets' Central Banks (10 out of 34, including large countries such as China and Egypt) make no mention of using derivatives.[12] Among the Central Banks in Table II, Norges Bank (Norway), Sveriges Bank (Sweden), the Reserve Banks of New Zealand and Australia, and the Banque de France are among the institutions providing detailed information on their end-of-year positions in various derivatives as well as explicit information on their futures market activities.

Table II shows that all the Central Banks (55) that report trading derivatives in 2009 mention using over-the-counter instruments such as forwards or swaps. About 60% (21 out of 36) of the Banks in advanced economies (Panels A and B) also mention using futures with much of the trading involving interest rate futures—some domestic, but mostly foreign. In contrast, very few (4 out of 34) Central Banks from emerging markets report trading futures.

[9]For example, the European Central Bank's (ECB) 2009 report mentions using interest rates futures (plus currency forwards and various swaps) "as part of the management of the ECB's foreign reserves and own funds" (p. 221).

[10]For example, the Reserve Bank of South Africa mentions that "the purpose of risk management emanating from reserves management operations is to protect the value of the country's gold and foreign exchange reserves … while *opportunistically* taking positions to *enhance returns*" (emphasis added). Online statement accessed on September 22, 2014: http://www.resbank.co.za/ReservesManagement/Pages/Reserves-management-framework.aspx

[11]The Bundesbank's 2009 report mentions derivatives in a general statement that "swaps, futures, forward rate agreements and other interest rate instruments shall be accounted for and valued on an item-by-item basis" (p. 147).

[12]We do not count references either to swaps with domestic banks meant to solve liquidity issues or to bilateral swaps between Central Banks (such as those between the US Federal Reserve and a number of foreign Central Banks during the 2008–2011 financial crisis).

Options are only mentioned in the reports of a few institutions. Also, confirming the results in Table I, most Banks discuss hedging (or liquidity) motives for derivatives positions.

In sum, the public information on Central Banks' derivatives positions has become more detailed over time. Still, what information is contained in annual reports is available at too low a frequency to test for the motives and profitability of Central Bank trading. To this end, we turn to the data on Central Bank positions in US futures markets collected daily by the CFTC.

4. METHODOLOGY

We investigate three characteristics of Central Banks' futures positions in an attempt to isolate their purpose. First, we consider whether their positions yield consistent profits. Certainly, Central Banks have access to superior information about their own actions that may affect market prices (e.g., Sarno and Taylor, 2001). Although the size of their futures positions seems large, it is small relative to the size of these markets, so Central Banks could disguise their actions and use these markets to their advantage. Conversely, if hedging some balance sheet holdings is the goal, we might find consistently negative or positive profits from futures positions (depending on the underlying being hedged and the interest rate environment). Section 4.1 devises a method to explore the daily profitability of Central Banks' futures positions.

Second, Section 4.2 proposes a test for hedging activity. The overall goal of hedging is to reduce or eliminate the effects of price fluctuations on underlying asset (or liability) values. Our test addresses whether Central Bank's futures positions are systematically affected by market price changes. If they are, there is evidence against a hedging purpose.

Lastly, the CFTC daily position data allow us to look for evidence of synchronized Central Banks reactions to common external shocks. Because futures market positions are a limited part of balance sheets, we cannot conclude synchronization in Banks' *overall* activities or policies. Section 4.3 explains the tests that we use to examine if Banks' *futures* trades are synchronized.

4.1. Profits from Positions and Net Trading

Central Bank participation in listed futures markets may be aimed at hedging specific interest rate risks on their balance sheet, particularly during the 2007–2009 Recession when these Banks' loan portfolios expanded. To examine this question, we evaluate the profitability of Central Bank positions and net daily trading both during and outside of the crisis period.

To compute profits, we first characterize the structure of our position data in light of the fact that it represents end-of-day holdings. Suppose a Central Bank begins day t with position $x^k_{0,t}$ in contract k and makes J_k trades to end the day with position, $x^k_{J_k,t}$, where for ease of exposition a positive value indicates a long position and a negative value indicates a short position. Let $\{x^k_{0,t}, x^k_{1,t}, x^k_{2,t}, \ldots, x^k_{J_k,t}\}$ denote the sequence of positions held by the bank during the day. Our dataset contains the daily open interest positions of reporting traders in each contract in each market, which means that we observe $x^k_{0,t}$ and $x^k_{J_k,t}$ but do not observe intraday position changes. Next, we show how we can represent daily profits as a function of observables and a single unobserved variable that we can approximate.

Aggregating over all trades ($j = 1, 2, \ldots, J$) and contracts ($k = 1, 2, \ldots, K$) on day t, we write the Bank's daily profit as

$$\pi^*_t = \sum_{k=1}^{K} \sum_{j=1}^{J_k} x^k_{j,t}\left(p^k_{j+1,t} - p^k_{j,t}\right), \tag{1}$$

where $p^k_{j,t}$ denotes the price of contract k at the time of trade j. The initial day t price, $p^k_{0,t}$, equals the previous day's closing price and the final price, $p^k_{Jk+1,t}$, is the day t closing price. We rewrite Equation (1) as

$$\pi^*_t = \sum\nolimits_{k=1}^{K} x^k_{0,t}(p^k_{Jk+1,t} - p^k_{0,t}) + (x^k_{J_k,t} - x^k_{0,t})(p^k_{J_k+1,t} - p^k_{*,t}), \tag{2}$$

where

$$p^k_{*,t} = \frac{\sum_{j=1}^{J_k}(x^k_{j,t} - x^k_{j-1,t})p^k_{j,t}}{\sum_{j=1}^{J_k}(x^k_{j,t} - x^k_{j-1,t})}$$

represents a *reference* price. It is a size-weighted average of trade prices for a given trader and is defined only if $\sum_{j=1}^{J_k}(x^k_{j,t} - x^k_{j-1,t}) \neq 0$ i.e., if the closing open interest differs from day $t-1$ to t.

Equation (2) represents daily profits as a function of observables and a single unobserved variable,$p^k_{*,t}$. Because the j subscript is redundant in (2), we consolidate notation and write

$$\pi^*_t = \sum\nolimits_{k=1}^{K} x^k_{t-1}\Delta p^k_t + \Delta x^k_t(p^k_t - p^k_{*,t}), \tag{3}$$

where $\Delta p^k_t = p^k_t - p^k_{t-1}$ denotes the change in closing price between day $t-1$ and t for the kth expiration and $\Delta p^k_t = x^k_t - x^k_{t-1}$ denotes the change in closing open interest position between day $t-1$ and t. We compute daily trading profits using (3). As proxy for $p^k_{*,t}$, we use the midpoint of the high and low prices observed during the day.

4.2. Hedging Tests

If a Central Bank is hedging an underlying position, then changes in its futures positions should be driven by changes in the sensitivity of its cash flow to US interest rates (Faulkender, 2005). This sensitivity is in turn driven by volatility: the more volatile are interest rates, the more volatile should a Bank's cash flows be.[13] In contrast, a Bank that believes it can predict future price changes, or follows a momentum or contrarian strategy, will change positions in response to price changes. Fishe, Janzen, and Smith (2014) show that speculative traders who disagree on the fundamental price will exhibit position changes that are correlated with price changes.

The key observation here is that price changes should not affect position changes in a pure futures hedge. This observation suggests a first-order test for hedging behavior. We estimate the regression model

$$\Delta Q^f_t = \alpha + \beta\Delta P_t + \gamma\Delta V_t + \varepsilon_t, \tag{4}$$

where ΔQ^f_t is the change in futures position, ΔV_t is the change in volatility of interest rates on day t, ΔP_t is the change in the futures price, and ε_t is an *i.i.d.* error term. In our estimation, we make each of these terms into relative changes, e.g., change in futures price relative to the previous (event time) futures price. The null hypothesis that a Bank is hedging is H_o: $\beta = 0$.

[13]If a Central Bank were following a minimum-variance rule, it would also adjust the hedge when the hedge ratio changes—which may be due to changes in the variance of futures or spot prices or the correlation between cash and futures prices. Because spot and futures prices are highly correlated (typically greater than 0.94), position changes in our context are more likely due to changes in the variance of futures prices than changes in the correlation.

Note that if the size of a Bank's *underlying* position is correlated with prices, then we may reject the null hypothesis even though it is hedging. We explore this possibility in Section 6.2.

4.3. Co-movement/Synchronization

To investigate co-movement or synchronization, we study the timing of *changes* in Central Banks' positions. Specifically, we test if contemporaneous changes in Banks' positions occur more than suggested by randomness. Fisher and Konieczny (2000) and Cavallo (2011) suggest such synchronization tests for retail prices. We adapt the FK methodology to examine Central Banks' actions in futures markets. The FK index of synchronization, adapted to position changes in a given futures contract, may be written as

$$FK = \sqrt{\frac{\sum_{t=1}^{T}(q_t - \bar{q})^2/T}{\bar{q}\,(1-\bar{q})}} = \frac{\sqrt{s_{q_t}^2}}{\sqrt{\bar{q}}(1-\bar{q})}, \tag{5}$$

where q_t represents the proportion of Central Banks that changed their holdings in a given futures at time t. The mean of q_t is given by $\bar{q} = \sum_{t=1}^{T} q_t/T$ with s_{qt}^2 representing the sample variance defined over T periods.

The intuition here is that if all Central Banks act simultaneously, they all change their positions ($q_t = 1$) or none of them change their positions ($q_t = 0$). In that case, q_t is a binary variable and the sample variance, s_{qt}^2, equals $\bar{q}(1-\bar{q})$. As such, FK equals 1 in the case of full synchronization. A complete lack of synchronization is referred to as a "staggering" of position changes. Full staggering is characterized by $q_t = \bar{q}\ \forall t$, which implies $FK = 0$. In other words, if Central Banks change positions such that a constant proportion $E(\bar{q}) = 0$ of all Banks change their holdings every period, then there is no synchronization, just randomness.

Further insight into the structural basis of the *FK* measure is provided by Dias, Robalo Marques, Neves, and Santos Silva (2005), who model a set of participants as one of two types: either fully synchronized or fully non-synchronized. These authors show that *FK* is a method-of-moments estimator of the proportion of synchronized participants. Thus, we can interpret *FK* to measure the fraction of Central Banks acting in a synchronized manner in US futures markets.

To implement the *FK* calculation, we examine changes in Central Bank positions on a weekly basis. We use a weekly measure because a daily measure could miss some synchronized actions due to trading decisions' arising in different time zones. On a given day, we aggregate the same-side positions across expirations, which gives a total long (x_{it}^L) and total short (x_{it}^S) for bank i at the end of week t and allows us to compute the total net position $x_{it} = x_{it}^L - x_{it}^S$.

We develop two directional measures of trading:

$$b_{it}^L = 1 \text{ iff } \Delta x_{it} > 0; \quad b_{it}^L = 0 \text{ otherwise, and}$$
$$b_{it}^S = 1 \text{ iff } \Delta x_{it} < 0; \quad b_{it}^S = 0 \text{ otherwise}$$

where $\Delta x_{it} \equiv x_{it} - x_{it-1}$. These two statistics define binary variables that indicate whether the net position change in week t is directed toward long-side or short-side profitability. Specifically, if a Central Bank increases a long futures position, then that is a profitable decision if the futures price subsequently increases. Similarly, if a Central Bank decreases a short futures position, that decision is also profitable in terms of opportunity cost provided the futures price subsequently increases. Both changes together would result in $b_{it}^L = 1$ and $b_{it}^S = 0$ in the data for Bank i. Because Banks remain neutral in some weeks, it is not always the case that $b_{it}^L = 1 - b_{it}^S$. We define these statistics in terms of position *changes* rather than levels because, if the trading of different Central Banks is synchronized, then we would expect their *actions* to be consistent with a specific direction in futures prices, regardless of their initial holdings.

We calculate the proportion of Central Banks who changed their holdings (q_t) for the two directional measures specified above. Specifically, $q_t^L = \frac{1}{m_t}\sum_{i=1}^{m_t} b_{it}^L$ and $q_t^S = \frac{1}{m_t}\sum_{i=1}^{m_t} b_{it}^S$, where m_t is the count of Banks holding positions in the futures market during week t. From these measures, we compute long-side (FK_L) and short-side (FK_S) synchronization indices. This approach yields a better statistic if such synchronization is asymmetric, i.e., Banks synchronize on one side (e.g., interest rates increasing) and not the other (e.g., interest rates decreasing).

If Central Banks' futures position changes are not synchronized, then we would expect position changes to appear staggered through time.[14] If they appear uniform across Banks, then FK is expected to equal zero for either the long-side or short-side direction calculation. The null hypothesis consistent with staggering of trade decisions is $\boldsymbol{H_o} : \boldsymbol{E}(\boldsymbol{q_t}) = \theta, \forall t$. Under this null, a constant proportion (θ) of Central Banks may randomly change positions each period. Dias *et al.* (2005) show that this hypothesis may be tested using a χ^2 goodness-of-fit statistic. The appropriate test statistic has the form:

$$Q = \sum_{t=1}^{T} \frac{N(q_t - \bar{q})^2}{\bar{q}\,(1-\bar{q})} = (NT)FK^2, \tag{6}$$

where, under the null, $Q \sim \chi_{(T-1)}{}^2$. Rejecting this null provides additional support for the view that at least some Central Banks' futures trades are synchronized.

5. CFTC POSITION DATA

We construct a database of end-of-day positions in interest-rate futures contracts. The raw data originate from the CFTC's Large Trader Reporting System, which represents more than 85% of the open interest in these interest rate futures markets. The volume that is not covered by this dataset is for consistently smaller traders; all large traders are captured by the reporting requirements. The CFTC provided data from July 2003 to December 2011.

5.1. Sample

We use information from the Bank for International Settlements (BIS) to identify alternative Central Bank names and the CFTC's list of "ultimate" position owners to find Central Banks in the CFTC data. This procedure identifies 31 Central Banks from around the world holding derivatives positions large enough to be reported at some point in our sample period.[15]

Several sample characteristics are worth noting. First, very few of those Central Banks trade options on futures. Instead, most take (outright or spread) positions in futures markets. We therefore focus our efforts on futures positions. Second, not all Central Banks are active in all futures markets, and not all Banks active in a given market are active in that market at all times. More than 10 of the 72 Central Banks in the IMF's SDDS database whose annual reports never mention activities in futures markets have reportable US futures positions for at least part of the past decade. Conversely, several of the Central Banks reporting non-zero

[14] Calvo (1983) and Taylor (1980, 1999) develop two macroeconomic models that embed sticky behavior by firms that results in staggered price setting. Kiley (2002) offers a comparison of these two models. For our purposes, we extend these concepts to sticky trade decisions, which then can result in staggered position changes through time.

[15] Conversations with officials from some smaller Central Banks reveal that their institutions take positions via trades through financial intermediaries. Because it is the intermediary that controls the trading in such cases, such Central Banks are not in our CFTC dataset. As a result, the number of "31" Central Banks in US interest rate futures markets understates the true number of Central Banks that hold positions in US futures markets.

TABLE III
Summary Statistics for Central Banks' Futures Positions

		Treasury Note Futures		
Variable	*Eurodollars*	*Two-Year*	*Five-Year*	*Ten-Year*
Panel A: Means				
Futures Long Positions	6,851	2,573	2,962	3,049
Futures Short Positions	4,366	4,769	2,629	2,755
Net Change in Long Positions	1,171	1,705	2,514	2,395
Net Change in Short Positions	710	2,740	1,742	1,386
Expiration Count	4.06	1.02	1.02	1.04
Time Remaining in Contract	12.1%	44.7%	37.6%	29.8%
Percent of Total Open Interest	0.40%	0.70%	1.10%	0.70%
Panel B: Medians				
Futures Long Positions	3,725	2,454	2,000	2,313
Futures Short Positions	2,498	1,626	1,450	2,125
Net Change in Long Positions	321	508	650	786
Net Change in Short Positions	192	640	471	500
Expiration Count	2.00	1.00	1.00	1.00
Time Remaining in Contract	10.5%	43.9%	36.5%	28.7%
Percent of Total Open Interest	0.25%	0.49%	0.77%	0.39%

Summary statistics are shown for end-of-day futures positions and the change in positions by long and short sides, the count of expirations, the percentage of time remaining in a contract, and the percent of open interest relative to total open interest for Eurodollars, Two-Year, Five-Year and Ten-Year Treasury Note contracts. Except for the percent of total open interest, these statistics are computed by first calculating the average and medians across days for a given participant, then summarized across participants to reduce skewness bias created by participants with higher participation rates and open interest levels. For the percent of total open interest, the calculation is made daily and the mean and median are computed across days in the sample.

market values for their derivatives positions in the SDDS dataset are not observed in our CFTC sample. This situation may arise because the positions held in US exchange-traded contracts are too small for reporting, because those positions are managed by an independent portfolio manager or because the Central Bank only trades OTC contracts or non-US futures.

Third, the positions held range from just large enough to be reported to substantial. However, Table III shows that even when Central Bank positions are substantial, they typically account for only a small percentage (less than 1% on average) of the overall open interest. Lastly, Central Bank positions are concentrated in four interest-rate futures: Eurodollars (17 Central Banks) and 2-year (23 Central Banks), 5-year (22 Central Banks), and 10-year (22 Central Banks) Treasury Notes. Other interest rate futures are traded by fewer Central Banks (e.g., Treasury Bonds for eight Central Banks; 30-day Federal Funds for seven Central Banks) and, in each case, are generally less actively traded than these four main contracts. In contrast, a minuscule number of Central Banks take large positions in other US futures markets.[16] We focus therefore on Eurodollars, as well as 2-year, 5-year, and 10-year T-Notes futures.

[16]Generally, at most one Central Bank in our sample takes reportable positions in futures contracts on the main currencies, commodities (gold, wheat, corn, or coffee), or US equity indices.

5.2. Summary Statistics

Table III provides summary statistics for our sample of Central Banks. We report means and medians for end-of-day futures positions and for the change in positions for both long and short sides of the market. We also show statistics for the count of expirations, the percentage of time remaining in a contract, and the percent of open interest relative to total open interest. These data are reported for each of the four instruments in our sample. Except for the percent of total open interest, mean and median statistics are computed by first calculating the averages and medians across days for each participant and then summarizing across participants. Our statistics thus reflect a representative bank rather than a representative day and so are not distorted by participants that trade more frequently. For the percent of total open interest, the calculation is made daily over all banks and the mean and median statistics are computed across days.

Table III reveals that Central Banks hold fairly large positions in these contracts. On the high side, the nominal value of the average Eurodollar long position is \$6.8 billion, and on the low side the nominal value of the average short position in 5-year Treasury Notes is \$262.9 million. Similarly, the daily change in positions is meaningful across these contracts with changes in long positions tending to be larger than changes in short positions (except for 2-year Notes).[17]

Expiration counts and the time remaining in a contract suggest that Central Banks typically hold the nearby contracts in the Treasury complex. For Eurodollars, the time remaining in a contract is fairly low—both mean and median. Expiration counts also suggest that Central Banks hold spread or butterfly Eurodollar futures positions.

Although Bank positions are monetarily significant, on average they are not meaningful given the size of these markets. Thus, the purpose behind such positions is likely not to influence US interest rates. In effect, the small size of these holdings relative to the market as a whole suggests that participation in these markets is likely driven by an internal calculation based on how policy decisions may affect a Banks' overall balance sheet or by portfolio management considerations for foreign reserve assets.

6. ANALYSIS

This section presents the results of the tests developed in Section 4. We investigate the profitability of Central Banks' positions and trading (6.1), their purposes for using interest-rate futures (6.2), and the possible synchronization of their trading activities (6.3).

6.1. Central Bank Profits from Holding Futures Contracts

Table IV shows the estimated daily average profits from Central Bank positions and net trading summarized by futures contract and across all contracts. The amounts shown are profits for long and short positions combined. Overall, Central Banks lost money on their futures market positions. For Eurodollars and 2-year Treasury notes, losses occurred on average both during and outside the recession of 2007–2009. However, their profitability in 5-year and 10-year notes differed between the recession and non-recession periods.

For the sub-sample of Euro-linked Central Banks, we find consistent overall losses for the period excluding the recession of 2007–09. During the recession, those Banks show

[17] Daily position changes do not correspond to trade sizes because participants may make many trades on both sides on the market during the day. The position changes reported here constitute the end-of-day changes in open interest.

TABLE IV
Position and Net Trading Profits

			Treasury Note Futures		
Sample Coverage	*Overall*	*Eurodollars*	*Two-Year*	*Five-Year*	*Ten-Year*
All Central Banks					
All Periods	$ (12,033)	$ (8,772)	$ (83,828)	$ 24,714	$ 39,184
2007–2009 Recession	$ (17,335)	$ (49,288)	$ (62,040)	$ (75,051)	$ 208,398
Excl. 2007–2009 Recession	$ (10,809)	$ (2,005)	$ (92,092)	$ 49,214	$ (1,896)
Euro-related Central Banks					
All Periods	$ (16,964)	$ (13,698)	$ (32,565)	$ 27,422	$ (45,786)
2007–2009 Recession	$ 20,020	n.a.	$ 1,140	$ 174,698	$ 4,039
Excl. 2007–2009 Recession	$ (20,471)	$ (13,698)	$ (45,854)	$ 12,711	$ (50,500)

This table reports the average daily position and net trading profits for the sample of all Central banks by period and futures instrument. Profits for the sub-sample of Euro-related Central banks are shown separately. This sub-sample includes some but not all of the Euro-related banks shown in Table III. Net trading profits during a given day use the midpoint of the high and low price as the reference trade price in Equation (2) in the text. Profits combine both long and short positions across all expirations with holdings on a given day. The 2007–2009 Recession is defined using the NBER dating calendar and represents the period December 2007 to June 2009.

positive average daily profits on their Treasury Notes positions, particular 5-year notes. This period witnessed declining interest rates, so holding larger long positions would generate this result.

As to the hedging motive, the *overall* profit column supports the statements of Central Banks in their annual reports. Specifically, no Bank would persist in holding or taking positions for losses in these markets if there was no material offset somewhere on its balance sheet. However, some contracts—5-year and 10-year Notes—and the group of Euro-linked Banks may reveal a different motive. For these contracts and Banks, substantial profits are found during various periods. Thus, a speculative motive may also be at work for selected Central Banks.

6.2. Dynamic Hedging Tests

The results in Table IV are indicative of Central Bank profits and motives but do not involve a statistical test for hedging. Next, we apply the hedging test described in Section 4.2.

Table V shows hedging test results for the entire sample period by commodity. Observations are for each Central Bank over time, so we use a pooled cross-section time-series model with a fixed parameter structure. For each Bank, we only include daily observations for which the net position change was non-zero and there is no weighing by the size of a Bank's position. The dependent variable is the ratio of the change in net long positions (long minus short) divided by the total of long and short positions. Price changes are measured using close-to-close prices between the included observations.

We compute the variance of futures prices using the prices of options on futures. We calculate option-implied volatilities using the formula that the Chicago Mercantile Exchange (CME) uses for its VIX calculation, which is in standard deviation units. For each trading day we use the nearest-to-maturity option with more than one month to expiration (e.g., for the October expiration in Treasury bonds, we use the December expiration options contract), and

TABLE V
Central Bank Hedging Behavior

		Treasury Note Futures		
Variables	*Eurodollars*	*Two Year*	*Five Year*	*Ten Year*
Intercept	1.444	1.082	0.597	0.761
	0.047	*0.048*	*0.120*	*0.025*
Relative Price Change	80.96	−1.56	1.30	97.65
	0.770	*0.982*	*0.974*	*0.008*
Relative Change in VIX	−4.572	0.019	0.184	−7.577
	0.118	*0.975*	*0.844*	*0.010*
Sample Size	1,330	3,142	2,240	3,036
R-Squared	0.2%	0.1%	0.1%	0.4%
DW-lower	*0.585*	*0.558*	*0.552*	*0.533*
DW-upper	*0.415*	*0.442*	*0.448*	*0.468*

We test for evidence of hedging using the sample of central banks from August 2003 to December 2011. Results are provided for position changes in four futures markets: Eurodollars and Two-, Five-, and Ten-year treasury note futures. These effects are measured using trade frequency data defined for each bank individually. That is, on a given day, positions are summed across all expirations for each central bank. Days are then ordered in sequence and an observation is retained in the sample if it shows a position change from the previous day. A model is estimated for each commodity. The dependent variable is the ratio of the change in net long positions (long minus short) divided by the total of long and short positions. Price changes are measured using close-to-close prices between the included observation days; the VIX index is computed using options on futures in each commodity market following the procedures used to compute the CME VIX. The lower (DW-lower) and upper (DW-upper) Durbin-Watson *P*-values are shown for an AR(1) model at the bottom of the table. The *P*-values for the coefficients are shown in italics below each coefficient estimate.

we omit any option contract with zero volume on the relevant trading day. We conduct robustness checks of our hedging tests using an implied volatility series from the Commodity Research Bureau, which is based on Black's formula and the two nearest-to-the-money puts and calls.[18] The lower (DW-lower) and upper (DW-upper) Durbin-Watson *P*-values are shown for an AR(1) model at the bottom of the table. The results in Table V support the view that Central Banks use futures markets for hedging purposes, because the coefficient on the price change tends to be statistically insignificant. The exception is the 10-year Note, which exhibits a significant positive coefficient on the price change variable.

In Table VI, we re-estimate our model by partitioning the sample into before, during, and after the Great Recession period. These three sub-periods are the "Pre-Crisis," defined as July 2003 to November 2007; "Crisis," defined as December 2007 through June 2009, i.e., as the period during which the United States was in a recession as identified by the National Bureau of Economic Research; and "Post-Crisis," defined as July 2009 to December 2011.

Panel A in Table VI shows that this partitioning of the sample has meaningful effects on these hedging tests. For every commodity, the relative price change variable is statistically significant during the crisis period and insignificant during the pre-crisis period. The positive sign indicates that Central Banks appear to use a momentum strategy; that is, they increase their net long positions when prices are increasing.

[18]The Commodity Research Bureau does not cover our entire sample period. Still, our results are robust to using this alternative measure in that, for the overlapping period, our results are substantially the same for both series. Hence, we report our findings using the VIX calculation. We confirm the stationarity of these relative-change variables using the adjusted Dickey–Fuller test and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) test for the full sample and each sub-sample.

TABLE VI
Central Bank Hedging Behavior Before, During, and After the Financial Crisis

	Eurodollars			*Two-Year T-Notes*			*Five-Year T-Notes*			*Ten-Year T-Notes*		
Variables	*Pre-Crisis*	*Crisis**	*Post-Crisis*	*Pre-Crisis*	*Crisis*	*Post-Crisis*	*Pre-Crisis*	*Crisis*	*Post-Crisis*	*Pre-Crisis*	*Crisis*	*Post-Crisis*
Panel A: All Central Banks												
Intercept	2.711	1.242	0.058	1.775	0.104	1.205	0.912	0.379	0.087	0.741	1.967	0.146
	0.050	*0.404*	*0.018*	*0.184*	*0.044*	*0.141*	*0.274*	*0.368*	*0.017*	*0.002*	*0.247*	*0.029*
Relative Price Change	222.09	33.09	115.37	95.38	92.39	−14.64	−168.38	190.14	7.73	0.69	373.67	49.94
	0.716	*0.037*	*0.000*	*0.816*	*0.000*	*0.823*	*0.167*	*0.000*	*0.006*	*0.983*	*0.028*	*0.000*
Relative Change in VIX	−7.496	0.466	−0.109	−0.776	0.038	0.687	1.329	0.231	−0.047	−4.230	−22.870	−0.641
	0.141	*0.177*	*0.317*	*0.699*	*0.351*	*0.535*	*0.661*	*0.834*	*0.468*	*0.047*	*0.058*	*0.315*
Sample Size	700	76	553	1,092	938	1,112	1,000	506	734	1,446	570	1,020
R-Squared	0.3%	44.9%	24.1%	0.0%	7.1%	0.0%	0.2%	3.3%	1.1%	0.3%	1.3%	6.2%
DW-lower	*0.593*	*0.726*	*0.460*	*0.532*	*0.774*	*0.561*	*0.545*	*0.394*	*0.921*	*0.711*	*0.492*	*0.730*
DW-upper	*0.407*	*0.274*	*0.540*	*0.467*	*0.226*	*0.439*	*0.455*	*0.606*	*0.079*	*0.290*	*0.508*	*0.270*
Panel B: Euro-related Central Banks												
Intercept	0.494	−0.016	0.039	0.140	0.071	0.153	1.476	0.051	0.163	0.666	0.253	0.080
	0.153	*0.718*	*0.119*	*0.081*	*0.182*	*0.000*	*0.309*	*0.158*	*0.037*	*0.016*	*0.160*	*0.516*
Relative Price Change	−473.00	45.81	146.04	−241.61	158.81	3.87	−231.05	−5.54	0.13	121.58	11.21	142.01
	0.002	*0.002*	*0.000*	*0.000*	*0.000*	*0.264*	*0.294*	*0.051*	*0.984*	*0.000*	*0.480*	*0.000*
Relative Change in VIX	−2.314	0.300	−0.273	0.133	−0.044	−0.052	2.822	0.039	−0.085	3.007	0.575	−1.152
	0.095	*0.192*	*0.039*	*0.237*	*0.341*	*0.420*	*0.668*	*0.738*	*0.568*	*0.232*	*0.659*	*0.250*
Sample Size	549	60	437	601	470	668	575	132	261	715	193	431
R-squared	2.3%	15.8%	38.6%	10.5%	28.5%	2.1%	0.2%	2.9%	1.1%	1.9%	0.5%	22.3%
DW-lower	*0.530*	*0.050*	*0.001*	*0.780*	*0.001*	*0.432*	*0.547*	*0.881*	*0.543*	*0.647*	*0.798*	*0.611*
DW-upper	*0.470*	*0.995*	*0.998*	*0.221*	*0.999*	*0.568*	*0.453*	*0.120*	*0.456*	*0.353*	*0.202*	*0.389*

We test for evidence of hedging using the sample of Central Banks in the futures markets before, during, and after the financial crisis of 2007–2009. Panel A shows results for all Central Banks combined and Panel B shows results for only Euro-related Central Banks. The analysis is divided into three sub-periods: "Pre-Crisis" defined as July 2003 to November 2007; "Crisis" defined as December 2007 through June 2009, i.e., as the period during which the United States were in a recession as identified by the National Bureau of Economic Research; and "Post-Crisis" defined as July 2009 to December 2011. Results are provided for position changes in four futures markets: Eurodollars; Two-, Five-, and Ten-y note sear US Treasury Notes The effects are measured using trade frequency data defined for each bank individually. That is, on a given day, positions are summed across all expirations for each CB. Days are then ordered in sequence, and an observation is retained in the sample if it shows a position change from the previous day. A model is estimated for each commodity. The dependent variable is the ratio of the change in net long positions (long minus short) divided by the total of long and short positions. Price changes are measured using close-to-close prices between the included observation days. The VIX index is computed using options on futures in each commodity market following the procedures used to compute the CME VIX. The lower (DW-lower) and upper (DW-upper) Durbin-Watson *P*-values are shown for an AR(1) model at the bottom of the table. Regressions marked with an asterisk ("*") are estimated after correcting for an AR(1) structure. The *P*-values for the coefficients are shown in italics below each coefficient estimate.

As an alternative to the momentum interpretation of these results, the findings shown in Table VI (Panel A) could be consistent with a hedging story if there were repeated, *unexpected* changes in interest rates. Suppose, for example, that during the crisis, Central Banks want to hedge the income stream on their short-term, dollar-denominated assets. As interest rates drop, Central Bank income drops. In order to protect against further decreases in income, Central Bank managers who had hedged only part of their exposure might increase their net long positions in interest rate futures. This story, however, requires that unexpected interest-based losses contemporaneously increase the incentive to hedge against further losses. The findings of Scalia and Sahel (2012), though, suggest that foreign reserve managers tend to respond to poor current year performance by increasing their exposure to selected risks.

Another possible story is that, as long-term interest rates dropped amid the financial crisis, the fear of possible capital losses in the event that rates rebounded might have led reserve managers to increase the hedge. Because T-Note futures prices and interest rates are inversely related, however, we would expect the signs of the regression coefficients to be the opposite of those in Table VI (Panel A). A third possibility is linked to the flow of dollar-denominated assets onto Central Banks' balance sheets. If foreign reserves' growth is inversely related to the level of US interest rates and unexpected flows arise, then hedging positions may change, which creates a correlation with price changes.

Although the coefficients in Panel A may admit a hedging strategy, such an explanation requires a sequence of *unexpected* price changes. The post-crisis period results in Panel A question these stories. The post-crisis coefficients confirm the significant positive relationship between positions and relative price changes for all commodities except 2-year notes. For Eurodollars in particular, the relative price change coefficient indicates that these effects increased by an order of magnitude. A hedging explanation may still be viable, but it is more difficult to believe that balance sheet changes were unexpected at this point. Given Central Banks' access to information during the crisis and afterwards, these post-crisis significant effects suggest that informed, strategic trading may be a better explanation for our findings.

Euro-linked Central Banks make up approximately one-third of our sample and constitute a reasonably homogeneous sub-group. We therefore re-estimated the hedging test for that sub-group of Banks. These results are shown in Panel B in Table VI. The results generally confirm the full sample findings, except that now the pre-crisis coefficient on the relative price change variable is significant for Eurodollars, 2-year, and 10-year Notes, suggesting a possible non-hedging motive in certain contracts prior to the crisis for these Banks. Combined with the previous observations for Panel A, these findings lean toward a speculative motive for futures positions, possibly because of information relevant to particular contracts.

To better understand the idiosyncratic features of these different Central Banks, we re-estimate the hedging-test model on each Bank separately. Because we are using daily frequency data, a few Banks drop out of our sample as they do not have enough variation for reliable estimation. The final sample contains 28 Central Banks. We report the sign of the relative price change variable and its P-value in Table VII. The R^2 range and the count of significant (5% level) coefficients for each commodity are shown at the bottom of this table.

The significance counts at the bottom of Table VII indicate that our findings are too frequent to be generated by chance. Thus, we are statistically confident that many of these Central Banks are adjusting futures positions coincident with price changes, which is not standard if they have adopted an effective hedging strategy. Importantly, the inconsistency in the sign of the coefficient on the relative price change variable suggests either quite different hedging instruments (assets versus liabilities) or selective use of information. Because some

TABLE VII
Individual Central Bank Hedging Decisions

	Eurodollars		*2-Year Notes*		*5-Year Notes*		*10-Year Notes*	
Central Bank	*Relative Price Change*	*P-Value*	*Relative Price Change*	*P-Value*	*Relative Price Change*	*P-Value*	*Relative Price Change*	*P-Value*
CB #1			pos	*0.501*	pos	*0.008*	pos	*0.101*
CB #2			pos	*0.001*	neg	*0.921*	pos	*0.776*
CB #3	pos	*0.001*	neg	*0.555*	neg	*0.521*	neg	*0.009*
CB #4			pos	*0.036*	neg	*0.704*	neg	*0.580*
CB #5	pos	*0.103*	pos	*0.007*	neg	*0.796*	pos	*0.013*
CB #6	neg	*0.060*					neg	*0.044*
CB #7	pos	*0.018*	pos	*0.130*				
CB #8			neg	*0.001*	pos	*0.361*	pos	*0.445*
CB #9			neg	*0.001*				
CB #10	pos	*0.832*	neg	*0.363*	neg	*0.001*	neg	*0.029*
CB #11	neg	*0.001*	neg	*0.001*	neg	*0.166*	pos	*0.001*
CB #12	pos	*0.001*	pos	*0.542*	pos	*0.597*	pos	*0.001*
CB #13			pos	*0.367*	pos	*0.547*		
CB #14	pos	*0.198*	pos	*0.248*	pos	*0.001*		
CB #15	neg	*0.001*	neg	*0.849*	neg	*0.442*	pos	*0.069*
CB #16					neg	*0.418*	neg	*0.738*
CB #17			neg	*0.024*	neg	*0.131*	neg	*0.613*
CB #18			neg	*0.001*	pos	*0.001*	neg	*0.046*
CB #19	neg	*0.260*	pos	*0.057*	neg	*0.001*	neg	*0.967*
CB #20					pos	*0.378*		
CB #21	pos	*0.501*	neg	*0.216*	pos	*0.001*	pos	*0.102*
CB #22			pos	*0.903*				
CB #23	pos	*0.001*	pos	*0.461*				
CB #24	neg	*0.089*			pos	*0.686*	pos	*0.767*
CB #25			neg	*0.363*				
CB #26			pos	*0.093*				
CB #27			pos	*0.775*	pos	*0.961*		
CB #28			neg	*0.424*				
Significant @ 5%	6/13		8/24		6/20		7/17	
R-Squared range	1.4%–91.5%		0.1%–92.1%		0.1%–60.4%		0.3%–89.9%	

We refine the test for hedging by estimating results for each Central Bank separately. The specification and estimation approach are the same as Table V. We report the sign of the price change variable and its *P*-value. The dependent variable is the ratio of the change in the net long positions (long minus short) divided by the total of long and short positions and each regression includes the relative price change variable and the relative change in price volatility as measured by the VIX. The R-squared range and the count of significant (5% level) coefficients for each commodity out of all tested banks are shown at the bottom of the table.

Central Banks show futures profits, the selective use of information motive cannot be readily dismissed.

Overall, these tests suggest that hedging is unlikely to be the sole purpose for Central Bank positions in US futures markets.

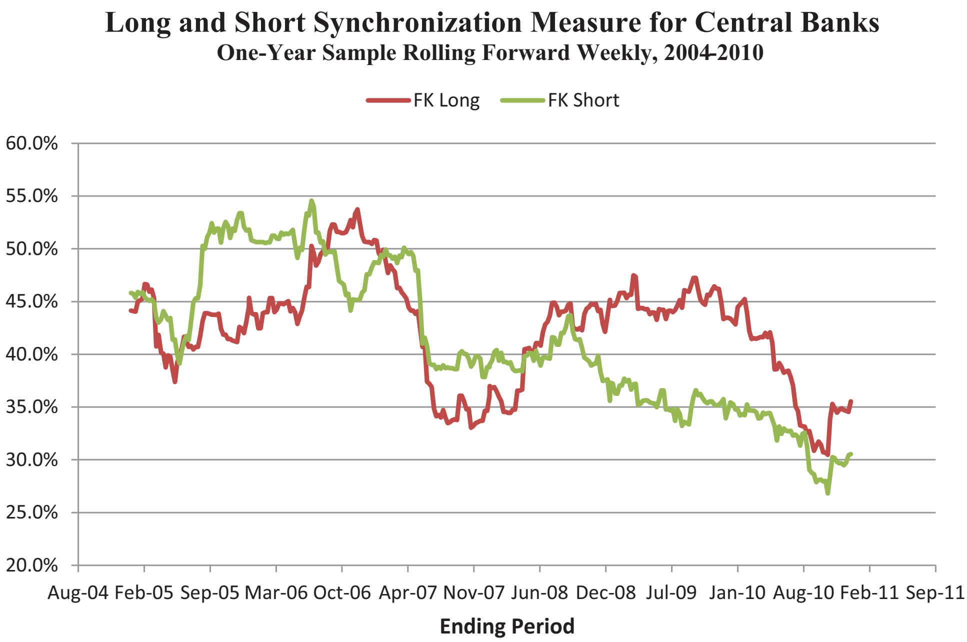

FIGURE 2

The *FK* measure of synchronization is shown for long- and short-side net trading decisions using all Central Banks with positions in 2-, 5-, and 10-year Treasury Notes and 90-day Eurodollar futures contracts. The annual calculation begins in 2004 and rolls forward weekly until the end of 2010. The date axis shows the period ending for each calculation. Calculations using data during the 2007–2009 Recession (December 2007 to June 2009) are then defined by the period December 2008 to June 2010. **[Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]**

6.3. Rolling Measure of Synchronization

We compute the *FK* synchronization measure for a one-year moving window starting in 2004. We roll this calculation forward using one week increments to the end of the sample. Figure 2 shows the pattern of synchronization for the long- and short-side versions of the *FK* measure. It shows some synchronization of position changes, particularly for long side holdings, but the degree of participation is at most around 50%.[19]

The plot makes it clear that after mid-2006, there was a decline in synchronization on the short side with a peak of 55% reached for the period ending July 2006 and a trough reached for the period ending October 2010 (22%). Rapid declines are observed from periods ending July 2006 to November 2006 (44%) and for April 2007 (49%) to July 2007 (39%), while fairly steady synchronization arises between the periods ending August 2005 to July 2006 and July 2007 to October 2008, with the latter being at a reduced participation rate. The evidence here suggests that participation on the short side decreased during the 2007–2009 Recession

[19]In the *FK* calculation, *T* is fixed but the number of Central Banks with positions may vary somewhat within a given year. To investigate any biases that arise because of this variation, we (i) exclude observations where there are less than five Banks in a given week; (ii) evaluate the *FK* calculation using only observations with an equal number of Banks and (iii) use the minimum, median, and average number of participating Banks to compute the chi-squared test of staggered changes in positions. All of these robustness checks lead to the same general observations about the synchronization of Banks' net trading decisions.

(which, for this rolling forward calculation, is for the period ending December 2008 to June 2010).

In contrast, the long-side measure shows greater fluctuation in synchronization than the short-side measure. There appears to be fairly high synchronization (>50%) between the period ending July 2006 to February 2007. In addition, sustained synchronization arises at a somewhat lower level (~45%) during the period ending December 2008 to January 2010, which overlaps the 2007–2009 Recession and continues six months beyond its official end date.

Because of the limited number of Banks in our global sample, we cannot systematically isolate each region to analyze if Banks in that region are more synchronized than the global sample. An exception, however, are Central Banks whose currencies are linked to the Euro. This group of Banks' participation in these futures contracts leads to a sufficiently large sample to use our methods while preserving trader confidentiality ($n = 10$).

Figure 3 shows the rolling calculation of the *FK* synchronization measure based on a sample of Euro-related Banks. To have sufficient size, this sample begins in October 2006. A noticeably different level of participation is observed for Euro-linked Banks for the entire period and during the 2007–2009 Recession. At the beginning of the 2007–2009 Recession, about 75% of Euro-linked Banks synchronized long-side net position changes and about 65% synchronized short-side net position changes. These rates increased steadily during the 2007–2009 Recession, reaching a peak of 92% long-side participation and 87% short-side participation in September 2009 (which effectively covers the second half of the Great Recession).

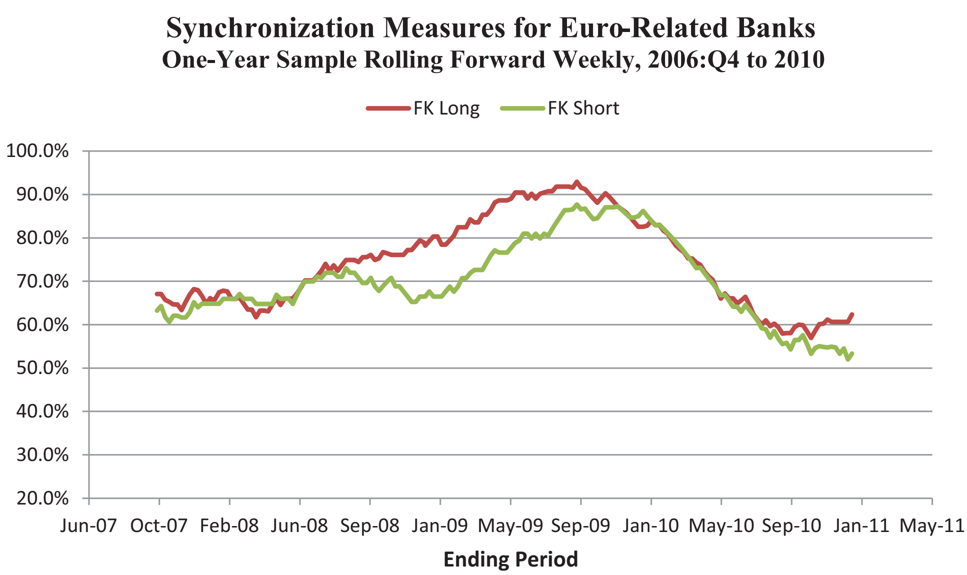

FIGURE 3

The *FK* measure of synchronization is shown for long- and short-side net trading decisions using only Euro-related Central Banks with positions in 2-, 5-, and 10-year Treasury Notes and 90-day Eurodollar futures contracts. Because of limitations in Bank participation, the calculation of the *FK* measure begins in October 2006 and rolls forward weekly until the end of 2010. The date axis shows the period ending for each calculation. Calculations using data during the 2007–2009 Recession (December 2007 to June 2009) are then defined by the period ending December 2008 to June 2010. [**Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.**]

6.4. Staggered Position Changes

The patterns appearing in Figures 2 and 3 show higher levels of synchronization during the 2007–2009 Recession for Europe-linked Banks than are found in our global sample of Central Banks. To weigh this evidence, we examine whether we can reject the staggered-price hypothesis for these data. Figures 4 and 5 provide a plot of the one-tail *P*-values for this chi-square goodness-of-fit test. Figure 4 shows all Central Banks and Figure 5 is for the sample using only Euro-linked Banks. The *P*-values are shown for each annual sample rolling forward weekly, identical to the sample definition used to calculate the *FK* measure.

Figure 4 shows that the long-side synchronization observations from Figure 2 are generally supported. The two periods with relatively high levels of long-side participation by Central Banks correspond to periods during which we can reject the hypothesis of staggered position changes arising at a constant rate. The short-side results in Figure 4 suggest that while there is a prolonged period of relatively high synchronization near the beginning of our sample, we cannot reject the position change staggering hypothesis—which lowers the weight that we place of the implications of the observed *FK* measure. Although there are brief periods of significance for the short-side measure of position change staggering, they do present a picture to support the view that globally, foreign reserve managers within Central Banks react similarly in an increasing-interest rate environment.

In contrast, Figure 5 offers consistent support for the view that Europe-linked Banks' long-side net position changes were synchronized during the 2007–2009 Recession and (for a limited period) that short-side changes were, too. Figure 5 shows a fairly sustained

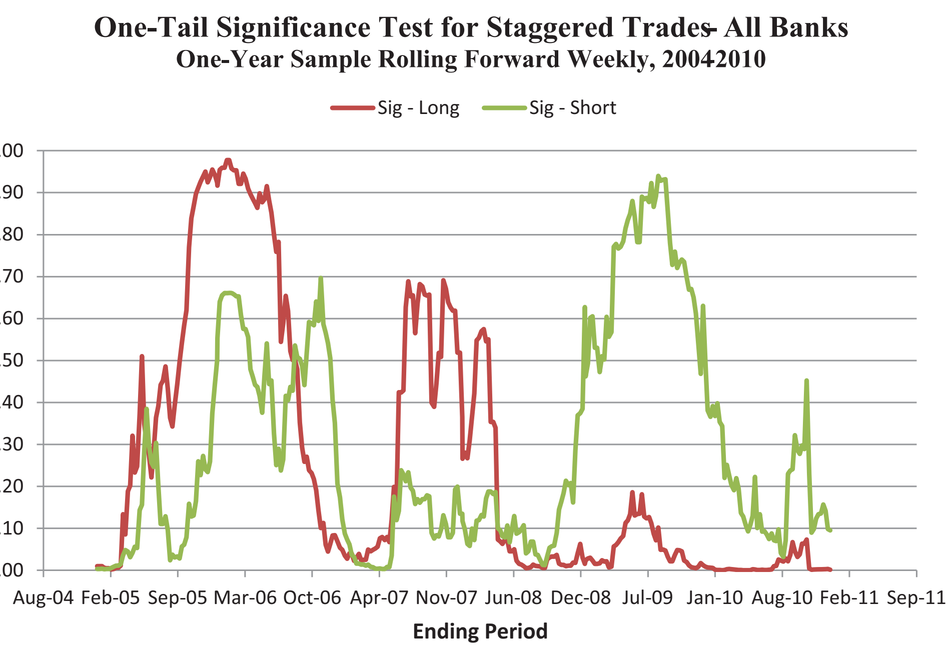

FIGURE 4

The *P*-value of the *Q* statistic is shown for long- and short-side net trading decisions using all Central Banks with positions in 2-, 5-, and 10-year Treasury Notes and 90-day Eurodollar futures contracts. The date axis shows the period ending for each calculation. Calculations using data during the 2007–2009 Recession (December 2007 to June 2009) are then defined for the period ending December 2008 to June 2010. [**Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.**]

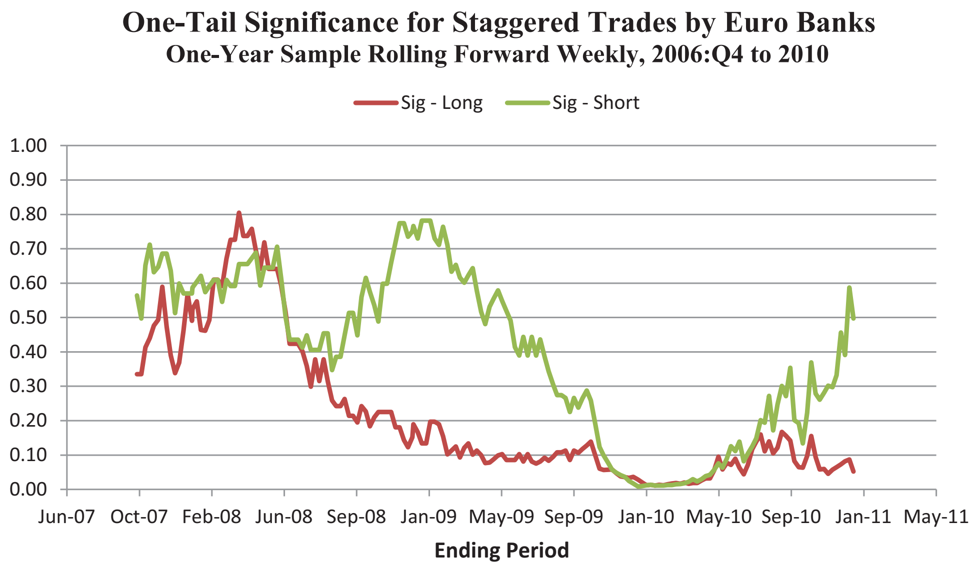

FIGURE 5

The *P*-value of the *Q* statistic is shown for long- and short-side net trading decisions using Euro-related Banks with positions in 2-, 5-, and 10-year Treasury Notes and 90-day Eurodollar futures contracts. The date axis shows the period ending for each calculation. Calculations using data during the 2007–2009 Recession (December 2007 to June 2009) are then defined for the period December 2008 to June 2010. **[Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]**

period (April/May 2009 to July 2010) in which we can reject the position change staggering hypothesis on the long side. During this interval of time, the short side also provides support for synchronization of net trade decisions (period ending November 2009 to June 2010).

7. CONCLUSIONS

We provide the first position-level evidence on derivative use by Central Banks in financial markets where there is no a priori reason to believe that their goal is to influence asset prices. We exploit a unique, comprehensive, non-public dataset of individual traders' daily positions in US interest-rate futures markets between 2003 and 2011 to test the rationale for such positions provided from limited public data—mostly the information contained in their annual reports.

On average, the actual trading behavior of the 31 Central Banks in our sample seems consistent with the hedging purposes mentioned by the vast majority of those institutions. However, an analysis using sub-samples (around the Great Recession and by country group) provides evidence of non-hedging motives for Central Bank derivatives holdings. During and after the 2007–2009 financial crisis, Central Banks (especially Euro-linked institutions) held, and profited from, directional positions in 5- and 10-year T-Note futures, which is indicative of a non-hedging strategy. We also find evidence that amid the 2007–2009 Great Recession and financial crisis, foreign reserve managers from a number of Central Banks reacted in a synchronized manner to the crisis.

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