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THE US TREASURY MARKET IN AUGUST 1998: UNTANGLING THE EFFECTS OF HONG KONG AND RUSSIA WITH HIGH-FREQUENCY DATA

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ABSTRACT

The second half of August 1998 was dominated by two events. From 14 to 28 August, the Hong Kong Monetary Authority (HKMA) intervened in Hong Kong equity markets to prevent a speculative double play against their currency board. On 17 August, Russia announced its default on sovereign bonds. This paper demonstrates that the HKMA interventions had a substantial impact on the outcomes for US Treasury markets during this period using a careful analysis of high-frequency bond market data. On this evidence the shocks emanating from Hong Kong provided liquidity to the US Treasury market when it was most needed. Copyright © 2007 John Wiley & Sons, Ltd.

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1. INTRODUCTION

During the third quarter of 1998 two major financial market events occurred almost simultaneously. On Friday, 14 August, the Hong Kong Monetary Authority (HKMA) began intervening in the Hong Kong equity market to prevent a speculative double play against their currency board. On the next trading day, Monday, 17 August, Russia announced that it would suspend its repayments of sovereign debt. The following months represent a period of unprecedented volatility in the secondary market for sovereign debt instruments.

This paper reveals the important role of the HKMA interventions in influencing the outcomes in the US Treasury market during the second half of August 1998, using high-frequency data to focus on the impacts of the Russian and Hong Kong financial crises during the period 14–28 August 1998. Most studies of this period concentrate entirely on the effects of the Russian default as the trigger for the subsequent financial market turmoil. For example, Jorion (2000) assessed the plight of long-term capital management (LTCM), Hwang and Salmon (2004) attributed the decreased herding effects in mid-1998 to the Russian crisis, Hernández and Valdéz (2001) considered the effects of trade links on crisis transmission, and Dungey *et al.* (2006) measured the contagion effects in bond markets. Each of these studies used the financial data sourced at daily or weekly frequency. An exception to this was Furfine and Remolona (2006), who also used transactions level data and analysed the price impact relationship during the periods of turmoil in 1998.

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Four distinct characteristics of high-frequency trading are considered for providing evidence here—trading volume, net order flow, realized variance and covariances and bid–ask spreads, in order to assess the importance of the HKMA actions. The volume of US Treasuries traded during this period was relatively high and peaked on 27 and 28 August, the last two days of the HKMA interventions. Net order flow indicates a predominantly sellers' market in some maturities for US Treasuries on key dates associated with the Russian default and on the last days of the HKMA intervention. Realized volatility for the fortnight declined from a quarter high achieved just prior to the period under examination, and the realized covariance between the assets increased only from 27 August onwards. Lastly, the bid–ask spread on US Treasuries was relatively stable until 27 August, followed by a sustained widening.[1]

The analysis suggests that the evolution of the data is consistent with a strong influence from the HKMA interventions; a finding aligned with the market participants' views in the review of the 1998 crises by the BIS Committee on Global Financial Stability; see Committee for Global Financial Stability (1999). The emerging conclusion is that the Hong Kong intervention had a substantial role to play in the behaviour of the US Treasury market during this period, in part by providing liquidity to the market when it was most needed.

The rest of the paper proceeds as follows. Section 2 sets the scene and briefly reviews the background of each event. Section 3 analyses the high-frequency data on the US Treasury market during the second half of August. Section 4 places this evidence in the context of events and characteristics of both the Russian and Hong Kong financial markets and economic developments at that time. It raises the question of which events may be considered as consistent with the observed empirical evidence and attempts to reconcile the observed data regularities with the events of the second half of August 1998. Section 5 provides some concluding remarks.

2. BACKGROUND TO THE CRISES

In the 10 months prior to August 1998, the HKMA had successfully defended against at least three speculative attacks on the Hong Kong dollar, largely through the use of higher domestic interest rates. However, these incidents and the corresponding decline of the Hong Kong stock market alerted speculators to a potential 'double play': speculators shorted the stock market through the Hang Seng futures market and simultaneously pressured the Hong Kong currency. The speculators stood to gain if the HKMA raised interest rates and equity values fell, or if the currency board broke and their foreign exchange positions became profitable. Speculators were only facing the risk that the HKMA would not behave as predicted by the previous experience and would somehow break the link between supporting the currency and raising the interest rates, thereby dropping equity markets—one possibility would be by direct intervention in the foreign exchange markets, but there the speculators had reasonably good models of central banks' difficulties in holding a currency peg against consistent attack.

The HKMA first intervened in the Hong Kong stock market on 14 August 1998; see Yam (1998) and HKMA (1998, p. 125). Intervention via the equity markets was a new strategy for any central bank, and as such was unanticipated by the markets. The intervention continued until 28 August, the settlement date of the Hang Seng futures contract on which the speculators' short position was based. In the event the HKMA was able to have sufficient impact on the market by making it unattractively expensive for speculators to roll positions into the next futures contract on the expiry of the current contract on 28 August 1998. The financial outlays by the HKMA to achieve this end were enormous. Goodhart and Dai (2003) documented that of the $HK118 billion that the HKMA announced it spent on the intervention between 14 and 28 August, approximately $HK11.5 billion were spent in the first week, $HK15 billion in the next three days, $HK19 billion on the day before the contract's expiration and a massive $HK72 billion on the final day. Subsequent (world-wide) rises in equity markets then made the interventions hugely profitable for the HKMA. Immediately following the futures contract's expiration, the HKMA ceased intervening and let the Hang Seng index fall, but was left with an unprecedented share portfolio of approximately $HK200 billion, of which the majority was to be returned to the market at some point; see HKMA (1998, p. 3). To fund its

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massive intervention program, the HKMA liquidated some of its portfolio of reserve assets, which primarily comprises US Treasuries (HKMA, 1999).[2] In the period from 14 to 28 August the HKMA potentially sold up to $US15 billion of US Treasuries to fund its positions. The means by which this may have actually occurred is not currently public knowledge. In much of what follows we perform the analysis under the presumption that direct sales were used. It is also possible that repo arrangements were in place, which would allow the intervention and sales of the Treasuries to be less directly connected. However, if repos were in place the evidence would be consistent with these repos being unwound at quite a rapid rate. The extent to which the one-sidedness of the market coincides with the known intervention activity of the HKMA is convincing.

July and August 1998 also witnessed deepening concerns about the Russian financial markets partly due to poor economic fundamentals and banking system weakness. Many industrial countries, including the US, had large exposures to emerging markets, including the Russian markets, through their banking systems; see Van Rijckeghem and Weder (2003). On top of this, the US was particularly exposed through the actions of hedge funds such as long-term capital management (LTCM) which had bet heavily on the narrowing of spreads between Russian and the US bonds. The effects of the Russian crisis on LTCM are well documented in Jorion (2000) and Lowenstein (2001). Essentially, the highly leveraged hedge fund experienced calls for cash to finance its outstanding positions which it simply could not raise extra funds to meet. To avert a crisis, the New York Federal Reserve co-ordinated a meeting of market participants, who formed a recapitalization plan released to the public on 23 September. The problems apparent with LTCM became increasingly public during September.

During July 1998 both the World Bank and the IMF released further funds to Russia. A crucial element of the IMF programme was that Russia make progress in restructuring its GKO debt market, particularly some settlement on debt write down. On 13 August a letter from George Soros calling for a 'modest devaluation of 15 to 25 percent' in the rouble and the formation of a currency board was published in the *Financial Times*. Despite President Yeltsin's 14 August declaration that there would be no devaluation, on 17 August Russia suspended its short-term debt payments and allowed the rouble to float.

Following the Russian bond payment suspension, a number of attempts were made to work out a credible plan for GKO debt restructuring. On 20 August the Russian Government announced an interim plan providing some payments to domestic creditors, but an indefinite freeze for international investors. Credit-rating agencies responded with a downgrade. On 23 August the incumbent Kiryenko government was dismissed and it was not until 11 September that a new government was successfully formed under Primakov. A workable GKO restructuring scheme was not set out until December 12, and even that did not come into force until almost four months later.

The role of the non-resident investors was a critical part of the GKO renegotiations; these investors continually rejected earlier schemes. Over 1998, many such investors were hedging their positions with forward rouble contracts with Russian banks (including LTCM[3]). Although many Russian banks had already transferred their previous GKO holdings to non-GKO assets, they were massively short in these forward contracts; see Steinherrr (2004) for details of some particular banks' exposures. The majority of this exposure was to foreign investors, prompting concern about the banks' default potential, and the resulting uncertainty may have risen towards the end of the month. However, the only bank with large forward exposure placed under administration in August was SBS-Agro, and the only major bank to have its licence revoked in this period was Bank Imperial, not noted as having a major forward contract exposure in July 1998.[4] In sum, most of the new information about the state of the Russian banking system and the subsequent collapses seems to have occurred primarily before 23 August or after 28 August.

The dating of events during August–September 1998 is quite problematic. As demonstrated in Furfine and Remolona (2006) there are many alternative-dating schemes that could apply in identifying stressful periods. For the purposes of what follows here it is worth noting that of the schemes they considered only one, which used the descriptive data from Lowenstein (2001), identified any particularly stressful days as falling within the fortnight of 14–28 August.

A crisis in an emerging market such as that experienced by Russia is often associated with a *flight to quality*, that is an excess demand for US Treasuries. In addition, uncertainty provokes a *flight to cash*, so

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that the demand for the short end of the US term structure is very high indeed; see Longstaff (2004). As the following sections show, the mix of the flight to quality and flight to cash provoked by the crisis in Russia, and the HKMA's intervention which was in all probability funded from the sales of US Treasuries, led to interesting interactions in the US Treasury market during the last fortnight of August. The role of events in Hong Kong is arguably greater than previously credited in the literature.

3. HIGH-FREQUENCY EVIDENCE

We use daily and high-frequency (5-min) GovPX trading data on the US Treasury market extracted from the tick-by-tick records of the 2-, 5- and 10-year maturities for the third quarter of 1998. Where the results are consistent across maturities only the 5-year case has been presented in what follows for brevity. Full documentation is available in the working paper version of this paper, see Dungey *et al*. (2005). According to Fleming (2003, p. 86), in 1998 the GovPX interbroker market covered approximately 57% of the total market (and has been falling dramatically since then). For the purposes of examining the 1998 crises, this is the most comprehensive US bond high-frequency database.[5]

3.1. Traded volume

Table 1 shows the average daily volume in $US billion for the 5-year maturity bond across three time zones for the period from 2 July 1998 to 30 September 1998. The time zones are Tokyo trading from 7:30 p.m. to 3.00 a.m. NY time, London trading from 3.00 a.m. to 7.30 a.m. NY time, after which time trading switches to NY. The trading volume data are presented for two relevant subperiods: a non-crisis period before 17 August 1998 (pre-Russian default), and a crisis period from 17 August to 30 September 1998 (post-Russian default).

Treasury volume traded on GovPX during the crisis exceeds that in the non-crisis period, consistent with the results of Furfine and Remolona (2002, 2006), although the crisis period here identifies a higher average daily volume than the selected days in Furfine and Remolona (2006). In the total and non-crisis data, the vast majority of trades clearly occurs in the NY time zone, with the Tokyo time zone quite inactive on average. Not only is total traded volume higher on average during the crisis period, but also this is disproportionately true in non-NY trading.[6] In NY trade, the average volume in the 5-year issue increased by around 150% during the crisis period, but by almost 200% and 250% in London and Tokyo, respectively.

The highest volume days in the sample for the 5-year securities were the 27th and 28th of August, the dates when the Hang Seng futures contract expired. Time zone considerations mean that the expiry of the Hang Seng futures contract in Asian trading time on the 28th of August is only just after the London opening and prior to the New York time. Trade in New York had to occur on the 27th of August prior to the expiration of the Hang Seng futures contract. The heavy volume in London and NY on the 27th and

Table 1. Volume traded in the 5-year maturity for non-crisis (2 July to 14 August) and crisis (17 August to 30 September) periods in $US million per day

Period	Volume	Day	Time zone		
			Tokyo	London	New York
Total		6724	225	412	6083
Non-crisis	Total	5555	130	281	4974
	Max	8746	397	685	8102
	Min	2947	2	60	2640
Crisis	Total	8148	326	551	7265
	Max	11 213	1199	1312	9943
	Min	4112	0	98	3657

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Table 2. Volume characteristics of 5-year maturity on particular crisis days in $US million per day

Volume	Sample average	14 August	17 August	27 August	28 August
Total	6724	5733	4112	10 513	11 213
Tokyo time zone	225	111	124	337	1199
London time zone	412	121	331	753	785
New York time zone	6083	5501	3675	9423	9229
Average volume per trade	8.72	9.15	9.05	8.94	7.35
Max volume in 5 min	—	231	132	240	224
Ratio of trades to activity[a]	0.14	0.127	0.126	0.144	0.141
Average time between trades	—	01:03	01:32	00:35	00:35

[a] Activity is defined as the sum of enacted trades + quotes observed. The number is necessarily an estimate as it is not always clear in the database which ticks clearly represent new market quotes.

28th of August was accompanied by unprecedented activity in the Tokyo time zone on the 28th. Table 1 shows that the average Tokyo trade volume in the 5-year maturity for the non-crisis period is $US130 billion, but this approximately doubled for the crisis period, influenced by the massive $US1199 billion traded in this time zone on 28 August. To put this in perspective, on average around 2% of the trade in the non-crisis period occurred in the Tokyo time zone, but this jumped to over 10% on this one particular day. Thus the anticipation of the Hang Seng futures contract expiry, and the actions of both speculators and the HKMA in playing out the speculative scenario seem to have been influential on the US Treasury market in that period. Although it was technically possible for the speculators to have rolled their futures market positions into the September contract, it seems that the HKMA acted in that market to make this an unattractively expensive option; Goodhart and Dai (2003, Chapter 5).

The two other dates singled out in Table 2 are 14 and 17 August, the first day of the HKMA intervention and the day of Russia's debt payment suspension, respectively. The volume on 14 August was higher than the average for non-crisis days. This trade was focused in the NY time zone, which occurred after the Hong Kong intervention. On 17 August, the Hong Kong market was closed, and uncertainty abounded about the implications of the Russian announcement.

Nevertheless, the volume traded on 17 August was below the sample average. The ratio of number of trades enacted to quotes posted is slightly lower on the mid-August days compared with the end-August days; however, this is not a pattern which is consistent across other maturities, see Dungey *et al*. (2005). In general these ratios remain relatively similar. However, the average time between trades in the NY trading zone does change during the crisis period. On the high volume days of 27 and 28 August the average time between trades is less than that recorded for the lower volume days of 14 and 17 August. The average trade size is either unchanged or slightly lower during the higher volume days at the end of August, consistent with the lower time between trades and, as noted by Fleming (2003, Chart 7), the quote size also falls. Additionally, the workup time is not notably different across the crisis days shown in the table, at around 14 seconds for the 5-year issue.[7]

The volume characteristics of the market strongly suggest that some of the higher volume of US Treasury trade observed in the latter half of August is likely to be associated with the situation in Hong Kong.

Seasonality. To get a better feeling on whether the volume observed was just coincidentally greater or smaller on the days of interest, we estimate controls for regular events known to affect the market. For example, Fleming and Remolona (1999) found that US Treasury trading volume responds to macroeconomic announcements: there is a muted initial response and a larger and prolonged subsequent lift in volume. Chaboud *et al*. (2004) have recently found a similar result for currency markets. Seasonal effects are estimated from the daily GovPX volume data from January 1992 to June 1998. Although high-frequency deseasonalizing can also be undertaken (Anderson and Bollerslev, 1997; Bollerslev *et al*., 2000), most interesting effects occur only a few times in the relatively short sample of high-frequency data

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available encompassing the crisis period. Using daily GovPX data on volumes it is possible to obtain a simple estimate of the size of day-of-the-week and end-of-the-month (issuance) effects on volume.

In the short sample examined above, 17 August is a Monday, 27 August is a Thursday, and 14 and 28 August are Fridays. Using a simple regression of day-of-the-week and end-of-month dummies on daily data, the volume effects, in $US million, for Mondays, Thursdays and Fridays, respectively, are found to be −1208, 779, and 380 in the 5-year note and the end-of-month effects are estimated at −87 million dollars.[8]

Applying the calculated seasonality adjustments to the data in Table 2 does not materially affect the picture presented in the previous section. For example, the largest adjustment is to the volume on Monday, 17 August, where assuming the seasonal adjustment is made only in NY trading; the NY trade volume figure would be around $(4112 + 1208) = 5320$ million, which is consistent with the total volume traded in NY on the 14 August, and well below the volumes traded on 27 and 28 August which are barely affected by the day-of-the-week adjustment. Adjusting for intraday seasonality using a flexible Fourier transform, as suggested in Bollerslev *et al.* (2000) with a news dummy for the release dates for the employment situation, the CPI and retail sales revealed no discernible impact from these effects during this period.[9]

3.2. Net order flow

Net order flow refers to net purchases made during the day, calculated by compiling signed trades (purchases less sales) from the tick-by-tick data. Figure 1 gives the net order flow for the 2-, 5- and 10-year maturities for the period 14–31 August. In this case the results for each maturity are presented. The columns in each case are the net order flow for each day. The thick line in each chart is the mean net order flow recently calculated by Brandt and Kavajecz (2004) for each maturity using GovPX data over the period from January 1992 to December 1999 (for on-the-run bonds with maturities of 1–2, 2–5 and 5–10 years; these authors report mean net order flows of 246.909, 307.857 and 144.751 $US million, respectively). The dashed lines represent 90% significance bands, again compiled from the data in Brandt and Kavajecz (2004).[10] They note that the average net order flow is positive in each of these maturities.

Considering the events of August 1998, on the one hand, news about the Russian default should have created a flight to quality and hence a desire on the part of market participants to buy US Treasuries, which should show up in the net order flow as strongly positive net purchases. On the other hand, the HKMA is known to have funded its intervention in the stock market using its foreign reserve portfolio, which comprises mainly US Treasuries. This would release US Treasuries into the market, and if nothing else was going on, create excess takes in the market, represented as strongly negative net purchases. As the intervention went on, the amounts released into the market by the HKMA were progressively larger; Goodhart and Dai (2003).

Figure 1 indicates significantly negative net purchases on 17 and 18 August in the 10-year maturity and on 18 August for the 5-year maturity. Later in the fortnight, there are strongly positive net purchases in all maturities. This pattern suggests that the flight to quality was not the dominant factor in longer-term bonds immediately following the Russian default. The exception to this is the 2-year maturity, where net purchases on 17 August were strongly positive.

Given the uncertainty about the composition of US Treasuries that the HKMA might have sold to fund its interventions, two potential explanations are possible. First, the flight to quality might have been accompanied by a flight to shorter maturity securities and cash; and, second, the role of the HKMA intervention might have been important in determining negative net purchases immediately following the beginning of the intervention period. An examination of high-frequency data for US Treasury bills suggests a strong component of flight to cash at the very short end. As shown in Figure 2, which plots the net purchases for the third quarter of 1998, in the 3-month Treasury bill net purchases were dramatically higher during this period than the remainder of the quarter. The two large peaks correspond to 14 and 19 August. To put these figures in perspective, the corresponding mean and standard deviation for 0–6-month securities for 1992–1999 reported by Brandt and Kavajecz (2004) are $US22.443 million and 322.111 million, respectively. The picture presented around 14–18 August suggests a strong element of flight to cash,

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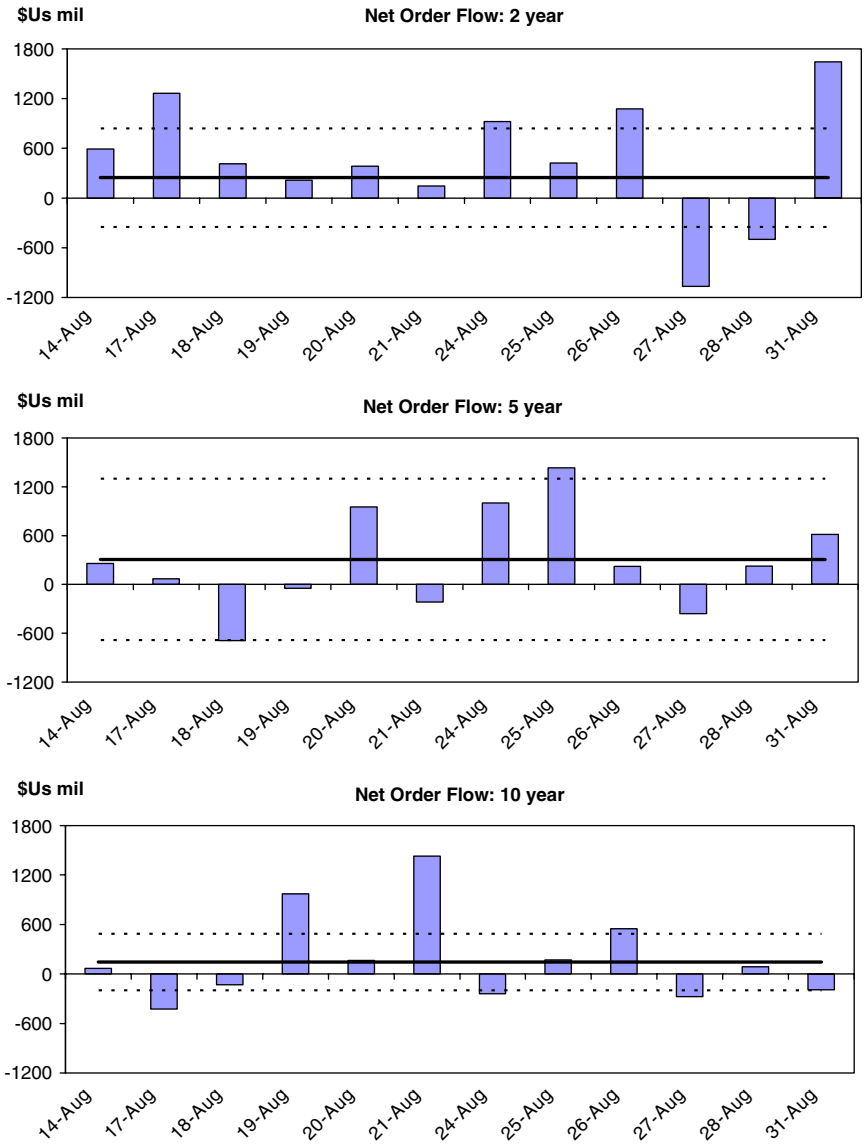

Figure 1. Net order flow across maturities.

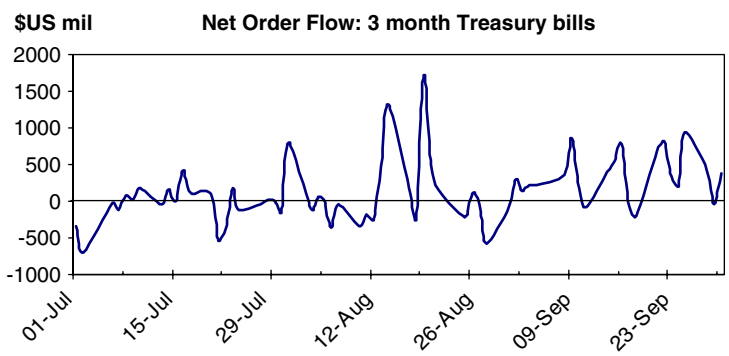

Figure 2. Net order flow short end.

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but is not completely consistent with a flight to quality at all maturities immediately following the Russian default.

However, on 27 August strong net sales are consistently evident across all maturities, including 3-month Treasury bills. This date was the last NY trading period before the expiration of the Hang Seng futures contract; in the last two days of intervention Goodhart and Dai (2003) estimated that some $HK91 billion was spent on intervention.[11] On 27 August, the evidence supports the hypothesis that sales from the HKMA to fund their intervention activities dominated flight to quality effects from Russia.

3.3. Realized volatility

The existing literature on price impact in the US Treasury market suggests that volume and price impacts are not related; see Boni and Leach (2004) and Green (2004). This is consistent with a number of similar studies on equity markets such as those by Farmer *et al.* (2004) for the London Stock Exchange.

In a crisis period with high volumes, a natural first response is to consider whether crisis days are related to large price movements. US Treasuries showed a slight decline in yields over the second half of August, and a more pronounced fall thereafter.

Figure 3 shows daily realized volatility figures compiled from the 5-min data for each of the 5-year maturity for the third quarter of 1998 as representative of the patterns observed in other maturities.[12] Notably the realized volatility shows a general decline across the fortnight from 14 to 28 August, having peaked in the lead up to this period.

Other evidence on volatility during this period is documented in Jorion (2000), who provided a figure on the volatility of credit spreads based on the commonly used RiskMetrics system. He particularly noted that 'volatility creeps up on 25 August . . . on 27 August, it moves and stays above 0.04, double its recent value.' (Jorion, 2000, p. 288). The pertinent subperiod from Jorion's data is shown in Figure 4.

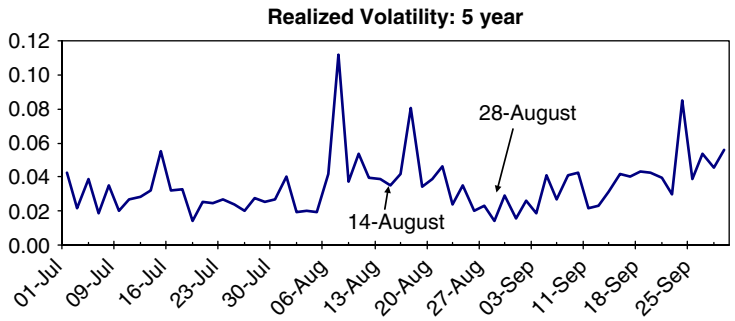

Figure 3. Realized volatility.

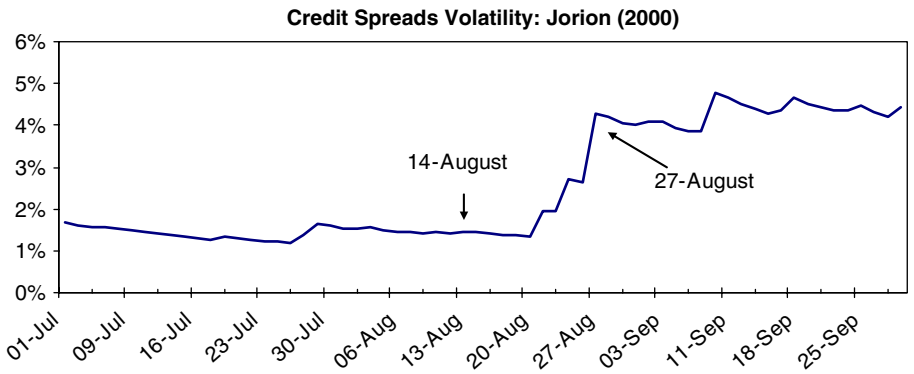

Figure 4. Credit spread volatility.

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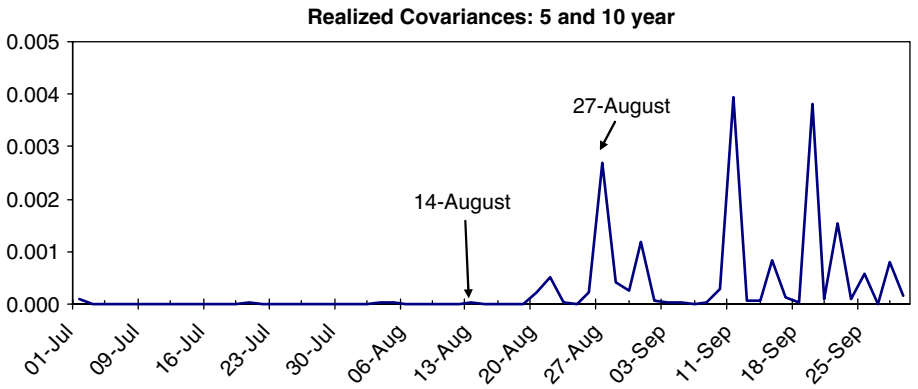

Figure 5. Realized covariance between 5- and 10-year maturities.

Another instructive metric in this case is that of *realized covariance*, constructed as the daily sum of the cross returns between the assets of different maturities. Figure 5 shows that the realized covariances between the 5-year and 10-year maturities are relatively unchanged in the period prior to the 27 August, and jump enormously on that date in each of the cases; the realized covariances between other combinations of the 2-, 5- and 10-year maturities display similar patterns. In each case, there is also a smaller increase on 21 August.

The realized covariances and the credit spreads volatility evidence of Jorion (2000) support the hypothesis that volatility increases in the US Treasury markets were not substantial until the end of August.

3.4. Bid–ask spreads

The bid–ask spread on US Treasuries may well be the most useful measure of liquidity available in the GovPX interbroker market at this time.[13] Of a range of liquidity measures, this spread most frequently reacts in an anticipated manner during various interludes of poor liquidity; see Fleming (2003). The spread is the difference between the posted bid and ask prices, with the transaction initiator also paying usually $\frac{1}{256}$th on each transaction as brokerage fee. The one-sided nature of the fee, only paid by the dealer responding to the posted quote, may encourage active participation in submitting quotes as a means of reducing costs; see Green (2004).

The bid–ask spread in US Treasury interbroker market is usually relatively stable at each maturity. Looking at intraday data clearly shows that the 'standard' 5-year maturity transactions had a bid–ask spread of $\frac{1}{128}$th of a percentage point in the non-crisis subperiod. The spread widens during the crisis; however, statistical tests of the difference in the average spread in three periods from 1 July to 13 August, 14 August to 27 August and 28 August to 30 September are statistically insignificantly different.[14]

Figure 6 shows intraday plots of spreads in each maturity.[15] From 27 August, the incidence of higher spreads is very pronounced. To illustrate, the ratio of 5-min trading intervals in which the spreads are higher than the 'standard' 5-year spread of $\frac{1}{128}$th of a percentage point rises is around 1 in 5 in the pre-crisis period, rises slightly to almost 1 in 4 in the period from 14 August to 27 August, and then rises to 3 in 5 in the period from 27 August onwards. The rising ratio of greater spreads is common across maturities and is particularly evident from 27 August. After 27 August, there is no evident increase in prominence of larger spreads.

The spreads did not noticeably rise in conjunction with either the initial Hong Kong intervention (August 14), or the Russian default announcement (August 17) or any of the following revelations about the proposals to alleviate it. The spreads then rose perceptibly by the time of the Hang Seng futures contract expiry, and *the majority of the sustained rise occurred on 27 August*, the US trading day associated with the failed double play, although there was also a rise in spreads on 21 August which was not sustained.

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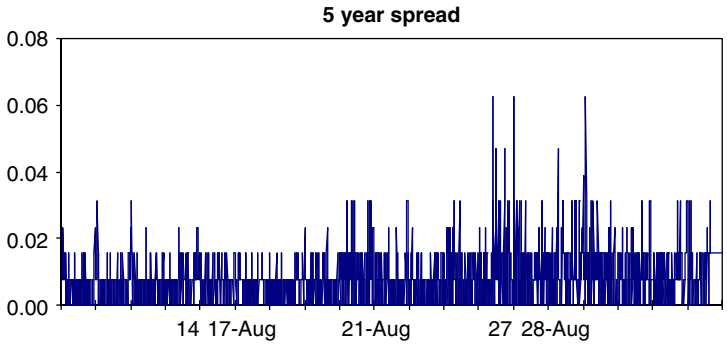

Figure 6. Bid–ask spread for 5-year maturity.

Although Lowenstein (2001) documented 31 August—the Monday after the expiration of the Hang Seng futures contract—as the date on which the HKMA stopped intervening, traders already knew the game was over during the Asian trade on 28 August, when the contract expired. The HKMA had been very clear that they were intervening to stop the double play (see Yam, 1998, for example); hence, the rise in spreads in the NY trade time on 27 August is consistent with the role of the failure of the speculative double play in affecting the market.

4. RECONCILING EVIDENCE AND EVENTS

The empirical findings from Section 3 are now placed in the context of events in the second half of August 1998, described in Section 2. The dominant influences are the Russian announcements of debt suspension and the subsequent statements on the GKO market and the HKMA interventions documented in Goodhart and Dai (2003). In all probability, the HKMA sold substantial amounts of US Treasuries to fund its intervention, although it is not clear how those Treasuries might have been released to the market. However, the empirical analysis of Section 3 provides some clues supporting the hypothesis that the HKMA interventions played an important role in the US Treasury market during this period.

4.1. Traded volume

The volume of US Treasuries traded increased after 14 and 17 August, and peaked on 27 and 28 August, the last two days of the HKMA intervention. The volume data suggest a strong response in the traded volume of Treasuries to the expiration of the Hang Seng futures contract around which the double-play speculation was based. Traded volume was relatively low following the Russian default.

4.2. Net order flow

A flight to quality should be associated with strong positive net purchases. Instead, the net order flow data show net sales in the 5- and 10-year maturities immediately following the Russian default (particularly on 18 August). At the shorter end, particularly 3-month bills, positive net purchases were observed. These data are probably most consistent with a flight to cash in conjunction with a flight to quality. However, on 27 August (the last trading day prior to the expiration of the Hang Seng futures contract) the net order flow shows strong net sales in all maturities. This points more clearly to the potential role of the HKMA in making sales in the market. The HKMA is estimated to have spent almost $HK90 billion on intervention on 27 and 28 of August. From 30 of August to the end of the quarter net purchases tend to be positive, with extremely high variance (not shown in the figures).

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4.3. Realized volatility

Realized volatility declined in the period from 14 to 28 August from the highest level for the quarter achieved just prior to this fortnight. Realized covariance, however, was relatively stable until the end of the intervention period, and was then observed at a substantially higher level.

4.4. Bid–ask spreads

Bid–ask spreads in US Treasuries remained at usual levels for most of August, and widened only around 27 August. During periods of low liquidity the bid–ask spread in the Treasury market is known to rise; see Fleming (2003). In the period under examination, this rise did not occur in a sustained manner until 27 August, consistent with the US trading day prior to the expiration of the Hang Seng futures contract. Although spreads widened around 21 August for several maturities, this was short lived. Between 14 and 27 August both the Russian default and the HKMA intervention were potentially affecting the US Treasury market. After 27 August the HKMA ceased intervention in the US trading time. The bid–ask spreads' behaviour suggests that liquidity was significantly affected by the HKMA supplying Treasuries to the market.

The reconciliation of the empirical evidence with the events of the fortnight of 14 to 28 August strongly suggests that the actions of the HKMA intervening in the Hong Kong stock market, most probably mainly funded by sales of US Treasuries, had an important role to play in determining the outcomes in the US Treasuries market during this period. In facing its own issues the HKMA provided liquidity to the US Treasury market at a time when it was most needed.

5. CONCLUDING REMARKS

The third quarter of 1998 was the first time in recent history that bond markets experienced substantial volatility, more akin to that associated with currency market crises. The period was marked by important international events; combined preemptive interventions in the Hong Kong equity market to stave off further speculative attacks on the Hong Kong currency, and the subsequent speculative pressure in Hong Kong markets up to the date of settlement of the Hang Seng futures contract on 28 August, on which the so-called double play in Hong Kong markets was based. On 17 August the Russian Government suspended payments on its sovereign debt, with details worked out in the ensuing months.

Although much of the literature on the 1998 crisis focuses on the Russian default as the springboard for the ensuing turmoil in international debt markets, we demonstrate through careful examination of high-frequency data that the Hong Kong interventions had a crucial role to play in providing liquidity in this period. The effects of both these events had an important role in outcomes for US Treasury markets. The US Treasury market played an important role in transmitting and absorbing the effects of the financial market shocks of the Russian bond default and the interventions associated with the Hong Kong speculative double play.

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NOTES

1. This contrasts with the behaviour of an alternative safe-haven of the German bund, which experienced an increase in volume traded, a decrease in transaction size, an increase in realized volatility and an increase in the bid–ask spread immediately following the Russian debt payment suspension; see Upper (2001) and Upper and Werner (2002).
2. In February 2005 Hong Kong was listed as the 10th largest foreign holder of the US Treasuries, holding some $US15 billion of securities. Data for 1998 were not available.
3. This information comes from private discussions with market participants at that time.
4. Eventually, some 200 banks had their licences revoked (Steinherr, 2004). There were three important bank mergers amongst banks with outstanding forward contracts announced on 25 August, 26 August and 3 September; a chronology is provided in Shuster (1998).
5. The GovPX database has been described by Fleming (1997) based on half-hour observations. It covers five of the six brokers in the interbroker market, constituting a substantial portion of trade in the short end of the US Treasury market, up to and including the 5-year maturity, and is somewhat less for longer-dated bonds. The database has recently been used by Brandt and Kavajecz (2004), Green (2004), Boni and Leach (2004) and Chordia *et al.* (2005). The algorithms used to extract the data analysed here are available from the first author.
6. The direction of the association between volume and liquidity is not clearly determined in the literature. There are a number of examples of higher volume during periods of stress; for example, see Fleming (2003).
7. The US Treasuries market operates as an expandable limit order book, meaning that once an initial bid or ask has been accepted the two parties negotiate the final volume to be transacted at this price. The time taken from the initial hit or take until the final transaction volume is agreed is known as the workup time; see Boni and Leach (2004).
8. The regressions run included the day-of-the-week effects for Monday, Tuesday, Thursday and Friday and the last trading day of each month, which is the day of issue for new securities.
9. Fleming and Remolona (1997) and Goldberg and Leonard (2003) found that the three categories of economic announcement with the greatest impact on the US Treasury market are employment, inflation and output statistics. A single news announcement dummy was included for the release dates for the employment situation (2 July, 7 August, 4 September), the CPI (14 July, 18 August, 17 September) and retail sales (14 July, 13 August and 15 September). The news announcements dummies are active for three periods (15 min) from the announcement time of 8:30 a.m. in each case, following the finding of Green (2004) that increased activity in the Treasury market associated with announcements is contained within a 15-min window. We also considered the Fleming and Remolona (1997) window of impact of 70 min after the announcement, but it makes no discernible difference to the outcomes.
10. Brandt and Kavajecz (2004) reported standard deviations of 594.361, 604.659 and 343.624 for on-the-run bonds of remaining maturity of 1–2 years, 2–5 years and 5–10 years, respectively; see Table 1 in their paper.
11. In practice, however, it is difficult to know when the HKMA sales of US Treasuries would have been enacted in the US market, and the issue is further complicated by the different and non-overlapping time zones.
12. The realized volatility of returns over the period is constructed as the sum of the squared 5-min returns, having controlled for intraday seasonality using a flexible Fourier transform following the 6th-order polynomial suggested in Bollerslev *et al.* (2000) with day-of-the-week, end-month and macroeconomic news effects included for the impact of the employment situation, CPI and retail sales as detailed in note 9. The resulting returns profiles (available from the first author on request) contain the usual volatility smile during the period between New York opening and about 3 p.m., similar to that reported in Bollerslev *et al.* (2000) for the Treasury futures market. Realized volatility without seasonal factors calculated by simply squaring daily returns as, for example, used in Hyung *et al.* (2006) show a similar pattern to that presented in the text.
13. Amihud and Mendelson (1991) demonstrated that there are liquidity effects in pricing US Treasury notes. Chordia *et al.* (2005) showed that adjusting for the Russian crisis removes a potential structural shift in the 10-year Treasuries bid–ask spread. They also reported that market depth is lower during crisis periods. Fleming (2003) noted increases in the spread during the 1998 crisis period. Smith and Tambakis (2007) investigated the spread between the on-the-run and first-off-the-run Treasuries of the same maturity looking for breaks, but the break points they found did not correspond to the third quarter of 1998.
14. The relevant average spreads (standard deviations) are from 1 July to 13 August, 0.005543 (0.004698), from 14 August to 27 August, 0.007146 (006487), and from 28 August to 30 September, 0.010367 (0.012131).
15. A few incidents of negative spreads have been trimmed from the database.

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