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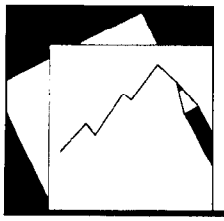

IMF Working Paper

Financial Contagion and Investor "Learning": An Empirical Investigation

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Abstract

There have been several episodes of financial market "contagion" in the 1990s. Is contagion driven by herd behavior? Does it reflect fundamental economic linkages between countries? Or are episodes of contagion driven by investor learning and risk reassessment about a select group of countries? We pursue these questions by studying the persistence in the spillover of shocks following the bond market developments in Hong Kong SAR in 1997. Our results suggest that this contagion, at least for a few countries, was a consequence of adverse sentiment shifts arising from investor learning and was not merely driven by changes in fundamentals.

JEL Classification Numbers: F30, G12, G14

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I. INTRODUCTION

In the past decade there have been many episodes of financial market "contagion."[2] These events and the severity with which countries have sometimes been affected[3] have led to a strong interest in the academic and policy literature, in analyzing the existence, nature, and causes of financial market contagion.

The theoretical literature has identified several causes and channels of cross-border transmission or correlation of shocks to financial markets. Some researchers (see, for instance, Masson (1998), Bikchandani et al (1992), and Calvo and Mendoza (1999)) have described spillovers driven by changes in investor sentiment toward third markets owing to herding behavior on the part of investors following financial crisis (or news) in one market. Others have proposed trade linkages—with currency devaluation following a crisis leading to competitive devaluation and crises elsewhere (see Eichengreen and others (1996b), Gerlach and Smets (1995)) and international liquidity effects—with investors divesting assets in other markets to cover financial crisis-induced losses in a given market (see Valdes (1996)). Equally, common interest rate shocks affecting multiple markets simultaneously have been analyzed by Hoffmaister and Végh (1994). Political links among countries, although less emphasized, have been mentioned in the literature sometimes to explain the EMS crisis (Drazen (1998)).[4]

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[2] "Contagion" is defined broadly as a spillover of an isolated episode of shock, including a large devaluation or debt default among others, from one financial market/country to a host of others. It is possible to identify at least four different episodes of financial market contagion: first, the crisis in the exchange rate mechanism of the European Monetary System (EMS) initiated by an attack on the British pound (September 1992), and subsequent speculative attacks on the Irish punt and French franc, threatening to spillover to other European countries; next, the financial market crisis in Mexico initiated by the large devaluation in December 1994 and resulting in a wave of investor stampedes across Argentina, Brazil, Chile, Philippines and others, comprising the Tequila crisis (1994–95); then, the Asian crisis (1997–98) which was initiated by the devaluation of the Thai Baht; finally, the August 1998 Russian debt and currency crisis—initiated by the 90-day debt servicing moratorium and the floating of the ruble—spilling over to Brazil among others.

[3] In the aftermath of the Mexican devaluation e.g., Argentina raised short-term interest rates to 44 percent (versus 7 percent to immediately before the Mexican devaluation) and still suffered a large outflow of reserves (Forbes 2001); again in Korea, the won had depreciated by more than 50 percent in just five weeks by end-December 1997 (IMF, 1997).

[4] The paper proposes that when a country belongs to an association or "club of countries," with an exchange rate arrangement, the political cost of devaluing is much lower when other countries have devalued. Therefore, crises tend to be clustered. A crisis in one country is followed by crises elsewhere.

Finally, investor learning and risk reassessment, where investors learn about the strength of a known but inaccurately observed fundamental shared by a group of countries, has been modeled by Basu (1998).

It is this last factor—learning-driven contagion—that this paper attempts to study empirically. Specifically, the objective is to examine whether there is evidence to support the idea that contagion is driven by learning behavior on the part of investors (about unobserved fundamentals that are shared by a group of countries) in addition to (or instead of) the other conjectured causes that we have discussed above (such as herd behavior unlinked to fundamentals or trade linkages). To get to this, our strategy is a simple one: We start by examining persistence in spillover of shocks.[5] [6] Persistent contagion is assumed to be driven by changes linked to fundamentals. Any residual persistence that emerges after controlling for a variety of observable fundamental factors (such as trade links) is taken to provide suggestive evidence of contagion driven by learning about unobservable or only partially observed fundamentals.[7]

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[5] There have been many important attempts in the literature to empirically study the phenomenon of contagion. However, most of the studies are focused on discerning contagion/causal channels of contagion over a single time horizon-long (annual frequency) or short (often daily frequency). By limiting the analysis to a single time horizon these studies fail to capture trends in the persistence of spillover, a phenomenon crucial not only for understanding evolution of contagion across markets but also for enabling us to make inferences regarding its causal factors as we have suggested above.

[6] Existing studies can be separated into two groups of cross-sectional analysis using low frequency and high frequency asset market data, respectively. While the first group of studies analyzes important sources and patterns of long-run (annual or quarterly) financial market shock spillovers, they fail to capture potentially interesting short-run market dynamics. These studies typically estimate probit models to test how a crisis in one country affects the probability of a crisis occurring in other countries. Eichengreen and others (1996) use this approach in order to establish evidence of contagion among 20 Exchange Rate Mechanism (ERM) countries. Other important studies (using variations of this approach) are Kaminsky and Reinhart (1998), Glick and Rose (1998), and Van Rijckeghem and Weder (1999), The second group of studies, on the other hand, focuses on high-frequency (daily), short-lived dynamics but is limited in terms of cross-country analysis. While Baig and Goldfajn (1998, 2000) use this approach to examine contagion within six Asian countries and (separately) between Russia and Brazil, Gelos and Sahay (1999) use it to study the Czech Republic contagion among transition countries.

[7] While this is likely an area of further research and empirical investigation, bond market specific institutional factors, off-balance-sheet derivative activities and factors related to institutional strength (existence of bankruptcy laws, etc.), could be plausible candidates for unobserved variables.

This paper pursues the issue of learning-driven contagion by studying international spillover patterns (to twelve different emerging market financial markets) following the turbulence in the bond market in Hong Kong SAR in 1997. The examination of the dynamics of shock spillover suggests bond market contagion over the long horizon prevailing strongly in markets in Indonesia, Russia, and South Africa and to a lesser extent in Malaysia, Brazil, Korea, and the Philippines. Furthermore, the analysis suggests that persistence of contagion in these markets is associated partly with changes in investor learning about unobserved fundamentals. In other markets (Argentina, Colombia, Poland, Mexico, and Thailand) our analysis of the data suggests that contagion was indeed temporary and likely driven by erratic and short-lived adverse market mood swings which disappeared over longer horizons.

Overall, then, this paper makes the following contributions: It is the first paper to examine persistence dynamics of contagion with a view to making inferences regarding the causal factors driving contagion. To do so, it utilizes both cross-country correlation-based tests over long (monthly) and short (daily) horizons and regression-based endogenous, recursive coefficient stability tests, the latter of which is as yet unexplored in the empirical contagion literature.[8] The study's results suggest that persistent contagion may indeed be partly explained by learning on the part of investors.

The rest of the paper proceeds as follows. Section II presents the data. Section III discusses the empirical methodology and the results of the empirical analysis. Section IV concludes with some thoughts on directions for future research.

II. DATA

The paper attempts to discern learning-driven contagion within a select group of emerging economies (albeit a more interesting and challenging exercise than looking for evidence across developed and emerging economies, which are by definition, evaluated differently by investors). The analysis is carried out using high (daily) and low frequency (monthly)[9] U.S. dollar-denominated bond market data. Dollar-denominated spreads have the advantage of being largely purged of expected depreciation and inflation effects under fixed and floating exchange regimes, respectively.[10] This allows easy cross-country comparability of spreads. The

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[8] Broadly, three different econometric techniques have been utilized in the literature to measure the transmission of shocks and test for contagion (Forbes and Rigobon (1999)): probit estimation (Eichengreen et al (1996)), GARCH frameworks (Edwards et al (1998), and Gelos and Sahay (1999)) and co-integration techniques (Longin and Solnik (1995)).

[9] To obtain monthly data we computed arithmetic averages of the daily spread over monthly intervals.

[10] To a smaller extent, U.S. dollars denominated yield spreads could indirectly be influenced by inflation and exchange rate expectations through liquidity and credit/solvency risk channels.

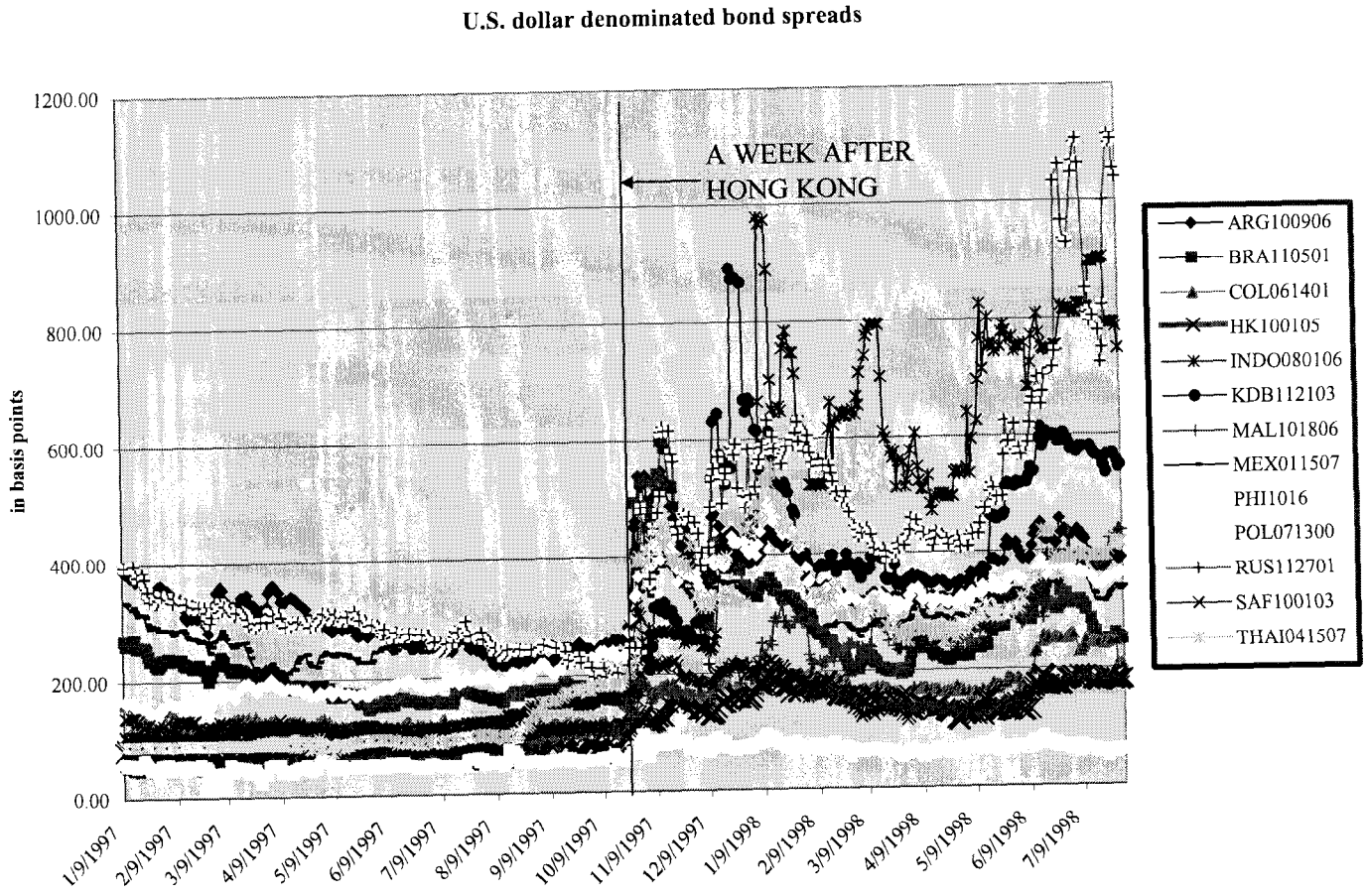
data was extracted from Bloomberg. Care was taken to construct a suitably comparable sample in terms of characteristics of the bond instrument—market liquidity and duration (see Appendix I). The data-set comprised of thirteen emerging economies randomly selected from various parts of the world including: six Asian economies—Hong Kong SAR, Indonesia, Korea, Malaysia, the Philippines, and Thailand; four Latin American countries—Argentina, Brazil, Colombia, and Mexico; two transition economies—Poland and Russia; and one African country—South Africa. The relatively recent inception of the Asian international bond markets limits the start date of the cross-country historical series to January 1997. However, the data limitations are not particularly inhibiting for the analysis as the relevant window is anchored around events occurring around late October 1997.

III. Empirical Evidence

As pointed out in Forbes and Rigobon (1998), one difficulty in testing for contagion is that no single event acts as a clean catalyst behind episodes of contagion. Although the evolution of contagion in Asia seems to have been spearheaded by the Thai baht float on July 2, 1997, followed by turbulence in Indonesia and others (see Appendix V for event chronology), data on cross-border bond spreads show more compelling evidence of global bond market turmoil post October 20, 1997—the initiation of turbulence in bond markets in Hong Kong SAR.[11] Overnight doubling of Hong Kong SAR bond spreads was followed by large bond market gyrations across the world (Figure 1). Therefore, focusing on Hong Kong SAR as one of the primary sources of bond market volatility and studying the effects of this volatility in other markets seem appropriate for a bond market contagion study. Furthermore, the data, together with anecdotal evidence (Appendix V; Goldfajn and Baig (2000)), suggests that the longest spillover window associated with the Hong Kong SAR turmoil is until August 17, 1998, the

[11]For our analysis, it is adequate to study patterns of shock spillovers originating from countries perceived to be "similar" by the market. The paper is simply interested in investigating if there is a systematic long–run pattern in shock spillover from these "similar" economies to a limited and select group of economics/countries. Any such evidence is then treated as suggestive indication (only) of markets selectively learning about that group of countries, and perhaps about some underlying common factor shared by those countries. Thus, spillovers of bond market pressures from Hong Kong SAR—which may well have been initiated by earlier pressures felt in Taiwan, an economy perceived by markets as being "similar" to Hong Kong SAR (see Appendix V para. 2), would suffice for our analysis. "I think the biggest thing to scare Hong Kong SAR was the devaluation in Taiwan," said John Bender, Vice President at HSBC James Capel. "Taiwan is a country with substantial foreign exchange reserves." In short, Taiwan Province of China is a lot like Hong Kong SAR and the former was unable to keep up the link.

Figure 1. Contagion From Hong Kong SAR Bond Market



onset date of the Russian ruble float. Thus based on these cross-market patterns, the "crisis"[12] window in the high frequency analysis is defined as October 20, 1997 until August 14, 1998, while the tranquil window spans January 9, 1997–October 17, 1997. Although these cut-off dates seem arbitrary, variations in the windows leave the results largely unchanged.

A. Herding and Sunspots Among Bond Traders

To identify quick changes (as opposed to long run shifts) in the transmission mechanism of shock propagation from Hong Kong SAR to other markets, we start with an analysis of structural breaks of cross-market contemporaneous correlations in daily bond spreads (see Appendix II for details of methodology). Evidence of breaks in high-frequency correlation coefficient between Hong Kong SAR and other markets is indicative of instantaneous and excessive co-movements across markets, driven perhaps by herding and/or reactions to the Hong Kong SAR sunspot.

Comparing correlations in daily bond market spreads before (January 9, 1997–October 17, 1997) and during the crisis period (October 20, 1997–August 14, 1998), the results (Table 1) reveal that there was a significant increase in correlation between Hong Kong SAR and bond markets in Argentina, Colombia, Russia, and South Africa.[13]

Note, however, that even during the crisis period the correlation of daily bond spreads with Argentina is quite low relative to other countries.

In principle these tests are sensitive to the choice of the tranquil and turbulent periods. This choice is necessarily somewhat arbitrary, but the results reported here are quite robust to the use of alternative windows as reported in Table 2. We see that markets in Colombia, Russia and South Africa continue to be affected strongly, while in Argentina markets seem to become responsive only over the last 71-day period. This response is consistent with the low value of observed correlation between Hong Kong SAR and Argentina over the longer crisis window,

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[12]The term "crisis" is used here very loosely and in keeping with the literature. As noted above, we have in mind here countries that have experienced substantially increased bond spreads. However, not all of these countries experienced financial or economic crisis in the literal sense of the word.

[13] The 1, 5 and 10 percent critical value for a one-sided test of the null hypothesis of no increase in correlation are -2.32, -1.64 and -1.28, respectively. If the test statistic is below that value, the null hypothesis is rejected. The above results are based on tests of increase in correlation, where the latter are corrected for heteroscedasticity. A test based on unadjusted correlations between the tranquil (January 9, 1997–October 17, 1997) and crisis (October 20, 1997–August 14, 1998) period shows that in addition to the countries listed above, bond markets in Indonesia, Korea, Malaysia, Mexico, the Philippines, and Thailand underwent significant perturbation over this crisis window.

Table 1. Hong Kong SAR Contagion—Test of Herding Using Daily Dollar-Denominated Bond Spreads[1]

Correlation	Tranquil	Crisis (Unadjusted)	Crisis (Adjusted)	Test-Stat (Adjusted)
		Contagious		
Argentina	-0.10	0.21	0.09	**-1.90
Colombia	0.02	0.74	0.42	***-4.32
Russia	-0.14	0.62	0.32	***-4.73
South Africa	0.04	0.44	0.20	**-1.65
		Noncontagious		
Brazil	0.01	0.00	0.00	0.14
Indonesia	0.30	0.59	0.29	0.08
Korea	0.26	0.64	0.33	-0.80
Malaysia	0.37	0.64	0.33	0.50
Mexico	0.07	0.32	0.14	-0.72
Philippines	0.17	0.49	0.23	-0.66
Poland	0.07	0.06	0.03	0.45
Thailand	0.33	0.64	0.33	-0.07

[1] Adjustment is given by equation (2) of Appendix II. Tranquil period: January 9 to October 17, 1997. Crisis period: October 20, 1997–August 14, 1998. Null hypothesis: no significant increase in correlation. The 1, 5, and 10 percent critical value for a one-sided test of the null hypothesis of no increase in correlation is -2.32, -1.64 and -1.28. One, two and three asterisks indicate significance at the 10, 5, and 1 percent, respectively.

reported in Table 1. We also observe that other markets such as in Brazil, Indonesia, Korea, Mexico, the Philippines, Poland, and Thailand become sporadically responsive over the shorter 72/71-day windows during the October 20, 1997–August 14, 1998 period of market turbulence.

Particularly noticeable are the increased flitters in the Thai market. While the Indonesian and Filipino markets appear sensitive to the early part of the Hong Kong SAR turmoil (October 20, 1997–January 27, 1998), other markets seem to react with a lag (respond sporadically over the

Table 2. Hong Kong SAR Contagion—Test of Herding Using Daily Dollar-Denominated Bond Spreads over Segmented 72-Day Windows[1]

Adjusted Correlation	Tranquil	Crisis 1	Crisis 2	Crisis 3
		Contagious		
Colombia	0.02	**0.27	***0.55	***0.56
Russia	-0.14	***0.41	***0.59	***0.31
South Africa	0.04	*0.25	***0.53	***0.48
		Sporadically Contagious		
Argentina	-0.10	0.02	-0.01	***0.23
Brazil	0.01	-0.03	**0.31	0.10
Indonesia	0.30	**0.52	0.15	0.23
Korea	0.26	0.36	**0.50	0.40
Mexico	0.07	0.07	-0.28	*-0.27
Philippines	0.17	**0.45	0.33	0.23
Poland	0.07	0.16	**0.32	-0.08
Thailand	0.33	0.36	**0.53	***0.69
		Noncontagious		
Malaysia	0.37	0.46	-0.14	0.51

[1] Adjustment in Table 2 is given by equation (2) of Appendix II. Tranquil period: January 1, 1997–October 17, 1997 (72 days). Crisis1: October 20, 1997–January 27, 1998 (72 days); crisis 2: January 28, 1998–May 7, 1998 (71 days); crisis3: May 8, 1998–August 14, 1998. Null hypothesis: no significant increase in correlation. The 1, 5, and 10 percent critical value for a one-sided test of the null hypothesis of no increase in correlation are -2.32, -1.64 and -1.28, respectively. One, two and three asterisks indicate significance at the 10, 5, and 1 percent levels, respectively.

January 28–May 7, 1998, and May 8–August 14, 1998 windows). Markets in Malaysia on the other hand remain virtually unaffected over all windows.[14]

[14] The above results are based on tests of correlation across tranquil and various crisis windows, after adjusting the correlations for heteroscedasticity. Tests based on unadjusted correlations yield similar results with stronger evidence of spillover to the Asian markets of Indonesia, Korea, Malyasia, the Philippines, Thailand, and also to Poland.

The erratic and random patterns of market sensitivity over these short-windows are indicative of temporary, herd-like market behavior, which could die out over longer horizons.

B. Persistence of Sovereign Spread Spillover

Next, we investigate whether the cross-border spillovers from Hong Kong SAR persist over time or die out after playing temporary havoc in the global bond markets. To study persistence we start by focusing on low frequency (monthly) dynamics of bond market data.[15] Accordingly, the spread data is aggregated by month (simple average of daily bond spreads), before testing for significant changes in co-movements pre-and post crisis.

The study suggests (Table 3) that there is virtually no evidence of persistence of contagion from Hong Kong SAR to any of the bond markets over the monthly horizon.[16] While test-statistics appear to be directionally consistent with results reported in Table 1, they are non-significant. These results prove the limitation of correlation analysis, especially over aggregated and small samples and its inability to distinguish between spillover dynamics driven by cross-market fundamental linkages as opposed to sentiments of bond traders.

We therefore, turn towards discerning the source of persistence in contagion using non-correlation based techniques in the next section.

C. Persistence in Contagion: Fundamentals or Learning?

Disentangling the sources of contagion is a difficult task. Nevertheless, we make the most of high and low frequency data analysis to tease out evidence of temporary versus persistent contagion and fundamental versus sentiment-driven persistence in contagion. Having discussed

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[15] Following the Cheung and Chinn (2000) nomenclature used to report the survey results of United States foreign exchange traders short-run (intra-daily), medium-run (shorter than six months) and long-run (periods over six months)—we associate short-run/temporary phenomenon with daily data analysis and long-run/persistence with monthly data analysis. Furthermore, the survey results in the Cheung and Chinn study confirms that economic fundamentals are perceived to be more important at longer horizons, while short-run deviations from the fundamentals are attributed to excess speculation and institutional customer/hedge fund manipulation. Hence to identify the source of persistent contagion in the next section—fundamentals or investor learning as opposed to short-run speculation/herding—we carry out our analysis using aggregated monthly/long-run data.

[16] Again, the above results (Table 3) are based on tests carried out with heteroscedasticity adjusted correlations. Tests based on unadjusted correlations indicate significant spillover even over the monthly horizon to markets in Colombia and Russia. However, there seems to be a growing consensus in the literature that correlation based techniques might be inadequate for assessing spillover. We therefore turn to other techniques in the next section.

Table 3. Hong Kong SAR: Test of Persistent Contagion Using Monthly Dollar-Denominated Bond Spreads[1]

Correlation	Tranquil	Crisis (Unadjusted)	Crisis (Adjusted)	Test-Stat (Adjusted)
Argentina	-0.09	0.39	0.08	-0.32
Brazil	0.15	0.14	0.03	0.22
Colombia	0.09	0.84	0.30	-0.39
Indonesia	0.57	0.74	0.21	0.78
Korea	0.50	0.83	0.28	0.48
Malaysia	0.79	0.72	0.20	1.54
Mexico	0.32	0.40	0.09	0.44
Philippines	0.37	0.66	0.17	0.39
Poland	0.42	0.19	0.04	0.74
Russia	-0.14	0.83	0.29	-0.79
South Africa	0.06	0.52	0.12	-0.11
Thailand	0.78	0.77	0.23	1.43

[1] Adjustment is given by equation (2) in Appendix II. Tranquil period: January to September 1997. Crisis period: October 1997–July 1998. Null hypothesis: no significant increase in correlation. The 1, 5 and 10 percent critical value for a one-sided test of the null hypothesis of no increase in correlation is -2.32, -1.64, and -1.28.

the former at some length in the previous sections, we are interested in separating fundamental versus sentiment-driven persistence in contagion in this section.

To do so we resort to the ideas of the sovereign credit-risk spillover model developed in Basu (1998). The model suggests that default probability in emerging sovereign bonds is a function of country-specific ability-to-pay factors, observed common market factors, and trader/investor perception of unobserved common credit-worthiness related factors, shared by a certain group of emerging countries. When new information is revealed about the unobserved, shared credit-risk factor (such as during a crisis), traders update their perception/valuation of that factor.

Subsequent to the update, negative evaluations result either in higher demands for risk premium or withdrawal of funds, leading to an increased probability of default among all countries sharing the common risk factor. Thus, contagion in this case will likely be driven by investor learning about a common (partially or) unobserved risk factor shared by a select group of countries.

The simplest translation of this logic into a testable hypothesis is to specify an empirical model of probability of sovereign debt default with appropriate exogenous controls and country-specific ability-to-pay controls (which are often affected by the exogenous factors) and then test

for selective structural breaks in coefficient and particularly in the constant term around the time of the event. This approach is similar to the contagion definition used sometimes in the existing literature—change in transmission mechanism of shock propagation across a small group of countries (Rigobon 1999). However, the approach differs from the existing literature in that instead of imposing external and arbitrary break dates we let the procedure determine coefficient break dates endogenously generated by a recursive regression process. Endogenous structural breaks in recursive coefficient, especially over long-horizons, are likely indicative of learning-driven sentiment shifts, (Bossearts (1995)). We then check which countries experience bunching of endogenous structural breaks and which don't as suggestive evidence for learning-driven contagion. Given the complex dependence of error structures across the thirteen emerging financial markets, we undertake a country-by-country regression analysis in order to implement the above logic. It should be noted that even if the model is mis-specified (as it is impossible to have a perfectly specified model), detection of *simultaneous* endogenous breaks in coefficients—and particularly in the constant term, around the time of a particular episode of turmoil (such as in Hong Kong SAR) for one group of countries, not others *(i.e., selectively)*, is suggestive of learning-driven contagion from Hong Kong SAR. In particular, selective and simultaneous endogenous breaks in the constant term is suggestive of sentiment shifts unique to a group of countries, and indirectly suggests a market response perhaps to a factor common to that group of countries.

Recasting dollar-denominated sovereign bond spreads as a measure of probability of sovereign debt default (our dependent variable), we proceed to search for appropriate exogenous and country-specific controls. Among exogenous credit-risk related fundamentals, we are interested in variables representing exogenous common shocks (at least partially, such as U.S. interest rates) and controls for other possible exogenous channels of credit-risk spillover such as through trade (real exchange appreciation rate). Among country-specific credit-risk variables we are interested in those that represent a country's ability-to-pay such as import cover, appreciation rates of nominal exchange rate (capturing wealth effect of net foreign assets), and controls for market specific liquidity risk (M2 to reserve ratios). Although these country-specific factors are affected by exogenous events/shocks, it is important to control for them so that *ceteris paribus* we can identify other factors (such as market sentiments) that might be driving changes in bond spreads across countries. Taking into account the above limitations, we specify a model of sovereign bond spread for each emerging country with five controls and a constant term.[17] Tables 4a and 4b present the results of the country-specific regressions. The overall F-statistic together with the adjusted R-square overwhelmingly rejects the null hypothesis that the five factors don't adequately explain the respective market bond spreads.

U.S. Interest rate: The study shows that for most countries the short-term U.S. interest rate—at least partially indicative of common exogenous shocks owing to the stance of U.S. monetary

[17] Appendix III describes in greater detail the source and rationale beyond the choice of the controls.

policy[18]—is a significantly important determinant of bond spread (except for Korea) and that increases in the rate lowers spreads (Tables 4a and 4b). This result is robust across other studies of bond spread determination including Kamin and Kleist (1999) and Eichengreen and Mody (1998).[19] As interpreted in Eichengreen and Mody, declines in U.S. interest rates cause increases in the supply of emerging market bonds that lowers their price hence raising their spread. While declines in U.S. interest rates may also raise the demand for emerging market bonds, which might tend, all else equal, to lower spreads, this effect is dominated by the effect of increased bond issuance.

Import Cover: This measure (the ratio of imports over international reserves minus gold) focused on the current account—is of use especially for judging reserve need for countries that have limited access to capital markets. Higher values of this variable indicate lower ability to finance imports, which is likely to be reflected in higher credit risk/spreads. The analysis shows that import cover was not very significant for determining short-run fluctuations in spread (except in Malaysia, and weakly in Russia). These findings support the hypothesis that the Asian crisis (measured as abnormal increases in sovereign spread across various markets) was not a result of market insolvency but perhaps related to inadequacies in short-run financing needs. To capture the impact on short-run vulnerability owing to foreign debt burden we turn to measures of short-run changes in net foreign asset position.

Appreciation of nominal exchange rate: A fall in the NEER level indicates weakening of the local currency (depreciation), which if the country has a large burden of foreign debt will lower its ability to pay due to adverse wealth effect. Hence lower values of this variable will culminate into higher spreads. The analysis shows that this effect prevails for markets in Russia, South Africa, and the Philippines, indicated by the significantly negative coefficient for nominal appreciation rates. However, depreciation may enhance a country's trade account

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[18] Note: Longer-term rates are affected by market inflation expectations and hence may not capture liquidity effects as precisely.

[19] The result is counterintuitive as it is commonly believed that increases in industrial country interest rates reduces the creditworthiness of emerging countries by increasing the debt service burden borne by borrower countries thereby increasing spreads. Also, a commonly held view expressed in the financial press was that the decline of emerging market spreads could be attributed to a general decline in industrial country interest rates, as international investors attempt to enhance portfolio returns in a low interest rate environment by increasing their risk exposure. This reasoning implies that spreads on risky assets in general, and emerging market debt instruments in particular, are positively related to levels of short-term interest rates in the industrial countries.

Table 4.a. Hong Kong SAR Contagion: Countries Demonstrating Persistent Learning-Driven Contagion; (Dependent Variable: Log Dollar-Denominated Spreads)[1]

Country	U.S. Interest (In logs)	Import Cover (In logs)	Nominal Appreciation (Ist. log diff. of NEER)	M2 Reserve Ratio (In logs)	Real Appreciation (Ist. log diff. of REER)	Constant	Adjusted *R*-Squared	Break date	
								Residual[2]	Constant[3]
Hong Kong SAR	-0.93	-0.84**	13.18	-1.12**	-16.48*	15.34***	0.76	7:97: 10:97	None
Indonesia	-4.86***	0.28	-1.52	-1.77***	1.89	23.52***	0.96	11:97	11:97-12:97
Philippines	-3.42***	0.74	-21.45*	-1.23	19.61*	16.04***	0.59	11:97	None
Russia	-10.62***	1.34*	-12.36***	-0.83	18.59**	23.68***	0.89	11:97	11:97-01:98
South Africa	-3.62***	-0.41	-39.09***	0.38	40.08***	9.59***	0.69	12:97	11:97-12:97
Korea	-2.63	1.01	-40.61	-4.29***	39.62	32.99***	0.69	03:98	12:97-03:98
Brazil	-3.86***	-0.37	9.63	1.24	-11.96	5.38	0.72	03:98	11:97-98:01
Malaysia	-7.42***	2.92**	-45.51	-4.99**	48.79	36.88***	0.71	11:97	11:97-02:98

[1] * indicates significance at 10 percent level. ** indicates significance at 5 percent level. *** indicates significance at 1 percent level, based on p-value or marginal significance level. The *F*-statistic is significant at the 1 percent level for all countries.

[2] First recursive break date for residuals, see Appendix IV for methodology. For Hong Kong SAR, the recursive residual path almost coincided with the +/- 2 recursive standard error (S.E.) line over this period, (along – 2.S.E. line until 9/97 reversing along +2 S.E. line thereafter, peaking in 11:97 and remaining slightly below the +2 S.E. line). In Brazil and Malaysia, the break points coincide with the 2 S.E. lines, for all other countries they cross the 2 S.E. lines.

[3] These breaks indicate increases in the recursive constant term. Evidence for Malaysia is weak.

Table 4.b. Hong Kong SAR Contagion—No Evidence of Persistent Learning-Driven Contagion Among These Countries
(Dependent Variable: Log Dollar-Denominated Spreads)[1]

Country	U.S. Interest (In logs)	Import Cover (In logs)	Nominal Appreciation (Ist. log diff. of NEER)	M2 Reserve Ratio (In logs)	Real Appreciation (Ist. log diff. of REER)	Constant	Adjusted *R*-Squared	*F*-Statistic
Argentina	-2.96***	-0.15	7.57	-2.81*	-8.30	27.72***	0.71	14.35***
Colombia	2.80***	-1.15*	1.49	-2.34***	-1.50*	12.63**	0.37	4.24***
Poland	-1.46***	0.57	-1.46	-3.94***	-0.10	26.48***	0.67	12.07***
Mexico	-3.05***	0.05	-4.27	-0.11	1.66	11.15***	0.82	25.87***
Thailand	-3.66*	-1.87	-35.07	-1.15	35.18	23.11***	0.43	5.23***

[1] * indicates significance at 10 percent level.
** indicates significance at 5 percent level.
*** indicates significance at 1 percent level, based on *p*-value or marginal significance level.

thereby countering the negative wealth effect on foreign debt. Thus to distinguish between these two effects we include a measure of trade competitiveness, the appreciation of real exchange rate.

Appreciation of real exchange rate: A rise in the REER level indicates an appreciation and is likely to increase spreads through a damaging effect on the trade account.[20]The analysis shows that impacts through these channels were most significant in Russia and South Africa with a marginal effect on the Philippines.

Broad money to reserve: The ratio is used as a proxy for: (i) market liquidity; (ii) credit-risk due to inadequate provisioning for bad credit; and (iii) cross-market liquidity risk spillover. The effect on bond spreads of this variable is ambiguous. While we are likely to expect a negative coefficient on account of logic (i)—greater intrinsic market liquidity would reduce the liquidity risk-premium and hence the overall spread—the coefficient is likely to be positive on account of (ii) and (iii). While channel (ii) suggests, lower the provisioning the higher the ratio of M2 to reserve and higher will be the credit-risk spread, channel (iii) implies the more liquid the market (higher the M2 to reserve) the more likely it is to suffer from crisis-induced cross-border liquidity related margin calls initiating a selling spree and resulting in higher spreads. It is therefore an empirical matter to distinguish which of these effects dominate. The negative coefficient for the broad money to reserve ratio for all countries except South Africa and Brazil (which maybe considered to be more mature and sophisticated markets, intermediated through equity rather than bank finance—capturing mostly credit risk and cross-border risks from margin calls in the ratio of broad money to reserve) implies that the liquidity effect dominates. This variable is significant for Indonesia, Korea, Malaysia, Argentina, Colombia, and Poland during the 29-month period.[21] The analysis shows that Indonesia, Russia, the Philippines, South Africa, Malaysia, Brazil (late), and Korea (late) demonstrate selective breaks in the recursive residuals, suggesting parameter instability/learning (see Appendix IV).[22] Furthermore, all of these countries, except the

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[20] The literature has also considered other quantity-based measures of trade competitiveness, including the percent of total exports destined for the first crisis country—serving as a control for bilateral trade competitiveness (Van Rijckeghem and Weder (1999)); and a measure of trade share index serving as a control for indirect trade effects via competition in third markets (Glick and Rose (1999)). However, these measures of competitiveness are usually calculated at low frequencies and hence not used for our analysis.

[21]The ratio of broad money to reserve has also been interpreted as a proxy for debt to reserves, whereby M2 can be thought of as a liability without a finite maturity. Also, it has been considered as a measure of the potential for resident-based capital flight from the currency and as a gauge of the impact of a loss of confidence in the domestic currency.

[22]Note: For the Hong Kong SAR market, shifts in interest premium/spread seem to have been more significant in the short-run (indicated by large movements in daily spreads) than in the long run (indicated by slightly weaker breaks in monthly recursive residual spreads). The

Philippines, demonstrate some increase in the constant term at an early date after the October 1997 Hong Kong SAR turmoil (around November/December 1997). This suggests that bond traders were learning selectively about these markets, and perhaps about a shared common credit-risk factor. Although the late break (March 1998) in recursive residuals for Korea and Brazil weakens the case for selective contagion between Hong Kong SAR and these markets, a closer look at the incremental evolution of the constant terms suggests an early and selective trader response (around November/December 1997) to some unknown factor for these countries.

The constant term explains the average behavior of spread after controlling for other risk factors. While changes in recursive coefficients in the above five controls indicate a change in sentiment/weights for the specified risk factors, a change in the recursive constant term captures the change in average spreads owing to sentiment change in traders about some unspecified factor. When this change is restricted to a select group of countries, simultaneously around the time of turmoil—as it did in Indonesia, Russia, and South Africa and weakly in Malaysia, Korea, and Brazil around the Hong Kong SAR turmoil—it raises suspicion that traders may have been reacting to information about a common unobserved/incorrectly measured risk factor.

One may argue, that such a *common factor* might have been the act of common lenders and a consequence of their losses spilling across various markets. The broad money to reserve ratio partially captures such common lender spillover effects, particularly, third market asset liquidation owing to crisis-induced losses suffered by lenders/traders. Other studies (Kaminsky and Reinhart (1998)) identify bank lending spillover channels as distinct from the liquidity and trade channels. They proceed to form clusters of countries based on these channels and show that these channels tend to be regional, providing a possible explanation of regional contagion. Two such bank clusters—Japanese and the United States—were identified in the study. While the Japanese cluster was comprised of Indonesia, Malaysia, and Thailand; the U.S. bank cluster included Argentina, Brazil, Chile, Colombia, Mexico, the Philippines, Uruguay, and Venezuela. Our study suggests, however, that selective contagion was not confined to geographic regions; the bond market turbulence in Hong Kong SAR transcended continental borders by spilling over to Indonesia, Russia, and South Africa among others. This observation further reaffirms our conjecture that such spillover patterns were perhaps driven by factors other than trade, banking, exogenous shocks, and country-

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recursive residual spread series seems to break early in 97:07 and continues weakly through 97:10, peaking in 97:11. This implies that while the initial turbulence persisted over the long run around July-August 1997, attacks on the market weakened by November 1997; implying that the market was stabilizing and that market participants had likely started revising their views favorably over the long-run. However, such corrections were yet to occur in countries such as Indonesia, South Africa, and Russia where adverse risk perceptions surfaced not only in the short-run (as per the daily data analysis) but seemed to persist over the long run following episodes of short-and long-run market turbulence in Hong Kong SAR.

specific variables, but rather by investors reacting to common information about a factor restricted to the selected markets.

The selective reaction negates spillover channels related to pervasive regulations such as those that disallow investors to hold non-investment grade securities in the event of a downgrade. The evidence suggests that even though Thailand suffered a more intensive downgrading than the Philippines, not only did markets not react homogeneously to the news of downgrading but discriminated more adversely against Philippines than against Thailand. Additionally, the evidence seems to reject theories that suggest that to the extent that investors allocate fixed proportions of their assets to individual emerging markets, changes in the weight given to the emerging market asset class as a whole affect all countries equally, (Buckberg, 1996) not selectively.

IV. Conclusion

The paper investigates whether abnormal increases in bond market pressures in Hong Kong SAR spilled over to a select group of countries through a mechanism of investor learning and risk reassessment. To do so the study analyses whether risk reassessment, if any, was temporary driven by herding—or persistent; and whether persistent contagion was driven by changes in cross-market fundamental linkages or shifts in investor risk sentiments.

By studying exogenous structural break patterns in correlation coefficients between Hong Kong SAR and twelve emerging bond markets, the paper finds suggestive evidence of contagion over short (daily) time horizon. Daily correlation patterns—over the crisis window, October 20, 1997–August 14, 1998—suggests that traders involved with bond markets in Argentina, Colombia, Russia, and South Africa responded to market turbulence in Hong Kong SAR over the short horizon. To ensure robustness of our findings, the paper also investigates patterns of shock persistence over different short-run windows. Focusing on daily correlation patterns across shorter windows (72-day slices instead of the longer 215-day window), we see that some markets become more responsive than before. Particularly noticeable are the increased flitters in the Thai market over the last two windows between October 20, 1997 and August 14, 1998, and sporadic turbulence in Brazil, Indonesia, Korea, Mexico, the Philippines and Poland. These random and temporary patterns in market gyrations are suggestive of herding psychology in these markets associated perhaps with erratic mood-swings of investors. Studying the dynamics of monthly correlations, we observe that these patterns apparently disappear over longer time horizons.

The results from monthly data analysis were significantly altered however, after controlling for effects of fundamentals. By studying the evolution of recursive monthly regression residuals and coefficients and identifying simultaneous, endogenous structural breaks in these series over post October 1997–early August 1998 window, the paper infers that some markets demonstrate suggestive evidence of longer-run sentiment shifts. In particular, the study suggests that only seven of the twelve emerging markets—Indonesia, Russia, South Africa, the Philippines, Malaysia, the Republic of South Korea, and Brazil—respond to the

Hong Kong SAR turmoil in a persistent fashion. While the sentiment shifts occur soon after the October 1997 Hong Kong SAR episode (suggested by the break in the residual term in November 1997) in most of these markets, the reaction occurred with some delay (in March 1998) in Korea and Brazil. Also, in most of the seven markets, traders appear to have changed their beliefs about both known and unknown fundamentals (partially evident from evolution of the coefficients of the known controls and the constant term, respectively), suggesting some evidence of learning by investors. While markets in Indonesia, Russia, and South Africa and to a lesser extent in Malaysia, Brazil and Korea, seem to suggest changes in trader perceptions about both known (the five controls) and unknown (reflected in the constant term) fundamentals during times of crisis, the Philippines mostly responds through changes in investor reassessment of known fundamentals. In other markets (Argentina, Colombia, Poland, Mexico, and Thailand) our analysis of the data suggests that contagion was temporary and likely driven by short-lived and adverse sentiment change.

While this paper makes a first attempt at unveiling suggestive evidence of persistent learning-driven contagion across emerging bond markets, it also raises plausible questions for future research. One important question that follows from the above analysis is related to unknown factors that seem to differentiate countries and generate selective investor responses. Alluding to earlier empirical studies in the contagion literature it seems that neither common bank/non-bank lenders nor crisis-related global investment regulations were the likely common response factors for selective contagion from Hong Kong SAR to markets in Indonesia, South Africa, and Russia and to a lesser extent to markets in Malaysia, Korea, and Brazil. However, further investigation is necessary to negate the common lender channel of contagion across these markets, and particularly those related to off-balance sheet derivative activities. Other and perhaps less intuitive factors in the Hong Kong SAR contagion case are those related to institutional strength of markets (existence of bankruptcy laws and other issues pertaining to corporate governance). Unveiling any supporting evidence for the above factors would be quite relevant for plausible explanations for the existence of market clusters and channels of cross-market shock transmissions. These issues also seem pertinent to the ongoing policy debate about the design of the new international financial architecture for global markets.

Bond Data

Table 1. Bond Data

Country	Sovereign Bond			U.S. Treasury Instruments	
	Par Amount (US $, ml.)	Coupon (In percent)	Maturity	Coupon (In percent)	Maturity
Argentina	1000	11.000	October 2006	7.00	July 2006
Brazil	750	8.875	November 2001	6.25	October 2001
Colombia	400	8.000	June 2001	8.00	May 2001
Mexico	1500	9.875	January 2007	6.50	October 2006
Hong Kong SAR	300	7.250	October 2005	6.50	August 2008
Indonesia	400	7.750	August 2006	7.00	July 2006
Korea	500	6.625	November 2003		
Malaysia[1]	800	7.125	October 2006	6.25	October 2006
Philippines	500	8.875	April 2008	4.75	November 2008
Thailand	600	7.750	April 2007	6.25	February 2007
Poland	250	7.750	July 2000	7.75	January 2000
Russia	1000	9.250	November 2001	5.875	November 2001
South Africa	500	7.000	October 2003	6.00	September 2003

Sources: Bloomberg; Merrill Lynch, Emerging Market Daily Report; J.P. Morgan, Deutsche Bank Research, Emerging Market Debt Strategy

[1] This is a corporate bond (issued by Petronas). It is used as a proxy for a sovereign bond, given data limitations.

For calculating the sovereign bond spreads, two characteristics of the instrument were taken into account: coupon rate and maturity date (and impacting duration). We then obtain the closest approximation of these characteristics in U.S. treasury instruments. The first priority was to achieve the closest match with the maturity date, as temporal differences have the greatest influence over price/yield calculations. The table above provides the details on various issues chosen.

Heteroscedasticity Adjustment

Forbes and Rigobon (1999) show that the estimated correlation between two stochastic variables, x and y, increases when the variance of x increases—even if the actual correlation between x and y does not change. The standard, unadjusted correlation coefficient is conditional on the variance of x. They show that the bias can be quantified as follows:

$$\rho_{\tau}^{\mu} = \rho_{\tau}\sqrt{\frac{1+\delta_{\tau}}{1+\delta_{t}\rho_{\tau}^{2}}} \qquad (1)$$

where,

$\delta_{t} = \frac{\sigma_{xx}^{h}}{\sigma_{xx}^{l}} - 1,$ the relative increase in the variance of x during the crisis

ρ_{τ}^{u} = unadjusted correlation coefficient during the time of crisis when $\sigma_{xx}^{h} > \sigma_{xx}^{l}$

ρ_{τ} actual correlation coefficient during the time of crisis when $\sigma_{xx}^{h} > \sigma_{xx}^{l}$

The unconditional correlation coefficient can be obtained by the following transformation of the unadjusted coefficient ρ_{τ}^{u}:

$$\rho_{t} = \frac{\rho_{\tau}^{u}}{\sqrt{1+\delta_{\tau}\left[1-\left(\rho_{\tau}^{u}\right)^{2}\right]}} \qquad (2)$$

After transforming the adjusted correlation coefficients with a Fisher transformation in order to ensure that they are approximately normally distributed, standard tests can be used to examine whether during crisis periods, the adjusted correlations increased significantly.

Fisher transformation:

The hypothesis being tested is:

$H_{o} : \rho_{x,y}^{o} \geq \rho_{x,y}^{1}$

(A-1)

$H_{1} : \rho_{x,y}^{o} \prec \rho_{x,y}^{1}$

where, $\rho^{t}_{x,y}$ is the correlation coefficients between country x (Hong Kong SAR) and other countries y over period t. The tranquil period is denoted 0 and the crisis period is denoted 1. The sample correlation coefficients are transformed using a Fisher $\rho^{t}_{x,y}$-to-Z transformation, given by the rule:

$Z_t = \frac{1}{2} loge\left(\frac{1+\rho^{t}_{x,y}}{1-\rho^{t}_{x,y}}\right)$, $t= 0$ indicates tranquil period, $t=1$ indicates crisis period

The test statistic is approximately normally distributed and is derived through the following equation (Morisson (1983)):

$T = \frac{Z_0 - Z_1}{\text{var}(Z_0 - Z_1)}$, where Z_0 and Z_1 are the transformed values for the tranquil and crisis periods, respectively and

$\text{var}(Z_0 - Z_1) = sqrt\left(1/N_0 - 3 + 1/N_1 - 3\right)$, N_0 and N_1 are the number of observations in periods 0 and 1, respectively.

Regression Model

The sovereign bond spread of a country reflects market risk (fluctuations in exchange rate and interest rates), liquidity risk and solvency/default risk.[23] While the Asian crisis revealed that the determinants of solvency risk (such as import cover) were mostly sound prior to and during the crisis, countries still suffered a drying up of external credit. This begs the question as to why we saw a stop in external credit to countries during the crisis and why the crisis spilled over selectively to some countries, not others? To pursue these questions we carry out a country-by-country regression analysis. We set up a model of sovereign spread determination and investigate whether selective spillovers in U.S. dollar-denominated sovereign spread was related to exogenous market risk factors, intrinsic liquidity/credit-worthiness factors or changes in investor perception about partially known common factors correlating the risks of these countries. In particular, we test to see if investors inferred something new about the credit-worthiness of these countries after observing a episodes in Hong Kong SAR which then might have led them to withdraw their funds, stop issuing new credit, or demand higher risk premium for other correlated countries, despite reasonable levels of traditional fundamentals. The test involves looking for simultaneous endogenous structural breaks in recursive coefficients of the spread determinants, including exogenous market risk factors and cross-market trade-related spillover factors and country-specific ability-to-pay/liquidity factors (some which are also affected by the exogenous factors), around the time of the 1997 Hong Kong SAR episode. In the next few paragraphs we explain the rationale behind the choice of the various risk factors in the determination and evolution of dollar-denominated spreads.

As mentioned above we control for various risk factors that determine spreads of bonds denominated in U.S. dollars. Dollar-denominated spreads have the advantage of largely being purged of expected depreciation and inflation effects under fixed and floating regimes respectively. Hence it frees us from the task of controlling for country-specific factors, such as large budget deficit, which—owing to domestic financing needs—are likely to enhance expectations of inflation/devaluation depending on the exchange regime. Instead, we control for external vulnerability factors that have a bearing on a country's ability to pay back their dollar—denominated debts mostly arising from external financing needs of budget deficits.

U.S. interest rate: To adjust partially for common aggregate market risk factors the model controls for three and twelve-month U.S. T-bill rates. The short-term three and twelve-month benchmark rates are intended to reflect the stance of U.S. monetary policy and effects of changes in U.S. market liquidity on U.S. dollar denominated bond spreads. The data was obtained from CEIC—a commercial economic and financial market database, focusing

[23] As mentioned in Appendix I we controlled for the coupon rate and maturity while calculating sovereign bond spreads for the thirteen countries.

mostly on Asian markets and a few mature markets. The robustness analysis shows that the twelve-month rate has a higher explanatory power for determining cross-country spreads.[24]

Import cover: Among the traditional ability to pay factors we include a measure of import cover (ratio of value of imports to international reserves excluding gold). The variable was created using monthly data from various *International Financial Statistics (IFS)* issues. It indicates the number of months a country can continue to support its current level of imports if all other inflows and outflows cease. This measure—focused on the current account—is of use especially for judging reserve need for countries that have limited access to capital markets.

Appreciation of nominal exchange rate: As an indirect measure of foreign currency risk, captured by the short-run burden of U.S. dollar-denominated debt, we include the appreciation rate of nominal effective exchange rate (NEER)—defined as first difference of logarithm of NEER. This data was extracted from the IMF INS internal database.

Appreciation of real exchange rate: To identify the impact of cross-market competitive devaluation pressures we include a monthly measure of competitive devaluation—appreciation of real effective exchange rate. This data was extracted from the IMF INS internal database.

Broad money to reserve: Financial contagion may spread through third market liquidation of assets in satisfying margin calls in the event of crisis-induced portfolio loss (Valdes (1996)). To control for such cross-market contagious liquidity effects we use a risk-adjusted liquidity proxy namely, the ratio of broad money to reserve. This is the most consistently available high-frequency indicator of liquidity across emerging markets. Empirical studies indicate (Goldstein and Turner (1996)) that a rising ratio of broad money aggregates to GDP is a good indicator of financial deepening for emerging economies. Financial market development in a maturing economy is often intermediated through extension of credit to the private sector, which then is reflected in growing broad money aggregates. This implies that borrowers in the rapidly expanding emerging economies are at least temporarily profitable and liquid, reducing risks of drying up of credit and government-bailouts. Higher values of this indicator should therefore lower liquidity risk and spread premium. Yet not all such increases are benign. If the growth of bank liabilities is very rapid relative to both the size of the economy and the stock of international reserves making it difficult to distinguish between good and bad credit; if bank assets differ significantly from bank liabilities in terms of liquidity, maturity, and currency denomination; if bank capital and loan-loss provisions have not expanded to compensate for the volatility of the assets and asset quality then one can have a recipe for increased banking system fragility. Confidence in domestic currencies is hence enhanced if backed by adequate reserves in relation to the monetary aggregates. On that account higher the ratio of broad money to reserves higher will be the risk. Thus it is an

[24]This was indicated by the improvement in adjusted R-square.

empirical matter to distinguish which effect—liquidity or credit risk—dominates in determining spreads.

Constant: The constant term explains the average behavior of spread after controlling for other risk factors. While changes in recursive coefficients in the above five controls indicate a change in sentiment/weights for the specified risk factors, a significant change in the recursive constant term captures the change in average spreads owing to sentiment change in traders about some unspecified factor.

Recursive Residual Tests of Parameter Inconsistancy

Assume the following model, (Johnston and Dinardo (1997)):

$$Y_t = x_\tau^{/}\beta + u_\tau \qquad \boldsymbol{t = 1, \ldots\ldots, n} \tag{1}$$

Where y_t is the t the observation on the dependent variable, and $x_\tau^{/} = \left[1, x_{2\tau} \ldots\ldots x_{\kappa\tau}\right]$ is the row vector of regressors at the tth sample point, using lowercase letters to denote the levels of variables. The complete sample matrix of regressors is

$$X = \begin{bmatrix} x_1^{/} \\ x_2^{/} \\ . \\ . \\ x_\eta^{/} \end{bmatrix}$$

The idea behind recursive estimation is to fit the model to the first k observations. The fit will be perfect since there are k regression coefficients to be estimated. Next we use the first k+1 data points and compute the coefficient vector again. Proceeding this way, adding one sample at a time the procedure generates a sequence of coefficients b_k, b_{k+1},……b_n, where the subscript indicates the number of sample points used in the estimation. In general,

$$\ldots\ldots\ldots\ldots b_\tau = \left(X_\tau^{/} X_\tau\right)^{-1} X_\tau^{/} y_t \tag{2}$$

where, X_t is t x k the matrix of regressors for the first t sample points, and y_t is the t-vector of the first t observations on the dependent variable. The standard errors of the various coefficients may be computed at each stage of the recursion, except at the first step, since the RSS is zero when $t = k$. Visual inspection of the evolution of each coefficient, plus and minus two standard errors, may suggest parameter constancy, or its reverse. As data are added, graphs sometimes display substantial vertical movement, to a level outside *previously* estimated confidence limits. This phenomenon is usually the result of the model trying to digest a structural change and leads one to suspect parameter inconstancy.

Existence of parameter inconstancy can also be identified by studying the evolution of the recursive residuals. The recursive error is given by

$$v_\tau = y_\tau - x_\tau^{/} b_{\tau-1} \tag{3}$$

The variance of the recursive error is given by:

$$\text{var}(v_\tau) = \sigma^2 \left[1 + x_\tau' \left(X_{\tau-1}' X_{\tau-1} \right)^{-1} x_t \right] \quad (4)$$

The unknown σ^2 in Equation (4) can be replaced by the residual variance estimated from the first (*t-1*) observations, provided (*t-1*) > k. Taking the square root gives the estimated standard error of regression (S.E.R.).

The break-dates in Table 4.a are based on figures showing the evolution of recursive residuals along with two standard error bands. A point on the graph lying outside the standard error bands is equivalent to a t-stat, being numerically greater than two and thus suggestive of break/parameter inconstancy.

Chronology of the Hong Kong SAR/Other Global Financial Market Developments[25]

October 20–23, 1997. Monday-Thursday. The **Hong Kong SAR** stock market suffers its heaviest drubbing ever, shedding nearly a quarter of its value in four days on fears over interests and pressures on the Hong Kong SAR dollar. The fall, more severe than 1987 crash, forces the Hang Seng index 23.34 percent down to 10,426.30 at Thursday's close, after 13,601.01 the previous Friday.

The devaluation of Taiwan dollar the previous week, the latest in a string of Southeast Asian currency devaluations, created doubt about Hong Kong SAR changing its long-standing peg to the U.S. dollar. "I think the biggest thing to scare Hong Kong SAR was the devaluation in Taiwan Province of China" said John Bender, vice president at HSBC James Capel. "Taiwan is a country with substantial foreign exchange reserves." In short, Taiwan is a lot like Hong Kong SAR and Taiwan Province of China was unable to keep up the link. The Taiwan dollar has fared poorly since the devaluation, dropping about 5 percent, and is currently valued at 30.23 to the U.S. dollar.

October 27, 1997. Monday. After regaining 718 points on October 24, the Hang Seng loses another 646.14 points or 5.80 percent to 10.498.20. The loss ripples through global markets. On Wall Street, the Dow Jones industrial average posts its single-biggest point loss ever, falling 554.26 points or 7.18 percent to 7,161.15. The NASDAQ plunges 115.43 points and the S&P 500 index tumbles 64.65 points. The decline is so steep it prompts stock exchange officials to suspend trading. Stock markets throughout Latin America suffered record losses Monday as Asia's markets crisis rippled to other vulnerable emerging markets and investors frantically sold their holdings. Stock prices in **Brazil, Argentina, and Mexico** saw their biggest single-day loss.

October 30, 1997. Thursday. Speculators scenting a fresh kill outside Asia's wounded financial markets took aim at **Latin America** stocks and currencies on Thursday, causing heavy duty losses in **Brazil and Argentina**. Fears about the value of Brazil's real currency and a liquidity crunch in its banking system quickly spread to neighboring Argentina and also infected Mexico's volatile markets -- sending prices to their lowest levels in months.

October 31, 1997. Friday. IMF gives **Indonesia** $23 billion financial support package. The International Monetary Fund announces a $23 billion multilateral financial package involving the World Bank and the Asian Development Bank to help Indonesia stabilize its financial system. The United States is willing to lend about $3 billion to Indonesia to back up the loan from the IMF to help Indonesia stabilize its financial system.

Concerns over the fate of the world financial markets dominate U.S. stocks in a week that saw both record losses and record gains posted in record volumes of trading. After several

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[25] Source: *http//www.stern.nyu.edu/globalmacro*; previously found in *http://www.stern.nyu.edu/~nroubini/asia/AsiaHomepage.Html*.

wide gyrations, stocks closed on a positive note on Friday, but ended the week well below where they were a week ago. The Dow Jones industrial average gained 60.41 points to close at 7,442.08, some 273.33 points down from last Friday's closing level of 7,715.41.

The market started the day with a boost from a 2.5 percent gain in Hong Kong SAR overnight. The blue-chip Hang Seng index, whose swings had been at the heart of world markets' recent troubles, was up 94 at 16,458.94, and Singapore, where the Straits Times industrial index gained 44.68 or 2.9 percent to 1,586.07.

Brazilian shares rose Friday after the nation's central back nearly doubled interest rates to fight off currency speculators. In early trading, the São Paulo exchange's benchmark Bovespa index gained 57 to 8912. Brazil's central bank raised its basic interest rate late Thursday to 3.05 percent monthly from 1.58 percent. The government was pushed into the move as speculators began an attack on the country's currency, the real, sensing that it would suffer the same fate as Asian currencies driven ever downward. A presidential spokesman said that the Central Bank already had spent $5 billion in defending the currency.

November 3, 1997. Monday. **Asian** stock markets rallied on Monday as a financial aid package for Indonesia helped restore calm to the region, enabling investors there to refocus on their domestic markets and helping European markets get off to a good start. On Monday, **Hong Kong SAR** saw some of the most dramatic gains, with the Hang Seng index rising 2.62 percent at the opening before zooming ahead amid fresh interest in China related shares. The **Dow Jones industrial average** soared 3.12 percent, or 232.31 points, on Monday to 7,674.40 spurred on by advances in Asian markets.

November 4, 1997. Tuesday. **Asian** stock markets got an early boost on Tuesday from Wall Street's powerful rally, but a big retreat in **Hong Kong SAR** spilled over to other markets in the region, erasing many of the early gains. The recent gains in Asia reflected optimism some calm may be returning to the region after Indonesia agreed on a financial aid package with the IMF. But many traders remained wary about whether the gains could be sustained.

November 6, 1997. Thursday. The Bank of **Korea** once again intervened Thursday in an attempt to halt the local currency's slide versus the dollar. The U.S. dollar is currently quoted at 973.63 Korean won. Traders said the U.S. dollar rise versus the won reflected the U.S. currency's strength versus the yen. The U.S. dollar's sharp rise against the Japanese yen in global trade boosted the U.S. currency against the won in the Republic of Korea, said a dealer at Seoul bank. In addition, dealers said sentiment about Korea is negative, based on media reports in the Western press stating that Korea's economic crisis is set to get worse. The IMF's (then) Managing Director Michel Camdessus said Thursday that the Fund's multibillion dollar financial support package for Indonesia should break a vicious cycle of economic destabilization in Asia. Camdessus said that although Korea has been affected by the crises in Thailand and in Indonesia, the measures the Korean government has taken seem adequate so far. Despite continuing turmoil on Korea's financial markets, Camdessus believes the country will be spared the sort of financial crisis which hit Indonesia, although the IMF is ready to provide help if needed.

Brazilian shares dropped 3.74 percent to 9,615 points in early trade as investors dumped equities on continuing uncertainty in the local financial markets after two weeks of global turmoil, traders said.

November 7, 1997. Friday. Asia stocks nose-dived on Friday as currency jitters shook **the Republic of Korea** and high interest rates and falling property prices rattled **Hong Kong SAR.**
Further details of events can be found on http://www.stern.nyu.edu/globalmacro.

August 17, 1998. marked the start of the **Russian** crisis. The ruble was allowed to float freely within the bounds of a new corridor expanded to 6.00/9.50 to the U.S. dollar from 5.27/7.13 previously. Also, a 90-day moratorium was declared on some foreign debt servicing.

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