Towards Decoding Currency Volatilities

D. Johannes Jüttner[a] and Wayne Leung[b]

Abstract

This study contributes, on the basis of economic theory, to an explanation of exchange rate volatilities for a large number of currencies. We relate daily changes in GARCH(1,1) volatilities of exchange rates to the volatility changes of several of their presumed fundamental economic determinants. The use of high-frequency data limits the choice of the explanatory economic variables that can be included. The first differences of GARCH(1,1) volatilities of share and bond price indices proxy for wealth uncertainty and the latter, in addition, for interest rate variability. Likewise, first differences of the gold price volatility, as an additional determinant, are related to exchange rate volatilities of two commodity currencies in the sample. The estimates produce coefficients with the expected signs and statistical significance.

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I. Introduction

Exchange rates fluctuate significantly even on a daily basis. A great deal of research has been carried out on the issue of explaining the statistical features of currency volatility. However, to our knowledge very little research is available on the topic of the relationship between the high frequency (daily) exchange rate volatility data with similar volatilities of their presumed economic determinants. Yet, financial markets, firms and policy makers have to make decisions involving currency volatilities on a daily, if not hourly, basis for a range of issues, encompassing the pricing of currency options, the marking-to-market of derivatives, the allocations of asset in portfolios, risk management and currency interventions. While implied volatilities from options are commonly believed to reflect the collective wisdom of the market, they provide no insights into the information set and processes that market participants apply to this task. Comparatively little is known about how markets form their expectations of foreign currency volatilities and their gyrations over time.

This paper studies the relationship between first differences of the GARCH volatilities of several currencies and the volatilities of their presumed economic determinants through time. Its contribution consists in relating daily changes in currency volatilities to the time-varying volatilities of several economic variables over a period from 1989 to 2003. For the selection of the fundamental economic factors that can be expected to contribute to an explanation of daily volatility changes we rely on a widely supported model of exchange rate determination.

A number of studies examine the relationship between changes in foreign currency volatilities and relevant economic variables in the event study framework. One group of investigations in this line of research examines the impact of scheduled announcements such as the release of the CPI, employment data, current account balance, etc. on share index, interest rate and currency volatilities. The studies by

Ederington and Lee (1996), DeGennaro and Shrieves (1997), Andersen and Bollerslev (1998) and Kim and Kim (2003) uncover announcement effects on foreign currency volatilities.

Moreover, there is no dearth of studies assessing the forecasting prowess of various currency volatility measures such as implied volatilities form options markets, GARCH techniques and historical volatilities methods. Examples include Ederington and Guan (2002), Jorion (1995), West and Cho (1995), Guo (1996) and Taylor and Xu (1997). However, the authors of these studies do not ask the further question of what causes volatility changes in the first instance.

A separate class of studies attempts to assess the relationship between official government intervention in foreign currency markets and exchange rate volatility. The evidence by Bonser-Neal and Tanner (1996), Hung (1997) and Dominguez (1998) appears to suggest that there exists, in general, a statistically significant relationship between interventions and currency volatility in the sense that intervention contributes to heightened volatility or dampens it (Kim, Kortian and Sheen, 2000). However, some of the measured correlation may be spurious as heightened volatility frequently prompts interventions by central banks. Moreover, most studies – the exception is Bonser-Neal and Tanner – do not control for the effects of contemporaneously occurring macroeconomic announcements or of other events on volatility.

Relatively few studies are directly devoted to explaining the relationship between changes in volatility of currencies and changes in volatilities of economic/financial variables that theory suggests can be expected to cause, or at least move with, currency volatility changes. The studies with the greatest affinity with our approach relate the volatility of share price indices, or currencies, to a number of their presumed fundamental economic influences. The studies include the investigations by Schwert (1989), Morelli (2002), Glatzer and Scheicher (2003) and Kim and Kim (2003). Schwert explains the expected stock price in terms of the dividend discount model. Under this setup, the conditional variance of the stock price at $t - 1$, $var_{t-1}(P_t)$, depends in the first instance on the conditional variances of expected future cash flows and of future discount rates. At the level of the whole economy the aggregate value of equity, as measured by the S&P500 index, depends on certain macroeconomic variables. Shocks to either or both side of the relationship will trigger co-movements in volatilities. Using monthly data, Schwert finds weak evidence for a relationship between financial asset volatility and the volatilities of industrial production, inflation, money growth and financial leverage. A similarly tenuous relationship is found by Morelli (2002) in the UK stock market. Glatzer und Scheicher extend this approach by recovering the whole risk neutral density (RND) of the DAX stock index from index options prices which they subsequently attempt to relate to the volatilities of a range of presumed economic determinants. By including the RND of the stock index as the independent variable they expand the limits of research. Their approach allows, in principle, the explanation of the skewness and kurtosis in addition to the implied volatility of the stock index return distribution. Kim and Kim (2003) explore the relationship between the implied volatilities of option on currency futures and corresponding returns on underlying futures returns without attempting to specify an underlying theoretical model. They also examine announcement effects on implied currency volatilities. However, the comprehensive investigation of high-frequency volatility processes of Andersen and Bollerslev (1998) reveals that the public information effects of announcements and calendar events are of minor economic importance for daily or lower-level frequency data of the Deutsche-mark-dollar volatility. A study dealing with theory-derived economic determinants of the volatilities of a broad range of exchange rates appears to be called for.

In the next section II we estimate the GARCH(1,1) volatilities for all variables that are included in the estimation process. This is followed in III by an analysis of the derivation of the estimation equation from reduced-form exchange rate determination models. We convert this relationship into an estimation equation containing daily volatility changes of those variables for which daily data are available. In the next part IV the estimation results are presented and interpreted. Conclusion are drawn from the estimation outcomes in V.

II. GARCH (1,1) Estimates of Daily Volatilities

In order to leave the door open for a range of volatilities of economic variables to exert their influence on, or exhibit a relationship with, exchange rate volatility, we decided to use

GARCH(1,1)-generated volatilities instead of implied volatilities for our study. Moreover, reliable time series data on implied volatilities are only available for instruments for which liquid options markets exist. This would have severely restricted the range of currencies we could have included in our investigation. Our estimation approach encompasses a far greater number of currencies (19) than have been investigated in related studies previously. In addition, we include two minor currencies that happen to be so-called commodity currencies, in our sample, namely the Australian and the Canadian dollars in order to test their dependence on commodity price volatilities. The exchange rates investigated in the literature range form one currency (Ederington and Lee, 1996) to five (Kim and Kim, 2003); to boot, without exception they are all major currencies with the US dollar as the counterpart. It is therefore less than clear whether the results achieved in the literature can be generalized. By broadening the investigative basis we expose our results, in principle, to a much larger number of potential rejections.

While a definitive verdict on the comparative performance of implied versus time-series volatilities is still outstanding, one obvious disadvantage of GARCH estimated volatilities concerns their inability to capture the volatility-generating effects of periodic macroeconomic public announcements such as inflation and unemployment rates. An option trader armed with a GARCH volatility forecast for the next day when an announcement is scheduled would presumably adjust the statistical volatility for the degree of uncertainty associated with the information release. The uncertainty associated with the expected announcement may vary over time. The same applies to unscheduled announcement. Adjustments of these kinds are included in implied but not in GARCH volatilities. However, as implied volatilities are derived form actual options prices and prices of the underlying instruments, they will reflect, in addition to pure expectations, liquidity, bid-ask spreads, and the discreteness, rather than continuity, of prices and rates (Jorion, 1995).

The GARCH model requires the joint estimation of a conditional mean equation and a conditional variance relationship. The GARCH(1,1) model has turned out to be the version most favoured by researchers of the group of ARCH approaches.

The mean equation is specified as

$$r_t = \text{constant} + \varepsilon_t \qquad (1)$$

where $r_t = \ln(S_t/S_{t-1})$; the term ε_t measures the return surprises.

Variance equation:

$$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \qquad (2)$$

where $\omega > 0$; $\alpha, \beta > 0$; $\alpha + \beta < 1$ for all variables

Table 1

GARCH(1,1) Model Parameter Estimates for Returns of Exchange Rates, Share Price Indices, Bond Indices and Gold Prices

	GARCH(1,1) model parameters			Mean equation checks Ljung-Box Q-Statistics for standardized residuals						Variance equation checks Ljung-Box Q-Statistics for standardized residuals squared						ARCH LM Test (at lag 7)		Sample period starts
	ω	α	β	Q(1)	Q(2)	Q(3)	Q(4)	Q(5)	Q(20)	Q(1)	Q(2)	Q(3)	Q(4)	Q(5)	Q(20)	F-stats	Obs*R^2	
AOI [a)]	0.00000303	0.08455600	0.86902000	0.089	0.130	0.746	1.551	1.709	14.456	0.918	1.876	5.874	5.945	7.494	17.079	0.088	0.088	2/06/92
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.766)	(0.937)	(0.862)	(0.818)	(0.888)	(0.807)	(0.338)	(0.391)	(0.118)	(0.203)	(0.186)	(0.648)			
SP500 [a)]	0.00000050	0.05450900	0.94208300	0.248	0.248	6.750	8.128	11.217	29.603	0.003	4.050	4.053	4.054	4.231	20.279	0.581	0.581	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.618)	(0.883)	(0.080)	(0.087)	**(0.047)**	(0.077)	(0.956)	(0.132)	(0.256)	(0.399)	(0.517)	(0.441)			
NIKKEI 225	0.00000576	0.08326000	0.89314400	0.263	0.400	0.404	0.462	0.964	11.692	2.179	2.184	2.217	3.398	3.479	19.199	0.546	0.545	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.608)	(0.819)	(0.939)	(0.977)	(0.965)	(0.926)	(0.140)	(0.336)	(0.529)	(0.494)	(0.627)	(0.509)			
FTSE 100 [a)]	0.00000136	0.07443300	0.91310300	0.373	0.524	3.223	4.055	7.035	24.201	0.107	1.774	2.770	3.985	4.160	23.555	0.739	0.739	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.541)	(0.770)	(0.358)	(0.399)	(0.218)	(0.234)	(0.744)	(0.412)	(0.428)	(0.408)	(0.527)	(0.262)			
STOXX	0.00000217	0.07815367	0.90737465	3.681	3.724	4.578	7.997	9.949	26.049	0.078	0.228	0.541	0.583	0.637	2.559	0.998	0.998	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.055)	(0.155)	(0.205)	(0.092)	(0.077)	(0.164)	(0.780)	(0.892)	(0.910)	(0.965)	(0.986)	(1.000)			
TSX [a)]	0.00000058	0.07663500	0.91769900	0.159	0.183	1.179	1.185	1.319	13.624	0.025	2.786	2.851	2.870	3.289	9.180	0.807	0.807	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.690)	(0.913)	(0.758)	(0.881)	(0.933)	(0.849)	(0.874)	(0.248)	(0.415)	(0.580)	(0.656)	(0.981)			
SPI [a)]	0.00000516	0.12688058	0.82188045	0.210	0.784	0.898	8.723	9.996	21.371	0.060	0.138	0.156	0.260	0.261	2.241	1.000	1.000	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.647)	(0.676)	(0.826)	(0.068)	(0.075)	(0.376)	(0.806)	(0.933)	(0.984)	(0.992)	(0.998)	(1.000)			
BI (USD)[a)]	0.00000012	0.03545708	0.94769763	0.151	0.250	2.040	4.019	4.124	26.813	0.003	0.226	2.241	2.649	6.736	23.634	0.328	0.328	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.698)	(0.883)	(0.564)	(0.403)	(0.532)	(0.141)	(0.953)	(0.893)	(0.524)	(0.618)	(0.241)	(0.259)			
BI (EUR)	0.00000005	0.05467840	0.92560454	5.640	6.887	7.826	8.469	9.763	24.668	0.283	0.286	1.295	1.342	1.366	16.522	0.988	0.988	1/01/99
	0.0018	(p < 0.001)	(p < 0.001)	**(0.018)**	**(0.032)**	(0.050)	(0.076)	(0.082)	(0.214)	(0.595)	(0.867)	(0.730)	(0.854)	(0.928)	(0.684)			
BI (GBP)[a)]	0.00000008	0.06263989	0.92490860	0.795	1.342	1.636	2.594	3.815	20.550	2.987	3.161	3.312	3.536	4.751	24.823	0.363	0.363	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.373)	(0.511)	(0.651)	(0.628)	(0.576)	(0.424)	(0.084)	(0.206)	(0.346)	(0.472)	(0.447)	(0.208)			
BI (AUD)	0.00000022	0.04271695	0.93328636	3.602	4.151	4.476	6.417	8.470	32.625	0.004	0.498	0.519	1.784	3.802	13.439	0.570	0.570	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.058)	(0.126)	(0.214)	(0.170)	(0.132)	**(0.037)**	(0.949)	(0.779)	(0.915)	(0.775)	(0.578)	(0.858)			
BI (CHF)	0.00000004	0.02147952	0.96954115	0.004	4.973	5.315	5.671	7.469	26.719	0.048	0.099	0.290	0.300	0.740	4.598	0.998	0.998	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.951)	(0.083)	(0.150)	(0.225)	(0.188)	(0.143)	(0.827)	(0.952)	(0.962)	(0.990)	(0.981)	(1.000)			
GOLD	0.00000054	0.07687100	0.91974000	1.673	4.895	5.621	5.728	5.848	21.809	9.122	9.246	10.582	10.646	10.749	22.813	0.061	0.061	12/12/90
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.196)	(0.087)	(0.132)	(0.220)	(0.321)	(0.351)	**(0.003)**	**(0.010)**	**(0.014)**	**(0.031)**	(0.057)	(0.298)			
USD/EUR [a)]	0.00000077	0.01740198	0.96534795	0.205	1.628	1.656	3.658	4.056	16.292	0.139	0.765	0.780	0.786	1.012	8.244	0.958	0.958	7/01/99
	0.1609 [b)]	0.0108	(p < 0.001)	(0.651)	(0.443)	(0.647)	(0.454)	(0.541)	(0.698)	(0.709)	(0.682)	(0.854)	(0.940)	(0.962)	(0.990)			
USD/GBP	0.00000034	0.03925365	0.95101868	0.445	1.021	1.023	2.727	4.440	14.198	8.985	9.066	9.074	9.418	9.773	20.399	0.091	0.091	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.505)	(0.600)	(0.796)	(0.604)	(0.488)	(0.820)	**(0.003)**	**(0.011)**	**(0.028)**	(0.051)	(0.082)	(0.433)			
USD/CHF	0.00000088	0.02715452	0.95646641	0.872	1.456	2.578	3.022	3.126	16.310	1.702	1.818	2.107	2.347	2.605	18.386	0.485	0.485	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.351)	(0.483)	(0.461)	(0.554)	(0.681)	(0.697)	(0.192)	(0.403)	(0.550)	(0.672)	(0.761)	(0.562)			
USD/CAD	0.00000007	0.04355722	0.95084330	1.041	1.140	1.149	1.617	2.671	16.019	0.715	1.033	1.312	1.517	2.037	15.391	0.825	0.825	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.308)	(0.566)	(0.765)	(0.806)	(0.751)	(0.715)	(0.398)	(0.597)	(0.726)	(0.824)	(0.844)	(0.754)			
USD/AUD [a)]	0.00000042	0.04294300	0.94545100	0.195	2.398	5.052	6.720	6.796	24.152	0.865	0.913	1.784	2.136	2.216	14.773	0.891	0.891	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.659)	(0.301)	(0.168)	(0.151)	(0.236)	(0.236)	(0.352)	(0.633)	(0.618)	(0.711)	(0.819)	(0.789)			
JPY/USD	0.00000105	0.03963300	0.94038200	1.636	1.806	1.809	1.830	2.457	23.507	1.240	1.254	2.940	3.022	4.035	20.316	0.700	0.700	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.201)	(0.405)	(0.613)	(0.767)	(0.783)	(0.265)	(0.265)	(0.534)	(0.401)	(0.554)	(0.544)	(0.438)			
JPY/EUR [a)]	0.00000013	0.01672132	0.98033622	0.064	0.208	1.939	2.145	2.305	20.814	0.476	8.292	13.498	15.790	17.704	25.657	**0.015 [c)]**	**0.015 [c)]**	4/01/99
	0.079 [b)]	0.0001	(p < 0.001)	(0.801)	(0.901)	(0.585)	(0.709)	(0.806)	(0.408)	(0.490)	**(0.016)**	**(0.004)**	**(0.003)**	**(0.003)**	(0.177)			
JPY/CHF	0.00000070	0.05519651	0.93319702	2.245	3.202	3.215	3.950	4.198	16.623	1.372	1.403	1.408	1.746	2.175	15.755	0.942	0.942	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.134)	(0.202)	(0.360)	(0.413)	(0.521)	(0.677)	(0.241)	(0.496)	(0.704)	(0.782)	(0.824)	(0.732)			
JPY/AUD	0.00000177	0.03719400	0.94041800	0.946	1.566	2.186	2.186	2.320	29.909	1.716	2.321	2.322	2.571	2.592	13.119	0.873	0.872	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.331)	(0.457)	(0.535)	(0.702)	(0.803)	(0.071)	(0.190)	(0.313)	(0.508)	(0.632)	(0.763)	(0.872)			
EUR/GBP	0.00000017	0.02465000	0.96806400	2.377	4.432	5.106	5.156	5.958	17.098	0.018	0.089	0.280	0.572	5.292	18.222	0.152	0.152	1/01/99
	0.0822 [b)]	0.0002	(p < 0.001)	(0.123)	(0.109)	(0.164)	(0.272)	(0.310)	(0.647)	(0.894)	(0.956)	(0.964)	(0.966)	(0.381)	(0.573)			
EUR/AUD	0.00000065	0.03575900	0.95071300	2.195	2.802	3.797	4.649	5.056	23.701	4.978	5.955	6.853	7.700	10.392	17.947	0.104	0.104	5/01/99
	0.0082	(p < 0.001)	(p < 0.001)	(0.138)	(0.246)	(0.284)	(0.325)	(0.409)	(0.256)	**(0.026)**	(0.051)	(0.077)	(0.103)	(0.065)	(0.591)			
GBP/AUD [a)]	0.00000100	0.04457039	0.93728289	0.306	3.122	3.302	3.515	3.690	17.410	4.405	4.965	5.768	7.963	8.407	23.557	0.109	0.109	14/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.580)	(0.210)	(0.347)	(0.476)	(0.595)	(0.626)	**(0.036)**	(0.084)	(0.123)	(0.093)	(0.135)	(0.262)			
CHF/EUR [a)]	0.00000009	0.08164644	0.90429616	0.373	2.779	2.800	2.804	3.728	10.983	3.006	3.764	3.804	3.807	3.938	22.498	0.150	0.150	6/01/99
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.541)	(0.249)	(0.423)	(0.591)	(0.589)	(0.947)	(0.083)	(0.152)	(0.283)	(0.433)	(0.558)	(0.314)			
CHF/GBP	0.00000076	0.03905572	0.93446439	3.821	5.287	5.290	5.556	5.776	16.925	4.813	5.206	5.240	5.768	7.713	26.215	0.141	0.141	11/12/92
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.051)	(0.071)	(0.152)	(0.235)	(0.329)	(0.658)	**(0.028)**	(0.074)	(0.155)	(0.217)	(0.173)	(0.159)			
CHF/AUD	0.00000181	0.04967430	0.92723961	0.128	0.677	0.960	1.570	16.245	1.671	0.787	0.787	3.962	4.020	4.210	19.345	0.587	0.587	6/01/92
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.720)	(0.713)	(0.811)	(0.814)	(0.701)	(0.892)	(0.375)	(0.675)	(0.266)	(0.403)	(0.520)	(0.499)			
CHF/CAD	0.00000151	0.03765597	0.93804084	0.365	0.392	0.394	0.723	1.081	8.254	0.078	0.081	0.113	0.139	0.139	9.760	0.920	0.920	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.546)	(0.822)	(0.942)	(0.948)	(0.956)	(0.990)	(0.780)	(0.960)	(0.990)	(0.998)	(1.000)	(0.972)			
CAD/AUD [a)]	0.00000059	0.04214800	0.94180900	0.147	3.828	7.741	10.807	10.966	27.633	0.190	1.722	2.593	3.792	3.795	12.503	0.746	0.746	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.702)	(0.147)	(0.052)	**(0.029)**	(0.052)	(0.118)	(0.663)	(0.423)	(0.459)	(0.435)	(0.579)	(0.898)			
CAD/EUR	0.00000079	0.02748000	0.95677700	3.620	3.810	4.767	5.335	5.767	24.039	0.271	1.142	1.790	2.307	2.697	21.583	0.736	0.735	5/01/99
	0.0250	(p < 0.001)	(p < 0.001)	(0.057)	(0.149)	(0.190)	(0.255)	(0.330)	(0.241)	(0.602)	(0.565)	(0.617)	(0.679)	(0.747)	(0.364)			
CAD/GBP [a)]	0.00000040	0.03541300	0.95419900	0.639	0.654	1.549	2.926	3.911	21.065	1.597	1.758	2.300	2.502	2.762	12.052	0.852	0.851	12/12/89
	(p < 0.001)	(p < 0.001)	(p < 0.001)	(0.424)	(0.721)	(0.671)	(0.570)	(0.562)	(0.393)	(0.206)	(0.415)	(0.513)	(0.644)	(0.737)	(0.914)			

The sample period ends for all variables on 10 December 2003.
The GARCH(1,1) model is specified by a mean and a variance equation.
Mean equation: $r_t = \text{constant} + \varepsilon_t$ where $r_t = \ln(S_t/S_{t-1})$

Variance equation: $\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2$ where $\omega > 0$; $\alpha, \beta > 0$; $\alpha + \beta < 1$ for all variables

a) A lagged dependent variable is included in the mean equation to control for autocorrelation which may be caused by non-synchronous trading in different time zones.
b) P values are not significant for the estimation of parameters ω at 5% confidence level.
c) P values are significant at 5 % confidence for the ARCH Lagrange Multiplier (LM) tests, indicating there may be additional ARCH left in the stardardized residuals.
The figures in bold relating to the mean and variance equation tables indicate significant values for Ljung-Box Q-statistics at 5% confidence level.

The daily return data for seven share and five bond price indices, nineteen currency combinations for seven currencies and gold are computed as continuously compounded rates of return from day t-1 to day t where for currencies we have $\ln(S_t/S_{t-1})$, with S_t as the exchange rate at day t.[1] All data are from Thomson Datastream. The starting points of the sample for our study are determined by the availability of daily data for the whole set of variables used, except for gold and the British pound/Swiss franc. Due to the looming Gulf War the first differences of the volatility of the gold price showed extraordinary fluctuations. For this reason we excluded the period from the 12 December 1989 and started the sample one year later on 12 December 1990. Including in the gold sample the omitted observations would have resulted in the sum of the coefficients of (2) to exceed one, ie. $\alpha + \beta > 1$. In this case the ω would have taken on a non-sensible negative value. Likewise the speculative attack on the pound in 1992 resulted in the pound leaving the European Exchange Rate Mechanism with an attendant unusually large change in the volatility of the pound sterling/Swiss franc exchange rate. This exchange rate, while not having problems with the weights, did not fit the variance equation of the GARCH(1,1) model. Our data for this exchange rate therefore starts on 12 December, 1992. The unique nature of the two episodes appears to justify the measure we have taken. The sample period ends for all variables on 10 December 2003.

GARCH models are estimated using maximum likelihood techniques. Table 1 contains the estimated parameter values for the mean and the variance equations for nineteen exchange

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[1] We culled the JPY/CAD and the JPY/GBP exchange rate from the sample due to low turnover in their respective home markets (for turnover data see Bank for International Settlements, March 2002, Table E.7),

rates among seven countries, their associated stock and bond indices and for gold. As well diagnostic statistics for all variables of both equations are given.

The daily rate of return estimations showed autocorrelation in the residuals, perhaps due to non-synchronous trading in different time zones. In order to control for autocorrelation we included a lagged dependent variable in the mean equation. Relating the rate of return to its own lagged value in (1) means that the rate of return-constant and the residual measure the return effect conditional on the level of the most recent return. For three of our nineteen variables the p-values are not significant at the 5-percent confidence level for the estimation of the ω-parameter which consists of the product of the long-run variance rate and its weight.

The highlighted p-values for the ARCH Lagrange Multiplier (LM) tests are significant at 5 per cent confidence level, indicating there may be additional ARCH left in the standardized residuals. The figures in bold relating to the mean and variance equation tables indicate significant values for Ljung-Box Q-statistics at 5% confidence level.

III. Relationship between Exchange Rate Volatility and Volatilities of Economic Factors

Structural exchange rate models in the mould of Meese and Rogoff (1983) include in their list of fundamental economic determinants of exchange rates domestic and foreign differentials of money supplies, GDP growth rates, inflation rates, interest rates and trade deficits. They are commonly augmented by more comprehensive portfolio balance models of exchange rate determination á la Branson and Henderson (1985), Bruce and Purvis (1995) and Tobin and de Macedo (1980). Portfolio balance models add domestic and foreign assets, consisting of bonds and the value of real capital[2], to the exchange rate determination equations.

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[2] For example, in Tobin and de Macedo capital is valued in current replacement costs and not expressed in current share prices.

A standard macroeconomic exchange rate determination model in the Meese and Rogoff (1983) fashion, expanded by portfolio variables representing domestic and foreign wealth, would have the form

$$s_t = (m_t^* - m_t) + a(y_t^* - y_t) + b(r_t^* - r_t) + c(p_t^* - p_t) + e(w_t^* - w_t) + e_t \qquad (3)$$

where *s* measure exchange rate change, *m* and *y* denote growth rates in the money supply and GDP, respectively; *r* and *p* stand for interest and inflations rates, respectively; *w* denotes wealth accumulation and *e* is a stochastic error term. An asterisk indicates a foreign variable. Equation (3) would only be a fitting description for the major currencies. As we are including two exchange rates with the sobriquet commodity currencies, we also included in the estimation equation the gold price as a proxy for the terms of trade for theses two currencies.

Now, if these macroeconomic variables drive exchange rates, their fluctuations as captured by their volatilities can also be expected to play an important role in engendering exchange rate volatility. That is,[3]

$$\sigma_{ijt} = \alpha + \sum_{f=1}^{n} \lambda_f \, \sigma_{ft} + \upsilon_t \qquad (4)$$

where

σ_{ij} standard deviation of the exchange rate between *i* and *j* currencies

σ_f standard deviation of *f* economic factors

υ stochastic error term

λ_f estimation parameter for factors *f*

α intercept term

However, while economic/finance theories provide guidance as to the relevant factors and their volatilities that impact the volatility of the exchange rate, most of the required data suggested by

[3] Schwert (1989) develops an analogous estimation equation for the volatility of stock returns and its relationship with the volatilities of its likely co-moving factors such as fluctuations of industrial production, inflation and stock market turnover.

(3) are only available on an infrequent basis, usually in monthly or quarterly intervals. We therefore have to limit the study of the volatilities of high-frequency (daily) data of exchange rates and their relationship to the volatilities of those variables in (3) that are available on a daily basis. This leaves us with only a few factors: share price and bond indices as wealth proxies as suggested by the portfolio balance approach and the gold price as a proxy for the terms of trade in the case of commodity currencies.

Consequently our estimation equation is as follows

$$\Delta\sigma_{ijt} = a_0 + a_1\,\Delta\sigma_{it}^{SI} + a_2\,\Delta\sigma_{jt}^{SI} + a_3\,\Delta\sigma_{it}^{BI} + a_4\,\Delta\sigma_{jt}^{BI} + a_5\,\xi\,\Delta\sigma_{t}^{Gold} + \varepsilon_{ijt} \qquad (5)$$

where

σ_{ij}	standard deviation of exchange rate between currency *i* and *j*
a_0 to a_5	parameters and ε denotes a stochastic error term
σ_i^{SI}	standard deviation of the relevant share price index, $\ln(SI_{it}/SIi_{it-1})$, for countries i
σ_j^{SI}	standard deviation of the relevant share price index, $\ln(SI_{jt}/SI_{jt-1})$, for countries j
σ_i^{BI}	standard deviation of the relevant total return bond index, $\ln(BI_{it}/BI_{it-1})$ for countries i
σ_j^{BI}	standard deviation of the relevant total return bond index, $\ln(BI_{jt}/BI_{jt-1})$ for countries j
σ^{Gold}	standard deviation of the return on gold, $\ln(G_t/G_{t-1})$ where G stand for the gold price in US$s
Δ	first difference operator
ξ =1	for the exchange rates involving the Australian or Canadian dollar
ξ = 0	for all other exchange rates

We use first differences of the respective standard deviations in order to induce stationarity in the volatility variables.

Explanatory Variables

What is the rationale behind the inclusion of the volatilities of the five variable on the right hand side of equation (5), namely domestic and foreign share and bond price indices and gold? We commence our discussion with the two wealth variables.

Wealth: In the portfolio balance model asset demand equations are homogeneous of degree one in wealth, implying a doubling of assets demands when wealth doubles.[4] According to the portfolio balance approach of modelling the financial sector, an increase in wealth of an economic agent, and by analogy of a country, will increase the demand of individuals and countries for securities (bonds and shares). The share indices are assumed to capture part of these asset demand effects. In addition, asset demands depend on expected domestic and exchange rate adjusted foreign rates of return (see Tobin and de Macedo, 1980). The 'new economy' sectors of the global economy with their often inflated expected rates of return would have undoubtedly benefited in terms of attracting capital inflows and thus contributing to share price index volatility. The share price indices are assumed to proxy for the wealth of a country. The indices for the seven countries included are: Australian All Ordinaries share price index AOI, the Standard&Poor's 500 Price Index (S&P500), the Nikkei225 Index (NIKKEI), Dow Jones Euro Stoxx 50 Index (Stoxx)[5] and the Swiss Performance Index (SPI, Price Index Version).

Logic requires that we include in bi-lateral exchange rates both respective share price indices in the estimation equation (5) as capital flows in both directions. However, since even the first differences of share price index volatility show significant correlations – in the case of the Swiss Share Price Index (SPI) and the Stoxx index the correlation has an amazing $\rho = 0.7$ – we included only the dominant index in the estimation equation under such circumstances.

We also incorporate bond *indices* in our estimation equation as international bond investors may also hold part of their wealth in bonds.[6] As bonds in general are imperfect substitutes for each other in global financial markets and by assumption in portfolio balance models,

4 Tryon (1983) provides a survey of the portfolio balance approach to exchange rate determination.

5 The Dow Jones Euro Stoxx 50 is a euro area-specific stock index. Even though it is narrowly based it has a correlation with the much broader pan European based MSCI Europe of 97% between January 1999 and 30 September 2003. Moreover, in contrast to the US experience where stock index trading focuses on the broad-based S&P500, the Euro Stoxx 50 is the most actively traded contract on European exchanges (Bank for International Settlements, December 2003). The index is therefore representative beyond its in size and in trading activity.

6 The global share and bond markets are about equal in size.

relative bond supplies/demands will affect exchange rates. Even though the countries we include in our sample are of the highest credit standing, their rates of return may differ due to non-synchronous business cycles. We therefore include the first differences of *both* bond indices in our regression equation relating first differences of the volatility of their corresponding exchange rate. For example, we would relate both the volatility change of the US and the Australian bond index in the equation of the US$/$A exchange rate. However, bond index volatility correlations ─ the UK and the European first differences of the volatilities of bond indices showed high correlation ($\rho = 0.604$) ─ forced us to discard one and retained the index of the dominant IBOXX Euro Bond Index 3 – 5 years. Moreover, failure to fit the GARCH-equation to the Japanese and Canadian bond indices forced us to exclude both from the sample. In estimates of the volatilities of both currencies we employ the bond indices of the respective companion currencies. Information about the bond indices is as follows:

Government Bond Indices

US Benchmark 5 Year DS Govt. Index – Total Return Index	12/12/89 to 10/12/03
IBOXX EURO Bond Index, 3 – 5 Years: – Total Return Index	01/01/99 to 10/12/03
UK Benchmark 5 Year Govt. Index – Total return Index	12/12/89 to 10/12/03
AUS Benchmark 5 Year DS Govt. Index – Total return Index	12/12/89 to 10/12/03
Swiss Benchmark 5 Year DS Govt. Index – Total return Index	12/12/89 to 10/12/03

Gold Price Some exchange rate determination models include the terms of trade amongst the variables.[7] Since daily data of terms of trade are unavailable, we have selected the volatility of gold as a proxy for the terms of trade. We include the first differences of the gold price volatility in estimation equations involving the Canadian and Australian dollars.

[7] The Canadian-US$ real exchange rate is linked by Amano and Norden (1995) to the terms of trade and Gruen and Wilkinson (1994) explore the relationship between the US$-$A exchange rate and the terms of trade.

For centuries, perhaps even for longer, investments in gold waxed and waned during turbulent and tranquil times. The possibility therefore cannot be discounted for gold's volatility to be correlated with the ups and downs of global uncertainties. For this reason we will include the first differences of the volatility of gold in all equations on an experimental basis. In the event, no convincing systematic relationship emerged.

Descriptive Statistics

The descriptive statistics for the variables used in the estimation of (5) are contained in Table A1 of the Appendix. All time series data of first differences of daily standard deviations are generated by a GARCH(1,1) procedure for returns on foreign exchange rates, share price indices and on the gold price. The sample size refers to first differences of daily standard deviations. Graphs of the first differences of the variables used are given in Fig A1 and A2 of the Appendix.

Table 2 presents the pairwise correlations coefficients of first differences of the standard deviations of the variables. As one would have expected sizeable correlation values are virtually non-existent for most of the first differences of standard deviations of the variables. The exceptions are the share price indices, to our surprise we register a correlation coefficient of as high as $\rho = 0.706$ between the STOXX and the SPI. The second highest correlation is between the STOXX and the FTSE. These high co-movements have been taken into account in the estimation design. As a consequence of the high correlation coefficients between some share indices, we omitted one of them in our estimation of (5). As a general rule we retained the share index presenting the larger market of the two pairs of indices.

Table 2:
Correlation Matrix of 1st Differences of GARCH(1,1) Standard Deviations

The highlighted numbers indicate high pair-wise correlations between variables.

	AOI	SP500	NIKKEI	FTSE 100	STOXX 50	TSX	SPI	BI(USD)	BI(EUR)	BI(GBP)	BI(AUD)	BI(CHF)	GOLD
AOI	1.000												
SP500	0.114	1.000											
NIKKEI	0.255	0.058	1.000										
FTSE 100	0.102	0.230	0.134	1.000									
STOXX 50	0.145	0.286	0.166	0.595	1.000								
TSX	0.100	0.545	0.054	0.227	0.230	1.000							
SPI	0.134	0.232	0.159	0.491	0.706	0.206	1.000						
BI(USD)	0.003	0.207	0.002	0.090	0.124	0.161	0.068	1.000					
BI(EUR)	0.011	0.082	0.058	0.203	0.252	0.091	0.177	0.296	1.000				
BI(GBP)	0.027	0.076	0.069	0.352	0.170	0.042	0.125	0.132	0.604	1.000			
BI(AUD)	0.230	0.036	0.097	0.072	0.095	0.035	0.099	0.005	0.112	0.101	1.000		
BI(CHF)	0.050	0.022	0.010	0.006	0.050	-0.003	0.020	0.013	0.138	0.025	0.030	1.000	
GOLD	0.022	0.073	0.051	0.166	0.161	0.122	0.157	0.014	0.075	0.076	0.076	0.021	1.000
USD/EUR	0.034	0.109	0.016	0.100	0.120	0.042	0.083	0.171	0.167	0.141	0.049	-0.023	0.089
USD/GBP	0.024	0.075	0.030	0.060	0.083	0.054	0.074	0.058	0.078	0.073	0.035	-0.017	0.036
USD/CHF	0.064	0.115	0.051	0.117	0.120	0.079	0.093	0.085	0.144	0.102	0.050	-0.014	0.098
USD/CAD	0.021	0.073	0.019	0.019	0.050	0.080	0.050	0.078	0.061	0.048	0.031	0.010	0.048
USD/AUD	0.102	0.051	0.085	0.031	0.036	0.088	0.033	0.016	0.022	0.012	0.120	-0.001	0.100
JPY/USD	0.048	0.051	0.078	0.029	0.049	0.025	0.044	0.028	-0.021	0.069	0.067	0.027	0.086
JPY/EUR	0.035	0.039	0.023	0.068	0.069	0.055	0.069	0.021	0.019	0.041	0.086	-0.008	0.075
JPY/CHF	0.106	0.045	0.119	0.051	0.081	0.027	0.070	0.009	-0.032	0.055	0.042	0.010	0.060
JPY/AUD	0.080	0.079	0.060	0.068	0.070	0.073	0.075	0.021	-0.012	0.058	0.117	0.023	0.101
EUR/GBP	-0.025	0.027	-0.032	0.035	0.070	0.031	0.027	0.107	0.106	0.083	0.064	0.060	0.024
EUR/AUD	0.103	0.147	0.050	0.157	0.140	0.049	0.105	0.010	0.037	0.060	0.046	0.013	0.108
GBP/AUD	0.087	0.083	0.083	0.135	0.141	0.102	0.124	0.021	0.047	0.152	0.132	-0.013	0.074
CHF/EUR	0.119	0.042	0.090	0.055	0.084	-0.008	0.109	-0.004	0.042	0.012	0.066	0.074	-0.001
CHF/GBP	0.037	0.032	0.011	0.082	0.117	0.030	0.083	0.072	0.100	0.107	0.035	0.057	0.046
CHF/AUD	0.144	0.068	0.036	0.057	0.115	0.041	0.097	0.006	0.032	0.038	0.101	0.062	0.039
CHF/CAD	0.214	0.082	0.047	0.060	0.151	0.045	0.144	0.014	0.037	0.048	0.093	0.023	0.038
CAD/AUD	0.087	0.064	0.059	0.015	0.023	0.097	0.035	0.024	0.014	0.006	0.099	-0.004	0.083
CAD/EUR	0.060	0.034	0.039	0.123	0.151	0.023	0.139	0.024	0.074	0.056	0.082	0.066	0.083
CAD/GBP	0.100	0.080	0.069	0.152	0.181	0.075	0.153	0.048	0.119	0.123	0.084	-0.006	0.052

Explanations:

AOI	Australian All Ordinaries share price index
SP500	Standard&Poor's 500 Price Index
NIKKEI	Nikkei225 index (Price Index
Stoxx	Dow Jones Euro Stoxx 50 (Price Index)
SPI	Swiss Performance Index (Price Index Version)
BI(USD)	Bond Index for US Market
BI(EUR)	Bond Index for Eurozone Markets
BI(GBP)	Bond Index for UK Market
BI(AUD)	Bond Index for Australian Market
BI(CHF)	Bond Index for Swiss Market

The other variables are as defined before.

Before reporting our estimation results, we investigate two further properties of our sample. First, we carried out ADF-tests for unit roots of the levels of the standard deviations and of their first differences. On the basis the test result only in the case of two (of the levels) of exchange rate volatilities were we not able to reject the hypothesis of unit roots. As for the first differences of the volatilities, none of our variables actually used in the test equations has unit-root features, that is, they are stationary. A second preliminary issue concerns the causality embedded in the test equation. In order to obtain a clearer picture about the relationship between the variables on both side of equation (5), we apply a Granger-causality test.[8] The evidence points in the great majority of equations to a causal link running from share and bond indices to exchange rates for 1-day and 10-day lags. For the first differences of gold price volatilities no clear directional relationship emerged. Thus the results pertaining to this variable portray a relationship rather than a causal linkage, between both sides of the equation. [9]

IV. Estimation Results

In this section the results of estimating (5) are presented. Considering the extent to which exchange rates fluctuate on a daily basis, we were surprised to find what appears to be some systematic links between change in exchange rate volatility and a well defined set of first differences of volatility factors.

The results for the estimation equation (5) are presented in Table 3. Overall, the estimation results provide strong support for our model which attempts to explain the first differences in the volatilities of our final sample of 19 currencies. All of the 28 coefficients of the share price indices have the expected positive sign. The vast majority of the coefficients, namely 23, are significant at least at the 10%-level, 21 at 5% and 13 have a significance level of 1%. The volatility changes of the share price indices appear to proxy for the uncertainty associated with wealth changes just as wealth changes impact on exchange rates as postulated by the portfolio balance models. We experimented with total return share indices and achieved remarkably similar results.

[8] A Granger causality test ascertains how much of current time series can be explained by its own past values and whether adding lagged values of another time series can improve the explanation. The Granger causality results are available for the corresponding author.

[9] It is worthwhile emphazising the fact most volatility studies involving exchange rates encounter similar problems which is most pronounced in intervention investigations. The question ‘Do central banks intervene at times because currency markets are disorderly or does intervention provide a fillip to volatility?’ remains largely unanswered.

An analogous picture emerges for the impact of changing bond market volatilities on currency fluctuations. A total of 19 of the 28 bond indices are significant at least at the 10% of which eight have a 1% significance level. Only two indices showed the wrong (negative) sign though the coefficients were insignificant. We chose the bond total return indices as a pendant to the share indices as both markets are of the same size on a global basis and presumably of similar importance for wealth management.

Instead of including the bond indices, we experimented with a whole host of short and longer term interest rates, from 1-day to 10-year maturities of the countries forming an exchange rate, however without success. The failure of the differences of shorter-term interest rates as well as their volatilities to make any contribute to the explanation of the change in currency volatility appears to attest to the relative stability of interest rate during the period of observation and/or that interest rates are set in efficient money and capital market that leaves little room for the exploitation of arbitrage opportunities. Alternatively, intra-day arbitrage may cause corresponding volatilities changes that do not spill over into daily data.

Of the ten equations with gold volatility changes, half are significant at 10% level or better and two are significant at the 1% level and all have the expected positive signs. Inclusion of the first differences of gold volatility in the remaining exchange rate equations of non-commodity currencies showed in four equations a significant relationship at the 5% level (JPY/USD, USD/EUR, USD/CHF and JPY/CHF).

The Durbin-Watson statistic suggests that no autocorrelation of the residuals exist and the F-statistic indicates overall significance of the results. The size of the coefficients of determination of adjusted R^2 is consistent with those achieved by similar studies that use first differences of daily data.

Table 3 Estimation Results

Regression equation

$$\Delta\sigma_{ijt}^{EX} = a_0 + a_1\,\Delta\sigma_{it}^{SI} + a_2\,\Delta\sigma_{jt}^{SI} + a_3\,\Delta\sigma_{it}^{BI} + a_4\,\Delta\sigma_{jt}^{BI} + a_5\,\xi\,\Delta\sigma_{t}^{Gold} + \varepsilon_{ijt} \qquad (5)$$

$\Delta\sigma_{ijt}^{EX}$		$\Delta\sigma_{it}^{SI}$	$\Delta\sigma_{jt}^{SI}$	$\Delta\sigma_{it}^{BI}$	$\Delta\sigma_{jt}^{BI}$	$\Delta\sigma_{t}^{GOLD}$	Durbin-Watson	Adj. R^2	F - stats	Prob (F-stats)
USD/EUR	C		SP500	BI(EUR)	BI(USD)					
coefficients	0.000		**0.012****	**0.168****	**0.128****		2.053	0.047	22.006	p < 0.0001
t - statistics	-(0.353)		(2.060)	(2.537)	(2.501)					
p - value	0.724		0.040	0.011	0.013					
USD/GBP	C		SP500	BI(GBP)	BI(USD)					
coefficients	0.000		**0.029****	**0.093****	**0.095****		1.930	0.011	13.935	p < 0.0001
t - statistics	-(0.082)		(2.284)	(2.141)	(2.055)					
p - value	0.935		0.022	0.032	0.040					
USD/CHF	C	SPI	SP500	BI(CHF)	BI(USD)					
coefficients	0.000	**0.012****	**0.032*****	**-0.036***	**0.131*****		1.981	0.021	20.283	p < 0.0001
t - statistics	-(0.061)	(2.309)	(3.423)	-(1.812)	(2.984)					
p - value	0.951	0.021	0.001	0.070	0.003					
USD/CAD	C		SP500		BI(USD)	GOLD				
coefficients	0.000		**0.014*****		**0.090*****	**0.010****	1.984	0.010	13.781	p < 0.0001
t - statistics	(0.559)		(2.655)		(3.690)	(2.178)				
p - value	0.576		0.008		< 0.001	0.029				
USD/AUD	C	AOI	SP500	BI(AUD)	BI(USD)	GOLD				
coefficients	0.000	**0.031*****	0.021	**0.150*****	0.020	**0.048*****	2.010	0.028	18.375	p < 0.0001
t - statistics	(0.128)	(3.099)	(1.639)	(3.829)	(0.530)	(3.627)				
p - value	0.898	0.002	0.101	< 0.001	0.596	0.000				
JPY/USD	C	SP500	NIKKEI	BI(USD)						
coefficients	0.000	**0.028****	**0.023***	0.072			1.943	0.008	10.427	p < 0.0001
t - statistics	(0.164)	(2.004)	(1.906)	(1.476)						
p - value	0.870	0.045	0.057	0.140						
JPY/EUR	C	STOXX	NIKKEI	BI(EUR)						
coefficients	0.000	0.008	0.002	0.003			1.946	0.003	2.161	0.0908
t - statistics	-(1.230)	(1.627)	(0.461)	(0.056)						
p - value	0.219	0.104	0.645	0.955						
JPY/CHF	C	SPI	NIKKEI	BI(CHF)						
coefficients	0.000	**0.018****	**0.036*****	0.031			1.967	0.016	20.921	p < 0.0001
t - statistics	-(0.095)	(2.333)	(4.033)	(0.639)						
p - value	0.924	0.020	< 0.001	0.523						
JPY/AUD	C	NIKKEI		BI(AUD)		GOLD				
coefficients	0.000	**0.014****		**0.277*****		**0.055****	1.984	0.023	30.244	p < 0.0001
t - statistics	(0.226)	(2.556)		(4.348)		(2.346)				
p - value	0.821	0.011		< 0.001		0.019				
EUR/GBP	C		STOXX		BI(EUR)					
coefficients	0.000		0.005		**0.128****		1.994	0.012	8.587	0.0002
t - statistics	(0.041)		(1.437)		(2.339)					
p - value	0.968		0.151		0.020					
EUR/AUD	C	AOI	STOXX	BI(AU)	BI(EUR)	GOLD				
coefficients	0.000	0.038	**0.030*****	0.041	-0.011	**0.029***	1.910	0.034	9.949	p < 0.0001
t - statistics	-(0.788)	(1.189)	(3.020)	(0.497)	-(0.103)	(1.780)				
p - value	0.431	0.235	0.003	0.620	0.918	0.075				

Table 3
(continued)

GBP/AUD	C	AOI	FTSE	BI(AUD)	BI(GBP)	GOLD				
coefficients	0.000	**0.025***	**0.039*****	**0.219*****	**0.272*****	0.026	2.002	0.051	33.307	p < 0.0001
t - statistics	-(0.092)	(1.854)	(2.790)	(3.212)	(2.674)	(1.637)				
p - value	0.927	0.064	0.005	0.001	0.008	0.102				
CHF/EUR	C	STOXX		BI(EUR)	BI(CHF)					
coefficients	0.000	**0.015****		0.033	**0.339****		1.883	0.010	5.289	0.0013
t - statistics	-(0.015)	(2.533)		(0.389)	(1.965)					
p - value	0.988	0.011		0.697	0.050					
CHF/GBP	C	FTSE		BI(GBP)	BI(CHF)					
coefficients	0.000	**0.017*****		**0.130*****	**0.219****		1.930	0.016	16.395	p < 0.0001
t - statistics	(0.263)	(2.818)		(3.355)	(2.008)					
p - value	0.793	0.005		0.001	0.045					
CHF/AUD	C	AOI	SPI	BI(AUD)	BI(CHF)	GOLD				
coefficients	0.000	**0.079*****	**0.029*****	**0.210****	**0.467****	0.018	2.001	0.034	22.234	p < 0.0001
t - statistics	-(0.103)	(3.056)	(2.895)	(2.253)	(2.047)	(1.156)				
p - value	0.918	0.002	0.004	0.024	0.041	0.248				
CHF/CAD	C		SPI		BI(CHF)	GOLD				
coefficients	0.000		**0.039*****		0.061	0.008	2.030	0.021	26.681	p < 0.0001
t - statistics	-(0.212)		(3.501)		(1.257)	(0.815)				
p - value	0.832		< 0.001		0.209	0.415				
CAD/AUD	C	AOI	TSX	BI(AUD)		GOLD				
coefficients	0.000	**0.023****	**0.028*****	**0.119*****		**0.036*****	1.984	0.027	21.471	p < 0.0001
		0.023	0.028	0.119		0.036				
t - statistics	(0.096)	(2.425)	(2.735)	(3.406)		(3.394)				
p - value	0.923	0.015	0.006	0.001		0.001				
CAD/EUR	C	STOXX		BI(EUR)		GOLD				
coefficients	0.000	**0.026*****		0.096		0.017	1.941	0.025	12.067	p < 0.0001
t - statistics	-(0.893)	(2.606)		(1.392)		(1.553)				
p - value	0.372	0.009		0.164		0.121				
CAD/GBP	C	FTSE		BI(GBP)		GOLD				
coefficients	0.000	**0.038*****		**0.097****		0.009	1.973	0.028	36.577	p < 0.0001
t - statistics	-(0.168)	(4.738)		(2.382)		(1.482)				
p - value	0.866	< 0.001		0.017		0.138				

Highlighted coefficients significant at least at 10% level.
***, ** , * indicates significance at 1% , 5% and 10%, respectively.
White Heteroskedasticity-Consistent Standard Errors and covariance have been used.

The inclusion of the first difference of the rate of return on currencies [$\ln(S_t/S_{t-1})$] in test equation (5) did not yield significant results. This is in contrast to Kim and Kim (2003) who include in their test equation (explaining changes in currency volatility) the rate of return on futures and obtain, by and large, significant results for this variable. We were similarly unsuccessful when including the rates of return on currencies futures, rather than the changes in their volatility.

V. Conclusions

Apart form announcement effects pertaining to information releases and official interventions in the event-study mode, no systematic and detailed analysis has been carried out into explaining the changes in currency volatility in terms of its presumed economic determinants. To boot, the number of currencies in extant intervention-volatility studies as well as announcement papers can easily be counted on the fingers of one hand. This time series study is the first to tackle the relationship between changes in exchange rate volatilities of major and several minor currencies and changes in the volatilities of their presumed major economic determinants. For the selection of factors that can be expected to influence or are related to, exchange rate volatility, we are guided by economic theory. Models of exchange rate determinations list relative growth rates in the money supply and GDP, inflations and interest rates, the relative wealth of counties and commodity prices (for some countries) as the prime determinants of exchange rates. We postulate, following Schwert (1989 for the explanation of stock market volatility) that a parallel and plausible relationship exists between changes in volatilities of currencies and the volatilities of their determinants. As our sample consists of daily GARCH(1,1) volatilities of the set variables used, a number of the determinants such as the money supply, GDP and inflation rates has to be omitted because they are only available monthly or quarterly. All of the volatility variables used are computed as first differences which are based on continuously compounded rates of return. As a proxy for the interest rates used in each exchange rate equation, we employ domestic and foreign (first differences of) volatilities of bond performance indices. The uncertainty of wealth of a country is proxied by the volatility of pairwise volatility changes of share price indices. Likewise, bond indices may also capture a country's wealth effects. We link the currency volatilities of so-called commodity currencies such as the Australian and the Canadian dollar to changes in the volatility of the gold price. A surprisingly large proportion of the coefficients of the share and bond indices has the expected positive signs and is significant at the commonly accepted levels. The same applies to the first difference of the gold price volatility for the exchange rates involving the Australian and Canadian dollars. The test DW-statistics suggest the absence of autocorrelation in the residuals. The F-statistic implies significance of the estimation equation as a whole and the coefficients of determination have comparable values to those in studies that use first differences of volatilities.

Do any policy or other useful implications flow from our study? It appears our test results contribute towards deciphering the enigma of daily changes of volatilities of exchange rates and their presumed associated economic fundamental determinants. More than anything else, the study highlights that volatility changes in currency markets do not appear to occur in isolation. There seem to be spill-over effects, causal relationships and concomitant volatility changes. In order to distil useful advice for policy makers, traders and investors, a more detailed study of individual exchange rate volatility equations would be required.

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Appendix
Table A1
Descriptive Statistics
1st Difference of GARCH(1,1) Standard Deviations for Returns of Foreign Exchange rates, Share Price Indices and Gold Price

	AOI	SP500	NIKKEI	FTSE	STOXX 50	TSX	SPI	GOLD
Mean	0.0000010	0.0000000	0.0000032	-0.0000001	0.0000016	0.0000003	0.0000003	-0.0000001
Median	-0.0001343	-0.0001138	-0.0002545	-0.0001486	-0.0001587	-0.0001176	-0.0001754	-0.0001034
Maximum	0.0102854	0.0091745	0.0180086	0.0080731	0.0152527	0.0118889	0.0207365	0.0097684
Minimum	-0.0018351	-0.0007199	-0.0022883	-0.0012495	-0.0015583	-0.0011381	-0.0024517	-0.0006937
Std. Dev.	0.0005785	0.0004806	0.0010438	0.0005825	0.0007918	0.0005944	0.0009892	0.0005268
Samples	3006	3651	3651	3651	3651	3651	3652	3651

	BI(USD)	BI(EUR)	BI(GBP)	BI(AUD)	BI(CHF)
Mean	0.0000007	0.0000004	-0.0000001	0.0000002	0.0000002
Median	-0.0000234	-0.0000202	-0.0000340	-0.0000320	-0.0000118
Maximum	0.0015570	0.0005426	0.0032835	0.0015279	0.0030933
Minimum	-0.0000943	-0.0000744	-0.0002646	-0.0001884	-0.0000681
Std. Dev.	0.0000856	0.0000710	0.0001521	0.0001225	0.0000914
Samples	3651	1288	3651	3651	3651

	USD/EUR	USD/GBP	USD/CHF	USD/CAD	USD/AUD	JPY/USD	JPY/EUR	JPY/CHF
Mean	-0.0000008	-0.0000002	-0.0000001	0.0000011	0.0000009	0.0000010	-0.0000039	-0.0000004
Median	-0.0000329	-0.0000596	-0.0000554	-0.0000328	-0.0000580	-0.0000696	-0.0000371	-0.0000951
Maximum	0.0011289	0.0033238	0.0019657	0.0013157	0.0050489	0.0070796	0.0016886	0.0045482
Minimum	-0.0001026	-0.0003104	-0.0002279	-0.0001668	-0.0003523	-0.0005145	-0.0001084	-0.0005402
Std. Dev.	0.0000947	0.0002240	0.0001774	0.0001173	0.0002343	0.0003204	0.0001134	0.0003429
Samples	1284	3651	3651	3651	3651	3651	1287	3651

	JPY/AUD	EUR/GBP	EUR/AUD	GBP/AUD	CHF/EUR	CHF/GBP	CHF/AUD	CHF/CAD
Mean	0.0000013	0.0000001	-0.0000050	0.0000001	-0.0000001	0.0000007	-0.0000008	-0.0000009
Median	-0.0000781	-0.0000304	-0.0000690	-0.0000802	-0.0000373	-0.0000502	-0.0001040	-0.0000768
Maximum	0.0057345	0.0011742	0.0024615	0.0043269	0.0024937	0.0018067	0.0066637	0.0047994
Minimum	-0.0003989	-0.0001031	-0.0002707	-0.0004550	-0.0003473	-0.0002243	-0.0005985	-0.0004431
Std. Dev.	0.0003200	0.0000964	0.0002196	0.0002840	0.0001761	0.0001749	0.0003886	0.0002750
Samples	3651	1288	1286	3651	1285	2868	3112	3651

	CAD/AUD	CAD/EUR	CAD/GBP
Mean	0.0000009	-0.0000046	-0.0000005
Median	-0.0000608	-0.0000543	-0.0000557
Maximum	0.0025563	0.0027634	0.0019169
Minimum	-0.0003167	-0.0002374	-0.0002545
Std. Dev.	0.0002154	0.0001826	0.0001846
Samples	3651	1286	3651

Table A2
ADF Unit Root Tests
GARCH Standard Deviations and 1st Difference of GARCH Standard Deviations

Null Hypothesis: The GARCH(1,1) standard deviations and their first differences of the variables have a unit root.

	Garch SD (p - value)	1st Difference of Garch SD (p - value)
AOI	0.0000	0.0001
SP500	0.0029	0.0000
NIKKEI	0.0000	0.0001
FTSE 100	0.0001	0.0001
STOXX 50	0.0001	0.0001
TSX	0.0001	0.0001
SPI	0.0000	0.0001
BI(USD)	0.0001	0.0000
BI(EUR)	0.0005	0.0000
BI(GBP)	0.0000	0.0001
BI(AUD)	0.0000	0.0001
BI(CHF)	0.0001	0.0001
GOLD	0.0000	0.0001
USD/EUR	0.0057	0.0000
USD/GBP	0.0002	0.0001
USD/CHF	0.0000	0.0001
USD/CAD	0.0075	0.0001
USD/AUD	0.0000	0.0001
JPY/USD	0.0000	0.0001
JPY/EUR	0.2461	0.0000
JPY/CHF	0.0000	0.0001
JPY/AUD	0.0000	0.0001
EUR/GBP	0.1934	0.0000
EUR/AUD	0.0035	0.0000
GBP/AUD	0.0000	0.0001
CHF/EUR	0.0005	0.0000
CHF/GBP	0.0000	0.0001
CHF/AUD	0.0000	0.0001
CHF/CAD	0.0000	0.0001
CAD/AUD	0.0000	0.0001
CAD/EUR	0.0028	0.0000
CAD/GBP	0.0001	0.0001

The high-lighted numbers indicate the existence of unit roots, no evidence of unit root is found in 1st difference of GARCH standard deviations.

Figure. A1
1st difference of GARCH(1,1) Standard Deviations of Share Indices, Bond Indices and Gold Prices
(11/12/1998 to 10/12/2003)

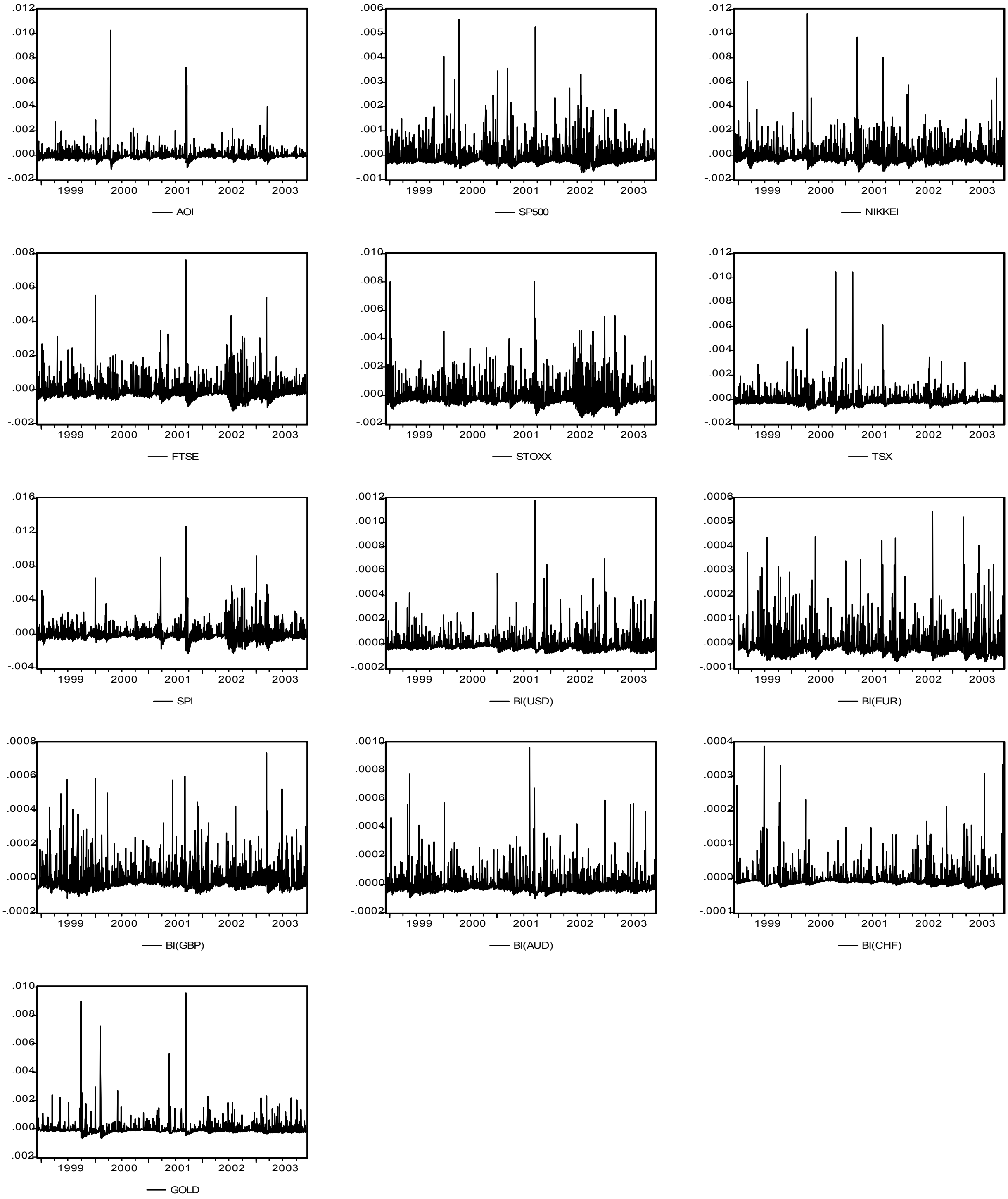

Figure. A2
1st Difference of GARCH(1,1) Standard Deviations of Exchange Rates
(11/12/1998 to 10/12/2003)