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Feedback trading and autocorrelation interactions in the foreign exchange market: Further evidence

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Abstract

This paper tests for presence of feedback trading, asymmetric behavior and autocorrelation linkages in several industrial and emerging economies' exchange rates, with respect to the US dollar, as well as the Euro. The issue is examined via the means of a GARCH-augmented feedback model for the period of 1990 to 2003. The empirical results indicate presence of feedback trading and/or asymmetric behavior in both types of economies' exchange rates but absence of such behavior in the Euro. Presence of asymmetric behavior implies that market traders rely on central banks to intervene so they can realize short-term profits. Furthermore, evidence of volatility persistence in several exchange rates implies inefficiency in those markets. Finally, there are instances where the first-order autoregressive parameter is positive and statistically significant in the exchange rates of both industrial and emerging economies but not in the Euro. For the latter currency, lack of asymmetric behavior and feedback trading implies a credible currency in the eyes of foreign exchange traders.

1. Introduction

Some investors attempt to identify trends in past stock prices and base their portfolio decisions on expectations derived from such trends. Such behavior is termed feedback trading. Feedback trading can either be positive or negative and each type presents some

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concerns for every market participant. The concern about positive feedback trading is that it makes financial asset prices to overreact to new information and can be considered desirable or unpleasant. For instance, investors with positive feedback strategies can be regarded either as destabilizers (or noise traders) or stabilizers. The first could occur because their sales contribute to the fall of the market and their purchases add to market advances. Therefore, if such trading tends to destabilize economies, it can have a serious impact on the emerging economies and the benefits from the liberalization of their markets can be diminished. Moreover, in several instances such strategies generate volatility in returns and create bubbles which may lead to market crashes when they burst. The second possibility could take place if trades of such investors are related to changes in risk premiums or permanent price changes. Financial market liberalizations of emerging economies usually attract more and diverse investors, which results in market appreciations and more inflows of capital. Such trading represents an important aspect of the functioning of financial markets since it reduces the risk of market crashes and eases the flow of transactions among participants.

Negative feedback trading exists when investors 'buy low and sell high', that is, engage in selling stocks following price increases and in buying stocks following price declines. Negative feedback trading can be the result of profit-taking as markets advance or from investment strategies that specify a target wealth in a portfolio. In the context of the foreign exchange market, positive feedback trading exists when traders buy/sell after a depreciation/appreciation of the exchange rate, whereas negative feedback occurs when traders buy/sell following an exchange-rate appreciation/depreciation. Essentially, positive feedback traders tend to stabilize the currency since their strategies typically follow hedging opportunities and extensive use of stop-loss orders. By contrast, negative feedback trading tends to emerge from the traders' efforts to realize profit as the exchange-rate appreciates (or depreciates) thereby driving the exchange rate's value away from its long-run value. These situations can be plausibly assumed because since emerging markets have fully opened up their markets to foreign investors and, additionally, their returns have become more closely correlated with the returns of developed economies.

Another consequence of the presence of a sufficient number of feedback traders in the foreign exchange market is the autocorrelation of returns, which is related to the extent of predictability in the foreign exchange returns. Recent evidence suggests that autocorrelation patterns are present and are multifaceted, at least in stock markets [e.g., see LeBaron (1992), for such dependencies in US stock returns, and Campbell et al. (1993), on the relationship between trading volume and stock return autocorrelation]. Regarding the foreign exchange market, Allen and Taylor (1990) indicate that most traders consider trend patterns at least as relevant as the market fundamentals in the determination of exchange-rate expectations in the short run. Similarly, Frankel and Froot (1987) find evidence of extrapolative expectations and credit it to the use of trend chasing (or charts) by professional traders. Vitale (2000) finds that noise trading in the foreign exchange market may be used to exploit expectations and exchange rates in order to achieve an informational advantage and ultimately a profit opportunity. Finally, Laopodis (2004) finds evidence of noise trading in the foreign exchange markets of both industrial and emerging economies. A related issue concerns the degree of efficiency in the foreign exchange market. Specifically, if volatility is persistent then the currency market in question is not efficient since news should be fully and immediately incorporated in the exchange rate and not take a long time to be assimilated.

A final and an equally important issue this paper seeks to address is the possibility of asymmetric behavior in feedback trading. Specifically, under the presence of asymmetry, is positive feedback trading more intense during exchange-rate appreciations than during exchange-rate depreciations? In other words, do informed traders have an informational advantage over the noise traders or is it the other way around? Evidence on these issues is mixed for the equity and foreign exchange markets (e.g., Sentana and Wadhwani, 1992; Frankel and Froot, 1987; Aguirre and Saidi, 1999; Vitale, 2000). A related issue concerns the credibility in the foreign exchange market, regarding a particular currency, under presence of feedback trading. For example, positive feedback trading connotes that noise traders expect further appreciations/depreciations to take place, based on past appreciations/depreciations, and thus engage in sell/buy actions. In other words, these traders believe that a currency can be sustained only when it has depreciated but not when it has appreciated, therefore suggesting that asymmetric behavior is prevalent in the market under exchange-rate appreciations.

Overall then, the purpose of this paper is to further empirically determine whether feedback trading exists in the foreign exchange market for several developed and emerging economies and whether, in particular, noise trading results in stabilization or destabilization in the foreign exchange market. In this respect, the paper adds to the insights found by Laopodis (2004) and extends his analysis by investigating more issues as well as the Euro's behavior. These issues will be addressed in this paper via the use of a positive feedback trading model augmented with a GARCH specification for the variance of the foreign exchange returns. The analysis includes an analysis of the specifics of the exchange rates and extends the empirical analysis by investigating the structural changes in these financial markets as well as the introduction of the Euro currency. Finally, a subperiod analysis is included for the purpose of examining the impact of specific financial crises on the nature of feedback trading in these markets.

The rest of the paper is organized as follows. Section 2 lays out the methodological design of the study and specifies the empirical model. Section 3 contains the data description and presents some preliminary statistics. Section 4 presents the main empirical findings and discusses them, while Section 5 summarizes and concludes the study.

2. Theoretical model specification and testable hypotheses

A number of researchers have advocated the use of the noise-trader model as an alternative to explain asset prices in general. This is so because, besides the presence of rational, maximizing agents (the 'smart money'), who relied on fundamentals, another group of investors existed (the 'noise traders'), who based their trades on random price movements or trends instead. The interaction of these two types of investors caused volatility in the prices of assets thereby pushing them far away from their fundamental values.

Assume that the first group of traders attempts to maximize their expected utility function of a portfolio (N) exclusively on return and risk factors (e.g., Sentana and Wadhwani, 1992). Accordingly, this group of investors will hold an optimal fraction of shares ($F_{1,t}$) of the market portfolio as follows:

$$F_{1,t} = \left[(E_{t-1}(R_t) - \alpha)/\kappa\sigma_t^2 \right] \tag{1}$$

where R_t is the ex post return at time t, E_{t-1} is the expectations operator at time $t-1$, α is the rate of return on a risk-free asset, σ_t^2 is the conditional variance at time t and κ a fixed coefficient representing the investor's degree of risk aversion. Assuming that κ is positive, the product $\kappa\sigma_t^2$ is the required risk premium at time t. Eq. (1) is the mean-variance model of any asset demand and implies that the demand for the risky asset increases with the expected excess returns $[(R_t-\alpha)]$ and is inversely related to the degree of riskiness σ_t^2.

The second group of investors, the noise-traders, is assumed to follow a positive feedback trading strategy, whereby they demand an asset when its price has increased and they sell it when its price has decreased. Thus, their demand function is $F_{2,t}=\rho R_{t-1}$, where $F_{2,t}$ is the proportion of shares held by this group and ρ is assumed to be positive. Such a strategy suggests trading on noisy information, which is usually irrelevant of economic fundamentals, thereby pushing asset prices like the exchange rate away from their essential values. Hence, we see negative serial correlation in returns as price increases are followed by increases in demand resulting in even higher prices in the future. Obviously, if $\rho<0$, then negative feedback trading is implied whereby traders buy low and sell high. Equilibrium in the market requires that all shares must be held by the two investor groups, that is,

$$F_{1,t} + F_{2,t} = 1 \tag{2}$$

Hence, using Eqs. (1) and (2) and with some rearrangement we obtain

$$R_t = a + \kappa\sigma_t^2 - \kappa\sigma_t^2\rho R_{t-1} \tag{3}$$

and via the use of the rational expectations assumption of $R_t=E_t(R_t)+\varepsilon_t$ Eq. (6) becomes stochastic as follows:

$$R_t = a + \kappa\sigma_t^2 - \left(\kappa\sigma_t^2\rho\right)R_{t-1} + \varepsilon_t \tag{4}$$

where the term $-(\kappa\ \sigma_t^2\rho)R_{t-1}$ connotes that, depending upon the type of noise trader, the presence of positive feedback traders will entail negative serial correlation in the returns. Naturally, the higher the degree of volatility the more negative the autocorrelation will be. This point is easily illustrated by a related form of Eq. (5) expressed below:

$$R_t = a + \kappa\sigma_t^2 + \left(\phi_0 + \phi_1\sigma_t^2\right)R_{t-1} + \varepsilon_t \tag{5}$$

where the direct impact of noise traders (at a constant level of risk) is dictated by the positive sign of ϕ_0.

However, to account for the impact of such intense trades during down markets it is necessary to augment (5) as follows:

$$R_t = a + \kappa\sigma_t^2 + \left(\phi_0 + \phi_1\sigma_t^2\right)R_{t-1} + \phi_2|R_{t-1}| + \varepsilon_t \tag{6}$$

where the existence of positive feedbacks is given by the negative sign of ϕ_1. Moreover, the last term ($\phi_2|R_{t-1}|$) reflects the possibility of asymmetric trading behavior where negative returns will be followed by higher volume of feedback trading, if $\phi_2>0$. Formally, asymmetry is expressed as:

$$\phi_0 + \phi_1\sigma_t^2 + \phi_2 \qquad \text{for } R_{t-1}\geq 0 \text{ and} \tag{7}$$

$$\phi_0 + \phi_1\sigma_t^2 - \phi_2 \qquad \text{for } R_{t-1}<0 \tag{8}$$

The essence of the model is to explore the nature of the relationship between smart money and noise traders as captured by the interaction of autocorrelation and volatility in the returns by imposing an a priori assumption about the noise traders' behavior of positive feedback trading.

The conditional variance of the returns (σ_t^2) of various asset prices such as the exchange rate is found to be plagued by conditional heteroscedasticity as thus it can be modeled as a GARCH (p,q) process as follows:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p}\alpha_i\left(\varepsilon_{t-p}^2\right) + \sum_{j=1}^{q}\beta_j\left(\sigma_{t-q}^2\right) \tag{9}$$

where ε_t is the innovation at time t and α_0, α_i, and β_j are non-negative parameters. The extent to which shocks in the returns persist is measured by the size of $\alpha_i+\beta_j$. If $(\alpha_i+\beta_j)\approx 1$, then a shock (to ε^2) at time t will persist for many future periods. For $(\alpha_i+\beta_j)<1$, the unconditional variance exists and is given by

$$\sigma^2 = \left[\alpha_0/\left(1-\left(\alpha_i+\beta_j\right)\right)\right] \tag{10}$$

In light of the ample evidence of the presence of non-normality in the asset returns, the assumption of normality (i.e., invoking the standard normal distribution) is misleading. Therefore, other parametric (and nonparametric) distributions (with fatter tails) were suggested and used such as the Student's t and the generalized error distributions (e.g., Nelson, 1991; Booth et al., 1992). In this paper we will employ the latter distribution and its density function is given by

$$f(\mu_t,\sigma_t,v) = v/2[\Gamma(3/v)]^{1/2}[\Gamma(1/v)]^{-3/2}(1/\sigma_t)\exp\left\{-[\Gamma(3/v)/\Gamma(1/v)]^{v/2}|\varepsilon_t/\sigma_t|^{v}\right\} \tag{11}$$

where $\Gamma(\cdot)$ is the gamma function and v is a scale parameter (or the degrees of freedom to be estimated endogenously) which controls the shape of the distribution. This specification is flexible in the sense that it allows for the nesting of several other densities. For instance, if $v=2$, Eq. (11) reduces to the normal distribution, whereas for $v=1$ it simplifies to the double exponential (or the Laplace) distribution.

3. Data and preliminary statistical investigation

Daily observations for the closing spot prices of the 11, non-European exchange rates (with respect to the US dollar) listed below were collected from January 1st of 1990 to

December 30th of 2003. These exchange rates are: the Australian Dollar (AD), British Pound (BP), Canadian Dollar (CD), Indian Rupee (IR), Japanese Yen (JY), Malaysian Ringgit (MR), Mexican Peso (MP), Singapore Dollar (SD), South African Rand (SR), South Korean Won (KW), and Thailand Baht (TB). For the six European exchange rates, namely the French Franc (FF), German Mark (GM), Greek Drachma (GD), Italian Lira (IL), Portuguese Escudo (PE), Spanish Peseta (SP), the period end on December 30, 1999, Finally, for the euro (EU) currency, the data period is from January 1, 2000 to December 30, 2003. The rationale for the starting point for the main period is that during the early 1990s many countries have begun liberalizing their markets by dismantling barriers to trade and investment so as to make them available to outside investors. All series were taken from the Federal Reserve's *FRED* database. These particular countries were chosen to comprise both developed and emerging economies, at different levels of integration, in order to examine the characteristics of different markets and infer conclusions accordingly. Daily returns for each exchange rate were calculated as the percentage logarithmic difference in the daily rate.

Table 1 exhibits the descriptive statistics on each series. Several points are worthy of mention from the table. First, the high variance values in the foreign exchange market for

Table 1
Sample statistics on daily exchange-rate returns

	Mean	Variance	Skewness	Kurtosis	ARUR	*D*-stat	LB(6)	LB(18)	$LB^2(6)$	$LB^2(18)$
AD	−0.020	0.3877	−7.2511*	10.532*	0.0314	0.3111*	3.447	9.773	1.1151	1.451
BP	−0.033	0.3466	−0.2471*	2.600*	0.0528	0.3321*	14.467*	22.291*	111.19*	144.98*
CD	0.012	0.0975	0.0301	2.066*	0.0330	0.3560*	14.566*	22.621*	129.01*	211.11*
FF	−0.004	0.4084	−0.0291	1.759*	0.0041	0.3368*	7.545	13.346	133.33*	187.22*
GD	0.034	0.4773	0.6442*	11.131*	0.0457	0.1301*	5.452	13.339	44.35*	67.33*
GM	−0.004	0.4452	0.0362	1.176*	0.0065	0.3377*	16.666	22.444*	109.52*	254.11*
IR	0.034	0.2441	10.923*	17.371*	0.0777	0.1351*	77.078*	123.28*	116.21*	228.21*
IL	0.014	0.4430	1.1321*	9.375*	0.0185	0.2349*	6.271	13.222	111.34*	234.99*
JY	−0.005	0.5229	−0.5124*	4.389*	0.0194	0.2482*	15.381	21.633	133.12*	233.77*
MR	0.014	0.3728	−0.6270*	18.398*	0.0400	0.2540*	41.399*	66.708*	124.33*	332.36*
MP	0.055	0.6717	3.3325*	26.221*	0.0614	0.2656*	67.881*	89.022*	123.32*	222.22*
PE	0.007	0.4626	0.1456	3.383*	0.0023	0.3732*	3.988	16.367	262.32*	345.32*
SD	−0.008	0.1335	−0.9516*	16.224*	0.0072	0.2812*	17.990	26.366	322.12*	454.21*
SR	0.048	0.3844	6.6631*	17.725*	0.0643	0.2932*	51.001*	76.367*	322.31*	344.32*
KW	0.028	0.7853	−1.2512*	13.326*	0.0256	0.3046*	66.781*	101.23*	322.10*	443.33*
SP	0.017	0.4462	0.2559*	4.327*	0.0165	0.3202*	6.288	12.322	233.32*	324.32*
TB	0.016	0.6171	−0.2661*	2.638*	0.0261	0.3334*	19.399*	33.339*	255.33*	334.32*
EU	0.0209	0.4249	−0.0347	0.6606*	0.0491	0.3103*	4.839	8.772	2.345	5.473

Notes: Australian Dollar (AD), British Pound (BP), Canadian Dollar (CD), French Franc (FF), German Mark (GM), Greek Drachma (GD), Indian Rupee (IR), Italian Lira (IL), Japanese Yen (JY), Malaysian Ringgit (MR), Mexican Peso (MP), Portuguese Escudo (PE), Singapore Dollar (SD), South African Rand (SR), South Korean Won (KW), Spanish Peseta (SP), Thailand Baht (TB), and Euro (EU); entire period (January 1, 1990 to December 30, 2003, for all exchange rates but the FF, GM, GD, IL, PE, SP; for these European rates the period end on December 30, 1999; and from January 1, 2000 to December 30, 2003, for the Euro); all series are in logarithmic first differences; ARUR is the Average Return per Unit of Risk (derived by dividing the mean by the Standard Deviation), in absolute sense; * denotes statistical significance at the 5% level; *D*-stat is the Kolmogorov–Smirnov statistic for normality (critical value is $1.36\sqrt{T}$ where T is the sample size; critical value is 0.0272); the LB are the Ljung–Box statistics for five and ten lags for the returns and the squared returns to check for conditional heteroscedasticity.

the won, the peso and the baht suggests higher risk for these markets relative to the other markets. Second, when we associate the risk with the average return (Average Return per Unit of Risk, ARUR), in an absolute sense, we can see that the peso and the rand, from the 10 emerging markets, along with the lira market earned the highest ARUR. Third, the returns of most of the markets displayed positive skewness, which means presence of fat tails in the distributions signifying positive returns, and positive kurtosis. From this perspective, these markets should appeal more to (institutional) investors for inclusion in their portfolios. Fourth, all returns failed the normality test (as seen from the significance of the *D*-statistics) and exhibit significant high-order nonlinearities, as indicated from the Ljung–Box statistics for the squared returns. This result implies that a GARCH-type model would be appropriate in reflecting such nonlinearities along with asymmetric conditional heteroscedasticity.

4. Empirical results and discussion

4.1. Entire period results

The maximum likelihood estimates for the model, as described by Eqs. (6)–(11), are reported in Table 2. The coefficients describing the conditional variance process, α_0, α_1, and β, are highly significant. Specifically, coefficient α_1, which represents the 'autocorrelation in volatility', implies that current volatility is a function of last period's squared innovation from a currency's value. Coefficient β, which represents the autoregressive nature of volatility, implies that current volatility is a function of last period's volatility. The last two coefficients together also provide us with an idea as to how much volatility lasts in each market, that is, the degree of volatility persistence. More concretely, in order to get an idea about how long volatility lasts, the Half-Life (HL) of a shock must be computed, which is defined as $\mathrm{HL}=\ln(0.5)/\ln(\alpha_1+\beta)$. Based on the values of the HL, volatility lasts less than a day in the cases of the baht, drachma, escudo, franc, peseta and peso to about 2 months for the yen and more than 3 months for the pound.

Inspecting now the mean estimated equation (Eq. (6)), we can see that parameter κ, or the GARCH-M effect, is statistically insignificant for all exchange rates except for the ringgit, rupee, pound, won and the peseta. The insignificance of this parameter is in accordance with the findings of Koutmos and Saidi (2001), at least in the case of emerging stock markets. Finally, the estimated values of the scale parameter, v, indicate that the Generalized Error Distribution yields the Laplace or the double exponential distribution in all rates except for the franc and the peseta, for which a normal distribution is implied (since $v=2$). Therefore, the departures from normality observed in the raw return series cannot be completely attributed to inter-temporal first- and second-order moment dependencies.

Continuing our inspection on the estimated parameters of Eq. (6), we will focus on those representing the autocorrelation of the returns, that is, φ_0, φ_1 and φ_2. Specifically, the constant component of the autocorrelation, φ_0, is negative and statistically significant for the pound, Canadian dollar, franc, mark, rupee, Singapore dollar, won and peseta. This parameter represents the autoregressive process in the

Table 2
Maximum likelihood estimates of the GARCH model, entire period

a	κ	φ_0	φ_1	φ_2	α_0	α_1	β	v	LF
Developed economies									
Australian Dollar									
0.0345*	−0.0244	0.0234	−0.0222	−0.0544*	0.0033*	0.0345*	0.9433*	1.1338*	−155.3
(0.021)	(0.022)	(0.016)	(0.013)	(0.041)	(0.021)	(0.023)	(0.007)	(0.033)	
British Pound									
−0.0033*	0.0945*	0.1333*	0.0345*	0.0421	0.3334*	0.0845*	0.9023*	1.4554*	−304.4
(0.001)	(0.001)	(0.023)	(0.015)	(0.032)	(0.022)	(0.011)	(0.011)	(0.024)	
Canadian Dollar									
−0.0022	0.0822	0.1144*	−0.5955*	−0.0033	0.0011*	0.0625*	0.8344*	1.4143*	−500.9
(0.002)	(0.068)	(0.034)	(0.024)	(0.003)	(0.000)	(0.003)	(0.034)	(0.013)	
French Franc									
−0.1123	0.3344	−0.3433*	−0.5454	0.3554*	0.0026*	0.1344*	0.3444*	1.9455*	−478.8
(0.093)	(0.214)	(0.033)	(0.394)	(0.025)	(0.001)	(0.031)	(0.064)	(0.074)	
German Mark									
0.0115*	1.1122	0.8833*	−0.1012	0.1445	0.0008*	0.6944*	0.0090*	0.9644*	−679.4
(0.004)	(0.890)	(0.033)	(0.092)	(0.094)	(0.001)	(0.034)	(0.004)	(0.044)	
Greek Drachma									
0.0147	−0.0011	−0.0395	0.0020	0.0205	0.3514*	0.1692*	0.0302*	1.2701*	−265.7
(0.010)	(0.001)	(0.021)	(0.002)	(0.017)	(0.033)	(0.061)	(0.013)	(0.068)	
Italian Lira									
0.0106	−0.1332	0.0223	−0.5412*	0.1122	0.2844*	0.1544*	0.7781*	1.2221*	−244.4
(0.011)	(0.082)	(0.022)	(0.082)	(0.082)	(0.044)	(0.074)	(0.001)	(0.032)	
Japanese Yen									
0.0222	0.0343	−0.0233	0.0223	−0.0559	0.0045*	0.0392*	0.9465*	1.2344*	−302.3
(0.021)	(0.023)	(0.021)	(0.029)	(0.044)	(0.002)	(0.002)	(0.023)	(0.014)	
Portuguese Escudo									
0.0230	−0.1362	−0.0317	0.0080	0.1488*	0.2436*	0.2190*	0.2637*	1.2000*	−217.3
(0.002)	(0.098)	(0.021)	(0.007)	(0.006)	(0.011)	(0.022)	(0.021)	(0.012)	
Spanish Peseta									
−0.0988*	0.3309*	−0.1445*	−0.0389*	0.0478*	0.3563*	0.0742*	0.3517*	2.1081*	−317.3
(0.001)	(0.033)	(0.011)	(0.002)	(0.001)	(0.011)	(0.001)	(0.021)	(0.013)	
Emerging economies									
Indian Rupee									
−0.0019*	0.0824*	−0.0671*	−0.0037*	0.0331*	0.0165*	0.8986*	0.0637*	0.3908*	−893.2
(0.000)	(0.003)	(0.003)	(0.001)	(0.018)	(0.002)	(0.022)	(0.003)	(0.011)	
Malaysian Ringgit									
−0.0016	0.0696*	−0.0002	−0.0018*	−0.0063	0.2624*	0.4204*	0.4383*	1.4781*	−114.3
(0.001)	(0.001)	(0.000)	(0.000)	(0.004)	(0.001)	(0.012)	(0.001)	(0.002)	
Mexican Peso									
0.0979*	−0.0162	0.0253	−0.0240*	0.0020*	0.0188*	0.2567*	0.0725*	1.2600*	−157.2
(0.001)	(0.011)	(0.017)	(0.001)	(0.001)	(0.001)	(0.022)	(0.001)	(0.077)	
Singapore Dollar									
−0.0083	0.0401	−0.0423*	−0.0607	0.0372	0.0015*	0.0222*	0.8698*	1.0500*	−174.7
(0.006)	(0.030)	(0.001)	(0.041)	(0.021)	(0.000)	(0.008)	(0.066)	(0.033)	
South African Rand									
0.0080	0.0374	−0.0321	−0.0142	0.0016	0.0035*	0.0766*	0.8161*	1.0061*	−173.6
(0.006)	(0.021)	(0.020)	(0.011)	(0.001)	(0.002)	(0.021)	(0.012)	(0.033)	

Table 2 (*continued*)

a	κ	φ_0	φ_1	φ_2	α_0	α_1	β	v	LF
Emerging economies									
South Korean Won									
0.0156*	0.0414*	0.1492*	−0.0082*	0.0742*	0.0193*	0.8091*	0.0090*	0.8378*	−345.9
(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.011)	(0.002)	(0.001)	
Thailand Baht									
0.0395*	−0.0037	−0.0012	−0.0023*	0.0021	0.0267*	0.2436*	0.0558*	0.6335*	−257.2
(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.011)	(0.002)	(0.014)	

Half-Life: Developed economies

AD	BP	CD	FF	GM	IL	JY
37.320	147.13	6.194	0.926	1.980	9.500	55.012

Half Life: Emerging economies

GD	MR	MP	PE	SD	SR	KW	SP	TB
0.430	4.552	0.624	0.952	6.080	6.133	3.465	0.810	0.578

Residual diagnostics

	Mean	Variance	Skewness	Kurtosis	D-stat	LB(6)	LB(18)	$LB^2(6)$	$LB^2(18)$
AD	−0.0463	1.0001	−0.4321*	3.3523*	0.0240	5.1545	11.7167	1.1526	1.2267
BP	−0.0371	1.0001	0.2178*	3.7124*	0.0203	12.3391	14.1667	1.2416	1.7819
CD	0.0165	1.0011	0.1432	1.4501*	0.0268	5.5019	11.1121	2.3198	2.9901
FF	−0.0545	1.0001	−0.0831	1.4051*	0.0299	12.9741	15.6751	27.0191*	32.991*
GM	0.0016	1.0011	0.0438	1.5761*	0.0217	4.7167	20.2212	45.2162*	51.226*
GD	0.0030	1.0001	−1.3571*	9.0189*	0.0328*	10.9910	14.3267	36.2171*	37.251*
IL	0.0011	1.0000	0.6078*	6.2941*	0.0535*	13.7701	16.2561	20.1256	21.9911
IR	−0.0167	0.9999	2.6751*	13.617*	0.0244	5.8617	10.3367	0.6715	1.0189
JY	−0.0220	1.0001	−0.4430*	2.7731*	0.0266	12.2152	13.2434	3.4928	4.5543
KW	−0.0342	0.9999	−0.5223*	2.2382*	0.0267	15.5549	16.7991	8.9536	10.1121
MR	−0.0071	0.9998	−0.0543	1.6435*	0.0267	14.6626	15.8819	4.5817	5.4501
MP	−0.0440	1.0001	1.1123*	2.7367*	0.0304*	9.4438	11.4135	5.6970	6.3321
PE	0.0085	1.0000	0.1020	3.5551*	0.0305*	2.9981	9.9918	23.9101	25.3617
SD	−0.0026	1.0010	−1.4444*	2.2356*	0.0201	15.4436	16.1061	6.7456	8.8191
SR	0.0440	1.0001	0.6200*	2.9716*	0.0202	15.4554	16.3882	7.8345	9.3245
SP	−0.0103	1.0011	−0.5489*	6.0256*	0.0321*	11.4325	13.2218	9.7637	10.1123
TB	−0.0130	1.0001	0.1091*	2.0228*	0.0230	6.3827	10.2117	9.0378	11.2220

Notes: * means statistical significance at the 5% level; LF is the Likelihood Function; HL is the Half-Life of a shock; see also legend in Table 1.

returns and implies that past deviations from the mean value affect the current value of the currency in the opposite direction. By contrast, when the φ_0 parameter is positive, as in the cases of the pound, Canadian dollar, mark, won and the peseta, it reflects the observation that past currency movements are followed by expectations of currency movements in the same direction. Another explanation that has been put forth for this counterintuitive result is that there could exist non-synchronous trading in the foreign exchange market.

Parameters φ_1 and φ_2 reflect presence of negative (if $\varphi_1>0$) or positive (if $\varphi_1<0$) feedback trading and the possibility of asymmetric behavior (if $\varphi_2>0$) in feedback trading.

Although a positive φ_1 is only found statistically significant in the case of the pound, a negative φ_1 emerges as significant in the cases of two industrial economies (the Canadian dollar and the lira) and of six emerging economies (the rupee, the ringgit, the peso, the won, the peseta and the baht). For the pound, this finding indicates that negative feedback trading plays a role in determining short-run movements of that currency, while for the other six currencies positive feedback trading is prevalent. For these exchange markets, the greater predictability, that is, negative autocorrelations, that is generated by feedback traders, is very unlikely to produce arbitrage opportunities for smart money investors because volatility also increases. Positive feedback trading, however, may very well reflect rational interventions by central banks in an effort to stabilize the value of their currencies or to maintain them at desired target levels. Some examples of such behavior are can be offered. First, the attempts of the European central banks such as those by the Bank of Italy during 1992 where severe speculative attacks on the lira forced it to withdraw for the European Monetary System to support the currency values within the specified bands (of $\pm 2.5\%$ or $\pm 15\%$) in accordance with the Maastricht Treaty criteria. Second, the overvaluation of the peso during the December 1994 crisis and the overvaluation of the baht during most of the 1990s and especially in (the period of) 1997–1998 during the Asian crisis.

Asymmetric behavior in currency trading is found for only the franc, from the advanced economies, and for five emerging economies (the rupee, peso, escudo, won and the peseta) since the asymmetry coefficient, φ_2, is positive and statistically significant. Asymmetry means that positive feedback trading is more intense during exchange-rate appreciations than exchange-rate depreciations. Several explanations are offered to explain why feedback traders would be more active when an exchange-rate appreciates. One possibility is that during instances where market volatility is present portfolio sell decisions are dominant. Another is that noise traders engage in intense trading in the currency when the exchange-rate appreciates because they follow strategies by ‘smart money’ in believing that the currency will weaken in the future. They may also believe that the central bank will not be able or willing to support the currency’s value and thus they rebalance their portfolio strategies accordingly by selling the currency. Finally, for those currencies that do not exhibit asymmetric behavior in feedback trading it is implied that the trading process is caused mainly by smart money such as trading and/or central banks and not so much by uninformed market traders.

The joint significance of the feedback coefficients φ_1 and φ_2 is tested on the basis of the Likelihood Ratio (LR) test, calculated as $LR = -2(LF_R - LR_U)$ where LF_R is the log likelihood under the null hypothesis H_0: $\varphi_1 = \varphi_2 = 0$, and LR_U is the log likelihood under the alternative. The test statistic is distributed as a χ^2 with degrees of freedom equal to the number of restrictions under the null hypothesis. The null hypothesis is rejected (results are available upon request) for the pound, rupee, Canadian dollar, ringgit, won, peseta, franc and baht. For the remaining returns, the null is accepted suggesting that feedback trading and asymmetric behavior are not important forces behind short-term exchange-rate price movements. To assess the validity of our results, Table 2 presents also some residual diagnostics regarding the four moments of the distribution, normality checks and linear and nonlinear dependencies. Most of the series continue to exhibit some skewness and kurtosis and, as a result, they fail the normality test (via the use of the Kolmogorov–Smirnov statistic). Linear and nonlinear dependencies are tested by the means of the Ljung–Box (LB) statistic. The calculated LB values for 6 and 18 lags show that the residual and the squared residual series follow an *i.i.d.* process. In sum, the feedback model with errors modeled as a GARCH(1,1) process is seen to adequately capture linear and nonlinear dependencies in the returns.

4.2. Subperiod analyses

The main purpose of subperiod analysis is to investigate the impact on the nature of the feedback behavior of the exchange rates studied in this paper of the several developments that took place in the 1900s. Although there have been numerous such developments, here we will concentrate and analyze only three. The first two refer to the severe currency crises namely, the 1992–1993 Exchange Rate Mechanism (ERM) during which some European countries' currencies witnessed speculative attacks, and the 1997–1998 Asian crisis during which several Asian countries such as (South) Korea, Malaysia, Thailand, and Singapore were forced to devalue their currencies. The third event refers to the introduction and the use of the Euro currency by 15 European countries since January 1, 2000. The results from the subperiod analyses are displayed in Table 3 in three Panels: Panel A exhibits the Asian crisis, Panel B contains the ERM crisis, and Panel C the Euro period.

To keep the discussion compact, we will concentrate on the interpretation of the values for the φ_1 and φ_2 parameters only, which represent positive or negative feedback trading and asymmetric behavior. During the Asian crisis, the won was the only currency that exhibited negative feedback trading behavior before the crisis but a positive feedback behavior after the crisis, while the Singapore dollar only positive feedback trading before the crisis. The ERM exchange rates revealed different insights as the lira, escudo and franc exhibited positive feedback trading behavior after the crisis but no feedback trading before the crisis. However, before the crisis the lira and the pound might have had some negative feedback trading but the mark after the crisis.

The asymmetry coefficient, being positive, surfaces significant in the cases of the won, Singapore dollar, escudo, lira and the franc during the pre-crisis period but it vanished for all but the won and emerged for the ringgit after the crisis. Perhaps after the crisis, the trading process for the first three currencies was mostly dominated by informed traders suggesting that these currencies became much more credible in the eyes of global traders. Finally, the other interesting result is that during the post-crisis period, along with the won, the ringgit appear to have experienced asymmetric behavior implying that these currencies did not manage to earn credibility and/or that in the future those currencies would depreciate. The above conclusions seem plausible in view of the great efforts several European governments such as Italy and Portugal made to sustain the value of their currency, in view of the upcoming monetary union, while the second one is consistent with the fact that the won and the ringgit had experienced rapid depreciations during the post-crisis period.

Finally, the estimates for the Euro period (January 1, 2000 to December 30, 2003) in Panel C suggest absence of both negative and positive feedback trading as

Table 3
Subperiod analyses

Panel A: Asian crisis

	Korea		Thailand		Malaysia		Singapore	
	Before	After	Before	After	Before	After	Before	After
φ_0	0.3417*	0.2292*	0.1671	0.2040	−0.0766*	−0.4071*	−0.0484*	−0.0133
	(0.002)	(0.011)	(0.112)	(0.123)	(0.025)	(0.012)	(0.012)	(0.011)
φ_1	0.7202*	−0.0647*	0.6032	−0.1237	−0.0944	−0.0000	−0.0382*	−0.0940
	(0.187)	(0.020)	(0.467)	(0.109)	(0.080)	(0.000)	(0.022)	(0.077)
φ_2	0.0449*	0.0987*	−0.0051	−0.0993	0.0154	0.5071*	0.0976*	0.0075
	(0.027)	(0.011)	(0.004)	(0.071)	(0.011)	(0.022)	(0.031)	(0.006)
α_1	0.7202*	0.7617*	−0.0000	0.1796*	0.6102*	0.8212*	0.9463*	0.1544*
	(0.032)	(0.007)	(0.000)	(0.021)	(0.021)	(0.074)	(0.106)	(0.022)
β	0.0445*	0.9087*	0.0011	0.5527*	0.3298*	0.0002	0.8485*	0.8045*
	(0.008)	(0.021)	(0.001)	(0.023)	(0.033)	(0.001)	(0.109)	(0.034)
v	0.9876*	1.9891*	1.3421*	2.0242*	0.9237*	0.0045*	0.8457*	1.1162*
	(0.021)	(11.21)	(0.062)	(0.211)	(0.035)	(0.002)	(0.025)	(0.042)
LF	107.231	−408.98	−796.32	−409.01	152.67	680.34	−148.89	−214.78

Panel B: ERM crisis

	UK		Italy		Portugal		Spain		Greece		Germany		France	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
φ_0	−0.0213	−0.2919	−0.1108	0.4240*	−0.0054	0.1145**	0.1706	−0.0619	−0.0863	−0.6319	−0.2788	0.2031*	−0.0054	0.1145**
	(0.012)	(0.187)	(0.177)	(0.004)	(0.004)	(0.064)	(0.120)	(0.045)	(0.062)	(0.587)	(0.173)	(0.021)	(0.004)	(0.064)
φ_1	0.1612*	−0.0213	0.2056*	−0.0468*	−0.0261	−0.4175*	−0.0853	0.1343	−0.1972	0.0623	−0.6976	0.1801*	−0.0261	−0.4175*
	(0.012)	(0.019)	(0.056)	(0.001)	(0.041)	(0.174)	(0.077)	(0.112)	(0.102)	(0.049)	(0.534)	(0.011)	(0.041)	(0.174)
φ_2	−0.1235*	−0.0023	−0.1986**	0.0957*	0.2579*	−0.0439	0.1948	0.2091	0.1230	0.1193	0.3746	−0.1978*	0.2579*	−0.0439
	(0.021)	(0.002)	(0.105)	(0.005)	(0.021)	(0.033)	(0.112)	(0.178)	(0.111)	(0.084)	(0.225)	(0.021)	(0.021)	(0.033)
α_1	−0.3153*	0.0841*	0.2956*	0.5998*	0.2371*	0.0583*	0.1223*	−0.4631*	−0.5403	0.1631*	0.0819*	0.0967*	0.2371*	0.0583*
	(0.021)	(0.022)	(0.010)	(0.001)	(0.070)	(0.022)	(0.012)	(0.021)	(0.421)	(0.032)	(0.011)	(0.022)	(0.070)	(0.022)
β	−0.2131*	0.8825*	−0.1312	−0.2248*	0.0900	0.9016*	0.9718*	0.1216*	0.1761	0.1895*	0.8571*	0.6450*	0.0900	0.9016*
	(0.022)	(0.071)	(0.111)	(0.018)	(0.064)	(0.033)	(0.002)	(0.061)	(0.122)	(0.031)	(0.111)	(0.064)	(0.033)	(0.002)
v	1.6001*	1.2356*	1.4871*	2.5089*	1.1653*	1.3761*	12.211*	4.1234*	4.5661*	1.1236*	1.6001*	1.5340*	1.1653*	1.3761*
	(0.022)	(0.011)	(0.128)	(0.032)	(0.056)	(0.081)	(0.021)	(1.212)	(0.022)	(2.431)	(0.134)	(0.056)	(0.081)	(0.021)
LF	−545.98	−1479.71	−512.32	−443.03	−1257.32	−874.83	−463.78	−381.54	−60.998	−1180.76	321.31	361.65	−647.28	−709.93

Panel C: Euro period

φ_0	φ_1	φ_2	α_1	β	v	LF
0.4018	−0.8522	−0.0477	0.0307	0.8419*	1.5871*	−977.32
(0.321)	(0.652)	(0.032)	(0.022)	(0.033)	(0.103)	
HL=4.025						

Note: Please see Table 2.

well as asymmetric behavior. These results strongly connote that the new currency is credible in the eyes of international foreign exchange market participants and that feedback trading is undertaken chiefly by central banks which attempt to support the currency. These conclusions are also supported by the finding that volatility in the Euro currency is low and that volatility persists for only 4 days (as seen by the HL value of 4.025).

4.3. Return autocorrelations

Positive feedback trading, which is similar to herding since agents buy after price increases, results in negative autocorrelation, whereas negative feedback trading, which is similar to profit-taking as traders sell after price increases, results in positive autocorrelation. Accordingly, the results for the entire period in the first column of Table 4 are, in general, in line with the notion that negative feedback trading induces positive return autocorrelation in the cases of the pound, Canadian dollar, mark, yen, ringgit, won and peseta. For the other currency returns, the evidence is mixed and for the euro there is clear absence of significant positive or negative autocorrelation. The autocorrelations based on the absolute returns (the second set of numbers in the first column) corroborate the earlier findings about the absence of asymmetric behavior in trading. Put differently, the fact that feedback trading, regardless of exchange-rate appreciations or depreciations, exhibits asymmetries in many currencies suggests that this process is caused by central bank interventions and smart money and not by the actions of noise traders.

The results for the pre- and post-crises subperiods for selected currencies are displayed in columns two and three in Table 4 along with the coefficients' standard errors. There is a mixed evidence as some currencies (e.g., pound, franc, mark, lira, ringgit and Singapore dollar) experienced negative autocorrelation due to positive feedback trading in the pre-crisis period, while others (e.g., won and baht) positive autocorrelation due to negative feedback trading during the pre- and post-crisis period. The different values for autocorrelation between the pre- and post-crisis periods also suggest that autocorrelation of currency returns is very volatile. Autocorrelation is inversely related to volatility taking on positive values during tranquil periods and negative values during turbulent periods.

4.4. Discussion of findings

The analyses for the entire period and the subperiods have revealed evidence of feedback trading and/or asymmetric behavior for both industrial and emerging economies' exchange rates but lack thereof for the Euro. Despite the efficiency in the foreign exchange markets of the developed economies, existence of noise trading along with smart money cannot be ignored. This conclusion is in accordance with similar results found by others (e.g., Vitale, 2000). Noise trading in foreign exchange markets may be a rational strategy for speculative profits because it can generate informational advantages. In other words, in a competitive dealer environment, in which no distinction can be made between smart money and noise traders, noisy market orders will interfere

Table 4
First-Order autocorrelations

	Entire	Period	Pre-crisis	Subperiod	Post-crisis	Subperiod
	Coeff.[a,b]	S.E.[a,b]	Coeff.[a,b]	S.E.[a,b]	Coeff.[a,b]	S.E.[a,b]
AD	0.0269	0.0191				
	−0.0593*	0.0271				
BP	−0.0613*	0.0181	−0.1029*	0.0221	−0.0516*	0.0112
	0.0684*	0.0267	0.0656*	0.0112	0.0112*	0.0011
CD	0.0379*	0.0110				
	0.0124	0.0100				
FF	0.0451*	0.0212	−0.3212*	0.0231	0.1123	0.1089
	0.0116	0.0100	0.1127*	0.0121	0.0716	0.0665
GM	0.0358**	0.0195	−0.2213*	0.0114	0.1236*	0.0122
	−0.0043	0.0031	−0.1121	0.0987	−0.0819	0.0771
GD	−0.0118	0.0100	−0.3321	0.2321	−0.1998	0.1133
	0.0738*	0.0261	0.1128	0.1022	0.0819*	0.0455
IR	0.0067	0.0051				
	0.0111*	0.0010				
IL	0.0315	0.0210	−0.3321*	0.0111	0.1352	0.1109
	0.0526	0.0299	−0.2213	0.1987	0.0977	0.0789
JY	0.0382*	0.0134				
	−0.0287	0.0177				
MR	0.0505*	0.0192	−0.2123*	0.0134	−0.3212*	0.0918
	0.0206	0.0189	0.0998	0.0776	0.1123	0.0997
MP	−0.0017**	0.0009				
	0.0494	0.0322				
PE	−0.0346**	0.0195	−0.3321*	0.1121	0.1123*	0.0211
	−0.0010	0.0008	−0.1123	0.0998	0.0451	0.0332
SD	−0.0503*	0.0166	−0.4514*	0.1121	−0.0675	0.0554
	0.1313*	0.0231	−0.2123*	0.0445	0.0231	0.0172
SR	−0.0497*	0.0181				
	0.0844*	0.0243				
KW	0.1464*	0.0112	0.3325*	0.0987	0.1097*	0.0413
	0.0921*	0.0332	0.1231*	0.0661	0.0887*	0.0112
SP	0.0274**	0.0140	−0.0878	0.0661	0.0334	0.0221
	0.0299	0.0200	−0.1089	0.0887	0.0112	0.0101
TB	0.4553*	0.0321	0.2212*	0.0112	0.1221*	0.0089
	−0.0086	0.0067	−0.1226*	0.0117	−0.1090	0.0932
EU	0.0422	0.0401				
	0.0493	0.0336				

Notes: *,** mean statistical significance at the 5% and 10% levels, respectively; [a],[b] denote the coefficients and the standard errors estimated with past returns and absolute returns, respectively.

with the ability of the dealers to learn the true, fundamental information within the order process. On the other hand, the uninformed trader will be able to deduce some of this fundamental information contained in the order process and, as a result, in future trades this trader will be able to gain some profits (e.g., Madrigal, 1996). The nature of feedback trading notwithstanding, presence of asymmetric behavior implies that market traders rely on central banks to intervene so they can realize short-term profits. Such actions, both by smart money and noise traders, could be destabilizing in the foreign exchange market. Moreover, evidence of asymmetric behavior suggests lack of credibility in those currencies and that the traders count on the country's central bank to alter its reserves in order to realize short-term profits. Finally, in instances where the autoregressive parameter is positive and significant, it represents the so-called bandwagon effect whereby past currency movements are followed by expectations of currency movements in the same direction.

The currency markets have been inundated with 'investors' and speculators who base their trading decisions on recurring chart patterns in currency values and/or take positions on the basis of rumors and news. These traders generally avoid taking long-run positions as they are more comfortable trading with the trend, that is, buying when the price is rising and selling when the price is falling. Those strategies, however, are largely regarded as destabilizing as they may lead to a considerable jump in the long-run exchange-rate values, which, in turn, may result in persistent misalignments of a country's currency and a worsening of its global competitiveness. Unfortunately, such price changes may not be counter-balanced by risk averse, fundamentally oriented investors and, consequently, the monetary authorities may be forced to intervene in order to reverse the trend and avert a disastrous speculative bubble.

5. Summary and conclusions

This paper examines the possibility of noise trading and autocorrelation patterns of 7 developed and 10 emerging economies' exchange rates with respect to the US dollar for the 1990 to 2003 period. The paper also considers the Euro's behavior from 1999 to 2003. More specifically, the paper seeks to empirically determine whether the presence of feedback trading strategies is a distinguishing feature of an emerging economy or it is a common element to both developed and emerging economies. Additionally, we examine whether there exist asymmetric behavior, volatility persistence, and credibility in the foreign exchange market following such trading. These questions are tested via the use of a GARCH-augmented feedback model.

The results reveal an evidence of feedback trading and/or asymmetric behavior in both types of economies. Presence of asymmetric behavior implies that market traders rely on central banks to intervene so they can realize short-term profits and such actions, both by smart money and noise traders, could be destabilizing in the foreign exchange market. However, we found an absence of feedback trading and/or asymmetric behavior in the case of the Euro, which suggests that the currency is viewed as credible in the eyes of foreign exchange participants. Further, for several exchange rates we found high volatility persistence, which implies inefficiency in these currency markets. This result also implies that during volatile periods, deviations from a long-run value in an exchange rate are likely to increase since informed and noise traders exert a greater influence on the exchange rate. Finally, there are instances where the first-order autoregressive parameter is positive and statistically significant, in the currencies of both developed and emerging economies. This finding implies the presence of the so-called bandwagon effect, whereby past currency movements are followed by expectations of currency movements in the same direction.

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