CARDIFF BUSINESS SCHOOL
WORKING PAPER SERIES

Cardiff Economics Working Papers

Michael G. Arghyrou, Andros Gregoriou, Panayiotis M. Pourpourides

Exchange rate uncertainty and deviations from Purchasing Power Parity: Evidence from the G7 area

E2009/23

Cardiff Business School
Cardiff University
Colum Drive
Cardiff CF10 3EU
United Kingdom
t: +44 (0)29 2087 4000
f: +44 (0)29 2087 4419
www.cardiff.ac.uk/carbs

ISSN 1749-6101
November 2009

Exchange rate uncertainty and deviations from Purchasing Power Parity: Evidence from the G7 area

Michael G. Arghyrou [a,*], Andros Gregoriou [b], Panayiotis M. Pourpourides [a]

[a] Cardiff Business School, Cardiff University, Colum Drive, Cardiff, CF10 3EU, United Kingdom.

[b] Norwich Business School, University of East Anglia, Norwich, NR4 7TJ, United Kingdom

* Corresponding author. Tel.: +442920875515; fax +442920874419

E-mail addresses: ArghyrouM@cardiff.ac.uk (M.G. Arghyrou); A.Gregoriou@uea.ac.uk (A. Gregoriou); PourpouridesP@cardiff.ac.uk (P.M. Pourpourides).

Abstract

Arghyrou, Gregoriou and Pourpourides (2009) argue that exchange rate uncertainty causes deviations from the law of one price. We test this hypothesis on aggregate data from the G7-area. We find that exchange rate uncertainty explains to a significant degree deviations from Purchasing Power Parity.

Keywords: Purchasing power parity; exchange rate uncertainty.

JEL classification: F31, F41.

1. INTRODUCTION

A well-established puzzle in international macroeconomics is the failure of standard time-series techniques to validate Purchasing Power Parity (PPP) among industrialised countries for the period of floating exchange rates (see Taylor, 1995). Even when PPP is confirmed as a long-run equilibrium condition, deviations from it are found to be excessively persistent. This gives rise to a second PPP puzzle, summarised by Rogoff (1996, p. 647) as follows: "How can one reconcile the enormous short-run volatility of real exchange rates with the extremely slow rate at which shocks [away from PPP] appear to damp out?"

Existing explanations of the PPP puzzles mainly focus on market imperfections and the low power of linear time-series techniques (see Sarno, 2005). In a recent paper Arghyrou, Gregoriou and Pourpourides (2009, hereafter AGP) provide a new explanation based on exchange rate uncertainty. They present a model in which risk-averse consumers facing exchange rate uncertainty and having no access to hedging instruments are willing to pay the domestic importer of a foreign good a risk premium over the good's foreign price. They do so in order to fix the cash outflow from the good's purchase in units of domestic currency. This drives a permanent wedge between domestic and foreign prices explaining violations of the law of one price (LOOP) even under frictionless markets. AGP test their theoretical argument using data from a market with minimum imperfections, reaching findings highly supportive of their hypothesis. Their findings motivate further research on the link between exchange rate uncertainty and deviations from PPP at the aggregate level.

This paper tests this link for bilateral US dollar exchange rates within the G7 area. We obtain significant evidence in favour of the AGP hypothesis. Overall, our findings provide further support to the latter's conclusion on Rogoff's question: Rather than describing a puzzle, coexistence of enormous exchange rate volatility and persistent deviations from PPP is possible: Indeed, and at least to a degree, the former may cause the latter.

2. EMPIRICAL METHODOLOGY

Our empirical investigation follows a three-step approach: First, we estimate deviations from PPP; second, we estimate exchange rate uncertainty; finally, we test the significance of exchange rate uncertainty in explaining deviations from PPP.

We estimate deviations from PPP using the error term y_t of the standard PPP regression given by equation (1) below:

$$s_t = \alpha + \beta_1 p_t + \beta_2 p^*_t + y_t \tag{1}$$

In eq. (1), s_t denotes the log of the nominal exchange rate (units of domestic currency per US dollar); and p_t and p^*_t the logs of domestic and USA consumer price indexes respectively. Long-run PPP requires y_t to be stationary and $\beta_1 = -\beta_2 = 1$, though measurement errors and different definitions of national price indexes may result in deviations from these restrictions.

Following the AGP approach, we estimate exchange rate uncertainty using the system of equations (2) and (3) below:

$$s_{t+1} = s_t + \kappa_{t+1}, \text{ with } E_t\kappa_{t+1} = 0 \text{ and } E_t\kappa^2_{t+1} = \theta^2_t \tag{2}$$

$$\kappa^2_{t+1} = \beta + \sum_{i=0}^{k}\gamma_i\kappa^2_{t-i} + \sum_{i=0}^{n}\delta_i u_{t-i} + u_{t+1}, \text{ with } E_t u_{t+1} = 0 \text{ and } E_t u^2_{t+1} = \phi^2_t \tag{3}$$

Eq.(2) models the mean of s_t as a random walk process,[1] with $E_t\kappa^2_{t+1} = \theta^2_t$ capturing the time-t expectation for the volatility of the exchange rate at time t+1. This is modelled by eq.(3) as a GARCH process where the u_{t-i} terms denote moving average components.

Finally, we test the significance of exchange rate uncertainty in explaining deviations from PPP. AGP estimate equation (4) below, regressing deviations from the LOOP observed in the market they analyse (air-tickets bought on line) on exchange rate uncertainty:

[1] This assumption is well-upheld by the data, as the estimated β coefficients obtained from an AR (1) model of the form $s_t = \alpha + \beta_1 s_{t-1} + u_t$ is 0.988 for Canada, 0.987 for EMU, 0.991 for France, 0.975 for Germany, 0.991 for Italy, 0.994 for Japan and 0.979 for the UK. The lag-length of the autoregressive and moving average terms in eq.(3) is determined using the Akaike information criterion. The results are available upon request.

$$y_t = \gamma_0 + \gamma_1\, E_t \kappa_{t+1}^2 + v_t \qquad (4)$$

For their hypothesis to be valid, AGP expect (and indeed obtain) γ_1 to be positive and statistically significant. Here, however, we work with aggregate price indexes posing an aggregation problem. More specifically, the model by AGP predicts that exchange rate uncertainty causes domestic consumers to pay a risk premium over the foreign price of imported goods (foreign-produced goods); and foreign consumers to pay a risk premium over the domestic price of domestic exported goods (domestic-produced goods). Therefore, from a domestic point of view, increased uncertainty causes positive deviations from the LOOP for imported goods and negative deviations for exported goods. These separate effects cannot be disentangled using aggregate price indexes. Their net effect, however, will result in a distance from the PPP-consistent exchange rate whose size (positive or negative) will be determined by the weights of domestic and foreign goods in the two countries' reference baskets and their relative degree of risk aversion. This has two implications. First, there exists no a priori expectation regarding the sign of γ_1 when eq. (4) is estimated using aggregate price indexes. Second, the net effect discussed above renders the absolute value of y_t, denoted by $abs(y_t)$, a preferable metric to capture the net effect of shocks in exchange rate uncertainty on deviations from PPP. This is captured by equation (5) below for which the model by AGP clearly predicts a positive link between the dependent and independent variables (i.e. $\gamma_1 > 0$).

$$abs(y_t) = \gamma_0 + \gamma_1\, E_t \kappa_{t+1}^2 + v_t \qquad (5)$$

Eq. (5), however, may still underestimate the link's strength. The reason is that shocks in exchange rate uncertainty may cause in consecutive periods net effects of similar absolute size but different sign. These will not be captured by the absolute value of y_t but will be captured by the absolute value of the first difference of y_t, denoted by $abs(\Delta y_t)$.[2] As a result,

[2] Assume, for example, that y_t takes for two consecutive periods (periods 1 and 2) the value of five percent and, as a result of a shock to exchange rate uncertainty occurring in period 3 changes to minus five percent. The

our preferred specification to test the significance of exchange rate uncertainty in explaining deviations from PPP is given by equation (6) below:

$$abs(\Delta y_t) = \gamma_0 + \gamma_1 E_t \kappa_{t+1}^2 + v_t \quad (6)$$

where v_t is a random error term and γ_1 is expected to be positive and statistically significant.

Finally, a point relating to estimation: The autoregressive terms on the right-hand side of eq.(3) have a smoothing effect on the estimated series of exchange rate uncertainty κ_{t+1}^2. This effect is not present in the y_t series obtained from eq.(1). Now, a regression whose independent variable is by construction smoothed whereas its dependent variable is not (and therefore includes more extreme values) may result in misleadingly low model fit. To address this point we estimate eq. (4), (5) and (6) twice. The first set of estimates, which does not account for the smoothing asymmetry discussed above, defines the regressions' dependent variables as the original series of y_t, $abs(y_t)$ and $abs(\Delta y_t)$ respectively, calculated using the residuals of eq. (1). The second set, which accounts for the smoothing asymmetry, estimates eq. (4), (5) and (6), defining as dependent variable the twelve-month moving average of the original y_t, $abs(y_t)$ and $abs(\Delta y_t)$ series respectively.

3. DATA AND EMPIRICAL FINDINGS

For our empirical estimations we use data of monthly frequency taken from the International Financial Statistics Databank, except from the Euro/USD exchange rate and the EMU CPI price index for which our data source is Eurostat. Our samples for the Canadian dollar and Japanese yen cover 1973:01-2009.03; for the euro (ECU before 1999:01) and the UK pound 1973:01-2009.04; and for the French frank, German mark and Italian lira 1973.01-1998.12, as these currencies were subsequently replaced by the euro.

---

absolute value of y_t will for all three periods be five per cent, falsely indicating no effect of the shock in exchange rate uncertainty on deviations from PPP. By contrast, the absolute value of the first difference of y_t will in period 3 change from zero per cent to ten per cent, capturing this effect.

Table 1 presents the estimates of eq. (1). All reported coefficients have the theoretically expected sign. We then estimate exchange rate uncertainty using the system of equations in (2) and (3) determining the latter's GARCH structure using the Akaike information criterion.[3] Finally, we estimate equations (4), (5) and (6). The results are reported in Tables 2, 3 and 4 respectively. Each Table includes two panels. Part A reports the findings obtained using the original series of y_t, $abs(y_t)$ and $abs(\Delta y_t)$ respectively. Part B reports the findings obtained using the latter's twelve-month moving averages.

Table 2 is generally not-supportive of a link between aggregate deviations from PPP (y_t) and exchange rate uncertainty. This, however, may be a reflection of the aggregation problem discussed in section 2, also indicated by the mixed nature of the estimated signs of the γ_1 terms. Table 3, modelling the absolute value of deviations from PPP, presents a mixed picture: In part A (modelling the original $abs(y_t)$ series) only two out of seven exchange rate uncertainty coefficients are statistically significant. By contrast, in part B, which models the twelve-month moving average of $abs(y_t)$, the number of significant uncertainty coefficients rises to five. The ambiguity is finally cleared in Table 4 presenting estimations of our preferred specification given by eq. (6). Both parts A and B report highly significant coefficients for all exchange rate uncertainty terms. Furthermore, part B, which addresses the smoothing asymmetry discussed in section 2 above, reports an impressive data fit, with five out of seven R^2 coefficients exceeding 70 per cent. The strong link between $abs(\Delta y_t)$ and exchange rate uncertainty is confirmed by a number of robustness tests and is also depicted in Figure 1.[4] Overall, Table 4 suggests that exchange rate uncertainty not only has a significant role in explaining deviations from PPP, but probably a very prominent one.

[3] For all countries except France, the Akaike information criterion suggested a GARCH(1,1) structure. For France, the preferred structure was a GARCH (2,1). All GARCH estimations account for residuals' non-normality. This correction does not change the results. All GARCH estimations are available upon request.

[4] We have repeated our empirical analysis using (i) producer price indexes in eq.(1); (ii) the 12-month moving variance of the nominal exchange rate series as the right-hand side variable in equations (4) and (5) and (iii)

4. CONCLUDING REMARKS

Arghyrou, Gregoriou and Pourpourides (AGP, 2009) argue that exchange rate uncertainty causes deviations from the law of one price. We test this hypothesis on aggregate data referring to bilateral US dollar exchange rates in the G7 area. We find that exchange rate uncertainty has a prominent role in explaining deviations from Purchasing Power Parity (PPP). Our findings provide further to support the view expressed by AGP, according to which rather than describing a puzzle, coexistence of high exchange rate volatility and persistent deviations from PPP is justified: Indeed, and at least to a degree, the former may be the cause of the latter.

REFERENCES

Andrews, D. W. K. (1991). "Heteroskedasticity and autocorrelation consistent covariance matrix estimation", *Econometrica* 59, 817-858.

Arghyrou, M.G., Gregoriou, A. and Pourpourides, P. M. (2009), "A new solution to the Purchasing Power Parity puzzles? Risk aversion, exchange rate uncertainty and the law of one price", Cardiff Business School, Economics Section, Working Paper No E2009/2

Rogoff, K. (1996), "The purchasing power parity puzzle", *Journal of Economic Literature* 34, 647- 668.

Sarno, L. (2005), "Towards a solution to the puzzles in exchange rate economics: Where do we stand?", *Canadian Journal of Economics*, 38, 673-708.

Taylor, M.P. (1995), "The Economics of Exchange Rates", *Journal of Economic Literature*, 33, 13-47.

GARCH estimates not correcting for residuals' non-normality in equations (2) and (3). In all cases the empirical findings remain unchanged. The results are available upon request.

Table 1: Purchasing Power Parity equations

	Canada	EMU	France	Germany	Italy	Japan	UK
α	-0.208 (0.046)	0.713 (0.060)	0.614 (0.070)	0.021 (0.259)	2.614 (0.279)	3.361 (0.245)	0.146 (0.155)
β_1	0.750 (0.333)	2.862 (0.646)	1.306 (0.183)	0.891 (0.287)	0.628 (0.165)	0.191 (0.224)	1.070 (0.181)
β_2	-0.587 (0.359)	-2.508 (0.633)	-1.185 (0.215)	-0.735 (0.161)	-0.258 (0.308)	-0.866 (0.111)	-1.257 (0.260)
R^2	0.41	0.42	0.84	0.59	0.94	0.81	0.40

Notes: Standard errors in parentheses have been calculated using Andrews's (1991) correction for autocorrelation and heteroskedasticity.

Table 2: Modelling deviations from Purchasing Power Parity on exchange rate uncertainty

	Canada	EMU	France	Germany	Italy	Japan	UK
A) Dependent variable: y_t							
γ_0	0.017 (0.008)**	-0.032 (0.011)*	-0.030 (0.006)***	-0.013 (0.008)	-0.007 (0.007)	0.041 (0.020)**	-0.014 (0.011)
γ_1	-283.3 (125.8)**	182.8 (114.9)	417.0 (62.0)***	173.8 (94.8)*	68.0 (43.2)	-193.7 (88.7)**	81.7 (63.5)
R^2	0.08	0.02	0.17	0.02	0.03	0.04	0.01
B) Dependent variable: Twelve-month moving average of y_t							
γ_0	0.020 (0.007)***	-0.027 (0.022)	-0.028 (0.006)***	-0.008 (0.008)	0.004 (0.006)	0.035 (0.020)*	-0.003 (0.014)
γ_1	-324.0 (91.7)***	159.5 (135.6)	371.8 (73.0)***	111.4 (96.3)	-43.25 (43.7)	-160.7 (98.3)	12.6 (90.4)
R^2	0.12	0.02	0.15	0.01	0.01	0.03	0.00

*Notes:**,** and *** respectively denote statistical significance at 10, 5 and 1 per cent level respectively. Standard errors in parentheses have been calculated using Andrews's (1991) correction for autocorrelation and heteroskedasticity.

Table 3: Modelling the absolute value of deviations from Purchasing Power Parity on exchange rate uncertainty

	Canada	EMU	France	Germany	Italy	Japan	UK
A) Dependent variable: *abs*(y_t)							
γ_0	0.025 (0.006)***	0.043 (0.011)***	0.014 (0.005)***	0.026 (0.004)***	0.030 (0.004)***	0.049 (0.014)***	0.023 (0.008)***
γ_1	155.1 (102.6)	60.4 (62.3)	142.1 (64.0)**	8.0 (48.8)	4.0 (19.7)	31.0 (59.7)	102.0 (47.7)**
R^2	0.07	0.01	0.06	0.00	0.00	0.00	0.05
B) Dependent variable: Twelve-month moving average of *abs*(y_t)							
γ_0	0.020 (0.004)***	0.024 (0.001)**	0.014 (0.004)***	0.018 (0.006)***	0.026 (0.003)***	0.038 (0.013)***	0.014 (0.008)
γ_1	244.5 (61.9)***	176.6 (56.7)***	145.2 (46.7)***	115.4 (82.9)	47.4 (22.8)**	84.7 (57.2)	160.2 (52.8)***
R^2	0.20	0.06	0.08	0.02	0.05	0.03	0.17

*Notes:**,** and *** respectively denote statistical significance at 10, 5 and 1 per cent level respectively. Standard errors in parentheses have been calculated using Andrews's (1991) correction for autocorrelation and heteroskedasticity.

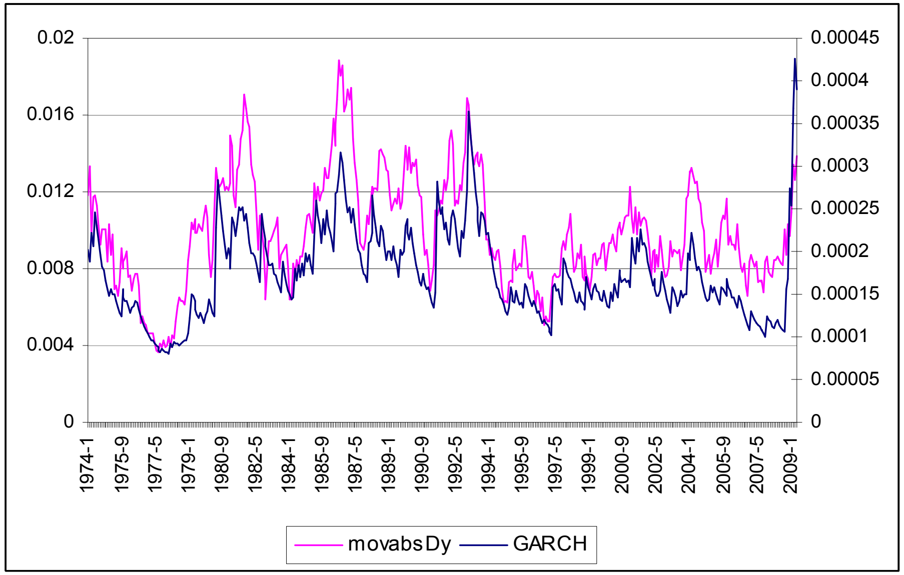
Table 4: Modelling absolute value of the first difference of deviations from Purchasing Power Parity on exchange rate uncertainty

	Canada	EMU	France	Germany	Italy	Japan	UK
A) Dependent variable: $abs(\Delta y_t)$							
γ_0	0.004 (0.0005)***	0.006 (0.0014)***	0.004 (0.0012)***	0.003 (0.0010)***	0.004 (0.0006)***	0.007 (0.0012)***	0.006 (0.0080)***
γ_1	25.5 (8.6)***	22.2 (7.6)***	30.74 (17.9)*	52.1 (12.0)***	19.1 (4.6)***	16.0 (5.7)***	21.9 (4.6)***
R^2	0.05	0.02	0.02	0.06	0.07	0.02	0.04
B) Dependent variable: Twelve-month moving average of $abs(\Delta y_t)$							
γ_0	0.003 (0.0004)***	0.002 (0.0008)***	0.002 (0.0006)***	0.000 (0.0004)	0.004 (0.0002)***	0.002 (0.0008)***	0.004 (0.0005)***
γ_1	43.94 (6.9)***	43.64 (4.9)***	57.8 (9.14)***	93.1 (5.7)***	19.9 (4.2)***	39.5 (3.9)***	36.7 (2.9)***
R^2	0.73	0.65	0.60	0.79	0.40	0.74	0.73

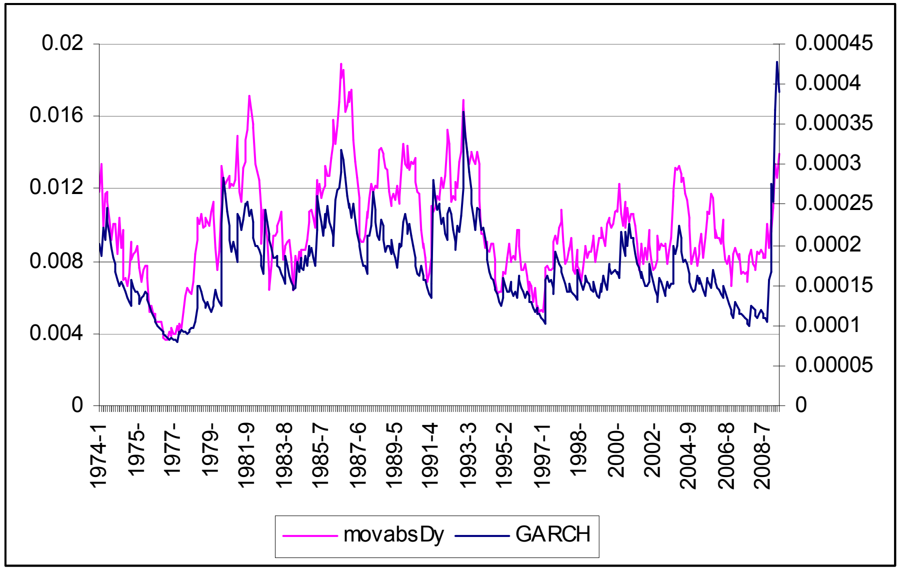
Notes: *,** and *** respectively denote statistical significance at 10, 5 and 1 per cent level respectively. Standard errors in parentheses have been calculated using Andrews's (1991) correction for autocorrelation and heteroskedasticity.

Figure 1: $E_t \kappa^2_{t+1}$ (GARCH) versus twelve-month moving average of $abs(\Delta y_t)$

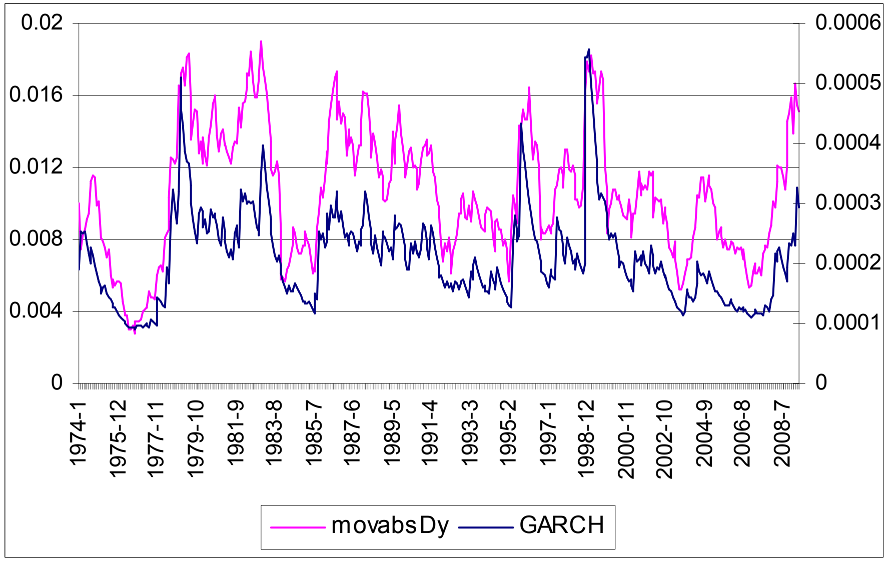
Canada



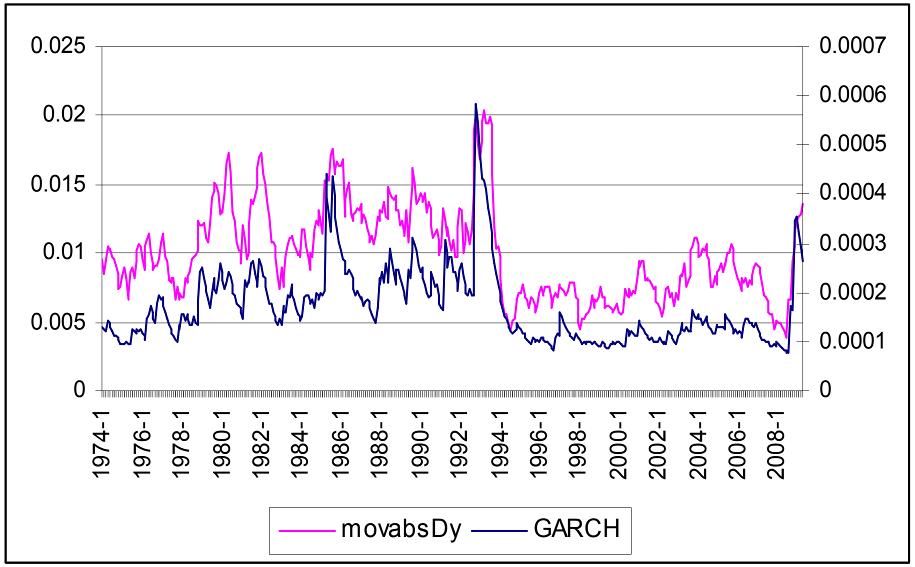
EMU



Japan



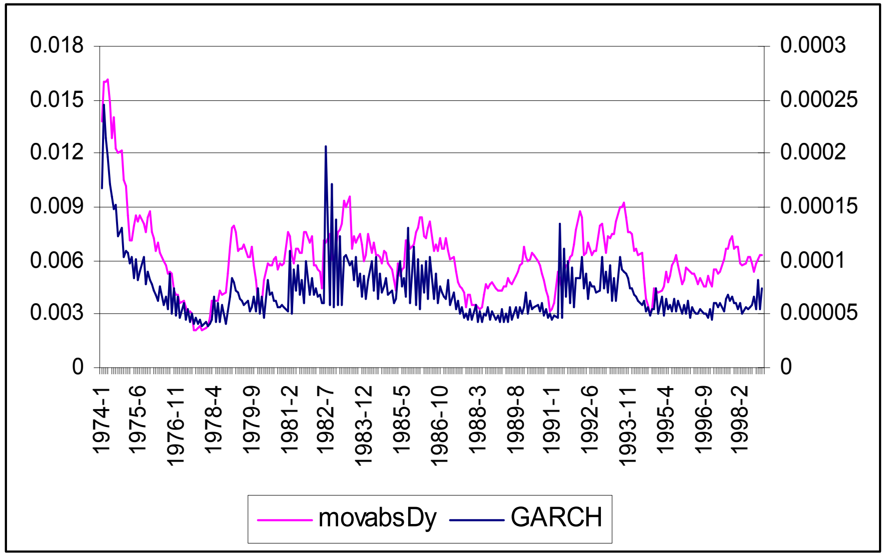
UK



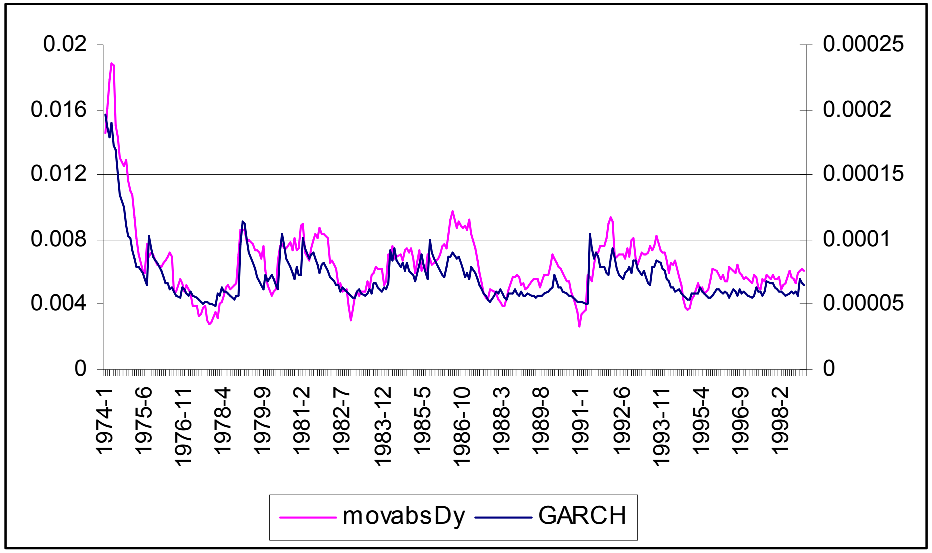
Note: Left-hand side vertical axis measures $abs(\Delta y_t)$; right-hand side vertical axis measures κ^2_{t+1} (GARCH)

Figure 1 (continued): $E_t \kappa_{t+1}^2$ (GARCH) versus twelve-month moving average of $abs(\Delta y_t)$

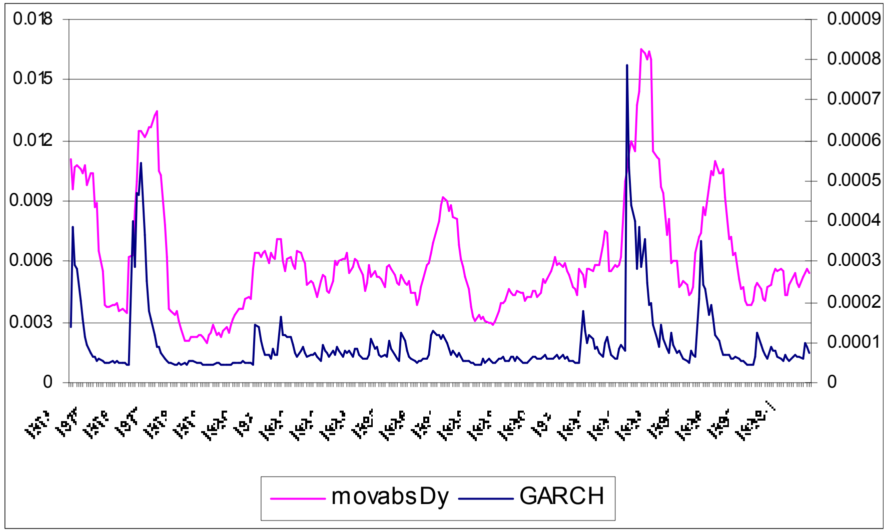
France



Germany



Italy



Note: Left-hand side vertical axis measures $abs(\Delta y_t)$; right-hand side vertical axis measures κ_{t+1}^2 (GARCH)