Asymmetric Volatility Spillovers between Stock Market and Real Activity: Evidence from UK and US

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Abstract

By estimating bivariate EGARCH (2, 1) models, we find significant short run dynamic relations between stock market and real activity for the UK and the US over the period 1970-2002. There is evidence of significant reciprocal volatility spillovers between the two sectors within a country, implying stronger interdependencies in UK rather than in US. Volatility spillovers, transmitted via the balance sheet channel, are found to be asymmetric only in the case of UK. Namely, a negative shock in the stock market increases volatility in the real economy more than a positive shock.

Keywords: Stock market, real activity, volatility spillovers, UK, US.
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1. Introduction

The present study examines the relation between real stock returns and real industrial production (IP) growth for the UK and the US. There is a plethora of empirical works dealing with this issue especially in developed countries. For the US, Fischer & Morton (1984), Barro (1990), Fama (1990), Schwert (1990) have found that real stock returns can lead changes in real activity. Furthermore, Hassapis & Kalyvitis (2002), using Granger causality in a VAR framework, and Choi et al. (1999), using the bivariate out-of-sample prediction test of Ashley et al. (1980) (AGS) also found evidence of causality from US stock returns to US industrial production growth. Under the framework of a VAR analysis, Lee (1992) and Rapach (2001) found a significant positive relation between stock returns and real activity in US. Nasseh & Strauss (2000), using a VECM, found significant long run relationships between stock prices and industrial production in five European countries, including the UK. Other studies in that field are Asprem (1989) and Estrella & Mishkin (1998). Although, the main interest is focused on developed countries, a study which examines this issue in developed as well as developing countries is that of Mauro (2003). He states that stock market developments should be taken into account in forecasting output, in both developed and developing countries. However, all these studies have not tested if volatility in one sector can be imported to the other. Most importantly, they have not taken into account any possible asymmetries in the volatility transmission mechanism between stock market and real economic activity.[1]

In this work, we attempt to examine the short run dynamic relationships between stock market and real activity for the UK and the US. Specifically, we investigate whether volatility of one sector can be transmitted to the other sector. The analysis of volatility spillovers between the stock market and real activity entails important economic and policy implications. Given that price stability and financial stability are highly complementary objectives, the question for policy makers is whether they should concern about stock market volatility. Bernanke & Gertler (2000) argue that monetary authorities should concern about asset price volatility if this is caused by

[1] However, there is a study which captures asymmetric effects, but not asymmetric volatility spillover effects. Domian & Louton (1997) have found evidence of asymmetry in the predictability of industrial production growth by stock returns for the US. Negative shocks in the stock market affect more industrial production growth than positive shocks.

"nonfundamental" factors. This is because "nonfundamental" financial instability can be seen as an independent source of real activity instability.

Moreover, we look for potential asymmetries in the volatility transmission mechanism between the two sectors, within an economy. We explicitly test whether a negative shock in one sector (for example, stock market) has exactly the same impact on the other sector (for example, real economy) with a positive shock. To capture this kind of asymmetry we estimate bivariate EGARCH (p,q) models. There are an adequate number of empirical studies which find that conditional volatility responds asymmetrically to innovations (good or bad news). For example, Koutmos & Booth (1995), Koutmos (1996) and Kanas (1998), find significant asymmetric spillover effects between international stock markets. The evidence in favor of asymmetric volatility spillovers sheds light on the selection of the appropriate monetary policy that should be applied. For example, evidence of asymmetry would imply that bad news (falling stock returns) exports more volatility to the real activity sector than good news (increasing stock returns). This means that policy makers should apply this monetary policy framework suitable for protecting real economic activity from unexpected stock market shocks in periods of financial instability.

To preview our results, we find significant bi-directional volatility spillovers between stock market and real activity for both countries. The results imply that the interdependence between the two sectors is stronger in UK rather than in US. Furthermore, asymmetric volatility spillovers effects are found only in the case of UK. Finally, the volatility transmission mechanism from stock market to real activity works out via the balance sheet channel.

The structure of the remaining paper is as follows. The next section describes the data used in this study and section 3 illustrates the econometric methodology. Section 4 presents our estimation output, while a final section summarizes and provides policy implications for developing economies.

2. Data

The data set consists of monthly observations over the period January 1970 – December 2002 for UK and US stock prices (s), UK and US industrial production (p) as well as UK and US producer price indices (ppi). Real industrial production is calculated by dividing the industrial production index by the producer price index, while its growth rate is calculated as the first difference of real IP. Real stock prices are calculated by dividing nominal stock prices by the price index, and real stock returns are calculated as the first difference of real stock prices. All variables are presented in natural logarithms. Preliminary statistics reveal that for all variables the hypothesis of normality is rejected. When it comes to the stationary nature of the variables, the ADF test provides evidence of non-stationarity for stock prices and industrial production. Accordingly, real stock returns and real IP growth rate appear to be stationary. The Johansen's trace test for cointegration between industrial production and stock prices, within a country, implies no evidence of long-run cointegrating relation. Given that real stock returns and the real IP growth rate are stationary, and that there is no cointegration, a VAR model for real stock returns and real IP growth rate should be used.[2]

3. Econometric Methodology

The dependence and the volatility spillovers between stock market and real activity are examined through a VAR-EGARCH model introduced by Nelson (1991).[3] The reason for employing the Exponential GARCH model is our concern on the asymmetric effects. A competitive GARCH model, which captures the asymmetric effect as well, is the Quadratic GARCH developed by Engle (1990). However, Engle & Ng (1993) and Hamilton (1994) provide evidence of better performance of the EGARCH model. One of the characteristics of the EGARCH (p,q) model is the log form of the conditional

[2] Data sources as well as evidence of preliminary statistics are provided in the Appendix section. The Johansen test implies no evidence of cointegration at 1% significance level. The Engle-Granger cointegration test implies stronger evidence against cointegration. The latter test is not reported. However, it is available on request.

[3] Actually, Nelson (1991) introduces the univariate EGARCH model.

variance, which guarantees the positive value of the variance. Here we employ a bivariate EGARCH (2,1) model[4], shown below:

$$r_t = \alpha_{r,0} + \sum_{i=1}^{k} \alpha_i \cdot r_{t-i} + \varepsilon_{r,t} \tag{1}$$

$$y_t = \alpha_{y,0} + \sum_{j=1}^{k} \alpha_j \cdot y_{t-j} + \varepsilon_{y,t} \tag{2}$$

$$\begin{aligned}\sigma_{r,t}^2 = \exp\{ & a_{r,0} + b_{r,1}\log(\sigma_{r,t-1}^2) + b_{r,2}\log(\sigma_{r,t-2}^2) + \delta_{rr}[(|z_{r,t-1}| - E|z_{r,t-1}|) + \vartheta_{rr} z_{r,t-1}] \\ & + \delta_{ry}[(|z_{y,t-1}| - E|z_{y,t-1}|) + \vartheta_{ry} z_{y,t-1}]\}\end{aligned} \tag{3}$$

$$\begin{aligned}\sigma_{y,t}^2 = \exp\{ & a_{y,0} + b_{y,1}\log(\sigma_{y,t-1}^2) + b_{y,2}\log(\sigma_{y,t-2}^2) + \delta_{yy}[(|z_{y,t-1}| - E|z_{y,t-1}|) + \vartheta_{yy} z_{y,t-1}] \\ & + \delta_{yr}[(|z_{r,t-1}| - E|z_{r,t-1}|) + \vartheta_{yr} z_{r,t-1}]\}\end{aligned} \tag{4}$$

$$\sigma_{r,y,t} = \rho_{r,y} \cdot \sigma_{r,t} \cdot \sigma_{y,t} \tag{5}$$

Equations (1) and (2) stand for the conditional mean equations where r_t is real stock return; y_t is real IP growth rate and ε_t is the stochastic error, which is assumed to be normally distributed with zero mean and variance σ_t^2. Conditional variance equations are presented by (3) and (4). Under the framework of the EGARCH model, the variance of the error term depends on its past values as well as on past values of the standardized residuals. So, in equation (4), the conditional variance equation for the real activity is a function of the lagged standardized residuals from the stock market ($z_{r,t-1} = \varepsilon_{r,t-1} / \sigma_{r,t-1}$) and of its own lagged standardized residuals ($z_{y,t-1} = \varepsilon_{y,t-1} / \sigma_{y,t-1}$).

The terms b_r & b_y measure the volatility persistence in stock market and real activity, while δ_{rr} & δ_{yy} capture the ARCH effect in the stock market and real activity,

[4] The lag lengths in the conditional variance equations, which determine the specification of the EGARCH (p,q) model, are established using the Akaike Information Criterion (AIC).

respectively. The coefficient of spillover from the real activity to the stock market is the δ_{ry}, while the spillover effect from the stock market to the real activity is represented by δ_{yr}. Since we are interested in the asymmetric nature of the spillover effects, the asymmetric volatility spillover effect is measured by ϑ. For instance, the term ϑ_{yr} measures whether a shock in the stock market affects symmetrically the real economy. This is the case if $\theta = 0$. Given that δ_{yr} is positive and significant, a negative and statistically significant ϑ_{yr} implies that a negative shock in the stock market increases volatility in the real economy more than a positive shock.

Equation (5) represents the conditional covariance ($\sigma_{r,y,t}$) which captures the relationship between the stock market and the real activity. Moreover, the term $\rho_{r,y}$ stands for the cross-variable coefficient of the standardized residuals between real stock returns and real IP growth. Following Bollerslev (1990), we assume constant conditional correlation.[5]

Finally, the log likelihood function for the bivariate EGARCH (2,1) model is given by:

$$L(\Theta) = -0.5(NT)\log(2\pi) - 0.5\sum_{t=1}^{T}(\log|S_t| + \varepsilon_t^{'} S_t^{-1}\varepsilon_t) \tag{6}$$

where N is the number of equations, T is the number of observations, Θ is the parameter vector to be estimated, ε_t is the 2x1 vector of residuals and S_t is the 2x2 conditional variance-covariance matrix: $\begin{pmatrix} \sigma^2{}_{ry} & \sigma_{ry} \\ \sigma_{yr} & \sigma^2_{yr} \end{pmatrix}$. The maximization of the L(Θ) is undertaken by the BFGS algorithm, while statistical inference is based on robust standard errors by Bollerslev & Wooldridge (1992).

[5] This assumption makes less complex our estimation procedure. The validity of this assumption is tested in the estimation section. This is performed by the Ljung-Box test statistic applied on the cross product of the standardized residuals for the two variables.

4. Empirical Results

We estimate a bivariate EGARCH (2,1) model to examine the relation between stock returns and industrial production growth, within a country. As mentioned above, we estimate an Exponential GARCH rather than a simple GARCH model in order to capture any asymmetries in the spillover effects. Focused on the estimated parameters of the conditional variance equations, Table 1 shows that all spillover coefficients ($\delta_{rr,}$ $\delta_{yy,}$ $\delta_{ry,}$ δ_{yr}) are statistically different form zero. This implies that short-term volatility dynamics between the stock market and the real economy, within a country, are characterized by conditional heteroskedasticity. Moreover, b_r and b_y coefficients in both countries are close to unity, implying that volatility is very persistent in stock market and real activity sectors.[6]

Table 1 about here

Next, we focus on the volatility spillover effects. For the case of UK, we find positive and significant reciprocal spillovers between stock market and real activity. Spillover effects from real activity to the stock market are slightly higher than spillovers from the opposite direction. Both are significantly high, which implies that an increase in stock return volatility entails an increase in IP growth volatility, and vice-versa. The volatility transmission mechanism can be explained by two possible channels: (a) the consumption channel, and (b) the balance sheet channel. The first channel shows that changes in asset prices may affect consumption spending by affecting households' wealth. However, this channel seems not be illustrative since much of the households' investment in stocks is held in pension accounts (Bernanke & Gertler, 2000). Indeed, the empirical evidence in literature presents no strong connection between stock market movements and consumption. Instead, the second channel is the most significant one. Bernanke & Gertler (1995) show that asset price fluctuations affect real economy through their effects on the

[6] The unconditional variance is finite if b_r<1 & b_y<1.

balance sheets of households, firms and financial intermediaries. For example, a decrease in asset prices reduces the available collateral (households and firms use their assets as collateral when they are borrowing) and shrinks the borrower's ability to have access to credit capital. This can have negative short run effects on aggregate demand and long run effects on aggregate supply.

A question arises is whether volatility transmission is symmetric or asymmetric. Both spillover effects are asymmetric since θ_{ry} and θ_{yr} are statistically significant and negative. This means that a negative shock (bad news) in the stock market increases volatility in real economy more than a positive shock (good news). In other words, a fall in stock return causes higher volatility in IP growth rate than an increase in stock return. This asymmetric effect is similar to the leverage effect, which states that stock returns tend to be more volatile when stock prices are falling. As a result, negative shocks increase stock market volatility which, through the balance sheet channel, is exported to the real economy. In other words, the leverage effect works in the direction of exporting more volatility to the real sector when stock returns fall (bad news).

When it comes to the US model, significant spillover coefficients imply that volatility can be imported from one sector to the other. Specifically, both coefficients (δ_{ry} & δ_{yr}) are statistically significant and positive, implying a bi-directional spillover effect. The spillover effect from the stock market to the real activity is slightly lower than this of the opposite direction. Furthermore, spillover effects are found to be symmetric, since the asymmetry coefficients are not statistically different from zero. This finding implies that a decrease in stock returns has the same effect on IP growth volatility as an increase in stock returns. The lack of asymmetry does not mean that the leverage effect is inactive in the US stock market. The leverage effect may hold but the applied US monetary policy may have weakened the linkage between the stock market and the real activity sector so that the leverage effect cannot export "extra" volatility to the real sector. In line with this statement, Bernanke & Gertler (2000) argue that an asset price decline may not affect the real economy only if balance sheets are initially strong. This is actually the case for the US economy during the 1990's (US balance sheets were in excellent condition). In addition, a negative shock in the stock market may have only transitory effects on the real economy if the appropriate monetary policy is applied. This policy is the inflation targeting regime applied by the FED during the 1990's. The key fact of this regime is that monetary authorities adjust interest rates in front of stock market instability in order to isolate the real economy from financial instability. Specifically, they apply the "leaning against the wind" policy, increasing interest rates when stock prices rise and reducing them when stock prices are falling. By lowering interest rates (i.e. expansionary monetary policy) in front of stock prices decline, the balance sheet channel has a neutral effect on the transmission mechanism reducing the vulnerability of the real economy. Namely, monetary policy easing makes access to credit less complex even if balance sheets become worse as a result of stock market losses.

Comparing the results from the UK model with those from the US model, we observe that in each economy both sectors are characterized by a dynamic short-run relationship, implying a bi-directional volatility spillover effect. The size of the spillover effects in UK is much higher than the corresponding spillovers in US. This means that there is stronger interdependence between stock market and real activity in UK rather than in US. This is also explained by the applied monetary policy in US, as outlined above. Similar results are derived from Laopodis (2006), who fails to find supportive evidence of the view that stock returns signal changes in future real activity in US. The author states that a possible explanation of this finding is that volatility in stock prices comes from "nonfundamental" factors. In this case, monetary authorities apply the appropriate monetary policy in order to weaken the link between the stock market and economic activity.

Moreover, there is evidence of symmetric spillover effects only in the case of US. In contrast, bad news in UK stock market increases volatility in UK real activity more than good news. A fall in stock returns causes excess stock market volatility in UK because of the leverage effect. So, the increased stock market volatility is exported, via the balance sheet channel, to the real sector. On the other hand, although US stock market does not escape from the leverage effect, the applied US monetary policy in the form of an implicit inflation targeting regime works as a shield, insulating the real economy from the stock market in periods of high financial instability.

Finally, we apply diagnostic tests, shown in Table 2, on the standardized residuals and cross standardized residuals to confirm robustness of our estimation.

Table 2 about here

The Ljung-Box statistics, applied on the standardized and squared standardized stock market-residuals, imply than in both models the residuals are serially uncorrelated. On the other hand, the same test applied on the standardized real activity-residuals implies, for both models, evidence of autocorrelation in the residuals. For the case of UK, serial correlation can be eliminated by including higher order of lags (i.e. 16 lags). In contrast, we cannot soak up serial correlation for the US, even by including higher order of lags. The Ljung-Box test statistic, applied on the cross product of the standardized residuals for the two variables, implies that the assumption of constant correlation can be accepted for both EGARCH models. Therefore, the validity of the above assumption and the robustness of our estimation are confirmed.

5. Conclusion

In this study we attempt to identify the short-run dynamic relationships between stock market and real economy for the cases of UK and US. Estimating bivariate EGARCH (2,1) models we find that volatility in both sectors is very persistent. Moreover, we find evidence that volatility from one sector can be transmitted to the other, implying significant interdependencies between stock market and real activity, within an economy. Although, there is evidence of stronger interdependence in UK rather than in US, volatility spillovers are found to be symmetric only in the case of US. This finding seems not to be strange if we examine the objectives of the monetary policy framework applied by the FED. The symmetric nature of the spillover effects means that negative shocks (bad news) and positive shocks (good news) in the stock market affect real activity's volatility in the same way. However, this does not happen in the case of UK. In line with the leverage effect, a decrease in UK stock returns has a greater effect on the volatility of the UK real activity than an increase in returns. Conversely, a decline in US stock returns affects equally US real sector's volatility as an increase in stock returns. Though US stock market does not escape from the leverage effect, the FED's policy to insulate the real economy from stock market instability explains the lack of asymmetry in the volatility spillover effects for the case of US. Accordingly, the volatility transmission mechanism from stock market to real economy for both countries is based on the balance sheet channel.

Beyond the above explanation, this study provides lessons for policy makers, especially in developing countries with unstable financial markets. So, the lesson states that policy makers should concern about financial instability and take steps in order to protect real activity from unexpected instability shocks. An appropriate monetary policy framework is of the form of flexible inflation targeting, adjusting interest rates in a stabilizing way in case of stock market instability. The necessity of policy steps is even stronger when stock returns are falling because the leverage effect produces more stock market volatility. Thus, in periods of high financial instability, monetary authorities should adjust interest rates in a systematic way until the economy and the financial system are stabilized. In front of stock prices decrease, the loosening of the monetary policy (i.e. lower interest rates) inactivates in some degree the balance sheet channel, making real economic activity less vulnerable to financial distress.

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APPENDIX

Data Sources:

UK producer price index: Monthly Digest of Statistics, various issues.

US producer price index: Monthly Digest of Statistics, various issues.

UK industrial production: Monthly Bulletin of Statistics, United Nations.

US industrial production: Monthly Bulletin of Statistics, United Nations.

UK stock prices: Monthly Bulletin of Statistics, United Nations.

US stock prices: Monthly Bulletin of Statistics, United Nations.

Preliminary Statistics

	UK		**US**	
	r	**y**	**r**	**Y**
Mean	0.0009	-0.004	0.002	-0.001
Median	0.007	-0.002	0.005	-0.0001
Standard Deviation	0.05	0.01	0.04	0.01
Skewness	-0.16	-0.69	-0.64	-1.26
Kurtosis	10.04	11.47	5.38	7.00
Jargue-Bera (probability)	820 (0)	1218 (0)	121 (0)	370 (0)

Unit Root Test

Variable	Augmented Dickey-Fuller Exogenous Term (lags)	Statistic (probability)
UK s	None (3)	1.83 (0.98)
UK r	None (0)	-17.55 (0.00)
UK p	Constant (8)	-2.71 (0.07)
UK y	Constant & Trend (0)	-21.56 (0.00)
US s	Constant & Trend (0)	-2.17 (0.49)
US r	None (0)	-19.04 (0.00)
US p	Constant (14)	-2.27 (0.18)
US y	Constant & Trend (2)	-7.45 (0.00)

MacKinnon (1996) one-sided p-values are shown in parentheses.

s = real stock prices

p = real industrial production

r = real stock returns

y = real IP growth

Johansen Cointegration Test

No. of Cointegrating Vectors	UK (s & p)	US (s & p)
	Trace Statistics (probability)*	
None	16.29 (0.01)	14.94 (0.01)

* MacKinnon (1996) one-sided p-values are shown in parentheses.
s = real stock prices
p = real industrial production

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Table 1: Bivariate EGARCH (2,1) model

Parameters	UK	US
b_r	0.97*	0.95*
	(76659)	(1704)
b_y	0.98*	0.93*
	(113580)	(1163)
δ_{rr}	0.31*	-0.06*
	(1677)	(-3.17)
δ_{yy}	0.57*	0.15*
	(1512)	(4.67)
δ_{ry}	0.68*	0.18*
	(2096)	(6.84)
δ_{yr}	0.43*	0.14*
	(2268)	(4.32)
θ_{ry}	-0.08*	0.013
	(-566)	(1.91)
θ_{yr}	-0.09*	-0.014
	(-310)	(-0.88)
ρ_{ry}	0.05	0.06
	(0.96)	(1.64)
Log Likelihood	***1608.67***	***1880.98***

* denotes statistically different from zero
robust t-statistics in parentheses

Table 2: Diagnostics

	UK	US
Residuals – Stock Market		
LB (4)	2.55	0.60
LB^2 (4)	2.55	1.57
Residuals – Real Activity		
LB (4)	13.52*	19.26*
LB^2 (4)	6.39	0.16
Cross Product		
LB (4)	1.15	0.95
LB^2 (4)	1.27	0.19

* denotes statistically different from zero.
LB(4) and LB^2 (4) are the Ljung-Box statistics for standardized and squared standardized residuals using 4 lags, which follows the $X^2(4)$ distribution.