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1. Introduction

Understanding and predicting the temporal dependence in the volatility of Euro exchange rate responding to the macroeconomics factors is important for many issues in risk analysis for global financial practices, especially for participating in unstable European financial market during recent years. Coming along with global economy slowing-down, the first season of 2016 was covered by an atmosphere of uncertainty and anxiety. The dovish monetary policy, which had adopted by the majority of central banks within Eurozone, joint its force to the significance of risks in European financial market: Mark Carney, the governor of Bank of England, declared in his speech on Jan 19\textsuperscript{th} that the British economy is not yet strong enough to contemplate raising rates from crisis-era lows, which made GBP-EUR slide to 0.76 and EUR-USD exchange rate surged to 1.09; Mario Draghi, the president of European Central Bank, followed the trail of Mark Carney announced that ECB “would prefer” to maintain their monetary policy unchanged and expanding the total amount of Quantitative Easing, which made a rapid appreciation on Euro exchange rate. Moreover, Euro exchange market was also witnessed a series of significant fluctuation affected by recent political and social events, such as Refugee Crisis, Brexit and Terrorist Attack in Belgium and France. Even though the observed fluctuation had already increased systematic risks in European financial market, it also provides investors with an ocean of opportunities and methodologies to “beat the market”. Therefore, it could be critical for financial participators to understand and analysis the relationships between macroeconomics factors and European financial market volatility.

Focusing on EUR-USD exchange rate volatility, this paper continues as following: Section 2 represents literature review following with factor analysis in section 3; section 4 will introduce data and methodology employed in this research; Section 5 will discuss the results generated from models following with the conclusion in section 6.

2. Literature Review

The series of recent empirical evidences provide a brief view about how macroeconomics factors affect the Euro Exchange rate. The investors worldwide were struggling from the collapse of Oil
market, the awkward inflation rate report, accelerated tension in middle-Eastern world and pessimistic global economic growth rate. At end of the month of 2016, the EUR-USD rate was reported to bottom at the 1.14095, almost 3000 base point decrease comparing to that of July 2014, the highest point since Greek Debt Crisis from 2010. The most dramatic daily volatile, approximately 150 based point picked at 1.12197, appeared after the European Central Bank unleashed a “bigger-than-expected” package of measures to stimulate the Eurozone economy, with expanded quantitative easing, incentives to banks to increase lending and further interest rate cuts, reported by Iran Daily (2016).

Researchers also focus their attention on the association between the volatility of Euro exchange rate and relevant changes in macroeconomics factors. Much of advance in empirical work on high frequency asset price volatility rooted from a series of researches conducted by Andersen and Bollerslev (1998). By analysing through a various of samples, they concluded that there existed a component structure in high frequency returns volatility that may rationalizes the stylised patterns observed in asset price volatility. Their opinion was supported by a thesis which linked Central Banks’ Open Market Operation with the respond of asset price volatility published under Bernanke and Gertler (2001)’s byline. Moreover, Gorter, Jacobs and Haan (2008) also analysed the ECB’s monetary policy by employing the Taylor Rules and had fund that the expected Eurozone inflation and output growth affected ECB’s decision on setting interest rate. The power of inflation absorbed Fuhrer and Tootell (2008)’s attention and they had taken inflation into the analysis of relationships between US equity value and FOMC (Federal Open Market Committee)’s manoeuvres. Young Wook Han (2008)’s contribution also verified the inherit connection between Macroeconomics shocks and high frequency Euro-Dollar exchange rate. Employed a FIGARCH model, his research implicated that the volatility process of 15-min Dollar–Euro spot exchange rates from 1999 to 2002 were determined by macroeconomics news published from both US and EMU, such as CPI and PPI. In addition to Han’s work, in 2011, Beckmann, Belke and Hi (2011)’s research also confirmed that there existed an instable but significant relationship between time-varying exchange rates and macroeconomics fundamentals of Eurozone.

3.1 The Relationship between Forex and Inflation

Central banks around world always regard inflation rate as determination of their monetary policies. Recent years, financial activates within Euro Zone are significantly affected by “target inflation level”(Kapoor, 2014) controlled by European Central Bank. Hence, European financial market was often bumped with a significant volatile if ECB’s new inflation expectation was announced. However, there are a various of literatures arguing that the relationship between inflation and euro-dollar exchange rate is determined by the equilibrium of euro demand and supply under the situation of open economy(Ouyang,Rajan and Li, 2016;NecȘUlescu,Consuela and Luminița, 2013;Consuela and Luminița, 2013).

Based on Quantity Theory of Money (Mankiw, 2016a) the equilibrium of Euro supply and demand with respect to expected inflation could be indicated as

\[ M^d = M^s \]

\[ \frac{PY}{V} = L(Y, r + \pi^e) \]

The “\( \frac{PY}{V} \)” represents the supply of Euro\((M^s)\) which is determined by velocity of Euro\((V)\). Euro Velocity measures the number of times per €1 changes hands constrained by a given time period, Price level\((P)\) and Output level \((Y)\). The “\( L(Y, r + \pi^e) \)” represents the social demand of Euro \((M^d)\), which was dominated by output level \((Y)\) and nominal interest rate \((i)\). According to Fisher equation (Mankiw, 2016a), the nominal interest rate equals to the sum of real interest rate and expected inflation that \( i = r + \pi^e \).

Moreover, inflation in both foreign market and domestic market has a significant affect to the euro exchange rate. Based on open economy theory (Mankiw, 2016b), the “Net Export”, defined as the gap between national saving \((\bar{s})\) and national investing \((I(r))\), is affected by nominal exchange rate which is the relative price of domestic currency in term of foreign currency, and real exchange rate which is the relative price of a domestic goods in terms of basket of foreign goods. The equation of real exchange rate is indicated as following:

\[ e = \varepsilon \times \frac{P^*}{P} \]
where $e$ represents quoted exchange rate, $\varepsilon$ is the real exchange rate and $P^*$ denotes the price level quoted as USD which is determined by

$$\frac{m_{us}^{us}}{P^*} = L(Y, i) = L(Y_{us}, r_{us} + \pi_{us}^e)$$

where $m_{us}^{us}, Y_{us}, r_{us}$ and $\pi_{us}^e$ represent the quantity of USD, output level, real interest rate and expected inflation rate in United States respectively. $P$ is the price level measured by Euro which is determined by

$$\frac{m_{EU}^{EU}}{P} = L(Y_{EU}, i_{EU}) = L(Y_{EU}, r_{EU} + \pi_{EU}^e)$$

where $m_{EU}^{EU}, Y_{EU}, r_{EU}$ and $\pi_{EU}^e$ represent the quantity of Euro, output level, real interest rate and expected inflation rate within Eurozone respectively. This equation could be rewritten as following:

$$\frac{\Delta e}{e} = \frac{\Delta e}{\varepsilon} + \frac{\Delta P_{us}^{us}}{P_{us}^{us}} - \frac{\Delta P_{EU}^{peu}}{P_{EU}^{peu}}$$

$$\frac{\Delta e}{e} = \frac{\Delta e}{\varepsilon} + \pi_{us}^e - \pi_{EU}^e$$

Based on the analysis above, we can observe that there exists a negative relationship between exchange rate and Money supply and inflation under an open economy.

Therefore, based on the quantity theory of money, the changes in the price of inflation related financial instruments is a dramatic factor of Euro exchange rate volatility.
3.2 The Relationship Between Stocks Indexes and Forex

Researchers have already donated various empirical literatures to the association between volatility of forex rate and daily return from stocks market. A survey conducted by Bartram and Karolyi (2006) suggested that “the Euro's launch was associated with an increase in total stock return volatility, significant reductions in market risk exposures arose for nonfinancial firms both in and outside of Europe” (Bartram and Karolyi, 2006). One year later, Söhnke M. Bartram, companying with Stephen J. Taylor and Yaw-Huei Wangin, published a paper to illustrate that the dependence of equity markets within Euro Zone was significantly increased after the introduction of the common currency (Bartram, Taylor and Wang, 2007). Based on Bartram’s researches, Antell, Antell and Vaihekoski (2011) published a survey for Pricing currency risk in the stock market. Taking the equity markets of Finland and Sweden as sample, they discovered that the currency risk had already priced in both stock markets, and that the price and the risk premium were strongly linked with the floatation of the currencies, especially for Finland (Antell, Antell and Vaihekoski, 2011). Theodore Panagiotidis, who studied relationship between Market efficiency and the Euro, also concluded in his thesis that the major stock indexes in Athens Stock Exchange, such as the General ASE Composite Index and the FTSE/ASE 20, were highly affected by the weak-form efficient market hypothesis (EMH) after the introduction of the common European currency (Panagiotidis, 2010). Another survey made by Maher Asal in same year also suggested that the introduction of Euro affects the return of the majority of sectors in equity market within Euro Zone (Asal, 2011). Moreover, Arfaoui, Arfaoui and Ben Rejeb (2015) focused on Return FOREX and Stock Markets in MENA Countries MENA stock market (namely, Bahrain, Egypt, Kuwait, Morocco, the Kingdom of Saudi Arabia, Oman, Qatar and the United Arab Emirates). They believed that there exists an “interdependence mechanisms” between forex Market and equity market caused by liberalized capital flows, financial integration and sustained international diversification. By employing a VAR-GARCH model, they concluded that “incorporating foreign exchange in a full stock, unhedged portfolio increases the risk-adjusted return while reducing its variance” (Arfaoui, Arfaoui and Ben Rejeb, 2015).

Based on the literatures above, we could conclude that volatility of European stocks market is observed as a significant macroeconomics factors affecting Euro-Dollar exchange volatility.
4. **Data and Methodology**

The daily-close prices of EuroStoxx50 index price, EUR/USD Rate and 5-year Inflation Swap Forward Rate spanning the period January 2008 to March 2016 were used for the study. This means that a total of 2095 data points are considered for each factors. The sources of data were Deutsche Bank Breakeven Inflation Swap EURO 5-Year Index, Bloomberg World Equity Indices and European Central Bank.

4.1 **Data: “The Proxy” of Macroeconomics Factors**

Though the volatility of both inflation and equity market is critical to Euro exchange risk, it is also a problem to match those factors with daily published Euro-Dollar exchange rate. Learning from related literatures, employing “the proxy” might be easier than using original macroeconomics factors directly. EUR 5-year Inflation swap is a common measure, which is used by central banks and dealers, to look at the market’s future inflation expectation. According to Hinnerich, Finansiell and Handelshögskolan (2008), inflation-indexed products are able to accurately reflect the investors expectation and worries on inflation and enable them to hedge future cash flow against inflation. Therefore, as one of inflation-traced products, the fluctuation of inflation swap rate represents the volatility of expected inflation in the future. As for expectation interval, 5-year inflation swap might work better than 1-year inflation swap (short-run inflation prediction) and 10- year inflation swap (long-run inflation expectation).

Graph 1 illustrates the relationship between inflation of Euro Zone and EUR 5-Year Inflation Swap Forward. During the period of both per-and post-financial crisis, the adjustment of EUR 5-year inflation swap Bid Price always followed the changes from inflation expectation. Dramatically, after the mid-2012, the return of 5-year inflation swap was slashed while the inflation rate was moving around 0% because of Greek Debt Crisis (Hope, 2012), Negative Interest Rate Policy (Stevenson, 2012) and European Quantitative Easing (Mackintosh, 2014).
Indexes could be the best proxy of performance measurement for entire equity market (Aloui, 2007). The Euro Stoxx50 index is recognized as one of leading benchmarks providing a “Blue-chip representation of super-sector leaders within Euro Zone” (STOXX.Ltd, 2016). The characteristics of EURO STOXX50 Index is described by Graph 2. The recession of European stocks started from November 7th 2007 due to the broadly concern of European companies defaulting (Hippin, 2007). Suffered from one year collapse, the potential ECB’s Sovereign Quantitative Easing forced the price of EURO STOXX50 to bottom at €1817 on February 25th, 2009 (Congdon, 2009). Experienced a 5-year turmoil, the whole European equity market witnessed a stable recovery that EURO STOXX50 Index peaked at €3829 on October 4th 2015 pushed by cooperation between ECB and IMF (Mallet, 2010).

The description above enables us to conclude that the movement of EURO STOXX 50 index not only displays the entire performance of European leading companies, but also represents the influence of economics events.
4.2 Multivariable GARCH Model and Diagonal VECH Model

Recent years have witnessed that the multivariable GARCH model becomes one of the major methodologies for risk analysis in financial market, especially the foreign exchange market. According to a survey made by Bollerslev, Engle and Wooldridge (1988), researchers used to investigate the returns of US Treasury Bills, gilts and stocks by employing the diagonal VECH model. Brooks, Henry and Persand (2002) used to analyse hedging efficiency for FTSE stocks index with a BEKK model, one of multivariable GARCH models. Brooks (2008) used to employ a diagonal VECH model to test the volatility of Euro with respect to GBP and JPY. Nortey, Ngoh, Doku-Amponsah et al. (2015) also introduced an example of analysing the relationship between exchange rate and macroeconomics factors by using a multivariable GARCH model.

A key advantage of employing a diagonal VECH model, comparing with the GARCH and ARCH model, is that it enable researches to consider affection from macroeconomics factors by specifying equations for both variances and covariances (Brooks, 2008). Additionally, the model meaningfully estimates the unknown parameters, which indicates the relationship between forex market volatility and macroeconomics factors. It also enable us to detect currency market volatility on stock market returns, derivatives market returns, and currency-stock-derivative cross-market.

Before the estimation of multivariable GARCH model, it is essential to test whether there exist
some relationships among returns of Euro-Dollar Exchange, EUR 5-year Inflation Swap and EURO STOXX50 Index. This test is conducted in two separated OLS equations:

\[ \Delta FX_t = \beta_0 + \beta_1 \times \Delta ISF_t + u_t \]
\[ \Delta FX_e = \beta_2 + \beta_3 \times \Delta STOXX_t + u_2 \]

Regarding to requirements of OLS function, some additional tests should also be processed in order to proof the validity of relationships indicated from OLS equations. These tests include Heteroscedasticity, Stationary, Autocorrelation and Stability of Parameters.

According to Brooks (2008), the Diagonal VECH model is characterised by

\[ VECH(H_t) = c + A \times VECH(\epsilon_{t-1} \epsilon'_{t-1}) + B \times VECH(H_{t-1}) \]

where \( C \) is a vector of constants, while \( A \) and \( B \) are the parameter matrices for ARCH and GARCH terms, respectively. Assuming that relationship among variables was valid, the VECH model could be arranged by

\[ H_t = \begin{bmatrix}
\text{VAR}(\Delta STOXX_{t-1}) & \text{COV}(\Delta STOXX_{t-1}, \Delta FX_t) & \text{COV}(\Delta STOXX_{t-1}, \Delta ISF_t) \\
\text{COV}(\Delta FX_t, \Delta STOXX_{t-1}) & \text{VAR}(\Delta FX_t) & \text{COV}(\Delta FX_t, \Delta ISF_t) \\
\text{COV}(\Delta ISF_t, \Delta STOXX_{t-1}) & \text{COV}(\Delta ISF_t, \Delta FX_t) & \text{VAR}(\Delta ISF_t)
\end{bmatrix} = \begin{bmatrix} h_{11,t} & h_{12,t} & h_{13,t} \\
    h_{21,t} & h_{22,t} & h_{23,t} \\
    h_{31,t} & h_{32,t} & h_{33,t} \end{bmatrix} \]

\[ \epsilon_{t-1} = \begin{bmatrix}
\text{Residual}(\Delta STOXX_{t-1}) \\
\text{Residual}(\Delta FX_{t-1}) \\
\text{Residual}(\Delta ISF_{t-1})
\end{bmatrix} = \begin{bmatrix} u_{1,t-1} \\
u_{2,t-2} \\
u_{3,t-3} \end{bmatrix}, \quad c = \begin{bmatrix} c_{11} \\
c_{12} \\
c_{13} \\
c_{23} \\
c_{33} \end{bmatrix} \]

where \( H_{it} \) where \( i = j \) represent the **conditional variance** of two-return series at time \( t \) and \( H_{ij} \) where \( i \neq j \) represent the **conditional covariance** of two-return series at time \( t \).

\[ VECH(H_t) = \begin{bmatrix}
h_{11,t} \\
h_{12,t} \\
h_{13,t} \\
h_{22,t} \\
h_{23,t} \\
h_{33,t} \\
\end{bmatrix} \]

\[ \epsilon_{t-1} \epsilon'_{t-1} = \begin{bmatrix} u_{1,t-1} \\
u_{2,t-1} \\
u_{3,t-1} \end{bmatrix} \times \begin{bmatrix} u_{1,t-1} \times u_{2,t-1} \\
u_{2,t-1} \times u_{3,t-1} \\
u_{3,t-1} \times u_{2,t-1} \end{bmatrix} = \begin{bmatrix} u_{1,t-1}^2 & u_{1,t-1} \times u_{2,t-1} & u_{1,t-1} \times u_{3,t-1} \\
u_{2,t-1} \times u_{1,t-1} & u_{2,t-1}^2 & u_{2,t-1} \times u_{3,t-1} \\
u_{3,t-1} \times u_{1,t-1} & u_{3,t-1} \times u_{2,t-1} & u_{3,t-1}^2 \end{bmatrix} \]

Therefore,

\[ VECH(\epsilon_{t-1} \epsilon'_{t-1}) = VECH \]

\[ \begin{bmatrix}
u_{1,t-1}^2 \\
u_{1,t-1} \times u_{2,t-1} \\
u_{1,t-1} \times u_{3,t-1} \\
u_{2,t-1} \times u_{1,t-1}^{2} \\
u_{2,t-1} \times u_{3,t-1} \\
u_{3,t-1} \times u_{1,t-1}^{2} \\
u_{3,t-1} \times u_{2,t-1}^{2} \end{bmatrix} \]

Hence, the diagonal VECH model employed in full is given by

\[ h_{11,t} = c_{11} + a_{11} \times u_{1,t-1}^{2} + b_{11} \times h_{11,t-1} \]
\[ h_{22,t} = c_{22} + a_{22} \times u_{2,t-1}^{2} + b_{22} \times h_{22,t-1} \]
\[ h_{33,t} = c_{33} + a_{33} \times u_{33,t-1}^2 + b_{33} \times h_{33,t-1} \]

\[ h_{12,t} = c_{12} + a_{12} \times u_{1,t-1} \times u_{2,t-1} + b_{12} \times h_{12,t-1} \]

\[ h_{13,t} = c_{13} + a_{13} \times u_{1,t-1} \times u_{3,t-1} + b_{13} \times h_{13,t-1} \]

\[ h_{23,t} = c_{23} + a_{23} \times u_{2,t-1} \times u_{3,t-1} + b_{23} \times h_{23,t-1} \]

5. Empirical Results and Discussion

5.1 Descriptive Statistics for Endogenous Variable

Table 1 presents the descriptive statistics for endogenous variables in VECCH model along with the European financial market. The mean daily changes for Euro Stoxx50, Euro exchange rate and 5-year Euro Inflation Swap Forward Rate are all negative array from -0.000156, the minimum average daily price volatile to -0.637535, the maximum daily average daily price change. These negative average returns have generated a picture of European financial market turmoil after Financial Crisis from 2007.

Table 1. Descriptive Statistics for Endogenous Variables

<table>
<thead>
<tr>
<th></th>
<th>ΔEurostoxx50</th>
<th>ΔEURUSD</th>
<th>ΔInflation Swap Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-0.637535</td>
<td>-0.000156</td>
<td>-0.000513</td>
</tr>
<tr>
<td>Median</td>
<td>-0.070000</td>
<td>0.000100</td>
<td>0.000000</td>
</tr>
<tr>
<td>Maximum</td>
<td>266.4500</td>
<td>0.055700</td>
<td>0.219500</td>
</tr>
<tr>
<td>Minimum</td>
<td>-292.1200</td>
<td>-0.067600</td>
<td>-0.196000</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>44.64484</td>
<td>0.008932</td>
<td>0.033114</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.078988</td>
<td>-0.210214</td>
<td>-0.180992</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>7.385335</td>
<td>6.960732</td>
<td>8.228047</td>
</tr>
<tr>
<td>Jarque-Bera</td>
<td>1679.294</td>
<td>1383.487</td>
<td>2395.047</td>
</tr>
<tr>
<td>Prob of B-J Test</td>
<td>0.000000</td>
<td>0.000000</td>
<td>0.000000</td>
</tr>
</tbody>
</table>

According to the standard deviations, the daily change of EUR/USD Rate is the least volatile series with a standard deviation of 0.008932 while the daily return of Euro Stoxx50 could be considered as the most volatile series with a standard deviation of 44.64484. This big difference in the standard deviation of daily return among endogenous variables indicated that stability of the European equity market was pumped with a huge volatility comparing with the Forex market and the derivatives market during both pre-and post-financial crisis periods.

Based on the skewness statistics estimated which are very close to 0, all endogenous variables are slightly left skewed. As expected with high frequency financial return series, the assessments of kurtosis are all more than 3 for all endogenous variable (Islam, Islam and Chowdhury, 2013).
Statistics of both skewness and kurtosis represent a nearly symmetric distribution that the series are spiker around mean with balanced tails on both sides. Additionally, Bera-Jarque Statistics shows that the null hypothesis of normal distribution at 1% of significance cannot be rejected for all those endogenous variables.

5.2 Relationship Validity among Variables

The accuracy of result highly depends on the validity of relationships among variables employed in the model. In order to test this, an ordinary least squares (OLS) estimation is often employed according to a various of literatures (Floros, 2008; Danmola, 2013). To be more specific, an OLS estimation is suitable for evaluating the affection of both inflation expectation and stock index to Euro exchange rate. Here are the two equations employed in this process and results are listed on Table 2 and Table 3

\[
\Delta \text{usdeuro}_t = c + \beta \times \Delta \text{inflationswaprate}_t + u_1 \quad (\text{Eq01})
\]

\[
\Delta \text{usdeuro}_t = c + \alpha \times \Delta \text{eurostoxx}_t + u_2 \quad (\text{Eq02})
\]

Before the conduction of equation estimation, we need to ensure all data employed are stationary. Table 2 collects the results from Augmented Dickey-Fuller Test for all of endogenous variables. The null hypothesis of having one-unit root for all variables should be rejected at 1% level of significance.

The upper chart of table 3 illustrates the correlation coefficient of daily changes in Euro Inflation Swap Forward Rate and Euro Stoxx50 Index, as statistics are showed above, independent variables are highly significant to the dependent variable at 99% confidence level.
The results reported in lower chart of Table 3 presents goodness of fit for both $Eq_{01}$ and $Eq_{02}$. Even though the statistics of R-square and adjusted R-square are insignificant, the standard errors of regression, a broad measure of fit of regression, are relatively small which means that the regressions are much closer to the fit line to the actual data (Brooks, 2008). Therefore, based on the conclusion above, we can conclude that $Eq_{01}$ and $Eq_{02}$ could well explain the relationship between daily changes in Euro exchange rate and daily return from Inflation swap forward rate, as well as the connection between the volatility in daily price of Euro Stoxx50 index and Euro Currency price quoted as USD. This goodness of fit could also be proved by the high Log Likelihood Statistics and p-value of F-test statistics which indicate that the parameters of all independent variables are significantly different from 0. Moreover, Durbin-Watson statistics , which are both close to 2 for both $Eq_{01}$ and $Eq_{02}$, suggest that the error terms of both estimated equation are free from autocorrelation (Brooks, 2008).

In addition to ordinary OLS analysis, other characteristics of regression should be also taken into consideration. Based on the assumption of OLS test, these characteristics are equally important as those showed in the results of Equation Estimation Process that included the heteroscedasticity, autocorrelation, stability of parameters and normality of residuals (Brooks, 2008).

In order to evaluate the fitness of model, additional heteroscedasticity tests were conducted on the residuals generated from $Eq_{01}$ and $Eq_{02}$ and the results, showed in Table 4, were satisfactory. The outcomes of White test implied that the null hypothesis of homoscedastic residuals at 1% level of significance is rejected for both equations.

It also important to test whether the residuals from both $Eq_{01}$ and $Eq_{02}$ are autocorrelated. If
autocorrelation were ignored, the coefficient estimates derived using OLS may be still unbiased, but they are inefficient, so that they are not BLUE even at large sample sizes, so that the standard error estimates could be wrong (Brooks, 2008). Durbin-Watson statistics from table 3 provide with a broad measure of autocorrelation suggesting that both Eq01 and Eq02 are free from autocorrelation. In addition to the Durbin-Watson test, results reported in Table 5 deliver a much more accurate conclusion by using Breusch-Godfrey test with 6 lags. The outcomes also satisfy the stipulation of OLS that the null hypothesis of non-autocorrelated residuals could not be rejected at 1% level of confidence.

Table 5. Breusch-Godfrey Serial Correlation LM Test:

<table>
<thead>
<tr>
<th></th>
<th>LM Statistics of Eq01</th>
<th>LM Statistics of Eq02</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-statistic</td>
<td>0.660248</td>
<td>0.755549</td>
</tr>
<tr>
<td>Obs*R-squared</td>
<td>3.969149</td>
<td>4.540815</td>
</tr>
<tr>
<td>Prob. F(6,2085)</td>
<td>0.6819</td>
<td>0.6050</td>
</tr>
<tr>
<td>Prob. Chi-Square(6)</td>
<td>0.6809</td>
<td>0.6039</td>
</tr>
</tbody>
</table>

In addition to heteroscedasticity test and autocorrelation test, it is important to know if the relationships among Euro Exchange Rate, European Stocks Market and Derivatives Market are stable over time. The stability of relationship relays on the stability of parameters (Brooks, 2008). If the relationships are not structurally stable, it implies that the coefficient estimates would be vary for some sub-samples of the data compared to others (Brooks, 2008). This is clearly not what we want. The chow test is often employed to test the stability of parameters.

The process of Chow test requires researchers select a specific date as a breakpoint separating total sample into two parts (Brooks, 2008). In this research, the breakpoints should be selected based on the characteristics of European Financial Market. In order to test the parameter stability of Eq01, we prefer to test equation by employing “2nd January 2012” as the breakpoint. It is a specific date after that Basel III and Dodd-Frank Act, which are the milestone of global economy recovery during the Subprime Crisis started in 2007 (Hull, 2012). As for parameter stability test of Eq02, the breakpoint date should be strongly related to the significant events in financial stocks market in both Europe and United States. Therefore, “1st March 2011” could be the best choice to test the performance of European leading companies under the supervision of Consumer Financial Protection Bureau and Financial Stability Oversight Council created by the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 (Mishkin and Eakins, 2012).
The results from the Table 6 show no evidence of parameter instability, which indicates that the parameters in both Eq01 and Eq02 should be hold during both pre- and post- financial crisis, because the null hypothesis that the parameters are stable over times couldn’t be rejected at 1% level of significance.

Table 6. Parameter Stability Test: Chow Breakpoint Test

<table>
<thead>
<tr>
<th>Breakpoint</th>
<th>Chow Statistics of Eq01</th>
<th>Chow Statistics of Eq02</th>
</tr>
</thead>
<tbody>
<tr>
<td>Null Hypothesis</td>
<td>1/02/2012</td>
<td>1/03/2011</td>
</tr>
<tr>
<td>F-statistic</td>
<td>0.921119</td>
<td>2.122771</td>
</tr>
<tr>
<td>Log likelihood ratio</td>
<td>1.844952</td>
<td>4.249355</td>
</tr>
<tr>
<td>Wald Statistic</td>
<td>1.842238</td>
<td>4.245542</td>
</tr>
<tr>
<td>F-statistic</td>
<td>0.921119</td>
<td>2.122771</td>
</tr>
<tr>
<td>Prob. F(2,2089)</td>
<td>0.3982</td>
<td>0.1200</td>
</tr>
<tr>
<td>Prob. Chi-Square(2)</td>
<td>0.3975</td>
<td>0.1195</td>
</tr>
<tr>
<td>Prob. Chi-Square(2)</td>
<td>0.3981</td>
<td>0.1197</td>
</tr>
</tbody>
</table>

5.3 Results of Diagonal VECH Model

In table 8, the own-volatility distress among Euro exchange market, European stocks market and derivatives market ($a_{1,1}, a_{1,2} \ldots a_{3,3}$) are significant and fluctuates from 0.007780 to 0.080987, suggesting the existence of ARCH effects. This illustrates that residuals are enable to impact the covariance of all variables and covariance of combination of any two variables. Observing from the Matrix of parameter $a_{ij}$, the magnitude of the estimated cross-vitality coefficient, $a_{ij}$ where $i \neq j$, is relatively smaller than own-volatility coefficient, $a_{ij}$ where $i = j$, which indicated that the past fluctuations in all variables have a significant influence on their own future unpredictability than those generated from others. Hence, it could be concluded that the volatility of EURO STOXX50, EUR 5-year inflation swap and Euro-Dollar exchange rate is significantly affected by their own lagged shocks (ARCH Influence), but their influences to currency market volatility are relatively low.

Table 8. Parameters of VECH Model.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>z-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>c(1,1)</td>
<td>32.81268</td>
<td>6.986745</td>
<td>4.696419</td>
<td>0.0000</td>
</tr>
<tr>
<td>c(1,2)</td>
<td>9.87E-05</td>
<td>0.000149</td>
<td>6.663695</td>
<td>0.5069</td>
</tr>
<tr>
<td>c(1,3)</td>
<td>0.004172</td>
<td>0.002135</td>
<td>1.954073</td>
<td>0.0507</td>
</tr>
<tr>
<td>c(2,2)</td>
<td>3.16E-07</td>
<td>8.94E-08</td>
<td>3.537417</td>
<td>0.0004</td>
</tr>
<tr>
<td>c(2,3)</td>
<td>7.50E-08</td>
<td>8.88E-08</td>
<td>0.844735</td>
<td>0.3983</td>
</tr>
<tr>
<td>c(3,3)</td>
<td>6.44E-06</td>
<td>1.38E-06</td>
<td>4.677064</td>
<td>0.0000</td>
</tr>
<tr>
<td>a(1,1)</td>
<td>0.066069</td>
<td>0.006897</td>
<td>9.580019</td>
<td>0.0000</td>
</tr>
<tr>
<td>a(1,2)</td>
<td>0.015397</td>
<td>0.003543</td>
<td>4.345474</td>
<td>0.0000</td>
</tr>
<tr>
<td>a(1,3)</td>
<td>0.025371</td>
<td>0.008176</td>
<td>3.102992</td>
<td>0.0019</td>
</tr>
<tr>
<td>a(2,2)</td>
<td>0.029755</td>
<td>0.003464</td>
<td>8.588721</td>
<td>0.0000</td>
</tr>
<tr>
<td>a(2,3)</td>
<td>0.007780</td>
<td>0.003776</td>
<td>2.060746</td>
<td>0.0393</td>
</tr>
</tbody>
</table>
The variance-covariance matrix is also presented in Table 8. The statistics of one-lag conditional variances and conditional covariance, $b_{ij}$, are all positive and significant, the magnitude of which are vary from 0.915566 to 0.980644. Contracting to ARCH influence, magnitude of cross-market coefficient, $b_{ij}$ where $i \neq j$, are relative higher than that of own-market coefficient. Moreover, it could be also observed that the coefficient of conditional covariance is lower than that of conditional variances. Those results suggest that the influence given by other market is relatively great than that from its own market. Base on the mentioned characteristics, we could conclude that there exists a valid relationship that the variances and covariances of all variables highly and positively depend on their lags (GARCH Influence).

The results from Diagonal VECH model are fully displayed as below:

$$VAR(\Delta STOXX_t) = 32.8126841876 + 0.0660689926804 \times u^2_{t-1} + 0.915566273573 \times VAR(\Delta STOXX_{t-1})$$

$$VAR(\Delta ISF_t) = 0.00000644241196501 + 0.0809871645612 \times u^2_{t-1} + 0.916370869893 \times VAR(\Delta ISF_{t-1})$$

$$COV(\Delta STOXX_t, \Delta ISF_t)$$

$$= 0.00417166292725 + 0.0253712006939 \times u_{t-1} \times u_{3,t-1} + 0.939294032076 \times COV(\Delta STOXX_{t-1}, \Delta ISF_{t-1})$$

$$VAR(\Delta FX_t) = 0.000000316161410505 + 0.0297549640369 \times u^2_{t-1} + 0.96663859068 \times VAR(\Delta FX_{t-1})$$

$$COV(\Delta STOXX_t, \Delta FX_t)$$

$$= 0.0000098714238304 + 0.0153973199502 \times u_{t-1} \times u_{3,t-1} + 0.980643591532 \times COV(\Delta STOXX_{t-1}, \Delta FX_{t-1})$$

$$COV(\Delta FX_t, \Delta ISF_t) = 0.000000075038441971 + 0.00778042117509 \times u_{2,t-1} \times u_{3,t-1} + 0.985141359672 \times COV(\Delta FX_{t-1}, \Delta ISF_{t-1})$$

Focusing on the Euro-Dollar exchange rate volatility, it could be observed from the comparison among the fully presented results that the impact of lagged residuals to covariance of $\Delta STOXX_t$ and $\Delta FX_t$ is greater than that of $\Delta FX_t$ and $\Delta ISF_t$ and this result is opposite when lagged covariances of those two combination are taken into comparison. This phenomenon illustrates that Euro Zone inflation could deliver much more influence to Euro-Dollar exchange rate volatility than that generated by European stock market. The comparison between residuals’
and covariances’ coefficients also illustrates that the fluctuation of euro exchange rate caused by stock market (or euro zone inflation) mainly depends on historical covariance rather than their shocks. Additionally, the gap between variances and covariances’ coefficient also confirms that the volatility in Euro exchange market depends more on other macroeconomics factors, such as stock market index and inflation, than previous close price.

6. Conclusion

The series of daily changes of both EURO STOXX50 index and EUR 5-Year inflation swap are best suited to measure the volatility of Euro Exchange Rate. In this paper, we employ the EUR 5-Year Inflation Swap rate as the proxy of Euro Zone inflation expectation and EURO STOXX50 index as the proxy of daily performance of European Stocks market. This paper finds that the volatility of Euro-Dollar exchange rate is dominated by European equity value and Eurozone expected inflation and is remarkably well described by the Diagonal VECH Model.

This study shows several important results. Firstly, the negative means of all variables generate a picture about European financial market recession affected by recent political and financial events. Secondly, according to results from OLS estimation, Both Eurozone expected inflation and European stocks market performance have a valid and positive association with Euro-Dollar exchange rate. Finally, based on the results given by diagonal VECH model, the volatility of daily return of Euro-Dollar exchange rate heavily depends on the its lagged variance and covariance. In particular, taking macroeconomics factors into consideration, it appears that the volatility of euro-dollar exchange rate depends more on Euro Zone inflation expectation than daily European stocks market performance.
7. Reference


