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"French Tobin tax and its effect on CAC40 stock market volatility"

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ABSTRACT:

Much debate has been given to the Tobin tax in Spain since the 2019 state budget proposal. Intended to stabilize financial markets by curbing speculative behavior, the effect of Tobin tax is studied for the case of France. Daily closing values of CAC40 and VCAC40 indexes, for the period 2000-2019, are used to model volatility as the variance in stock market returns and percentage change in VCAC index. GARCH family type of models are used to conclude that the Tobin tax helps reducing stock market volatility but in a very small amount.

Key words: heteroskedasticity, stock market returns, volatility clustering, Tobin tax

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1. Introduction

Stock market volatility, understood as big swings in stock prices, has raised concerns of policy makers in Europe since 2008 Great Recession. The idea behind the so-called "Tobin tax"[1] is the implementation of an FTT, an ad-valorem Financial Transaction Tax. According to the Efficient Market Hypothesis increasing transaction costs should curb speculative behavior and enhance long term or fundamental investment. Problem arises when rational agents are driven away from the market as its liquidity goes down which further amplifies volatility to the benefit of arbitragers. Due to scarcity of literature on theoretical models and the mixture of its results, this study will empirically test the effect of the Tobin tax on stock market volatility.

The Spanish 2019 General State Budget proposal failed to be approved, thus the effects of the Tobin tax on stock prices' volatility cannot yet be studied. As a result, the aim of this paper is to give Spanish policymakers a hint on the subject by reviewing the overall performance of the tax in France. Inspired by the French system, the Spanish Tobin tax aims to replicate the design and mechanisms of their neighboring partner. In practice the Tobin tax in France is an STT, Security Transaction Tax. A tax rate of 0.02% is charged at the transfer of ownership of French equity securities. Only companies above one billion euros of market capitalization and high liquidity ratio would be subject to the tax. Such companies amount to those listed in the CAC 40 index, the Paris stock market. Subject to those same characteristics are all companies listed in IBEX35, the target companies of Spanish government. Despite its market stabilizing goal, the tax has been used as a political tool. Low tax rate and broad tax base have been the two key attractive components. Instead, easiness of its avoidance is its biggest critic. Only financial intermediaries operating in France are subject to the tax. Added to that stocks

[1] Named after American economist James Tobin in 1972, its original purpose was to lower exchange rates volatility

purchased and sale within the same day are not are subject to the tax. Average Tobin tax revenues in France are below one billion euros, whereas in the UK, the stamp duty tax[2] collects and average revenue in between 2.5 and 4.0 billion pounds per year. Given this amount empirical proof of the Tobin tax efficiency is worth considering specialize after bailouts granted during EMU[3] crises.

As opposed to theoretical models' empirical findings often tend to either reject the effectiveness of FTTs on reducing volatility or actually argue that under certain circumstances it does increase it. (Bratis, Laopodis & Kouretas, 2017) make use of the GARCH family type models to measure volatility of French stock market. They test the significance of the announcement of the Tobin tax on abnormal market returns. Concluding that the announcement had no significant effect as they ague French Tobin tax will only be significant if applied globally. If not, arbitrage opportunities may arise with tax heaven being target of capital outflows.

In (Deng, Liu & Wei, 2018) double differencing approach is used to compare companies listed in both Hong Kong stock market and Mainland China market. These markets are of interest as they are subject to different tax rates. They conclude that the effect depends on the maturity of the market. In immature markets marked by speculative behavior the Tobin tax reduces volatility significantly. Instead in more mature markets, it discourages both noise traders and fundamental investors. Dragging down liquidity and further increasing volatility. (Capelle-Blancard, Havrylchyk, 2016) follows the same approach but instead of comparing firms in two different markets, it compares small French firms, not subject to the tax with big firm's subject to it. He concludes that the Tobin tax does not mitigate speculative behavior as it does not affect

[2] British counterpart of the Tobin tax

[3] EMU stands for European Monetary Union

volatility neither market liquidity. Reason for it is found to be in the fact that 85% of overall transactions are exempted from the tax. While none of the previous studies found significance for the French case (Becchetti, Ferrari & Trenta, 2014) found significance. Likewise, diff-in-diff is used by looking at intraday volatility and turnover measures of volatility rather than stock indexes. They conclude the FTT reduces trading volume and volatility significantly, with respect to liquidity the effects are not so clear.

The aim of this paper is to look at the effect of the Tobin tax in volatility but from a different perspective than diff-in-diff. Only volatility will be taken into account, neither liquidity nor traded volume. CAC40 index and VCAC40 index will be the two subjects of study. VCAC 40 index is an index of the volatility of all companies listed in CAC40 index. The idea behind this paper is simple. Capture two different measures of French stock market volatility and compare the performance of the Tobin tax across them. Tobin tax will take its form in this study as a dummy variable rather than its actual value. Several dummies will also be included to control for economic cycle at the moment, either in the form of recession dummies or just months of economic deceleration. GARCH family type of models will be used in order to capture the presence of time-varying variance and heteroskedasticity of financial time series. First approach to model variance willlook at the variance in the rate of return on CAC40 index. Second approach instead will look at the growth rate of VCAC index.

The structure of the paper is as follows. Section 2 provides information about my data set and the methodology used to capture stock market volatility. In section 3 data processing and main empirical results will be presented to judge the performance of the Tobin tax compared across models. And finally, section 4 states my conclusions about CAC40 index and its Tobin tax effect.

2. Data

2.1 Data set

The data set used in this study comprises daily realizations of CAC40 & VCAC indexes, Monday to Friday, for the period January 3rd, 2000 to March 31st, 2019. Several sources have been used for its construction. Daily realizations of CAC40 and VCAC indexes have been obtained from Yahoo Finance and Investing.com respectively. VCAC index series was firstly constructed on January 2000, thus limiting the time frame to be studied. OECD indicator of business cycles have been obtained from FRED.

2.2 Variables

Independent Variables:

- *R*: Stok Market Returns are measured as the logarithim rate of change of CAC40 index prices. Pt represents dailay closing price of CAC40 index at time t, and Pt-1 is the index at day t-1. Therefore the daily growth rate of prices represents daily stock market

$$R_t = 100 * ln(P_t/P_{t-1})$$

- *CACvol*: represents the volatility growth rate of VCAC also measured as the logarithmic rate of change in order to capture volatility changes in more familiar terms.

$$CACvol_t = 100 * ln(VCAC_t/VCAC_{t-1})$$

Dependent Variables:

Main Explanatory Variable of Interest:

- d_tobin: Dummy variable taking a value of 1 for every day after the implementation of the tax on August 2012.

Economic Variables {X's}: Looking at Figure 2.1.1 and Figure 2.1.2 in the appendix, economic cycle and stock volatility appeared to be correlated. (Schwert,1989) and (Schwert,1989, September) reinforce the idea of stock's price movement being a business cycle predictor. On the other hand (Corradi, Ditaso and Mele, 2013) found that business cycles help explain more than 75% variation of the VIX[4] for the period 2007-2009 subprime crises. In this study I control for such relationship by including two dummy variables.

- d_deceleration: dummy variable taking a value of 1 for all days within a month declared as a recessionary period. Zero for all those months of expansionary periods. Therefore, this variable shows economic turning points, showing just economic GDP growth.
- d_Recession: dummy variable taking a value of 1 for all days within a quarter officially declared as recessionary period.

It may look senseless to make use of both dummy variables as they seem to measure the same thing. Far from that, there are many more months of economic deceleration than there are of actual recessions being declared. Reason for that lies on the requirements for such official declaration compared to those of just concluding that GDP, during a month, has grown less than previous ones without further implications. At same time, recessions are declared far after the recession has happened, while economic turning

[4] VIX: volatility index of the S&P500 stock market

points may have a much more direct effect on stock markets. All values of one in d_Recession are also included in d_decelertion, hence both variables will be taken into account separately to avoid perfect multicollinearity.

2.3 Methodology

This section focuses on how to capture the effect of Tobin tax on French stock market returns volatility. Since (Engel, 1982) much credit has been given to the presence of heteroskedasticity and time-varying variance in financial time series. (Bollerslev, 1996) extended Engle´s work by allowing the conditional variance to follow an ARMA process. To the best of my knowledge, when dealing with stock indexes, as I do in this study, GARCH model and those developed in (Nelson, 1991) and (Zakoian, 1994) often tend to perform at best, as they control for the effect of good and bad news, thus they would also be considered.

Two approaches same objective, how to capture the effect of Tobin tax on two different measures of French stock market volatility. For the first approach I inspired my work in that previously done in (Bratis et al, 2017). In their study stock market returns (*Rt*) are modelled as the independent variable in the conditional mean equation. Simultaneously, a dummy variable for the announcement of the Tobin tax is introduced in the conditional variance equation. Instead, in this study, first approach proceeds in the same manner but considering the actual presence of the tax over time. Additionally, economic dummy variables would also be included in the variance equation. In the second approach, volatility of stock market returns (*CACvolt*) is the independent variable in the mean equation. Therefore, d_tobin and economic dummy variables are included as regressors in the mean equation not the variance. To have a clear picture of these models refer to last page in the appendix.

Data processing and modelling of both time series *Rt* & *CACvolt* will proceed as follows: summary statistics, unit root testing, ARCH effects test and finally estimation results.

3. Empirical Results

3.1 Descriptive Statistics

Before proceeding with the data, it can be seen, by looking at Figure 2.1.1 and Figure 2.1.2, that both, stock market returns (*Rt*) and *CACvolt* show a slight presence of price instability and volatility clustering around periods of economic deceleration, especially for those of the early 2000´s.

Table 3.1.1 and Table 3.1.2 show relative frequency and summary statistics for both *Rt* and *CACvolt* respectively. For the period 2000-2019 French stock market has had mean return around -0.00118% and standard deviation of 0.61704%. Difference between highest and lowest return equals almost 8%, a signal of high volatility and spread of returns if we also have in mind its excess of kurtosis. Normality of its distribution is rejected as Jarque-Bera statistic equals 5604.62 with a p-value of zero. On the other hand, Table 3.1.2 reveals an average volatility growth rate of -0.0055% in stock returns while having a standard deviation of -2.923%. Difference between highest and lowest peak of volatility growth amounts to almost 52%. Again, added to its excess of kurtosis, volatility seems to cluster arounds certain periods. J-B statistic equals 12.577,9 with p value of 0.000, thus rejecting the normality distribution of *CACvolt.*

3.2 Unit Root test and ARCH effects test

Next, stationary of both time series should be tested by means of the Augmented Dickey Fuller test. Table 3.2.1 and table 3.2.2, correlogram tables of both varaibles, help deciding the lag order of the test. Finally, a lag order of ten was chosen for stock market return series *Rt* and lag order of 15 was chosen for *CACvolt* series. Results are given below:

Variable	ADF	p-value
Stock Market Return (*R*)	-35.038	0.0000
CACvol	-31.9391	0.0000

P-values of both variables are smaller than 1% confidence level. Null hypothesis that both series have a unit root is therefore rejected. Now that we know that our variables are stationary let's check for presence of ARCH effects.

ARCH effects reveal themselves in financial time series as large fluctuations being followed by large fluctuations, and small fluctuations by small fluctuations too. Puzzling sounding, in the context of this study the implications are yet quite simple. Shocks to stock prices, of a given magnitude, are followed by further shocks of the same magnitude. In terms of modelling stock returns 'volatility, that would imply that the error term is correlated with its own lags. ARCH-LM test will be used to test for heteroskedasticity in the error term for both *Rt* & *CACvolt.* The procedure is as follows.

1st Selection of lag-order in the mean equation:

Looking at table 3.2.3 it can be seen that according to the BIC criterion the "best fitting" ARMA models, for both variables, are those with only one autoregressive term and one moving average term.

2nd Residuals autocorrelation test:

Once we know ARMA (1,1) is the "best fitting" model in both cases, LM test is run on the squared residuals.

	LM	p-value
Stock market Return (*R*)	166.92	0.0000
CACvol	794.4	0.0000

With q=1 degrees of freedom, null hypothesis of no ARCH effect is then rejected as both p-values are below 1% significance level. Now that we have confirmed that our time series are both stationary and heteroskedastic, lets estimate the models and evaluate the effect of the Tobin tax.

3.3 Estimation Results

R-squared values of models in Table 3.3.1 & Table 3.3.2 have not been included. They were often close to zero or even below it. Not surprising since these models are about the variance not the mean. Instead BIC criterion has been used to choose which models fit, at best, the given data.

1st Approach

Across all models listed in Table 3.3.2 d_Recession shows no significance in any of them. On the contrary d_deceleration is statistically significant at 99% level, having a positive effect in stock returns' volatility. The effect of Tobin tax is negative and statistically significant only in those models that include d_deceleration, which are also those with the lowest BIC value. No surprising since highest frequency of deceleration periods have happened after the tax was implemented.

According to Table 3.3.2 TARCH (1,1) model with d_tobin and d_deceleration as regressors in the variance equation is the "best fitting" model. Presence of both, Tobin tax and deceleration economic periods affect returns' volatility significantly at 95% and 99% confidence level. Mean and variance equations would then be:

(3.3.1) $R_t = -0.0019 - 0.0254R_{t-1}$

(3.3.2) $\sigma_t^2 = 0.0084 + 0.0624\varepsilon_{t-1}^2 + 1.280\varepsilon_{t-1}^2 d_{t-1} + 0.9250\sigma_{t-1}^2 - 0.0016d.tobin_t + 0.0023d.deceleration$

Rt shows to have a threshold effect as Γ>0 and statistically significant at 99% level. Leverage effect is present as downward shifts in stock prices have a stronger effect (Γ+α=1.3424) on future volatility than does upwards shifts in stock prices (α=0.0624). As expected by advocates of the tax, the effect of the Tobin tax on stock market return's volatility is negative and statistically significant at 95% level, yet its magnitude could be considered non-significant (-0.0016).

2nd Approach

Once again d_Recession seems to have no significant effect in all models listed in Table 3.3.2. On the contrary, d_deceleration is significant at 95% and 99% level in two out of three models. As opposed to first approach, d_deceleration has a negative effect on volatility for these models.

According to Table 3.3.3 TARCH (1,1) model with d_tobin, as the only regressor in the mean equation, is the "best fitting" model. Mean and variance equations looks as follows:

(3.3.3) $CACvol_t = -0.1769 - 0.0582CACvol_{t-1} - 0.1991d.tobin$

(3.3.4) $\sigma_t^2 = 0.371 + 0.0442\varepsilon_{t-1}^2 - 2.440\varepsilon_{t-1}^2 d_{t-1} + 0.9249\sigma_{t-1}^2$

No leverage effect is found present in *CACvolt* series ($\Gamma<0$). Explanation for such difference against 1st approach, may lie in the fact that threshold effect in *CACvolt* series measures the effect of good and bad news on the variance equation of a volatility index which intuitively is like dealing with its higher order moments. The effect of the Tobin tax is again negative (-0.1991) and statistically significant at 99% level. Once more, Tobin tax reduces volatility growth rate but in an insignificant amount.

4. Conclusion

Implementation of the Tobin tax has been at the core of policy debate in Spain for the past year. Intended to curve speculative behavior and stabilize market returns the Tobin tax has not yet been implemented. With France as a case study, this paper tries to cast light on the possible effects financial transaction taxes may have. While theoretical work doesn't add much light, empirical findings often tend to reject the effectiveness of the Tobin tax.

This study solely tries to explain the effect of the Tobin tax by understanding the volatility process behind its prices. Two different perspectives of volatility have been taken into while controlling for the economic cycle at the moment. Results in both approaches give the same conclusion. The Tobin tax reduces volatility but in a very small amount. Easiness in its avoidance has already been pointed out by the Cours de comptes[5] and the AMF[6] in 2017 as the reason that explains it. But such lack of effect might not be a problem. If looked from the perspective of market equilibrium. We are dealing with a tax that barely distorts behavior while raising a lot of revenue. So even though speculative behavior is not corrected, at least further externalities don't arise.

[5] Cours de comptes is the Court of Auditors in France. Body in charge of auditing public accounts.

[6] AMF: financial markets regulator in France

I finished this paper by acknowledging its main limitations which at the same I believe are its main strengths. Simplicity of the regressors. None of them included actual values the variables. Also, the fact that liquidity and dividends were not taking into to measure returns. simplicity of the volatility measures. To sum up the use of macroeconomic variables but not of microeconomic variables. Finally, I finished this article with a question I asked myself and that I believe should motivate further research and design of the tax. If those who were meant to be the target of the tax are not being affected by it, who is it then?

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APPENDIX:

Figure 2.1.1 Stock Market Returns (*Rt*)

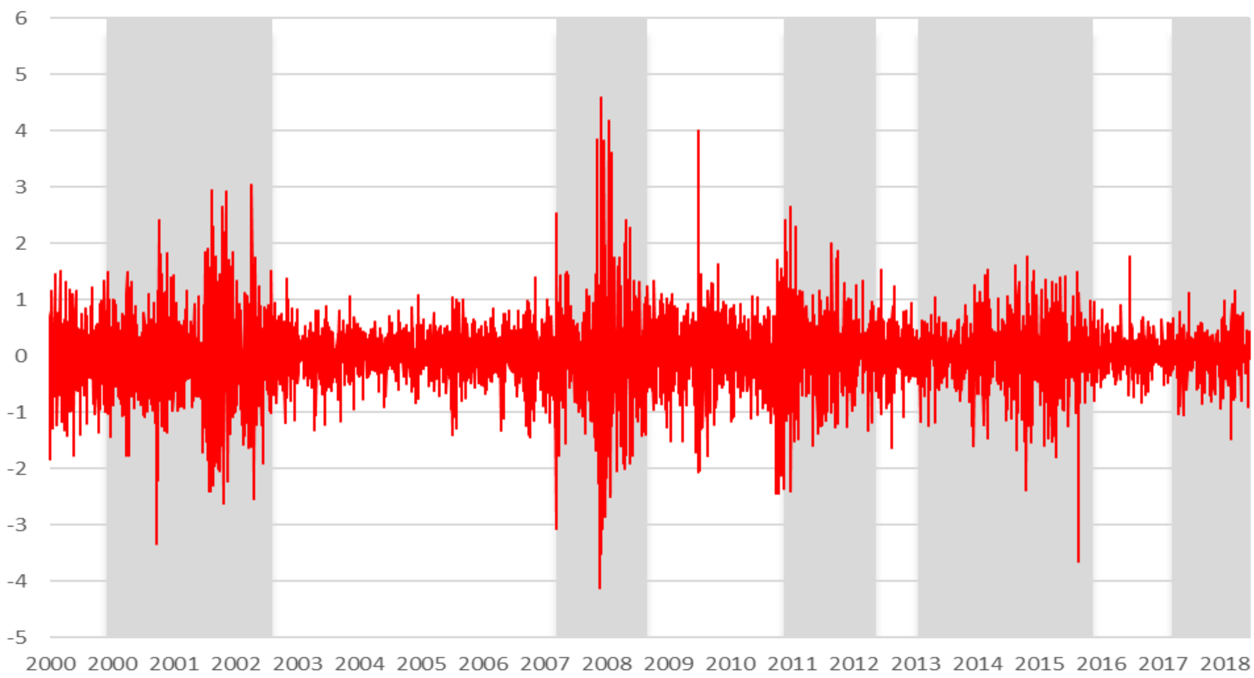

Figure 2.1.2: *CACvolt:* volatility growth rate

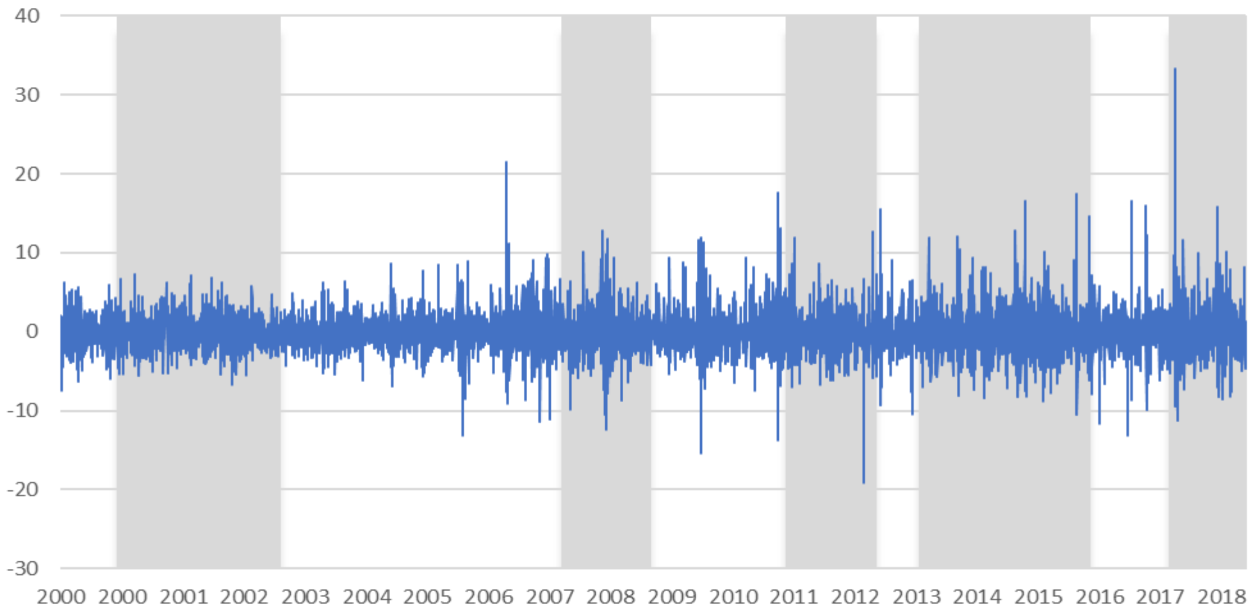

Table 3.1.1

Series:	Rt
Observations	4950
Mean	-0,011865
Median	0,011578
Maximum	4,6012
Minimum	-4,1134
Std Dev	0,617504
Skewness	-0,045369
Excess Kutosis	5,2121
J-B statistic	5604,62
Probability	0

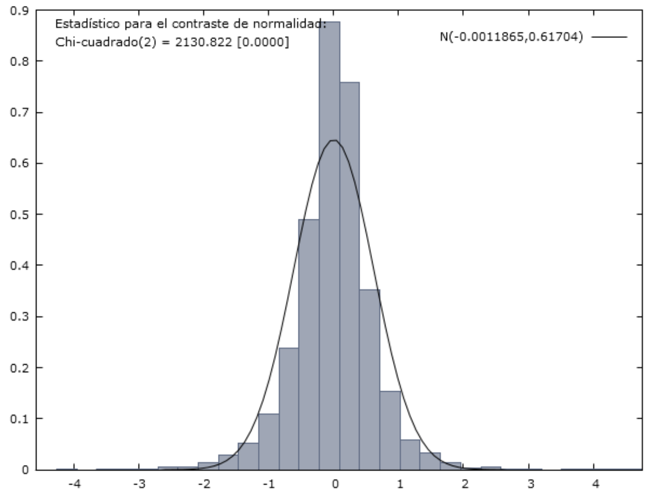

Table 3.1.2

Series:	CACvolt
Observations	4950
Mean	-0,005546
Median	-0,15472
Maximum	33,364
Minimum	-18,968
Std Dev	2,9231
Skewness	0,87392
Excess Kutosis	7,6199
J-B statistic	12577,9
Probability	0

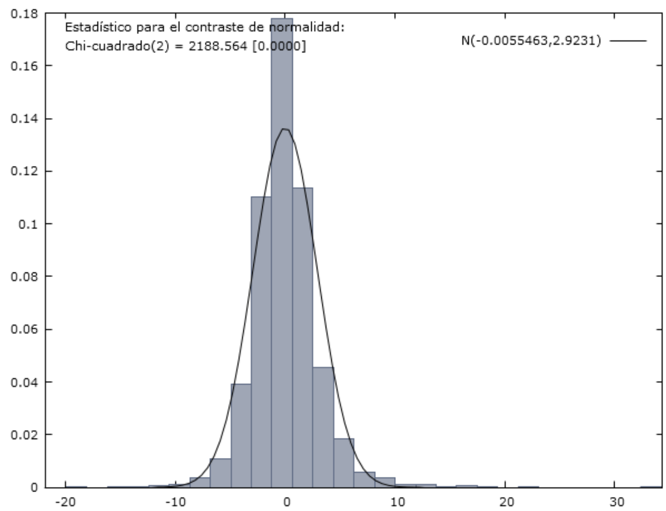

Table 3.2.1 Correlogram for *Rt* series

LAG	AC		PAC		Q-stat	[p-value]
1	-0.0274	*	-0.0274	*	3.7296	[0.053]
2	-0.0310	**	-0.0318	**	8.4945	[0.014]
3	-0.0504	***	-0.0522	***	21.0716	[0.000]
4	0.0145		0.0106		22.1175	[0.000]
5	-0.0642	***	-0.0670	***	42.5219	[0.000]
6	-0.0181		-0.0239	*	44.1421	[0.000]
7	0.0165		0.0122		45.4904	[0.000]
8	0.0306	**	0.0233		50.1467	[0.000]
9	-0.0297	**	-0.0280	**	54.5093	[0.000]
10	-0.0254	*	-0.0279	*	57.7095	[0.000]
11	-0.0032		-0.0069		57.7590	[0.000]
12	0.0030		-0.0012		57.8045	[0.000]
13	0.0071		0.0088		58.0577	[0.000]
14	0.0110		0.0088		58.6604	[0.000]
15	-0.0014		-0.0056		58.6708	[0.000]

Table 3.2.2 Correlogram for *CACvolt*

LAG	AC		PAC		Q-stat	[p-value]
1	-0.0655	***	-0.0655	***	21.2188	[0.000]
2	-0.0705	***	-0.0751	***	45.8224	[0.000]
3	-0.0240	*	-0.0343	**	48.6871	[0.000]
4	-0.0340	**	-0.0440	***	54.4274	[0.000]
5	-0.0292	**	-0.0397	***	58.6601	[0.000]
6	-0.0381	***	-0.0507	***	65.8414	[0.000]
7	-0.0367	**	-0.0521	***	72.5065	[0.000]
8	-0.0037		-0.0220		72.5738	[0.000]
9	-0.0279	**	-0.0440	***	76.4454	[0.000]
10	0.0372	***	0.0215		83.3231	[0.000]
11	-0.0022		-0.0118		83.3466	[0.000]
12	-0.0040		-0.0095		83.4274	[0.000]
13	-0.0019		-0.0102		83.4452	[0.000]
14	-0.0362	**	-0.0428	***	89.9423	[0.000]
15	0.0099		-0.0005		90.4260	[0.000]
16	-0.0148		-0.0232		91.5108	[0.000]

Table 3.2.3: ARCH effect table

Variable	Lag order	AIC	BIC
(*R*)	1	9250.560	9276.589
	2	9265.601	9290.953
	3	9262.218	9296.020
CACvol	1	24566.3	24592.33
	2	24569.19	24608.23
	3	2455.84	24605.89

Table 3.3.1: estimation results for *Rt* series

	Conditional Mean		Conditional Variance							
	const	R_{t-1}	ω	α	Γ	β	d_tobin	d_Recession	d_deceleration	BIC
GARCH (1,1)	0.0215*** (0.007)	-0.0381** (0.015)	0.0045*** (0.001)	0.0953*** (0.014)	-	0.8946*** (0.0142)	-0.0008 (0.001)			7574.474
	0.0214*** (0.007)	-0.0379** (0.015)	0.0048*** (0.001)	0.0963*** (0.014)	-	0.8914*** (0.015)	-0.0008 (0.001)	0.0103 (0.007)		7577.479
	0.0228*** (0.007)	-0.0386** (0.015)	0.0056*** (0.001	0.0978*** (0.014)	-	0.8837*** (0.015)	-0.0028** (0.001)		0.0046*** (0.002)	7563.899
EGARCH (1,1)	-0.0014 (0.006)	-0.0258* (0.016)	-0.1081*** (0.015)	0.1042*** (0.015)	- 0.1369*** (0.012)	0.979*** (0.004)	-0.0040 (0.003)			7320.112
	-0.0013 (0.006)	-0.0257* (0.016)	-0.1089*** (0.016)	0.1046*** (0.016)	- 0.1373*** (0.013)	0.9793*** (0.004)	-0.0039 (0.004)	0.0025 (0.008)		7328.410
	0.0003 (0.006)	-0.0263* (0.015)	-0.1269*** (0.017)	0.1084*** (0.015)	- 0.1448*** (0.014)	0.9720*** (0.005)	-0.0128** (0.006)		0.0159*** (0.006)	7311.041
TARCH (1,1)	-0.0041 (0.006)	-0.0245 (0.015)	0.0069*** (0.001)	0.0600*** (0.009)	1.265 (0.147)***	0.9335*** (0.009)	-0.0004 (0.001)			7302.786
	-0.0039* (0.002)	-0.024* (0.012)	0.0070*** (0.001)	0.0605*** (0.009)	1.2694*** (0.1461)	0.9324*** (0.009)	-0.0004 (0.001)	0.0014 (0.002)		7310.386
	-0.0019 (0.006)	-0.0254 (0.016)	0.0084*** (0.001)	0.0624*** (0.008)	1.280*** (0.145)	0.9250*** (0.009)	-0.0016** (0.001)		0.0023*** (0.001)	7292.636

Table 3.3.2: estimation results for *CACvolt* series

			Conditional Mean			Conditional Variance				
	const	$CACvol_{t-1}$	d_tobin	d_Recession	d_deceleration	ω	α	Γ	β	BIC
GARCH (1,1)	-0.0544 (0.038)	-0.0596*** (0.016)	0.045 (0.092)			0.7610*** (0.258)	0.1403*** (0.032)	-	0.7738*** (0.054)	23995.384
	-0.0474 (0.039)	-0.0597*** (0.016)	0.0384 (0.093)	-0.0818 (0.134)		0.7627*** (0.259)	0.1404*** (0.032)	-	0.7735*** (0.054)	24003.581
	-0.0278 (0.047)	-0.0599*** (0.047)	0.0667 (0.097)		-0.0715 (0.077)	0.7595*** (0.258)	0.1401*** (0.032)	-	0.7741*** (0.054)	24002.929
EGARCH (1,1)	0.1677*** (0.036)	-0.0570*** (0.016)	-0.1986*** (0.058)			0.0477** (0.019)	0.0660*** (0.021)	0.1961*** (0.019)	0.9513*** (0.009)	23702.962
	0.1712*** (0.037)	-0.0568*** (0.016)	-0.2021** (0.059)	-0.0447 (0.066)		0.0478** (0.019)	0.0658*** (0.021)	0.1962*** (0.019)	0.9514*** (0.009)	23711.114
	0.2139* (0.111)	-0.0556*** (0.017)	-0.1586 (0.161)		-0.1062*** (0.040)	0.0557** (0.024)	0.0514** (0.020)	0.2026*** (0.019)	0.9531*** (0.011)	23701.704
TARCH (1,1)	0.1769*** (0.037)	-0.0582*** (0.016)	-0.1991*** (0.057)			0.3710*** (0.076)	0.0442*** (0.012)	-2.440*** (0.619)	0.9249*** (0.016)	23698.94
	0.1804*** (0.0375)	-0.0582*** (0.016)	-0.2026*** (0.058)	-0.0482 (0.067)		0.3695*** (0.077)	0.0441*** (0.012)	-2.446*** (0.623)	0.9251*** (0.016)	23707.49
	0.2143*** (0.018)	-0.0575*** (0.006)	-0.1668*** (0.060)		-0.0875** (0.044)	0.3665*** (0.073)	0.0398*** (0.011)	-2.755*** (0.739)	0.9291*** (0.015)	23701.169

*X's are the economic variables

Stock Market Return (*R)* mean eq $R_t = a_0 + a_1 R_{t-1} + \varepsilon_t$

Variance equation: (1) GARCH, (2) EGARCH, (3) TARCH

(1) $$\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_i \sigma_{t-j}^2 + z_1 d.tobin_t + \sum_{i=1}^{2} \lambda_i x_{i,t}$$

(2) $$ln(\sigma_t^2) \ = \ \omega \ + \sum_{i=1}^{q} \left(\alpha_i \left| \frac{\varepsilon_{t-i}}{\sigma_{t-i}} \right| + \gamma_i \left(\frac{\varepsilon_{t-i}}{\sigma_{t-i}} \right) \right) + \sum_{j=1}^{p} \beta_i \sigma_{t-j}^2 \ + \ z_1 d.tobin_t \ + \sum_{i=1}^{2} \lambda_i x_{i,t}$$

(3) $$\sigma_t^2 = \omega + \sum_{i=1}^{q} \left(\alpha_i \varepsilon_{t-i}^2 + \gamma_i \varepsilon_{t-i}^2 d_{t-1} \right) + \sum_{j=1}^{p} \beta_i \sigma_{t-j}^2 + z_1 d.tobin_t + \sum_{i=1}^{2} \lambda_i x_{i,t}$$

CACvol model mean equation: $CACvol_t = b_0 + b_1 CACvol_{t-1} + z_1 d.tobin + \sum_{x=1}^{2} \lambda_i x_i + \varepsilon_t$

Variance equations:

(1) $$\sigma_t^2 = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_i \sigma_{t-j}^2$$

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

(3) $$\sigma_t^2 = \omega + \sum_{i=1}^{q} \left(\alpha_i \varepsilon_{t-i}^2 + \gamma_i \varepsilon_{t-i}^2 d_{t-1} \right) + \sum_{j=1}^{p} \beta_i \sigma_{t-j}^2$$