PRACE NAUKOWE UNIWERSYTETU EKONOMICZNEGO WE WROCŁAWIU
RESEARCH PAPERS OF WROCŁAW UNIVERSITY OF ECONOMICS nr 482 • 2017

Wrocław Conference in Finance: Contemporary Trends and Challenges ISSN 1899-3192
e-ISSN 2392-0041

Ewa Majerowska
University of Gdańsk
e-mail: ewa.majerowska@ug.edu.pl

SHOULD WE RELY ON FORECASTS OF PRICES OR RETURNS? THE SHORT TERM APPROACH

CZY MOŻNA POLEGAĆ NA PROGNOZACH CEN LUB STÓP ZWROTU? PODEJŚCIE KRÓTKOOKRESOWE

DOI: 10.15611/pn.2017.482.15
JEL Classification: G12, C53

Summary: Investors make their decisions on the basis of the information coming from the market. The main features of assets are prices and investment risk. The rates of return are calculated based on the prices. For modelling the returns, capital asset pricing models can be applied; for the prices, methods of technical analysis could be taken into account. The purpose of this paper is to evaluate both approaches. First – financial modelling of the assets' returns, and the second – the analysis of the assets' prices. In order to verify the effectiveness of the forecasting processes, forecasts and ex-post type forecasting errors were calculated. The empirical analysis is based on the stock prices of ten food companies traded on the Warsaw Stock Exchange. The traditional CAPM and the extension of the CAPM by the GARCH(1,1) process are in use. As the technical analysis tool for price modelling, three period moving averages are calculated. The obtained results allow indicating the superiority of modelling the returns, in terms of short-term forecasting. Unfortunately, the hypothesis about the advantage of the application of GARCH for modelling, and then for forecasting, must be rejected.

Keywords: modelling returns, CAPM with GARCH, moving average.

Streszczenie: Inwestorzy podejmują decyzje na podstawie informacji pochodzących z rynku. Głównymi cechami aktywów, branymi przez nich pod uwagę, są ceny i ryzyko inwestycji. W oparciu o ceny obliczane są stopy zwrotu. Przyszłe ruchy cen można przewidywać z pomocą narzędzi analizy technicznej. Do modelowania stóp zwrotu wykorzystuje się głównie modele wyceny aktywów kapitałowych. Celem niniejszej pracy jest ocena zastosowania obu podejść: modelowania ekonometrycznego stóp zwrotu aktywów i analizy cen aktywów oraz sprawdzenie skuteczności obu podejść do prognozowania. Analiza empiryczna obejmuje dzienne notowania akcji dziesięciu spółek sektora spożywczego, notowanych na Giełdzie Papierów Wartościowych w Warszawie. Dokonano porównania tradycyjnego podejścia do wyceny aktywów za pomocą modelu CAPM z modelem uwzględniającym zmienność wariancji GARCH(1,1). Narzędziem analizy technicznej do modelowania cen jest trzyokresowa średnia ruchoma. Wyniki wskazują na przewagę modelowania stóp zwrotu w kontekście prognozowania nad narzędziem analizy technicznej. Nie pozwalają jednak na wskazanie przewagi uwzględnienia zmienności wariancji w przypadku prognozowania krótkookresowego.

Słowa kluczowe: modelowanie stóp zwrotu, CAPM z efektem GARCH, średnia ruchoma.

1. Introduction

All investment decisions are made on the basis of past prices or returns. The members of the capital market take into account the expected future price movement and the expected risk of investment. For modelling the rates of return, usually assets pricing models are applied, mainly The Sharpe model, the CAPM or the multifactor APT model. All of them assume that investors are rational, have full access to the market and are interested only in the expected return on the investment and the level of the expected risk. On the other hand, it is assumed that the rates of return are normally distributed and have constant variances. As it was tested and showed in the literature, for daily or even monthly data these conditions are not always fulfilled – see e.g., Doman [2004]. If variances of the error terms are heteroskedastic, then it is suggested to apply the GARCH or its extended versions e.g. the GARCH-M.

On the basis of the estimated models, forecasts can be calculated. In such cases, the rates of return are forecasted. However, some economists follow a technical analysis. They believe in trends and price patterns that repeat over time. Technicians try to predict the future price behaviour based on the price charts, followed by volumes.

The purpose of the paper is to evaluate whether the technicians or the econometricians are right that the prices or returns should be forecasted in order to get more accurate forecasts of the future price movements. For modelling of the returns, the traditional CAPM is proposed. Therefore, the first hypothesis states that the forecasts obtained on the basis of econometric models, such as asset pricing of returns, provide better forecasts, as far as short-term analysis is concerned. The second hypothesis states that due to the financial series, the CAPM should be extended by the GARCH process, which is better fitted to the real data and provides more accurate forecasts.

The paper is organized the following manner. The first section includes a short introduction, the second a brief literature overview concerning modelling the returns. In the third section, the methods of modelling and elements of the technical analysis are explained, while in the following section an empirical analysis of ten selected companies from the food sector of the Warsaw Stock Exchange is presented.

2. Literature overview

The problem of modelling the prices on the stock exchange has been well known in literature, beginning with Sharpe [1964], who first applied the CAPM, up to the recent years. Application of the traditional CAPM can be found in many financial textbooks, for example, in Haugen [2000] or Elton et al. [2014]. Fama and French [1997] had proposed an extension of the CAPM into a three-factor model. Also, Davis, Fama and French [2000] had tested the three-factor risk model during the period of 1929-1997. Four years later, Fama and French [2004] pointed out the disadvantages of the traditional CAPM.

Many authors evaluated the CAPM with conditional variance. For example, Bollerslev, Engle and Wooldridge [1988] estimated the GARCH model, but their results were inconclusive. Engel and Rodrigues [1989] proposed an international asset pricing model based on CAPM with time-varying covariances. Ng [1991] examined the CAPM allowing for the conditional expected excess return and the level of risk to change over time. She found the time variability represented by the conditional expected excess asset returns and the risks statistically significant.

Schwert and Seguin [1990] pointed out heteroskedasticity in the rates of return and applied time-varying betas for testing the CAPM. They found that heteroskedasticity is related to the company size. Monthly and quarterly data were modelled by Bodurtha and Mark [1991]. They applied the CAPM, with time-varying risk and return. Ultimately, they suggested application of a third order ARCH process for modelling the returns.

De Santis and Gerard [1997] tested the conditional CAPM using a parsimonious generalized autoregressive conditional heteroskedasticity parameterization (GARCH). They tested the conditional version of the CAPM and its implications for an international portfolio diversification. Their findings support most of the restrictions of the conditional CAPM. They showed that the market risk, represented by the conditional covariance between the return on each asset and the world index, is priced at the same level all around the world. Applying quarterly German data, Jansen [1995] rejected the static (traditional) CAPM, because of the non-constant variance, and suggested application of the two-stage approach.

The advantage of the GARCH(1,1) model above AR(1), MA(1) was shown by Bali, Cakici and Tang [2009]. They examined time-varying conditional betas by estimating the models for all NYSE, Amex and NASDAQ financial and nonfinancial firms. The results confirm that the average portfolio returns increase when moving from low-beta portfolios to high-beta portfolios.

Some economists suggest extensions of the GARCH model. A survey of application of the multivariate GARCH is presented in the paper by Bauwens, Laurent and Rombouts [2006]. The authors described the most important developments in this type of models.

The paper by Turtle, Buse and Korkie [1994] presents tests of conditional capital asset pricing models in a multivariate GARCH framework. Applying weekly data from July 1983 to December 1989 they rejected the CAPM under a constant market risk and found that the interest rate risk was statistically significant.

Hafner and Herwartz [2000] modelled German stock returns utilizing GARCH, TGARCH and stochastic volatility. They found that the standard quasi--maximum-likelihood inference for the autoregressive parameter is interfered by the misspecification of the volatility process.

On the other hand, practitioners argue for analysis of the market behaviour to be based on price movements presented on charts. Additionally, some of them suggest application of elements of technical analysis for explaining and forecasting the financial series. Charles Dow, the forerunner and the originator of the technical analysis, stated that technical analysis should help diagnose the market behaviour, not predict the prices [Murphy 1999]. However, Li and Tsang [1999] claimed for the moving average rules to be widely used by the economists for market assessment and timing. They suggested that analysts take some known technical rules and adopt them to solve prediction problems. The application presented in their paper, based on the DJIA index, showed that there is some predictability in the analysed index that is based only on the past data, thus some important issues, such as capital and transaction costs, can be ignored.

In his paper, Zielonka [2004] claimed that in spite of the zero efficiency for stock market forecasting, technical analysis seems to be the most popular analytical tool used by practitioners.

Application of the moving average is suggested by White [1996]. Moving averages, according to White, have been widely used because they are very simple to calculate and to apply, as well as allow running profits while cutting the losses. Dormeier [2001] tested 60 securities over 2,000 days and showed that volume--weighted averages performed better than simple moving averages in 60% of the cases. There was no significant difference in the 12% of the sample.

A simple linear moving average can often perform as well as a good filter. According to Hutson [1984] in some cases, very good results require investigation of filters, where only slightly inferior results can be obtained by using relatively simple filters. Because of the nature of the price movements, for example the changes in Friday closing prices, filters would smooth the series. Lambert [1984] states that among all trading systems that are commonly in use, two of them would be dominating. Mainly, they are simple moving averages (SMA) and exponentially smoothed moving averages (ESMA). Borowski [2006] proposed the application of financial time series of the fractal adaptive moving average in analysis, as a compromise between the smoothing series and as a way of selecting false signals.

An application of the simple moving average, compared to the price modelling with trends and dummy variables, for nine bank companies traded on the WSE, can be found in Majerowska [2015]. The results do not allow answering the question whether a moving average clearly provides more accurate forecasts than a model of price movement. A study by Schulmeister [2009] shows interaction between the trading behaviour of the moving average, the momentum models and the fluctuations of the yen-dollar exchange rates. The author proved strong interaction between the exchange rate movements and the transactions triggered by technical models.

3. Methods of modelling

As mentioned before, both the prices and the returns of assets can be modelled. As far as the returns are concerned, econometric models are proposed. For modelling the prices, application of selected technical analysis tools can be used.

3.1. The CAPM and GARCH

A widely known approach to financial modelling of the returns is the Sharpe [1964], Lintner [1965] and Mossin [1966] capital asset pricing model (CAPM), in the general form:

$$r_{it} = \beta_0 + \beta_1 r_{Mt} + \xi_{it} ,$$

where r_{it} is the excess return of the asset (or a portfolio) above the risk-free rate, r_{Mt} is the excess return of the market portfolio above the risk-free rate, β_0, β_1 are the structural parameters and ξ_{it} is the error term. The β_1 parameter measures the level of the risk of an asset (or a portfolio).

First, the model needs to be estimated and then verified in the quality and quantity sense. Therefore, the variables r_{it} and r_{it} need to be stationary, the error terms need to be normally distributed and the variances of error terms should be constant in time. Parameter β_0 needs to be statistically insignificant, while β_1 significant and constant in time. According to Fiszeder [2009, p. 306], the CAPM can be written in a dynamic form:

$$E(r_{it}|\psi_{t-1}) = r_{ft} + \beta_{it}[E(r_{Mt}|\psi_{t-1}) - r_{ft}],$$

where ψ_{t-1} is the set of all information given in time $t-1$. The above model can be rewritten as a two-equation one. If λ is assumed to be the constant market price of risk:

$$\lambda = [E(r_{it}|\psi_{t-1}) - r_{ft}] / \text{var}(r_{Mt}|\psi_{t-1}) .$$

The model can be written as:

$$r_{it} = r_{ft} + \lambda \,\text{cov}(r_{it}, r_{Mt}|\psi_{t-1}) + \xi_{it} ,$$

$$r_{Mt} = r_{ft} + \lambda \,\text{var}(r_{Mt}|\psi_{t-1}) + \xi_{Mt} ,$$

where $\xi_{it} = r_{it} - E(r_{it}|\psi_{t-1})$ and $\xi_{Mt} = r_{Mt} - E(r_{Mt}|\psi_{t-1})$. The conditional variances and covariances need to be defined. It is suggested that the rates of return are described by a multivariate GARCH, thus $\mathrm{var}(r_{Mt}|\psi_{t-1}) = E(\xi_{Mt}^2|\psi_{t-1}) = h_{Mt}$, $\mathrm{cov}(r_{it}, r_{Mt}|\psi_{t-1}) = E(\xi_{it}, \xi_{Mt}|\psi_{t-1}) = h_{iMt}$.

Brzeszczyński and Kelm [2000], Doman and Doman [2004], as well as Fiszeder [2009] have shown in their papers that for modelling financial series, the GARCH approach should be employed. The general form of the GARCH(q, p) model, according to Bollerslev [1986] and Taylor [1986], is as follows:

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \xi_{t-i}^2 + \sum_{j=1}^{p} \gamma_j h_{t-j}.$$

Such extension of the CAPM is used in order to forecast the rates of returns of the modelled assets.

The ARCH or the GARCH effect, according to Tse [2002], can be tested jointly (Box, Pierce and Ljung statistic) by applying LM tests or tests based on residuals.

3.2. The technical analysis

The first person who developed and described the theoretical background of the technical analysis (TA) was an American journalist Charles Dow. Principal assumptions of the TA point out that the averages discount everything, three types of trends can be recognized in price movements, averages and volumes must confirm the price movements and the trend can be assumed to be effective as long as the signals are clear to be recognized [Murphy 1999].

Technical analysis is based on an analysis of the price movements, believing that history repeats itself and the patterns that appeared in the past probably will repeat again in future. Investors who apply technical analysis tools, the so-called technicians, make investment decisions on the basis of the price movements presented on different kinds of charts. They try to recognise the trends or the patterns by looking at the price charts. The major reversal patterns are the head and shoulders reversal pattern, double or triple top and bottom patterns. Continuation of the price movement patterns is e.g. triangular, rectangular. The trends usually are confirmed by the moving averages (one, two, or three averages on a chart). The simple moving average, which gives the same weight to all observations, is the most popular one. If new data is more important, then the exponential moving average or the weighted moving average should be applied. Numerous elements selected to calculate the moving average can vary, depending on the data (daily, weekly, monthly or yearly) and on the preferences. If short period analysis or forecasting is the case of a study, then three or five observation averages are usually calculated. For long period forecasting, there could be fifty or even more elements counted in the average. Some instrument can only provide signals for buying or selling the assets. For example, the Bollinger bands are in use [Pring 2002].

Evaluation of the calculated forecasts can be carried out ex-post or ex-ante. In this analysis, the ex-post type errors of the forecast have been calculated. One of the measures is the root mean square error (RMSE), which could be expressed as:

$$RMSE = \sqrt{\frac{1}{m}\sum_{t=1}^{m}(y_t - y_t^p)^2} ,$$

where y_t is the real value of the series, y_t^p is the predicted value of the series and m stands for the prediction periods. Also, the percentage share of the RMSE in the mean value of the series can be calculated.

4. Empirical results

The empirical analysis was based on daily data from 03.01.2014 to 31.05.2016, which constitutes 601 data points. The applied methods employed 598 data points. The last three observations were used for forecasting and testing the accuracy of the forecasts (ex-post errors of forecasting).

From among all the sectors, the food sector was selected. This is due to the fact that it seems to be the most stable sector on the stock market (which was confirmed by previous analysis). Ten largest companies listed on the WIG-food Warsaw Stock Exchange sub-index were analysed (the companies selected covered over 92% of the sub-index portfolio). The market portfolio was represented by the main market index WIG. The risk-free rate represents the weighted average yield on Treasury bills.

All estimations were made using the Gretl software.

The descriptive statistics of the rates of return of the analysed companies are provided in Table 1. It can be noticed that the distributions of all series were skewed with a high excess kurtosis.

Table 1. Descriptive statistics of the rates of return on the assets, daily data 03.01.2014-31.05.2016

	Mean	Median	Standard deviation	Skewness	Excess kurtosis
KERNEL	0.00049	0.00000	0.46166	–0.59621	8.63858
WAWEL	–0.00026	0.00000	0.22994	–0.02264	3.50930
ASTARTA	–0.00088	0.00000	0.66911	0.36810	6.24661
COLIAN	–0.00011	0.00000	0.28838	–0.33138	4.19752
KRUSZWICA	0.00001	–0.00015	0.19952	0.36300	3.35238
OVOSTAR	0.00001	0.00000	0.26584	–0.95967	11.31737
INDYKPOL	0.00107	0.00000	0.30564	–0.15037	6.80741
GRAAL	0.00105	0.00000	0.23912	0.43959	3.99789
AMBRA	–0.00065	0.00000	0.21338	–1.03742	9.66501
KANIA	–0.00087	0.00000	0.28512	0.52181	3.90643

Source: own study based on [Stooq.pl 2016].

First, the unit-root tests for excess returns were applied. The statistics calculated for all series allowed the rejection of the null hypothesis about the existence of the unit roots, therefore the series were stationary.

Then the traditional CAPM was estimated. In all cases the intercept was statistically insignificant at 0.05 significance level, which was in line with the financial portfolio theory. This confirms the fact that the assets were not systematically under- or over-valued. The parameter that measures the influence of the excess of the market return over the risk-free return was significant for all companies. Quantitative verification of the model pointed out that in 8 cases (out of 10), the variance of the error terms was heteroskedastic. To allow for volatility in the variance, the extended version of CAPM with GARCH process was estimated. The lags of GARCH usually are selected according to information criteria (Schwarz, Akaike or Hannan-Quinn). Typically, to model the financial series, application of the GARCH(1,1) process is suggested [Fiszeder 2009, p. 28]. The models were estimated with the maximum likelihood method. The results are provided in Table 2.

Table 2. Estimates of the parameters of the CAPM model and the CAPM extended by multivariate GARCH

	CAPM		GARCH(1,1)				
	const	WIG	const	WIG	alpha(0)	alpha(1)	gamma(1)
KERNEL	0.001	1.111	0.001	0.826	0.000	0.180	0.686
WAWEL	–0.000	0.649	0.000	0.636	0.000	0.166	0.583
ASTARTA	–0.001	0.806	–0.001	0.662	0.000	0.326	0.388
COLIAN	0.000	0.880	–0.000	0.804	0.000	0.146	0.448
KRUSZWICA	0.000	0.329	–0.000	0.321	0.000	0.101	0.855
OVOSTAR	0.000	0.592	–0.000	0.285	0.000	0.222	0.636
INDYKPOL	0.001	0.524	0.001	0.528	0.000	0.104	0.659
GRAAL	0.001	0.693	0.001	0.672	0.000	0.127	0.677
AMBRA	–0.001	0.417	–0.001	0.376	0.000	0.119	0.231
KANIA	–0.001	0.720	–0.001	0.633	0.000	0.490	0.253

Source: own study based on [Stooq.pl 2016].

If the GARCH process was considered, estimates of all the intercepts were statistically insignificant at the 0.05 significance level and the rest of the parameters were statistically significant. The values of the information criteria demonstrate the superiority of the estimated model extended by the GARCH process of the traditional CAPM. As such, the GARCH extension of the model seems to be more precise in describing the rates of return (Table 3). Also, the statistics of the likelihood ratio test, in all cases, suggest rejection of the null hypothesis about the GARCH effect not being significant at the 0.05 level of significance. In consequence, while referring to the hypothesis formulated in the introduction, more accurate forecasts based on this model, in comparison to those calculated on the basis of the traditional CAPM, are expected.

Table 3. The statistics of the likelihood ratio test and the information criteria for the traditional CAPM and the CAPM extended by a multivariate GARCH

	Likelihood ratio	Criteria for the CAPM			Criteria for the GARCH(1,1)		
	$\chi^2(2)$	Akaike	Schwarz	Hannan--Quinn	Akaike	Schwarz	Hannan--Quinn
KERNEL	57.596	–2670	–2662	–2667	–2720	–2694	–2710
WAWEL	24.574	–3059	–3050	–3055	–3076	–3049	–3065
ASTARTA	85.692	–2389	–2384	–2389	–2470	–2444	–2460
COLIAN	28.369	–2952	–2943	–2949	–2973	–2946	–2962
KRUSZWICA	59.514	–3094	–3094	–3099	–3154	–3128	–3144
OVOSTAR	128.83	–2955	–2947	–2952	–3076	–3050	–3066
INDYKPOL	16.218	–2859	–2850	–2855	–2867	–2841	–2857
GRAAL	18.084	–3038	–3033	–3038	–3051	–3025	–3041
AMBRA	17.699	–3071	–3062	–3068	–3081	–3054	–3070
KANIA	87.360	–2930	–2921	–2926	–3009	–2983	–2999

Source: own study based on [Stooq.pl 2016].

Subsequently, on the basis of the estimated models, forecasts for the next three periods were calculated. One of the most important problems in forecasting is how to predict the expected values of the explanatory variables. In this research, the values of the WIG index needed to be predicted. For this purpose, the real rates of return from the sample (598 data points, as mentioned above) were sorted according to the day of the week. Then it was assumed that the market return on a forecasted day will be equal to the average value of returns from a particular day of the week. The forecasted returns included Friday, Monday and Tuesday, thus the market returns covered the same days' averages respectively.

Additionally, in order to answer the question whether the returns or the prices should be predicted, a technical analysis instrument was employed. Three-period simple moving averages were calculated. As literature shows, this is the most utilized tool by practitioners. Such averages are suggested for a short period analysis of daily data. So, then the forecasts based on the technical analysis approach were calculated.

The results for the first and the last forecasted periods, obtained by all the applied methods, are presented by Fig. 1 and Fig. 2.

As it can be observed, the real rates of return were best fitted by the forecasts calculated on the basis of the traditional CAPM, as far as the first two periods are concerned. The smallest average errors for all the companies together were obtained for the last forecasted day. Such results are confirmed by the values presented in Table 4.

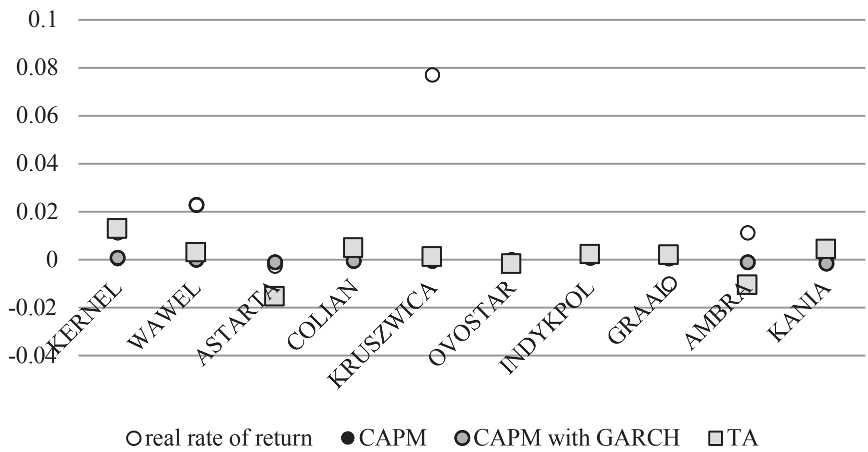

Fig. 1. Forecasted and real rates of returns as of 27.05.2016

Source: own study based on [Stooq.pl 2016].

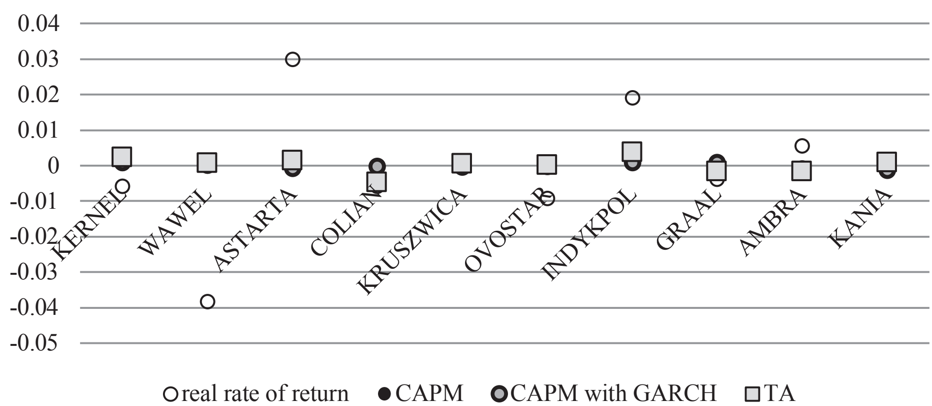

Fig. 2. Forecasted and real rates of returns as of 31.05.2016

Source: own study based on [Stooq.pl 2016].

Table 4. Average errors of the forecasts for the shares of all the companies for each period

Date	CAPM	GARCH(1,1)	TA
27.05.2016	0.02629	0.02632	0.02643
30.05.2016	0.01729	0.01722	0.01846
31.05.2016	0.01711	0.01720	0.01665

Source: own study.

The root mean square errors of the forecasts, calculated for three forecasted periods, are presented by Fig. 3. It can be noticed that the smallest errors of the forecast depend on the company. For six of them, those that were obtained with help of the moving average – the tool of technical analysis, the forecasting errors were the smallest. For the last four, the CAPM with the GARCH extension gave the best forecasts.

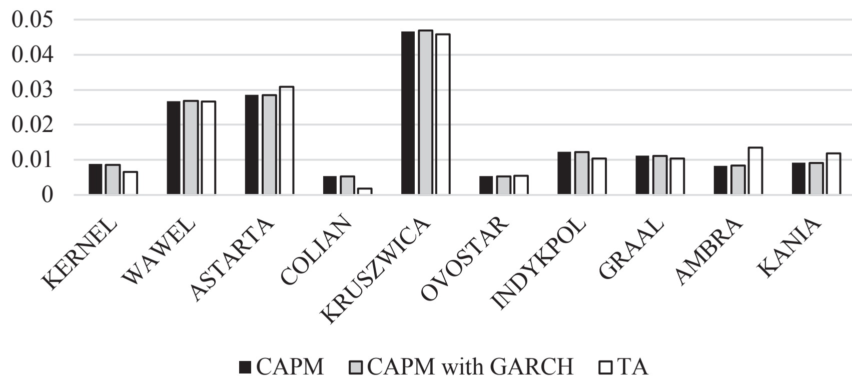

Fig. 3. The root mean square errors of the forecasts for each company

Source: own study based on [Stooq.pl 2016].

Table 5. Average errors of the forecasts for the shares of all the companies for all periods

	CAPM	GARCH(1,1)	Technical analysis
Average RMSE	0.01624	0.01621	0.01635
Percentage mean error	225.9062	225.0196	200.4581

Source: own study.

The forecast errors presented in Table 5 were calculated for all companies together, for all three periods of the forecast. As we can see, the aggregated results are relatively close. There were no statistically significant differences in the means. There were no outliers in the sample, so it can be concluded that for this particular sample, all the applied methods gave the best forecasts.

5. Conclusion

Generally, the above-presented analysis shows that both the CAPM and the extension of the CAPM with GARCH(1,1) model can be applied for modelling the return rates of the companies traded on the stock exchange. Estimates of the parameters are statistically insignificant for the intercepts and significant for the rest of the structural parameters. However, the advantage of the GARCH is confirmed by the heteroskedastic variance of the error terms and the information criteria. Such results are not surprising and basically are in line with the findings presented by other authors.

Comparison of the forecasts calculated on the basis of the returns of assets using the CAPM and the GARCH with those that were calculated based on the prices of assets using the technical analysis shows that lower errors of forecasting were obtained when different methods were used. The results depend on the company and on the forecasted period. For the first forecasted period, the traditional CAPM seems to be the best in the forecast accuracy, for the last period, the third one, the moving average. Accordingly, the technical analysis tool gave better results. It does not confirm the fact that even if other models are more accurate for describing the return rate movement, the traditional CAPM is the best tool for calculating the forecasts, while forecasts with the smallest ex-post forecasting errors are calculated on the basis of the returns. However, for speculative investors, a forecast for the closest period of time is the most important. If we assume that the hypothesis stating that the econometric models better forecast the future price movement than the technical analysis tools cannot be rejected, this means that the returns should be predicted.

The results show that there are advantages of the traditional financial modelling methods in the case of short term analysis, thus the second hypothesis should be rejected. Yet, we have to remember that the analysis concerned only a small number of companies from a selected sector and was carried out over a given period of time. It would be interesting to extend the research to the asset portfolios over other periods of time and to apply other technical analysis tools.

References

Bali T.G., Cakici N., Tang Y., 2009, *The Conditional Beta and the Cross-Section of Expected Returns*, Financial Management, no. 38, p. 103-137.

Bauwens L., Laurent S., Rombouts J.V.K., 2006, *Multivariate GARCH Models: a survey*, Journal of Applied Econometrics, no. 21, p. 79-109.

Bodurtha J.N., Mark N.C., 1991, *Testing the CAPM with Time-Varying Risk and Return*, Journal of Finance, no. 46, p. 1485-1505.

Bollerslev T., 1986, *Generalized Autoregressive Conditional Heteroskedasticity*, Journal of Econometrics, no. 31, p. 307-327.

Bollerslev T., Engle R.F., Wooldridge J.M., 1988, *A Capital Asset Pricing Model with Time-Varying Covariances*, Journal of Political Economy, no. 96, p. 116-131.

Borowski K., 2006, *Fractal Adaptive Moving Average and its Application in Technical Analysis*, Studia i Prace Kolegium Zarządzania i Finansów, no. 69, p. 49-57.

Brzeszczyński J., Kelm R., 2000, *Econometric models of financial markets: stock exchange indices and exchange rate models*, WIG-Press, Warsaw.

Davis J.L., Fama E.F., French K.R., 2000, *Characteristics, Covariances and Average Returns: 1929--1997*, The Journal of Finance, no. 55, p. 389-406.
De Santis G., Gerard B., 1997, *International Asset Pricing and Portfolio Diversification with Time-Varying Risk*, The Journal of Finance, no. 52, p. 1881-1912.
Doman M., 2004, *Forecasting Polish stock indices volatility using GARCH model and high frequency data*, Folia Oeconomica, no. 177, p. 291-309.
Doman M., Doman R., 2004, *Econometric Modeling Dynamics of the Polish Financial Market*, The Publishers of the Poznań Economic University, Poznań.
Dormeier B., 2001, *Buff Up Your Moving Average*, Technical Analysis of Stock & Commodities, no. 19, p. 48-56.
Elton E.J., Gruber M.J., Brown S.J., Goetzmann W.N., 2014, *Modern Portfolio Theory and Investment Analysis*, Wiley, New York.
Engel C., Rodrigues A.P., 1989, *Tests of International CAPM with Time-varying Covariances*, Journal of Applied Econometrics, no. 4, p. 119-138.
Fama E.F., French K.R., 1997, *Industry costs of equity*, Journal Financial Economics, no. 43, p. 153-193.
Fama E.F., French K.R., 2004, *The Capital Asset Pricing Model: Theory and Evidence*, The Journal of Economic Perspective, no. 18, p. 25-46.
Fiszeder P., 2009, *Modele klasy GARCH w empirycznych badaniach finansowych*, Wydawnictwo Naukowe Uniwerystetu Mikołaja Kopernika, Toruń.
Hafner C.M., Herwartz H., 2000, *Testing for linear autoregressive dynamics under heteroskedasticity*, Econometrics Journal, no. 3, p. 177-197.
Haugen R.A., 2000, *Modern investment theory*, Pearson, New York.
Hutson J.K., 1984, *Filter Price Data: Moving Averages Versus Exponential Moving Averages*, Technical Analysis of Stock & Commodities, no. 2, p. 102-103.
Jansen W.J., 1995, *Why Do We Reject the Mean-Variance Model?*, Scandinavian Journal of Economics, no. 97, p. 137-144.
Lambert D.R., 1984, *Exponentially Smoothed Moving Averages*, Technical Analysis of Stock and Commodities, no. 2, p. 182-183.
Li J., Tsang E.P.K., 1999, *Improving Technical Analysis Predictions: An Application of Genetic Programming*, Proceedings on the Twelfth International FLAIRS Conference, http://www.aaai.org/Papers/FLAIRS/1999/FLAIRS99-019 (02.10.2016).
Lintner J., 1965, *Security Prices, Risk and Maximal Gains from Diversification*, Journal of Finance, no. 20, p. 587-615.
Majerowska E., 2015, *Decision making process: technical analysis versus financial modelling*, Research Papers of Wroclaw University of Economics, no. 381, p. 199-210.
Mossin J., 1966, *Equilibrium in a Capital Asset Market*, Econometrica, no. 34, p. 768-783.
Murphy J.J., 1999, *Technical analysis of the financial markets*, New York Institute of Finance, New York.
Ng L., 1991, *Tests of the CAPM with Time-Varying Covariances: A Multivariate GARCH Approach*, Journal of Finance, no. 46, p. 1507-1521.
Pring M.J., 2002, *Technical analysis explained*, McGraw-Hill, New York.
Schulmeister S., 2009, *Aggregate trading behaviour of technical models and the yen/dollar exchange rate 1976-2007*, Japan and the World Economy, no. 21, p. 270-279.
Schwert G.W., Seguin P.J., 1990, *Heteroskedasticity in Stock Returns*, Journal of Finance, no. 45, p. 1129-1155.
Sharpe W.F., 1964, *Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk*, Journal of Finance, no. 19, p. 425-442.
Stooq.pl, 2016, *Notowania*, www.stooq.pl (02.10.2016).
Taylor S.J., 1986, *Modelling Financial Time Series*, Wiley, Chichester.

Tse Y.K., 2002, *Residual-Based Diagnostics for Conditional Heteroscedasticity Models*, The Econometrics Journal, no. 5, p. 358-373.

Turtle H., Buse A., Korkie B., 1994, *Tests of Conditional ASSET Pricing with Time-Varying Moments and Risk Prices*, Journal of Financial and Quantitative Analysis, no. 29, p. 15-29.

White A., 1996, *The Derivative Moving Average*, Technical Analysis of Stock & Commodities, no. 14, p. 253-257.

Zielonka P., 2004, *Technical analysis as the representation of typical cognitive biases*, International Review of Financial Analysis, no.13, p. 217-225.