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Contents

Preface	7
Piotr Bednarek , Evaluating the usefulness of quantitative methods as analytical auditing procedures / Ocena użyteczności metod ilościowych jako audytowych procedur analitycznych	9
Kateryna Berezka, Vadym Masliy , ARCH-building models of time series prediction for investment / Budowa arch-modeli szeregów czasowych do prognozowania inwestycji portfelowych.....	19
Natalia Bielous, Valeria Sopko , Implementation of the results phase of the estimation system of the economic security of enterprises / Wdrożenie wniosków z systemu oceny bezpieczeństwa ekonomicznego przedsiębiorstw	27
Magdalena Chmielowiec-Lewczuk , The impact of the implementation of Solvency II on the financial reporting of insurance companies in Poland / Wpływ wdrożenia projektu Solvency II na sprawozdawczość finansową zakładów ubezpieczeń w Polsce.....	38
Elżbieta Jaworska , Diversity management and reporting in selected companies / Zarządzanie różnorodnością oraz raportowanie informacji o różnorodności w wybranych przedsiębiorstwach.....	48
Ganna Karmeliuk, Svitlana Plaskon , Econometric modeling of the external debt of Ukraine / Ekonometryczne modelowanie długu zewnętrznego Ukrainy	63
Joanna Koczar , Responsibility for accounting of a business entity in Russian accounting law / Odpowiedzialność za rachunkowość podmiotu gospodarczego w rosyjskim prawie bilansowym.....	69
Mykhailo Kuzub , Ways of improvement of accounting of production stocks in agricultural enterprises / Sposoby poprawy księgowego ujęcia zapasów w księgach rachunkowych przedsiębiorstw rolnych	79
Lesya Leshchiiy , Valuation models of Investment Property / Modele oceny nieruchomości inwestycyjnych.....	92
Marek Masztalerz , Why narratives in accounting? / Skąd narracje w rachunkowości?	99
Ruslan Motoryn , Estimation of services in global added value chains / Ocena udziału wartości usług w globalnych łańcuchach wartości dodanej	108
Vasyl Mukoviz, Kateryna Obertas , The impact of accounting policy on formation of the valuation of assets, obligations and company's capital / Wpływ polityki rachunkowości na wartość aktywów, zobowiązań i kapitału własnego	116

Maria Nieplowicz , The use of performance-based budget to measure the efficiency of public transport in metropolises in Poland / Wykorzystanie budżetu zadaniowego do pomiaru efektywności transportu publicznego w polskich metropoliach.....	125
Edward Nowak , Deviation analysis as an instrument of cost control in an organization / Analiza odchyleń jako instrument kontroli kosztów przedsiębiorstwa	140
Marta Nowak , Quantitative assessment of culture and its usage in accounting / Ilościowa ocena kultury i jej zastosowanie w rachunkowości	148
Stepan Popina, Olesia Martyniuk , Some aspects of security portfolio optimization / Wybrane aspekty optymalizacji portfela papierów wartościowych.....	159
Michał Poszwa , Problems of determining the costs in the calculation of tax result / Problemy ustalania kosztów w rachunku wyniku podatkowego....	166
Olga Sharapa , Methodological approaches to determining the level of transaction costs of sales of agricultural enterprises / Metodyczne podejścia do określenia poziomu kosztów transakcyjnych gospodarstw rolnych	174
Alfred Szydelko, Anna Warzybok , Risk associated with research and development projects and its consequences for the financial accounting system / Ryzyko w projektach badawczo-rozwojowych i jego konsekwencje dla rachunkowości finansowej	181
Marcin Wierziński , Performance management in a water and sewerage company / Zarządzanie dokonaniem w przedsiębiorstwie wodociągowo-kanalizacyjnym.....	190

Preface

This book presents the results of Polish-Ukrainian scientific cooperation. It contains the papers prepared for the 10th international conference “Quantitative Methods in Accounting and Finance”. Accounting and finance face nowadays many challenges. They require both an international and local approach, they need to be considered from the theoretical and practical point of view, and they also encourage general and specific analysis.

Support from quantitative methods is needed in order to discover, implement and verify new finance and accounting trends, methods and instruments. The research papers which are part of this book present different aspects of accounting and finance combined with a quantitative, in particular Econometric, approach.

Some of the papers focus on methodology of measurement, estimation and forecasting of financial phenomena, especially those related to investment processes. Others address specific problems of accounting such as accounting solutions for different branches, legal issues of accounting, responsibility and reporting. An alternative approach was also undertaken and the roles of a narrative and culture in accounting were presented.

The variety of papers selected for this issue ensures the complexity of the book. It provides theoretical as well as empirical material which can be used in further research and in business practice, particularly in accounting and finance. We hope that the content of the book provides a starting point for scientific discussion and practical changes.

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ARCH-BUILDING MODELS OF TIME SERIES PREDICTION FOR INVESTMENT

BUDOWA ARCH-MODELI SZEREGÓW CZASOWYCH DO PROGNOZOWANIA INWESTYCJI PORTFELOWYCH

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Summary: Nowadays, due to the increased internationalization of financial markets and the increasing openness of national economies, there is increasing cross-border movement of portfolio investments as a form of international economic relations. The objects of portfolio investment could be shares, bills, debt securities, derivatives etc. Direct and portfolio investments are different in nature and do not have the same influence on the economy of the resident. Since portfolio investments are providing the purchase of securities and other financial instruments and have a speculative nature due to the potential risk of rapid outflows, it can be concluded that they are largely volatile and, therefore, cannot be predicted by standard predictive models and ARIMA-models. The aim of our study is to attempt to apply econometric models of conditional and generalized heteroscedasticity (ARCH-model and GARCH-model) and to predict the volume of portfolio investments in Ukraine. The scope of portfolio investments in Ukraine is researched, and there is also built an econometric model of ARCH family. Evaluation of ARCH models options is made by maximum likelihood method. Checking the adequacy of models is done by selected the most optimal one and made for the forecasting period. Research was conducted using the package EViews 6.

Keywords: portfolio investments, conditional heteroskedasticity, volatility, maximum likelihood method, ARCH-models.

Streszczenie: Aktualnie wskutek internacjonalizacji rynków finansowych, jak również w wyniku coraz większej otwartości gospodarek narodowych dokonuje się aktywizacja przepływu transgranicznych inwestycji portfelowych jako jednej z postaci stosunków gospodarczych w wymiarze międzynarodowym. Przedmiotami inwestycji portfelowych mogą być akcje, weksle, dłużne papiery wartościowe, derywaty itp. Inwestycje bezpośrednie oraz inwestycje portfelowe mają różne pochodzenie, w różnym stopniu oddziałują też na gospodarkę kraju rezydenta. Inwestycje portfelowe mają niekiedy charakter spekulacyjny, co oznacza, że istnieje ryzyko ich znacznego zmniejszenia w krótkim czasie. Można zatem dojść do wniosku, że są one zmienne, a więc nie mogą być prognozowane za pomocą standardowych modeli prognozujących oraz modeli ARIMA. Celem badania jest próba zastosowania modeli ekonometrycznych o heteroskedastyczności warunkowej oraz uogólnionej (ARCH-modele oraz GARCH-modele) dla prognozowania skali inwestycji portfelowych na Ukrainie. W artykule

została zbadana wartość inwestycji portfelowych na Ukrainie, a także opracowano modele ekonometryczne rodziny ARCH. Ocena parametrów modeli ARCH była prowadzona na podstawie metody maksymalnej wiarygodności. Modele sprawdzono pod względem adekwatności, a następnie wybrano model optymalny. Na podstawie tego modelu wykonano prognozowanie na jeden okres. Badanie przeprowadzono za pomocą pakietu EViews 6.

Słowa kluczowe: inwestycje portfelowe, heteroskedastyczność warunkowa, metoda maksymalnej wiarygodności, ARCH-modele.

1. Introduction

Nowadays, due to the increased internationalization of financial markets and the increasing openness of national economies, there is increasing cross-border movement of portfolio investments as a form of international economic relations.

The structure of foreign direct investments (hereinafter – FDI) includes: joint-stock (buying share of foreign company by direct foreign investor, at least 10% of the stated capital); intercompany loans and debt transactions; reinvested earnings; intangible assets such as technologies, trade marks (brands), managerial experience and more. The main reason for the implementation of FDI is to obtain a significant effect on the management of the business in which there is invested capital.

Portfolio investments represent capital that is invested by a resident of one country into shares and debt securities of companies in another country to obtain income. Objects of portfolio investment could be shares, bills, debt securities, derivatives etc. Main causes for the implementation of portfolio investments are profit and reduce the risk diversification of portfolio capital; they are financial transactions and are not accompanied by the transfer of intangible assets, management experience, know-how.

Direct and portfolio investments are different in nature and do not have the same influence on the economy of the resident. The main differences between them are:

- FDI, in contrast to a portfolio, give to investor the right to control.
- In most cases, direct investments are long-term investments, a portfolio, on the contrary – short-term.
- Various sources of funding and the motives of committing.
- Different effects on the economy and the state of the financial markets in the country of the investor and the recipient country.
- Portfolio investments are more destabilizing than FDI.
- Different levels of accessibility to the recipients.
- Various timing and degree of liquidity.

2. Problem statement and analysis of recent research

Taking into consideration the major differences between these types of investments, we consider it expedient to predict their streams separately from each other.

Since portfolio investments, as mentioned above, providing the purchase of securities and other financial instruments and have a speculative nature due to the potential risk of rapid outflows, it can be concluded that they are largely volatile and, therefore, cannot be predicted by standard predictive models and ARIMA-models.

The aim of our study is to attempt to apply econometric models of conditional and generalized heteroscedasticity (ARCH-model and GARCH-model) and to predict the volume of portfolio investments in Ukraine. The main difference between these models and standard approaches is that the predicted volatility (variance) is not constant, but depends on the previous states of the process, from the assessment level variance prior periods (GARCH-effect) and develops in time.

The tasks of estimation and forecasting of volatility are of considerable interest among economists. They were reviewed in their writing, in particular by such scholars as: T. Bollerslev, R. Chou, K. Kroner [1992], C. Brownlees, R. Engle, B. Kelly [2012], R. Chou [1988], J. Ding, N. Meade [2010], F. Klaasen [2002].

The ARCH concept was introduced by Engle in 1982, realizing the idea that variance of the error in time depends on the square of errors in the previous periods. The ARCH process (q) is following [Engle 1982, p. 994]:

$$\sigma_t^2 = \mu + \gamma_1 \varepsilon_{t-1}^2 + \gamma_2 \varepsilon_{t-2}^2 + \dots + \gamma_q \varepsilon_{t-q}^2 ,$$

For ARCH(1):

$$\sigma_t^2 = \mu + \gamma_1 \varepsilon_{t-1}^2 .$$

It is assumed that, $\mu > 0$, $\gamma_k \geq 0$, the variance was not negative.

In 1986 Bollerslev proposed GARCH model. GARCH (p, q) is as follows [Bollerslev 1986, p. 310]:

$$\begin{aligned} \sigma_t^2 &= \mu + \delta_1 \sigma_{t-1}^2 + \delta_2 \sigma_{t-2}^2 + \dots + \delta_p \sigma_{t-p}^2 + \gamma_1 \varepsilon_{t-1}^2 + \gamma_2 \varepsilon_{t-2}^2 + \dots + \gamma_q \varepsilon_{t-q}^2 = \\ &= \mu + \sum_{k=1}^p \delta_k \sigma_{t-k}^2 + \sum_{k=1}^q \gamma_k \varepsilon_{t-k}^2 , \\ \mu &> 0, \gamma_k \geq 0, \delta_k \geq 0. \end{aligned}$$

For GARCH(1,1):

$$\sigma_t^2 = \mu + \delta_1 \sigma_{t-1}^2 + \gamma_1 \varepsilon_{t-1}^2 .$$

In models GJR(p, q), the equation for the conditional variance is the following [Glosten, Jagannathan, Runkle 199, p. 1783]:

$$\sigma_t^2 = \mu + \sum_{k=1}^p \delta_k \sigma_{t-k}^2 + \sum_{k=1}^q \gamma_k \varepsilon_{t-k}^2 + \sum_{k=1}^q L_k I(\varepsilon_{t-k} < 0) \varepsilon_{t-k}^2 .$$

Where $I(\varepsilon_{t-k} < 0)$, If $\varepsilon_{t-k} < 0$, $i I(\varepsilon_{t-k} < 0) = 0$ otherwise, constrained

$$\begin{aligned} \sum_{k=1}^p \delta_k + \sum_{k=1}^q \gamma_k + \frac{1}{2} \sum_{k=1}^q L_k &< 1 , \\ \mu \geq 0, \gamma_k \geq 0, \delta_k \geq 0, \gamma_k + L_k &\geq 0 . \end{aligned}$$

This model is often called TARCH(p,q) model (threshold ARCH).

In models EGARCH(p,q) the equation for the conditional variance is given [Nelson, p. 351]:

$$\ln \sigma_t^2 = \mu + \sum_{k=1}^p \delta_k \ln \sigma_{t-k}^2 + \sum_{k=1}^q \gamma_k \left[|z_{t-k}| - E(|z_{t-k}|) \right] + \sum_{k=1}^q L_k z_{t-k},$$

where have been introduced standardized (with unit variance) investigated indicators $z_{t-k} = \varepsilon_{t-k} / \sigma_{t-k}$, at that $E(|z_{t-k}|) = \sqrt{2/\pi}$ for the normal distribution of standardized indicators. Restrictions on the parameters of the model are due to the fact that all the roots of the characteristic equation:

$$\lambda^p - \delta_1 \lambda^{p-1} - \delta_2 \lambda^{p-2} - \dots - \delta_p = 0$$

have been within the circle of radius.

For forecasting purposes, the GARCH model is usually complemented by any model that describes the behavior of the conditional or unconditional average number of observations. For example, it can be assumed that there is not ε_t , but ε_t plus a constant, that is, the observed series has a constant unconditional expectation β , to which is added a bug ε_t in a GARCH process: $y_t = \beta + \varepsilon_t$. It can be simulated as the unconditional mathematical expectation using linear regression, that is $y_t = X_t \alpha + \varepsilon_t$. This allows considering linear trend, deterministic seasonal variables, etc.

3. Results of the analysis

Estimation of ARCH model's parameters is held by the method of maximum probability and implemented in many application packages of statistical data. The econometric time-series analysis was conducted using the EViews 6 package in this study.

The first stage of the study is to identify the ARCH-effect. ARCH-test allows making conclusions about the volatility clustering, the presence of volatile periods and periods of relative quiet, which is to test the hypothesis that occasional errors of residues described by the ARCH model.

After examining a number of dynamic volumes of portfolio investments in Ukraine for the period from I quarter 1998 till IV quarter 2015 (Figure 1a), it is found that the ARCH effects have the first distinction of the series (Figure 1b – fluctuations for the period from I quarter 1998 till I quarter 2004 – low, from IV quarter 2004 till IV quarter 2015 – High; Figure 1c – statistics value $\chi_p^2 = 0.0123$ is less than 0.05, which means that – there exists the ARCH effect).

Calculate parameters of following econometric models ARCH family: ARCH (4), ARCH (5), GARCH (1,1), TARCH (1,1,1) and EGARCH (1,1,1). So: ARCH(4)

$$\sigma_t^2 = 1\,253\,672 + 0.232\varepsilon_{t-1}^2 - 0.079\varepsilon_{t-2}^2 - 0.024\varepsilon_{t-3}^2 + 0.217\varepsilon_{t-4}^2, \quad \beta = 25.743.$$

ARCH(5)

$$\sigma_t^2 = 1\,310\,153 + 0.403\varepsilon_{t-1}^2 - 0.121\varepsilon_{t-2}^2 - 0.045\varepsilon_{t-3}^2 + 0.290\varepsilon_{t-4}^2 + 0.037\varepsilon_{t-5}^2, \beta = -46.390$$

GARCH(1,1)

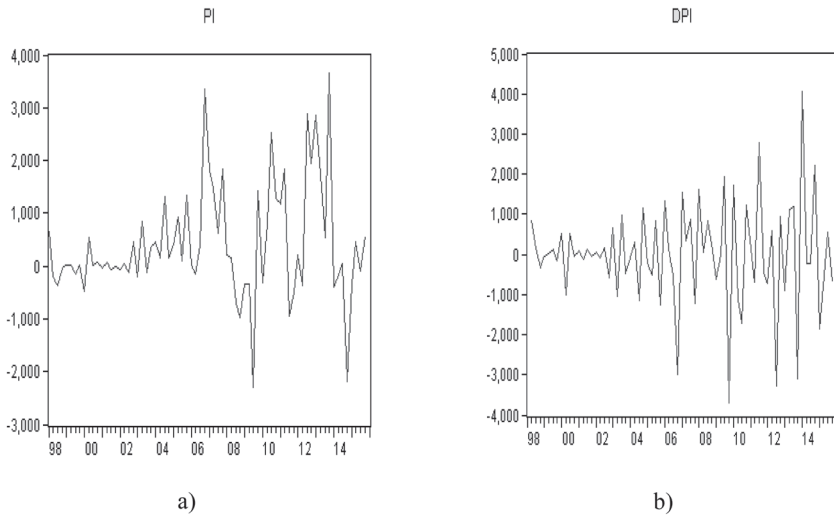
$$\sigma_t^2 = 1\,072\,263 + 0.526\varepsilon_{t-1}^2 - 0.117\sigma_{t-1}^2, \beta = 9.458$$

TARCH(1,1,1)

$$\sigma_t^2 = 949\,034.2 + 0.697\varepsilon_{t-1}^2 + 0.291\varepsilon_{t-1}^2(\varepsilon_{t-1} < 0) - 0.111\sigma_{t-1}^2, \beta = -84.715$$

EGARCH(1,1,1)

$$\log(\sigma_t^2) = 12.886 + 1.175 \frac{|\varepsilon_{t-1}|}{\sigma_{t-1}} - 0.177 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + 0.023 \ln(\sigma_{t-1}^2), \beta = -52.001.$$



Heteroskedasticity Test: ARCH

F-statistic	6.743206	Prob. F(1,61)	0.0118
Obs*R-squared	6.271064	Prob. Chi-Square(1)	0.0123

c)

Fig. 1. a) Chart of portfolio investments; b) Chart of first distinctions; c) the results of research using ARCH-test

Source: own study.

To compare the quality of models, use Akaike information criterions (AIC) and Schwarz (the SCI) (Table 1). The lower criterion value, the higher the relative quality of the model.

Table 1. Akaike and Schwartz value criterion

Model	AIC	SCI
ARCH(4)	16.79	16.99
ARCH(5)	17.16	17.40
GARCH(1,1)	17.09	17.23
TARCH(1,1,1)	17.12	17.29
EGARCH(1,1,1)	17.05	17.22

Source: own study.

The table shows that the best model is the GARCH (4), after it is GARCH (1,1).
 Checking ARCH(4) model for adequacy do by the following algorithm:

1. Autocorrelation coefficients of residues for ARCH (4) model are shown in Figure 2. They are small, located in the vicinity of zero in the range. $\pm 2/\sqrt{n}$.

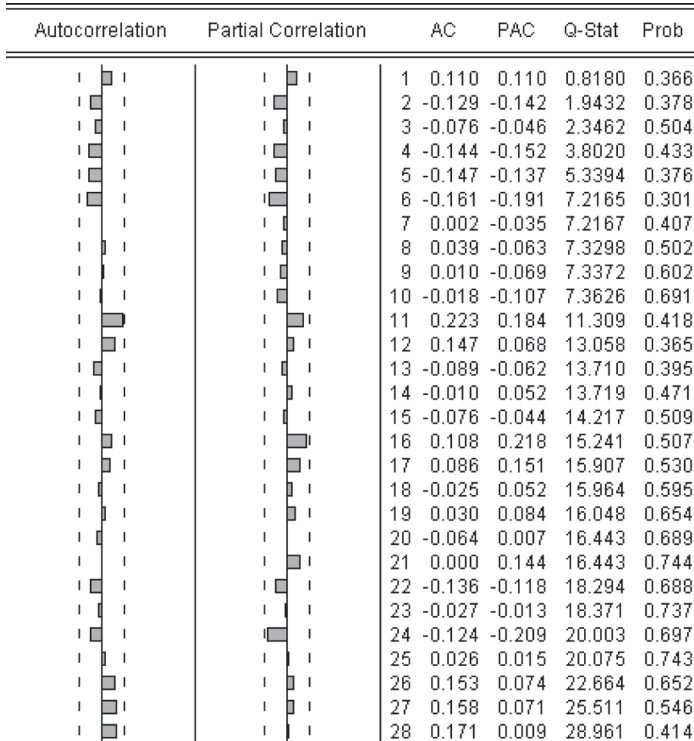


Fig. 2. Correlogram for squares of standardized residues

Source: own study.

In addition, check autocorrelation coefficients of residues through test χ^2 (“x-square”) which is based on *Ljung-Box Q statistic*. This test evaluates the overall

sizes of the autocorrelation coefficients of residues. If the value Prob, related to Q statistic small (Prob), then there is autocorrelation. Correlogram shown in Figure 2 indicates that the autocorrelation in the model residues is absent.

2. Check existence of ARCH-effects in residues (Figure 3). Value of statistics $\chi_p^2=0.3784$, which is more than 0.05, which means – there is no ARCH effect.

Heteroskedasticity Test: ARCH

F-statistic	0.760498	Prob. F(1,61)	0.3866
Obs*R-squared	0.775760	Prob. Chi-Square(1)	0.3784

Fig. 3. The results of research using ARCH-test

Source: own study.

Thereby, the model adequately reflects residues.

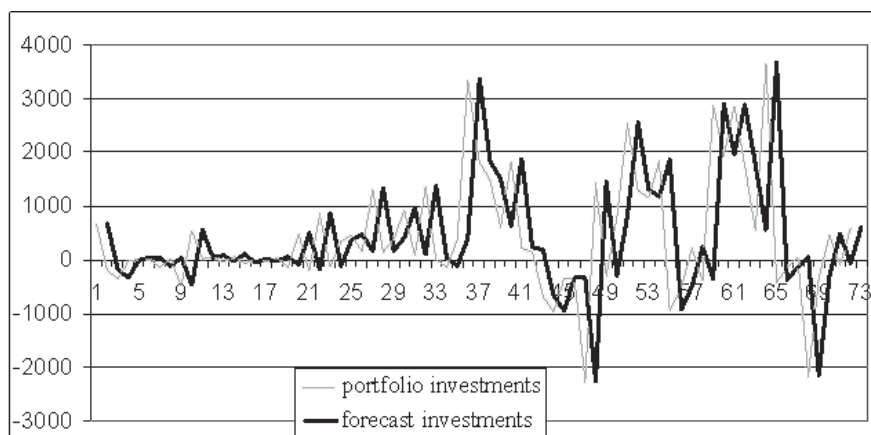


Fig. 4. Actual and forecast volumes of portfolio investments in Ukraine

Source: own study.

Figure 4 shows the real data of portfolio investments and forecast values ARCH4 model.

4. Conclusion

Taking into account that the focus of portfolio investments is on financial tools, and considering the characteristics of them, we consider that it is appropriate for forecasting to apply the ARCH model family. According to the outcomes of our research, this makes it possible to obtain good results. Forecasting the volatility

of portfolio investments may have practical significance with respect to their management and in terms of the theoretical expansion of foreign investment forecasting methods.

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