UDC 004.942+338.27
DOI: 10.31339/2313-8114-2020-1(13)-184-191

Generalised Autoregressive Conditional Heteroskedasticity Modeling of One-Year Maturity Government Bonds of Greece During Sovereign Debt Crisis of Eurozone in 2010

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(Received: 23.01.2020, Revised: 22.02.2020, Accepted: 25.03.2020)

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Abstract. The relevance is determined by the need to investigate the 2010 eurozone sovereign debt crisis and the factors that led to it. These factors range from a combination of international trade imbalances, the impact of the global crisis from 2007 to 2012, the failure of European governments' bailout approaches that created barriers for bondholders in both banking and the private sector, and high-risk lending policies and loans, forced by unregulated credit requirements between 2002 and 2008 and fiscal policy choices related to government revenues and expenditures. The aim of the study is to model data to identify a set of primary risk factors and identify economic variables and their impact on both the local economy of Greece and the financial markets associated with it. As a result of the study, a set of primary risk factors and their impact on the local economy of Greece, the domestic financial market based on external sources, was identified to validate the analysis. Methods of statistical analysis and macroeconomic modeling of data were used for this purpose. Generalised models of autoregressive conditional heteroskedasticity based on data provided by the World Bank Data Portal have become a method of modeling. As a result, the autoregressive conditioned heteroskedastic (ARCH) and the generalised autoregressive conditioned heteroskedastic (GARCH) models, built and trained on the data of 2006-2009, were obtained, predicting volatility from 2010. It was found that the model of the autoregressive integrated moving average is not suitable for the task because there was no noticeable autocorrelation. It was found that volatility has a tendency to fade. This observation coincides with reality. Systemic risk indicators, mainly used to forecast national risk, are usually based on insider data from rating agencies or financial institutions. This article provides results close to the composite indicator of systemic stress provided by the European Central Bank (ECB) using the ARCH and GARCH models on publicly available data. Practical significance refers to the principle of model formation, which allows creating risk indicators based on publicly available state financial data

Keywords: economy, Single financial market, macroeconomic models, prices for goods, risk indicators

The Problem Statement

Despite much effort and decades to build a strong Single Financial Market, some member states of the area didn't have proper crisis resolutions and mechanisms at the time of the Global Financial Crisis of 2008. There was a threat of widespread bank failures in EU countries and near collapse of their financial systems. This led to a constant sovereign debt arising from the need to refinance government debts. The sovereign debt crisis threatened the Euro Area and European Union in general to near facing a new recession [1-3]. Credit agencies' ratings and indexes are black

Suggested Citation:
Baryshych, L.M., & Dusengumukiza, D. (2020). Generalised autoregressive conditional heteroskedasticity modeling of one-year maturity government bonds of Greece during sovereign debt crisis of eurozone in 2010. *Scientific Bulletin of Mukachevo State University. Series "Economics"*, 7(1), 184-190.

boxes, based on insider data unavailable to most investors. The paper identifies and analyses the effects of (interest rates, market concentration, and monetary supply or commodities prices) and their effect on both the economy and traditional approaches to portfolio risk management.

Analysis of Recent Research and Publications

As the crisis faded off, the interest in its analysis of Greece economy slowly went down. The last major macroeconomic research was done by the Business Insider journal to rate Greece recovery rate [4]. The main studied publication in this paper was European Central Bank report on Greece [5]. It provides analysis of Greece fall and recovery and uses SSSI to measure risk. A more academical source used was a series of Kenton, W papers based on usage of GARCH models in macroeconomics. Systemic risk indicators, primarily used for forecasting statewide risk, are usually built on insider data of rating agencies or financial institutions. In this paper we obtain results close to Systemic Stress Indicator provided by European Central Bank (ECB) using ARCH and GARCH models on public data [6]. The unresolved part of a common 'black box' problem is GARCH modeling.

Setting the Objectives

The objective is to model the boiling state of the Greek local financial market before the peak of the Sovereign Debt Crisis of Eurozone in 2009, modeling the insights of foreign investors and credit rating organisations. We will identify a set of primary risk factors and their effect on both the local economy and the markets involved to validate the analysis done.

Results and Discussion

The Euro Area also called Eurozone is a monetary union of 19 of the 27 European Union (EU) member states which have adopted the euro as their common currency and sole legal tender. European Union has initially been established in 1993 with the aim of achieving economic integration via stimulating members economic growth, encouraging industrial specialisation and enhancing supplemental gains from international trade. The Euro Area has been expanding from time to time and other members of European Union have been integrated by agreeing to adopt Euro as their currency.

The paper provides extended traditional data modeling workflow used in both research and industry. Data has been selected, sourced and modelled to provide insights fed into the analysis. Analysis is driven by analytic graphs, exploratory analysis, and has been discussed to validate statistical and macroeconomic models (Autoregressive Conditional Heteroskedasticity (ARCH) and Generalised Autoregressive Conditional Heteroskedasticity (GARCH)) chosen and applied from a set of provided techniques [7-10].

This paper will use both statistical analysis and macroeconomic data modeling techniques to identify a set of primary risk factors or economic variables and their effect on both the local economy of Greece and the markets involved. The selected method of modeling is Generalised autoregressive conditional heteroskedasticity models. The research is based on the data provided by World Bank Data Portal. Experiment – building and fitting ARCH and GARCH models. Subject – Greek government bond triple A with 1-year yield maturity and SSSI. The authors decided to build a model around variance. The point is to study spread, which can be used to indicate panic and turbulence in the finance market. Those swings are typical for Sovereign Debt Crisis (as stated by the EU commission report studies). The authors will forecast possible variance based on data, observable before the crisis peak. This allows to predict data with the same conditions as experts during the crisis.

The ARCH/GARCH models are suitable because the authors are expecting the data to be a trendless white noise. As the data is turbulent in the presence of the crisis, there should be no significant trends in volatility and no shared variance. The authors have not used the ARIMA (autoregressive integrated moving average) model because of the decision to focus on shocks and deviations of the series and not on the forecast itself. This paper uses ARCH/GARCH time series model to analyse data. ARCH stands for Autoregressive Conditional Heteroskedasticity (ARCH) and it is a time-series analysis tool for securities markets with the principle that periods of low volatility are often followed by periods of high volatility. Meaning that the variance of the error term describing these markets would vary depending on the variance of previous periods. If the change in variance can be correlated over time, then it can be modeled using an autoregressive process, such as ARCH.

On the other hand, GARCH process is often preferred by financial modeling professionals because it provides a more real-world context than other ARCH and other models when trying to predict the prices and rates of financial instruments [11; 12]. It is an extension of the ARCH model that incorporates a moving average component together with the autoregressive component. Specifically, the model includes lag variance terms (e.g., the observations if modeling the white noise residual errors of another process), together with lag residual errors from a mean process [13]. The introduction of a moving average component allows the model to both model the conditional change in variance over time and changes in the time-dependent variance.

The authors selected SSSI as an external risk measurement to show high-risk exposure. The indicator is based on the work of D. Holló, M. Kremer, and M.Lo Duca [14]. This paper plots "CISS – a composite indicator of systemic stress in the financial system" on the graph to view changes over the years from 2008 in the Euro Area (Fig. 1) [15]. The budget to Gross Domestic Product (GDP) spending was selected as it is, partially, a cause of the Sovereign Debt Crisis. The authors fetched Greece and overall Eurozone data to visually show how drastic were the changes in spending of Greece compared to overall situation (Fig. 2).

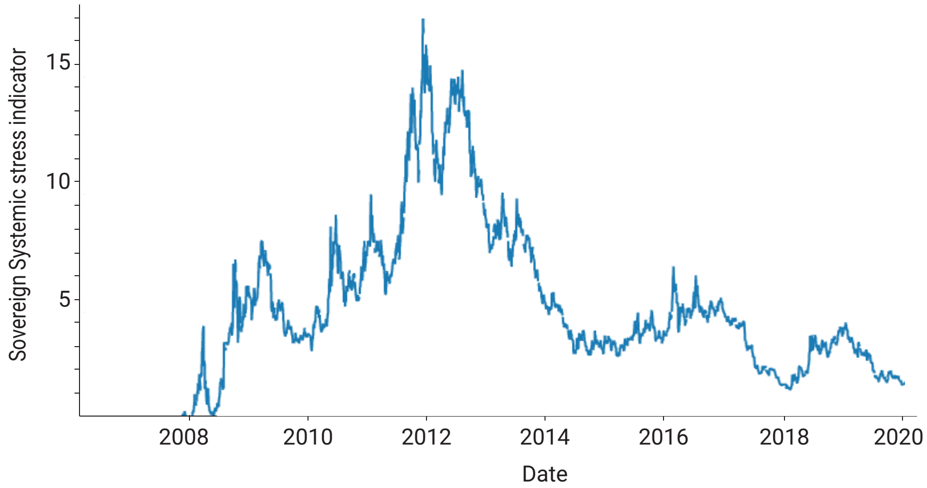

Figure 1. Sovereign Systemic Stress indicator

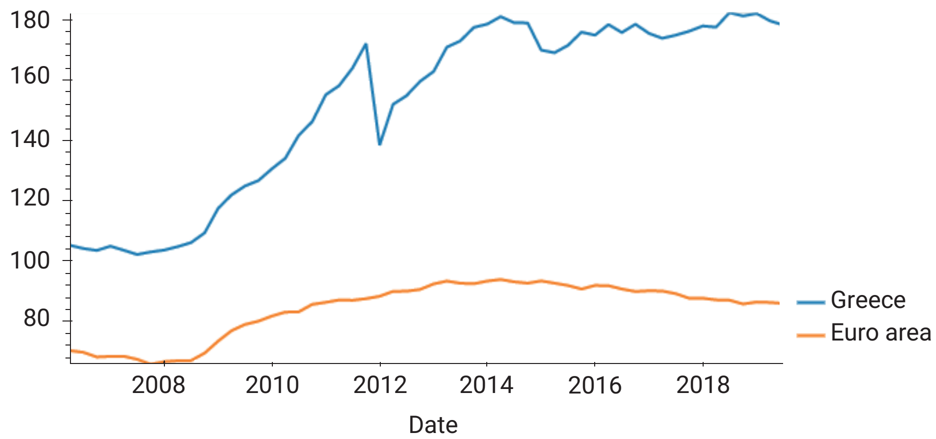

Figure 2. Spending to GDP ratio

To show how the crisis affected financial markets, we selected Euro area bonds with 1-year maturity. The authors intentionally selected grouped eurozone bonds dynamics without specifying the emitting country (Greece, for example) to show how wide the crisis was. The data is Euro area (changing composition) – Government bond, nominal, all issuers whose rating is triple A – Svensson model – continuous compounding – yield error minimisation – Yield curve spot rate, 1-year maturity – Euro, provided by ECB.

The paper uses European Central Bank "Yield curve spot rate, 1-year maturity – Government bond, nominal, all issuers whose rating is triple A – Euro area (changing composition)" as cited in the code section in the appendix. Based on the work of D. Holló, M. Kremer, and M. Lo Duca [14], this paper plots CISS (a composite indicator of systemic stress) in the financial system on the graph to view changes over the years from 2008 in the Euro Area [first graph], and shows government bond interest in the area (Fig. 3).

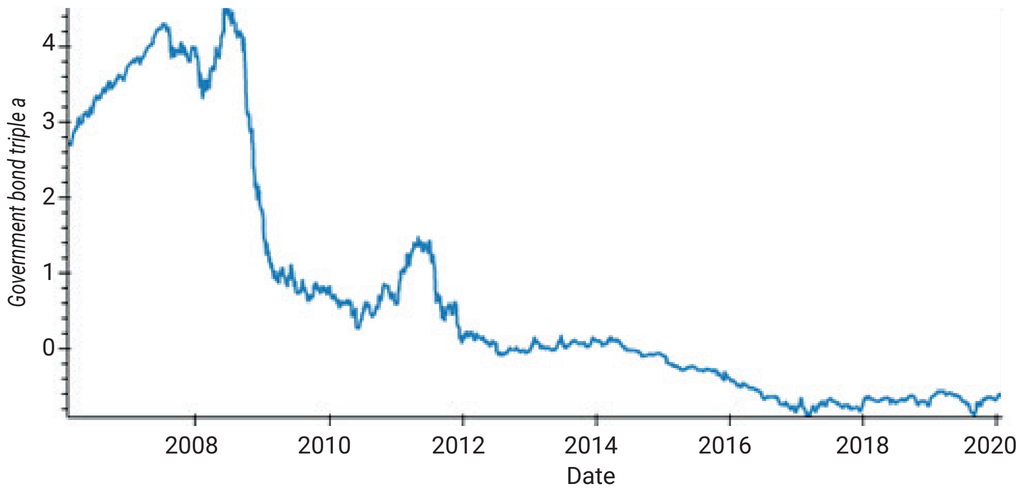

Figure 3. Government bond triple A

First, the range from 2006-04-01 (the first data observations) to 2009-02-01 is selected – before the peak of the crisis. It is essential to build models on data obtained before the crisis started to cool down. Then, it is necessary to check autocorrelation function (ACF) to see, does the obtained data contain trends or is it a random noise. The authors are taking squares of data returns and building ACF graphs. The ACF of the series below shows that the series looks to be white noise. So, it is possible to try to fit ARCH/GARCH. Additionally, the authors used Value at risk (VAR) method to display risk exposure in the given environment. The calculation is listed in appendix, and here are the results: Parametric VAR is -0.081 and Historical VAR is -0.072; Simulated VAR is -0.0782096667041426 (NB: here, the VAR is negative as it is the money lost) (Figs. 4-5).

As it is seen, the Auto Regressive Integrated Moving Average model is not suitable here, as here is no notable autocorrelation (Figs. 6-7).

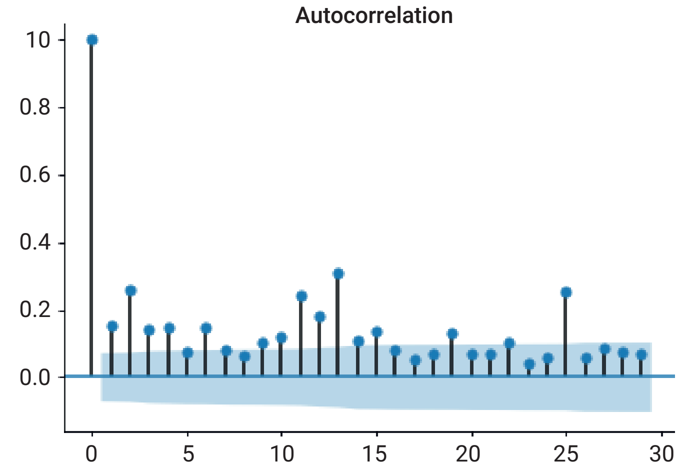

Figure 4. Bond yields autocorrelation

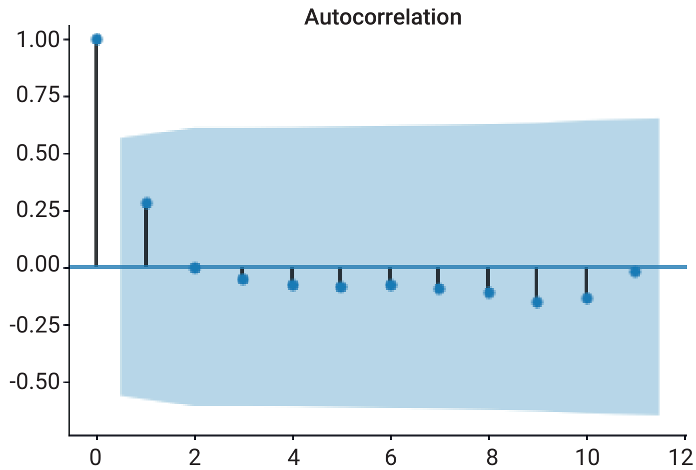

Figure 5. Debt to GDP rate of Greece autocorrelation

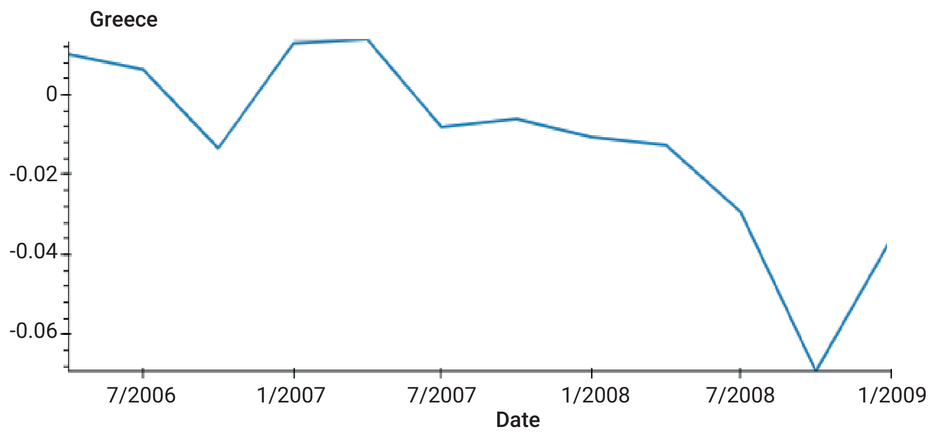

Figure 6. Debt to GDP rate in the selected range

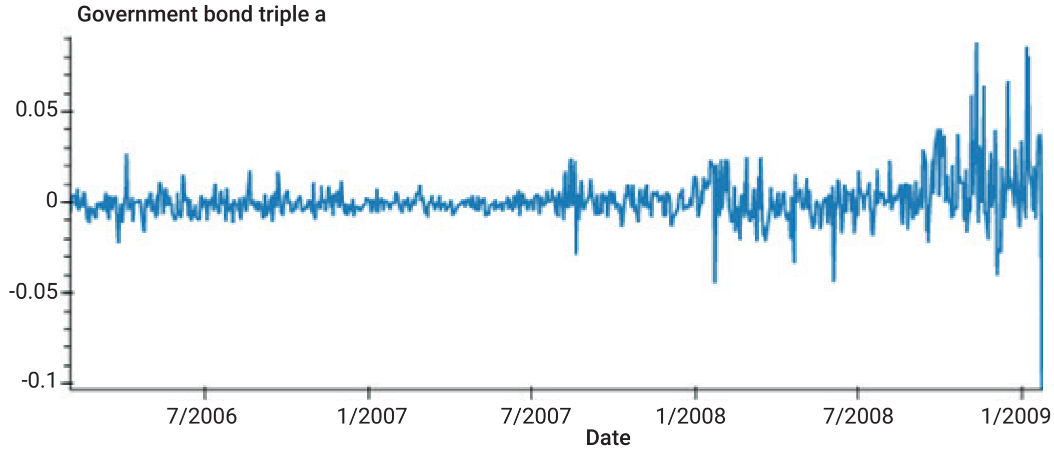

Figure 7. Government yields in the selected range

Now it's time to fit ARCH and GARCH models. The model build and fit part is listed in the code appendix. Then it is possible to forecast the next 100 ticks of data. This is 100 days for the bond yields and 50 years for the government spending (Fig. 8).

```
                              Mean Model
          ==============================================================
========================
                 coef    std err       t     P>|t|      95.0% Conf. Int.
          --------------------------------------------------------------
mu            0.0531 1.487e-02    3.569  3.581e-04  [2.392e-02,8.220e-02]
                              Volatility Model
          ==============================================================
========================
                 coef    std err       t     P>|t|      95.0% Conf. Int.

omega          0.0156  4.932e-03    3.155  1.606e-03  [5.892e-03,2.523e-02]
alpha[1]       0.0879  1.140e-02    7.710  1.260e-14  [6.554e-02, 0.110]
beta[1]        0.9014  1.183e-02   76.163    0.000    [ 0.878, 0.925]
          ==============================================================
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Figure 8. Short listing of GARCH model summary

As it is seen, the coefficients alpha, omega and mu have a small std, so it is possible to proceed with it. Let's analyse ARCH and GARCH outputs. The volatility seems to fade out. This observation coincides with reality, as the crisis is about to peak and descend. Before settling down, the volatility of bond yields swings a lot. This shows a high level of uncertainty in the boiling market (Figs. 9-10).

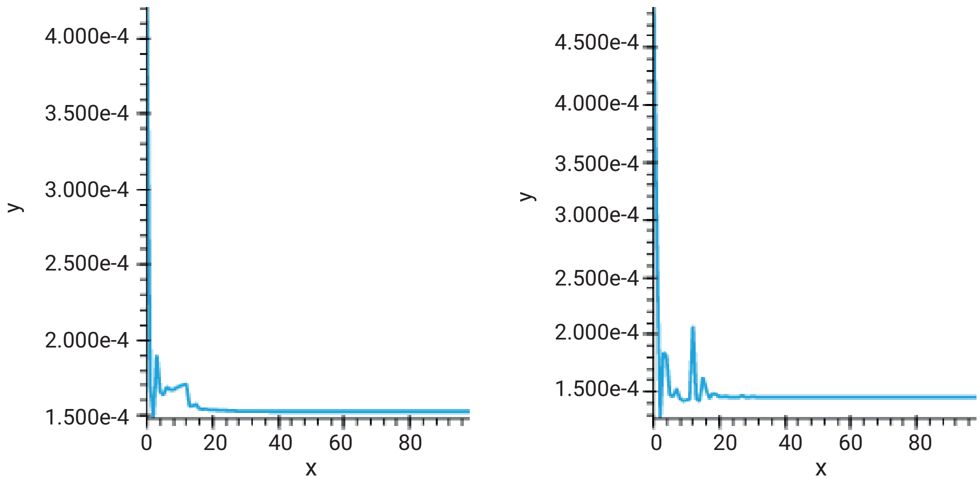

Figure 9. ARCH and GARCH models output for bonds yields

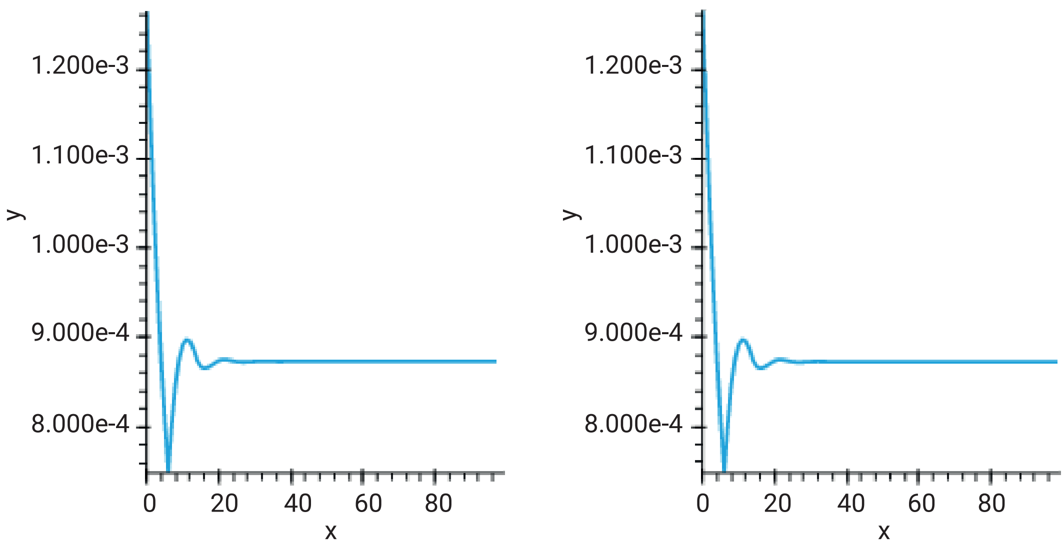

Figure 10. ARCH and GARCH models output for spending to GDP ratio

Conclusions

A similar pattern can be observed with spending volatility prediction. It is uncertain what Greece's actions might be right away, but in the end, they should pick a rate and settle down. Both of these observations, based on models, are close to the real historical state of the market. This information explains the state of the market before the peak – high uncertainty and high volatility of government bond yields adding to uncertainty, relatively low VAR shows that even with observed volatility, the risks of default are still relatively high – approx. 8%. This adds to the panic and explains the high yields of the bonds.

The authors have modelled the boiling state of the Greek local financial market before the peak of the Sovereign Debt Crisis of Eurozone in 2009, obtaining the insights of foreign investors and credit rating organisations. Obtained results explain the state of the market before the peak – high uncertainty and high volatility of government bond yields. The obtained forecast is relatively close to the one provided by ISSS and based solely on publicly available data. Generalised autoregressive conditional heteroskedasticity modeling is a general and effective tool, that can be used in risk forecasting of macroeconomic stress.

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Узагальнене моделювання авторегресійної умовної гетероскедастичності однорічних державних облігацій Греції під час кризи суверенного боргу Єврозони у 2010 році

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Анотація. Актуальність полягає у необхідності дослідити кризу суверенних боргів єврозони 2010 року та чинників, які її спричинили. Ці фактори варіюються від поєднання міжнародної торговельної диспропорції, впливу глобальної кризи з 2007 по 2012 рік, невдачі підходів рятувальних заходів європейських урядів, які створювали перепони для власників облігацій водночас з банківської галузі та приватного сектору, політика кредитування та позики з високим рівнем ризику, що примушувалися нерегульованими вимогами до кредитів у період з 2002 по 2008 рік та вибір фіскальної політики, пов'язаний з доходами та витратами уряду. Метою дослідження є моделювання даних для виявлення набору первинних чинників ризику та визначення економічних змінних і їхнього впливу як на місцеву економіку Греції, так і на фінансові ринки, що пов'язані з нею. Унаслідок дослідження було визначено набір первинних чинників ризику та їхній вплив на місцеву економіку Греції, внутрішній фінансовий ринок на основі сторонніх джерел, для валідації проведеного аналізу. Для цього використовувалися методи статистичного аналізу та макроекономічного моделювання даних. Методом моделювання стали узагальнені моделі авторегресійної умовної гетероскедастичності, що базуються на даних, наданих Порталом даних Світового банку. Унаслідок отриманого побудовані та натреновані на даних 2006–2009 років авторегресивно умовну гетероскедастичну (АРУГ) та узагальнено авторегресивно умовну гетероскедастичну (УАРУГ) моделі, що прогнозують волатильність від 2010 року. Виявлено, що модель авторегресивної інтегрованої ковзної середньої не підходить для поставленої задачі, оскільки не було помітної автокореляції. Виявлено, що волатильність має схильність до згасання. Це спостереження збігається з реальністю. Показники системного ризику, що в основному використовуються для прогнозування загальнодержавного ризику, зазвичай будуються на інсайдерських даних рейтингових агентств або фінансових установ. У цій статті отримано результати, близькі до Системного показника напруги, наданого Європейським центральним банком (ЄЦБ), використовуючи моделі АРУГ та УАРУГ на загальнодоступних даних. Практичне значення має принцип формування моделі, що дозволяє створювати показники ризику на основі публічних державних фінансових даних

Ключові слова: економіка, Єдиний фінансовий ринок, макроекономічні моделі, ціни на товари, показники ризику