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## MODELING OF EURO STOXX 50 INDEX PRICE RETURNS BASED ON INDUSTRIAL PRODUCTION SURPRISES: BASIC AND MACHINE LEARNING APPROACH

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**Abstract.** There are a big number of researches which analyzing stock price returns. Some of them is based on fundamental analysis theory. Meanwhile other studies are based on efficient market hypotheses and financial behavior theories. However, there is not enough researches combining the characteristics of these theories into one. Such kind of researches in the scientific literature is usually referred to macroeconomic news, announcements, surprises, expectations studies. These studies examine not only the actual but also the predictive values of macroeconomic indicators announcements, normalizing them and thus creating absolutely a new surprise indicator. Purpose of this paper is modeling EURO STOXX 50 index price returns based on Industrial production surprise indicator. Empirical part shows that the best models for explaining EURO STOXX 50 index price returns was obtained at the 40 and 42 in different surprise indicator scenario. The coefficient of determination was obtained respectively 24.70% and 21.80%. Meanwhile applying machine learning method of artificial intelligence, a much more accurate models were obtained. The coefficient of determination respectively was 33,22% and 26,60%.

**Keywords:** surprises; price; return; EURO STOXX 50; Industrial production

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**Additional disciplines:** mathematics, statistics, law

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## 1. Introduction

Attempts to explain and predict changes of stock price returns have been trying for decades. Some of them is based on fundamental analysis theory (Tetteh, et. al., 2019; Abed, Zardoub, 2019; Ho, 2018). Meanwhile other studies are based on efficient market hypotheses (Altinkilic, et. al., 2015; Fama and French, 2015; Yen and Lee, 2008) and financial behavior theories (Kozel, 2015; Pasquariello, 2014; Nawrocki and Viole, 2014). However, there are not enough researches combining the characteristics of these theories into one. Such kind of researches in the scientific literature is usually referred to macroeconomic news, announcements, surprises, expectations studies (Alexiou, et. al., 2018; Cakan, Gupta 2017; Nadleri, and Schmidt, 2016; Chen, et. al., 2015; Miao, et. al., 2014; Gurgul, Wójtowicz, 2014; Harju, Hussain, 2011; Gupta, Reid 2012; Hussain, 2010; Masood et al., 2020 and others). These studies examine not only the actual but also the predictive values of macroeconomic indicators announcements, normalizing them and thus creating absolutely a new surprise indicator.

However, the high frequencies analysis is not sufficiently developed in those studies. As a result, it becomes unclear how quickly the stock price returns adapt to the economic indicators announcements. The above-mentioned studies examine the stock markets of the USA, South Africa, Poland, and China, but there is a lack of research examining the stock market of the Eurozone. None of them uses scenario analysis. There is also not enough research to model stock price returns based on Industrial production announcements. Lastly, there are not enough studies which modeling stock price returns based on basic and machine learnings methods and at the same time compared them to each other. By reasons mention above a scientific problem is formulated further. What is the specificity of economic indicators surprises and how to model stock price returns based on Industrial production surprises?

The main purpose of the article is to construct, test, analyze and compare models for predicting the impact of industrial production surprises on EURO STOXX 50 returns changes based on basic and machine learning approaches. The following tasks are pursued: 1. To reveal the methods of modeling stock price returns based on economic indicators surprises and to review legal regulations related to securities in the EU and the USA. 2. To create methodology for modeling stock price returns based on economic indicators surprises. 3. To construct, test, analyze and compare models for predicting EURO STOXX 50 index price returns based on Industrial production surprises.

Research methods: 1. Systematic analysis of the scientific and law literature. 2. Comparative analysis. 3. Correlation analysis. 4. Analytical-logical method. 5. High frequency data analysis. Regression analysis based on OLS method (both basic and machine learning approaches)

## 2. Literature review: modeling stock returns based on economic indicator's surprises

Studies which is aimed at modeling changes in stock price returns and incorporating individual elements of fundamental analysis, efficient market hypotheses and financial behavior theories in the scientific literature is usually referred to macroeconomic news, announcements, surprises, expectations studies (Zhai, et. al., 2020).

Researchers Alexiou, et. al. (2018) analyzed the response of 25 equity portfolios to macroeconomic surprises spanning the period from April 1998 until May 2017. The three methodological methods used in this study which shown that the ISM Institute of Supply Management non-manufacturing index, the number of employees working in the non-agricultural sector (employees on non-farm payrolls), retail sales, personal consumption personal

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consumption expenditure and initial jobless claims have a significant impact on portfolio returns. It was also found that the surprises in the ISM non-production index, personal consumption expenditure and unemployment claims indicators shape certain trends in various portfolios. It is observed that by creating portfolios with companies that have higher operating profitability and investment level, the investor can potentially reduce the risk of volatility arising from the above three macroeconomic indicators.

The US macroeconomic indicators such as “PPI, CPI, state employment, employment situations, labour turnover, and job openings, US export/imports, unemployment, real earnings, earnings of wages and salary, business employment dynamics and employment cost index” and their uncertainty play a significant role in the equity market and other markets (Shaikh, 2020). Cakan and Gupta (2017) modeled the impact of U.S. inflation and unemployment rate surprises on South African stock price volatility. The study found that bad news about U.S. inflation does not affect the volatility of South African stock returns, while good news increases volatility. It has also been studied that the country’s stock market fluctuates more with an unexpected rise in the U.S. unemployment rate and fluctuates less with an unexpected decline in the U.S. unemployment rate. And even more the last effect being stronger than the former. Thus, an unexpected slowdown in inflation and an increase in the unemployment rate increase stock market instability, which in turn would mean that financial conditions in the country would deteriorate and adversely affect the real economy, according to researchers. Meanwhile, positive surprises in US inflation and employment are contributing to more stable, and therefore less volatile, stock markets in developing countries.

Researchers Nadleri and Schmidt (2016) analyzed the response of the ETF’s price to macroeconomic surprises spanning the period from January 2009 until July 2013. It was found that the average daily return of the ETF’s on the days of publication of indicators may be significantly higher than the buy-and-hold strategy, although their difference may be statistically insignificant. It was observed that the surprises of the ISM Manufacturing index of non-agricultural employees Non-Farm Payrolls, International Trade Balance, Index of Leading Indicators, Housing Starts and Jobless Claims have the largest and statistically significant impact to ETF’s.

Researchers Chen, et. al. (2015) examine the role of investor attention in planned macroeconomic reports to explain price fluctuations in China’s future stock index. It has been observed that the attention of investors, as indicated by the Baidu search index, is the highest in anticipation of the consumer price index. Only the CPI has been found to have a significant short-term impact on the price, liquidity, and volatility of the CSI 300 futures index. In addition, price fluctuations in the CSI index are greater in the face of bad CPI surprises and a period of high inflation.

Researchers Miao, et. al. (2014) analyze the impact of macroeconomic indicators on the futures price of the S&P 500 index. Research confirms a strong correlation between macroeconomic indicators and index price fluctuations. More than 60% of jumps between 10:00 and 10:05 and more than 75% of jumps between 8:30 and 8:35 are related to one or more indicators released at 10:00 and 10:30 respectively. Attention is also drawn to the positive impact of surprises in GDP (GDP), the production price index (PPI), factory orders and CPI, advanced retail sales on the S&P 500 index prices.

Gurgul and Wójtowicz (2014) analyzed the impact of US macroeconomic indicators on the price changes of four Warsaw stock indices (WSE, WIG20, WIG40, WIG80). Stock index price changes were analyzed 1 minute after the indicator appears. Consumer price index, producer price index, indicators were observed to be below expert forecasts and durable goods orders, retail sales, industrial production, number of employees in the non-agricultural sector announcements above expert forecasts are times of good news and have a positive impact on

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the price of the WSE stock index. It was also observed that the price of the WIG20 stock index reacts more sensitively than the WIG40, WIG80 indices after the first minute of the news.

U.S. Securities and Exchange Commission is responsible for investor oversight. The mission of the U.S. Securities and Exchange Commission is to protect investors, maintain fair, orderly, and efficient markets, and facilitate capital formation. The world of investing is fascinating and complex, and it can be very fruitful. But unlike the banking world, where deposits are guaranteed by the federal government, stocks, bonds and other securities can lose value. There are no guarantees. By far the best way for investors to protect the money they put into the securities markets is to do research and ask questions.

The laws and rules that govern the securities industry in the United States derive from a simple and straightforward concept: all investors, whether large institutions or private individuals, should have access to certain basic facts about an investment prior to buying it, and so long as they hold it. To achieve this, the SEC requires public companies to disclose meaningful financial and other information to the public. This provides a common pool of knowledge for all investors to use to judge for themselves whether to buy, sell, or hold a particular security. Only through the steady flow of timely, comprehensive, and accurate information can people make sound investment decisions (U.S. Securities and Exchange Commission, 2020).

MiFID II (Markets in Financial Instruments Directive) and MiFIR (Markets in Financial Instruments Regulation) started to apply in January 2018, bringing significant improvements to the functioning and transparency of EU financial markets. Right now, the consultations on improving these legal instruments are taking place. Under MiFID II it is more difficult for national regulatory authorities to waive the pre-trade transparency obligations in respect of listed shares. The pre-trade transparency obligations have been extended to financial instruments other than listed shares. MiFID II distinguishes in this connection between equity and non-equity instruments. Equity instruments are shares, depositary receipts, ETFs, certificates and other similar financial instruments. Non-equity instruments are bonds, structured finance products, emission allowances and derivatives (Busch, 2017). MiFIR introduced wide-ranging pre-trade and post-trade transparency requirements to EU markets.

In United States of America, The Economic Growth, Regulatory Relief, and Consumer Protection Act introduced relaxed rules on financial institutions in year 2018. A revised framework for applying prudential standards for U.S. financial institutions have been established. Still legal regulation in U.S. is quite variegated and complicated. It is believed (Kress, Turk, 2020) that policymakers have effectively ignored potential adverse consequences of looser financial institutions oversight. While reducing examination frequency and reporting requirements will lessen banks' administrative burden, the trade-off will be increased societal costs in the form of excessive risk taking and more frequent bank failures.

Gupta and Reid (2012) in their work investigated the impact of macroeconomic indicator surprises on changes in the price indices of South African industrial stocks. A study conducted using the event study method shows that in the long run, only the surprises of consumer price index (CPI) indicators significantly and negatively affect the return of stock indices. Meanwhile, a study conducted by Bayesian Vector Autoregressive analysis shows that surprises in the production price index (PPI) also have a significant impact on stock index prices. It is true that in the last method, the volatility of the prices of both CPI and PPI stock indices is short-lived - as soon as the indicators appear.

Researchers Harju and Hussain (2011) in their work analyze the impact of macroeconomic indicator's surprises on the largest fluctuations in European indices prices. The authors analyzed the changes in stock index prices 5

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minutes after the indicator appears. The findings of the study show that the price volatility of European indices increases significantly with the start of U.S. trading. Unexpected macroeconomic indicators also have a direct and significant impact on the daily returns and changes in European stock indices. According to the researchers, the research suggests that interdependencies in the stock market between the U.S. and Europe should be further explored. Also, strong daily fluctuations in stock indices in the European market have a significant impetus for researchers and investors not only to analyze and model short-term index returns, but also the dynamics of the behavior of financial market participants. The EU has established a comprehensive set of rules on investment services and activities with the aim to promote financial markets that are fair, transparent, efficient, integrated. The first set of rules adopted by the EU helped to increase the competitiveness of financial markets by creating a single market for investment services and activities. They also ensured a high degree of harmonised protection for investors in financial instruments, such as shares, bonds or derivatives (European Commission, 2020).

Hussain (2010) in his own article examined the impact of European and U.S. monetary policy indicator's surprises on indices prices in these markets. Stock indices price changes were analyzed 5 minutes after the indicator appears. The study shows that surprises in monetary policy indicators have a significant impact on the price and volatility of indices. In addition, the author noted that the press conference of the European Central Bank (ECB), which takes place 45 minutes after the same day's monetary policy decisions, also has a significant impact on the price and volatility of European stock indices.

Looking at the scientific literature above, we see that researchers get quite different stock return results with different economic indicators. In some cases, surprises in economic indicators have a positive effect on stock returns, while in others they have a negative effect. All the studies include at least a few indicator surprises and model their impact on stock returns. It has been observed that the results are quite contradictory regarding the industrial production indicator. Researchers agree that, in theory, better-than-expected news on this indicator should have a positive impact on stock returns, but the results are contradictory. Researchers Alexiou, et. al. (2018) found a positive but not statistically significant relationship when examining the impact of industrial output surprises on the stock market. Nadleri and Schmidt (2016), meanwhile, demonstrated that the relationship is negative but insignificant. Other researchers Chen, et. al. (2015) found a negative and at the same time statistically insignificant relationship when examining the Chinese stock market. In the European market, according to U.S. the surprise of the industrial production indicator, researchers Gurgul and Wójtowicz (2014) and Harju and Hussain (2011) obtained positive and statistically significant results. Thus, as can be seen, the results are quite contradictory, therefore, in the opinion of the authors, it would be relevant to examine the surprises of this indicator separately from other indicators. Also, as can be seen, many researchers study U.S. indicator's and its markets, but a few is done on the European indicators and its market, so in this study we are going to modeling European stock market returns based on European industrial indicator.

Moving on to a more detailed analysis of researches mentioned above it is worth presenting the methods used by scientists on this topic.

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**Table 1.** Stock price returns analysis methods based on economic indicator’s surprises

Years	Authors	Research period	Data frequency	Research methods (in short)
2018	Alexiou, et. al.	1998 - 2017	Daily	- REGRESSION (OLS) - SUR - MM WEIGHTED LEAST SQUARES
2017	Cakan, Gupta	1994 - 2016	Daily	- GJR-GARCH
2016	Nadleri, Schmidt	2009 - 2013	Daily	- ARMA – GARCH
2015	Chen, et. al.	2011 - 2014	Minute	- REGRESSION
2014	Miao, et. al.	2003 - 2010	Minute	- REGRESSION
2014	Gurgul, Wójtowicz	2007 - 2013	Minute	- ES - ARMA
2012	Gupta, Reid	2002 - 2011	Daily	- BVAR - REGRESSION - ES
2011	Harju, Hussain	2000 - 2006	Minute	- ARMA – GARCH
2010	Hussain	2000 - 2008	Minute	- ARMA – GARCH

\*REGRESSION (OLS) – regression analysis ordinary least square method

\*GJD - Generic jump-diffusion method

\*GARCH - Generalized Autoregressive Conditional Heteroskedasticity method

\*ARMA - Autoregressive–moving-average method

\*ES - Event studies method

\*BVAR - Bayesian Vector Autoregressive method

*Source:* compiled by the authors based on the above sources

The table 1 above shows that the average period of research is 9 years. Thus, the developed models cover several periods of the economic cycle, which is good because ups and downs are estimated. By data frequency, authors collect daily and minute stock price data. The choice of data frequency type usually depends on whether data is easy to obtain. Usually use more frequency data leads to the more reliable models. Thus, according to the above-mentioned studies, the most objective models are based on per-minute stock price data. From table above was noticed that many researchers are calculating surprise indicator which shows how economic announcements impact stock price returns (see Formula 1)

$$S_{k,t} = \frac{A_{k,t} - E_{k,t}}{\hat{\sigma}_k}; \quad \hat{\sigma}_k = \sqrt{\text{var}(A_{k,t} - E_{k,t})} \quad (1)$$

From here:

$S_{k,t}$  - standardized surprise value of the economic indicator k, on the trading day t.

$A_{k,t}$  - the actual value of the economic indicator k, on the trading day t.

$E_{k,t}$  - the predictive value of the economic indicator, which is obtained by interviewing experts, household, or business.

$\hat{\sigma}_k$  - standard deviation of the surprise value of the economic indicators k.

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Although as we can see from table 2 the methods are diverse, the authors usually choose regression analysis or ARMA-GARCH methods to do their research. The ARMA-GARCH model is usually used to analyze continuous time series when the model equation also includes fluctuations the values of a variable for a previous period. For this reason, this method is not suitable for this case because past stock price returns are not examined in this work. Therefore, one of the research methods chosen in this study is the least square method (OLS). The second method that the authors have chosen and that is innovative is the machine learning method. It is a method belonging to the class of artificial intelligence methods, which is characterized not by a direct solution of the problem, but by learning. None of the mentioned scientists have used this method and this is a novelty of this study. The use of these two methods will allow to choose and understand which, the model is better on this problem

Research limitation / assumption: We assume that only surprises in economic indicators can affect stock returns and other factors are not included in the model.

### 3. Research methodology

Regression analysis is used to investigate the dependence of one variable on one or more variables and to predict subsequent mean values of the variables. To construct regression models, it is necessary to perform whether a data is passing regression analysis assumptions.

1. Whether the dependent variable is normally distributed. In this paper we are using Shapiro-Wilk test. A test p value of  $\geq 0.05$  indicates that the standardized errors are normal.
2. Whether the residual errors of the different observations are not correlated. In this paper Durbin-Watson statistic are used. If the value obtained is between 1.5 and 2.5, it usually means no autocorrelation.
3. Whether the regressors correlate with each other. In this paper we are NOT calculating variance reduction coefficient (VIF) because we have just one regressor.
4. Whether there are outliers in the data. In this paper the Cook measure is calculated. Cook measure calculated for each set of regressors. If the sample size is n, then the cook's measure will be n as well. If the value of n of at least one cook measure exceeds 1, it is said that there are outliers in the data.
5. Whether the data are homoscedastic. In this paper we calculated by the Breusch-Pagan test. If the test p value is  $\geq 0.05$  then the data are homoscedastic (no heteroskedasticity).

After checking whether the data are suitable for constructing a regression model, the model itself is further constructed. The regression model is usually described by the following indicators:

1. Coefficient of determination ( $R^2$ ). This is the most important indicator of model confidence in the data, which is mandatory in all descriptions of regression models. The interpretation of  $R^2$  is as follows - what percentage of Y's behavior is explained by the behavior of the variables X, Z, W. The coefficient of determination values acquires between 0 and 1. The higher value indicates more reliable model.
2. T - (Student's) test for each regressor. It helps to decide if a regressor is statistically significant or not. If the value of the regressor p is  $< 0.05$ , then we can say that the regressor is statistically significant and we do not delete it. If the value of the regressor p is  $\geq 0.05$ , then the regressor is statistically insignificant and we remove it from the model.

The EURO STOXX 50 stock index price returns were modeling in this paper. The analysis period between 2008-02-29 - 2019-10-01, and the frequency of the data is minutes. The data was obtained from the Bloomberg terminal, which includes the following information: index opening price and closing price. Having the closing and opening price of an index minute, it is possible to calculate the price return of an index for a specific minute, which is the dependent variable of the model to be predicted. The return on the index is calculated further

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$$G_m = \frac{U_m - A_m}{A_m} \times 100 \quad (2)$$

From here:

$G_m$  % – EURO STOXX 50 index return on minute (m).

$U_m$  – EURO STOXX 50 index close price on minute (m).

$A_m$  – EURO STOXX 50 index open price on minute (m).

As mentioned before EURO STOXX 50 stock price returns are modeling which is based on Industrial production surprises. This indicator reflects the state of the industrial sector. The industrial sector includes manufacturing, mining, and utilities. Although these sectors account for only a small share of GDP, they are highly sensitive to interest rates and consumer demand. This makes the industrial production index an important tool for forecasting future GDP and economic activity.

Moving on to the design of the empirical research, it involve three stages. In the first step, correlation matrices are developed that show the biggest relationship between the surprise indicator and the price returns of the index. In this way, it is possible to decide at which minute, after the announcement of industrial production, the surprise indicator and the index price return correlate the most. To make the models as accurate as possible, correlation matrices are created in five scenarios:

- a) Included all surprise values
- b) When surprise value > 0
- c) When surprise value >= 0
- d) When surprise value < 0
- e) When surprise value <= 0

The aim of this split is to obtain as much refined and filtered correlation information as possible, which will then allow more reliable regression models to be developed under the five contingency scenarios.

Further regression models are selected according to these criteria:

- a)  $R^2 >= 0$ .
- b) Industrial production p-value < 0,05.
- c) Count of events > 20.

In the second step of this study, these regression models are tested to see whether they meet the assumptions of the regression analysis discussed above. The remaining models are analyzed. In the third step of the research, by applying the artificial intelligence method, we create new regression models based of the machine learning method, which are compared with the previously developed models.



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**4. Empirical research results**

Following the methodology described above, the table 2 table presents regression models with ten different surprise values scenarios with the highest index price returns correlation between.

**Table 2.** Industrial production regressions models

Economic indicator	Regression model	R <sup>2</sup>	R <sup>2</sup> in minute	P-value	Count of events	Scenario
Industrial Production (Y/Y)	Index return Chg % = -0.0069 + 0.0218 * surprise	6,00%	3	0,004	140	All
Industrial Production (Y/Y)	Index return Chg % = -0.0071 - 0.0238 * surprise	2,50%	13	0,063	140	All
Industrial Production (Y/Y)	Index return Chg % = -0.1040 + 0.1745 * surprise	24,70%	40	0,000	61	>0
Industrial Production (Y/Y)	Index return Chg % = -0.0949 + 0.1401 * surprise	13,90%	43	0,004	59	>0
Industrial Production (Y/Y)	Index return Chg % = -0.0876 + 0.1705 * surprise	21,80%	42	0,000	70	>=0
Industrial Production (Y/Y)	Index return Chg % = -0.0641 - 0.1159 * surprise	10,10%	43	0,008	69	>=0
Industrial Production (Y/Y)	Index return Chg % = -0.0395 - 0.0658 * surprise	7,00%	20	0,026	70	<0
Industrial Production (Y/Y)	Index return Chg % = 0.0514 - 0.0454 * surprise	1,60%	31	0,288	71	<0
Industrial Production (Y/Y)	Index return Chg % = 0.0204 - 0.0531 * surprise	4,60%	20	0,059	79	<=0
Industrial Production (Y/Y)	Index return Chg % = 0.0363 - 0.0357 * surprise	1,10%	31	0,354	81	<=0

Source: created by the author

These regression models can be economically interpreted as follows: What change in the price return of the EURO STOXX 50 index can be expected at a given minute when economists have correctly or incorrectly predicted the actual values of the Industrial production indicator.

The value of R<sup>2</sup> indicates the percentage of the economic indicator surprise that explains the change in the return of EURO STOXX 50 in given minute. The table shows the minute at which the maximum R<sup>2</sup> value was recorded in 45 minutes. The P-value indicates whether the indicated regression model is statistically reliable. If the p-value estimate is less than 0.05, then the model is considered statistically reliable.

Only two models meet the research assumptions. This is R<sup>2</sup> > 20%, p-value less than 0.05, and number of events more than 20. In this case, in this scenario, this study will be continued only with these indicators.

In the next stage of the study, the remaining models is checked to see if they meet the assumptions of the regression analysis.

**Table 3.** Verification of the regression model assumptions on Industrial production (Y/Y) indicator in scenario >0

Assumptions of regression model	Results of assumption / method
1. Is the dependent variable normally distributed?	<b>Yes</b> Shapiro-Wolf p-value equal 0,63
2. Are the residual errors of different observations correlated (autocorrelation problem)?	<b>No</b> Durbin-Watson value equal 1,979
3. Is there no multicollinearity between the regressors?	<b>Not relevant in this paper</b>
4. Are there outliers to the data?	<b>No</b> All Cook values do not exceed 1
5. Is the data homoscedastic?	<b>Yes</b> Breusch-Pagan p-value equal 0,30

Source: created by the authors

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As we can see from table 3 above the model meets all the assumptions required for the regression analysis, therefore it can be stated that the developed model is statistically reliable to predict the returns of the EURO STOXX 50 index.

The next model regression analysis assumption in another scenario is checked further.

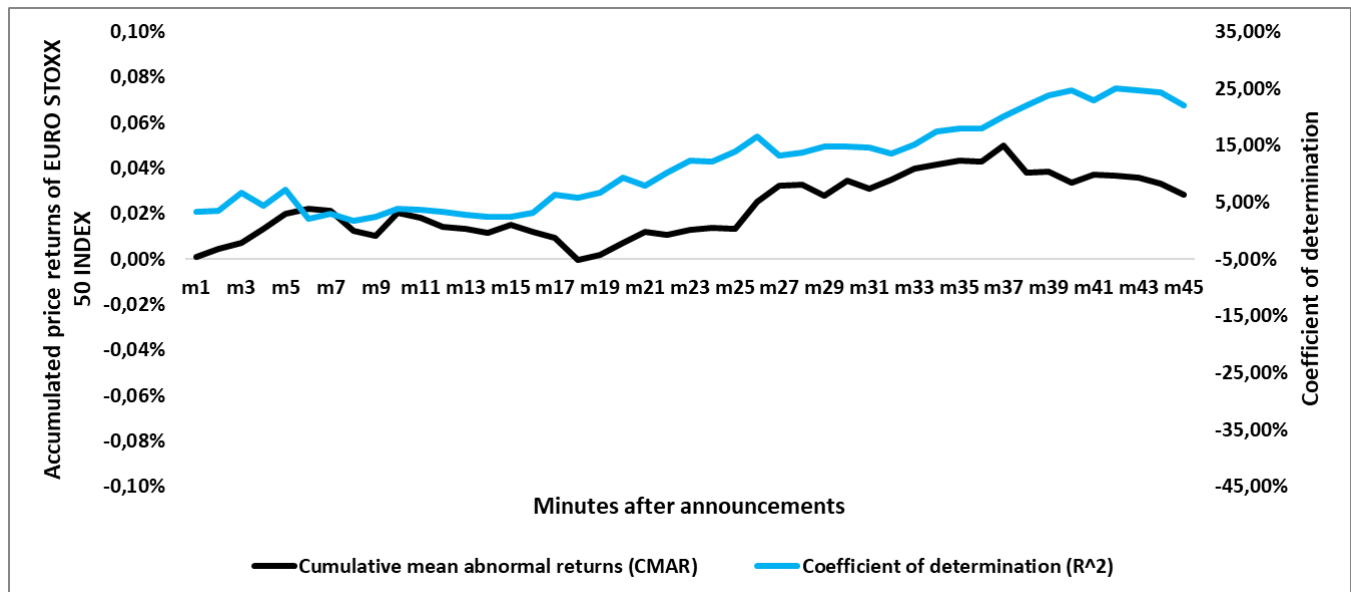
**Table 4.** Verification of the regression model assumptions on Industrial production (Y/Y) indicator in scenario  $\geq 0$

Assumptions of regression model	Results of assumption / method
1. Is the dependent variable normally distributed?	<b>Yes</b> Shapiro-Wolf p-value equal 0,64
2. Are the residual errors of different observations correlated (autocorrelation problem)?	<b>No</b> Durbin-Watson value equal 1,866
3. Is there no multicollinearity between the regressors?	<b>Not relevant in this paper</b>
4. Are there outliers to the data?	<b>No</b> All Cook values do not exceed 1
5. Is the data homoscedastic?	<b>Yes</b> Breusch-Pagan p-value equal 0,14

Source: created by the authors

As we can see from table 4 above the model meets all the assumptions required for the regression analysis, therefore it can be stated that the developed model is statistically reliable to predict the returns of the EURO STOXX 50 index.

Turning to the analysis of the Industrial production indicator and EURO STOXX 50 index, a figure 1 was created which contains information of EURO STOXX 50 price returns and Industrial production surprises values which are  $> 0$



**Figure 1.** EURO STOXX 50 price returns analysis based on Industrial production surprises in scenario  $> 0$

Source: created by the authors

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Assessing the impact of this indicator on the price return of the index, both Figure 1 and Table 3 show that under the positive surprise values scenario, its impact on the price return on the EURO STOXX 50 index is positive (index price return increases). As we can see, the highest values of CMAR and  $R^2$  are seen between 31 and 40 minutes. It is difficult to justify economically why this is so, as it can be influenced by many factors. One of them is the behavior of market participants in connection with the fact that forecasts have been confirmed and decisions on purchase or sale transactions do not need to be made very quickly.

Best coefficient of determination for the regression model is 24.70%. From a statistical point of view, this is a relatively small value, which explains approximately one quarter of the return on the EURO STOXX 50 index at 40 minute. However, from an economic point of view and knowing that stock markets are multifaceted and affected by huge flows of information, events, moods, speeches, and so on. - this percentage is quite high and weighty. If a quarter of the return on an index can be explained by only one economic indicator, then by extending the research to include more indicators or factors, this percentage should increase.

Turning to the analysis of the second model, a figure 2 was created which contains information of EURO STOXX 50 price returns and Industrial production surprises values which are  $\geq 0$ .

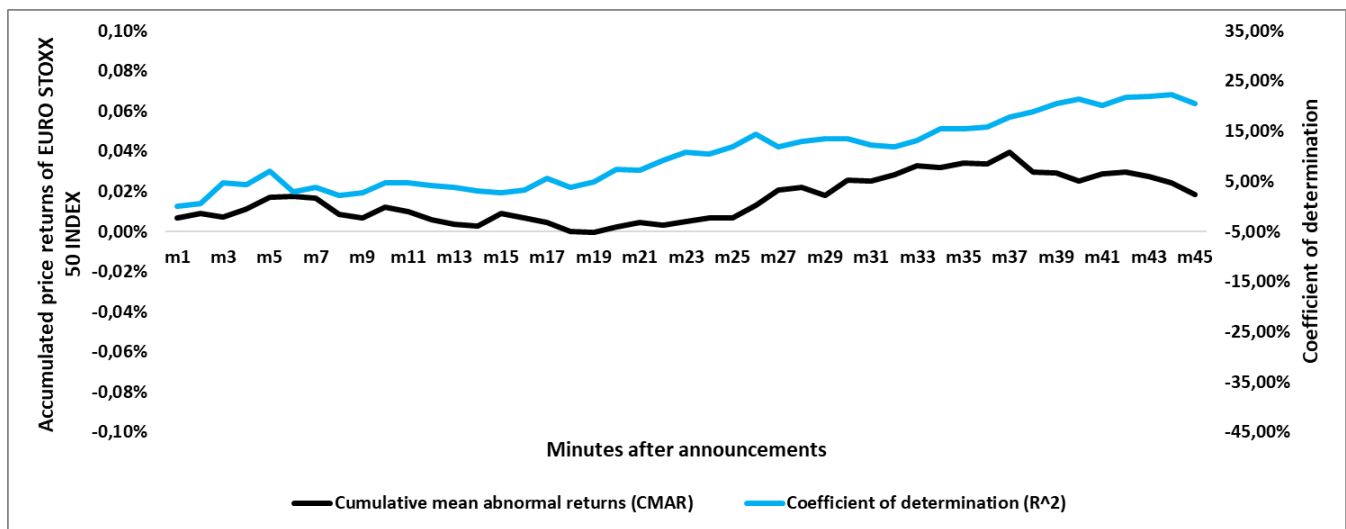


Figure 2. EURO STOXX 50 price returns analysis based on Industrial production surprises in scenario  $\geq 0$

Source: created by the authors

Assessing the impact of this indicator on the price return of the index, both Figure 2 and Table 3 show that under the positive surprise values scenario, its impact on the price return on the EURO STOXX 50 index is positive (index price return increases). As we can see, the highest values of CMAR and  $R^2$  are seen last 15 minutes. It is difficult to justify economically why this is so, as it can be influenced by many factors. One of them is the behavior of market participants in connection with the fact that forecasts have been confirmed and decisions on purchase or sale transactions do not need to be made very quickly.

Best coefficient of determination for the regression model is 21.80%. From a statistical point of view, this is a relatively small value, which explains approximately the fifth of the return on the EURO STOXX 50 index at 42

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minute. However, from an economic point of view and knowing that stock markets are multifaceted and affected by huge flows of information, events, moods, speeches, and so on. - this percentage is quite high and weighty. If a quarter of the return on an index can be explained by only one economic indicator, then by extending the research to include more indicators or factors, this percentage should increase.

Last part of the empirical research - the comparison between the already shown models and the newly developed artificial regression models. This method is innovative and has not been performed often, therefore it is relevant to investigate which EURO STOXX 50 price return models can be obtained using this method.

**Table 5.** Comparison between ML and Basic regression analysis models

Economic indicator	Regression model	R <sup>2</sup>	R <sup>2</sup> in minute	Count of events	Scenario
Industrial Production (Y/Y) basic model	Index return Chg % = -0.1040 + 0.1745 * surprise	24,70%	40	61	>0
Industrial Production (Y/Y) ML model	Index return Chg % = - 0.0819 + 0.1365 * surprise	33,22%	40	21	>0
Industrial Production (Y/Y) basic model	Index return Chg % = - 0.0876 + 0.1705 * surprise	21,80%	42	70	>=0
Industrial Production (Y/Y) ML model	Index return Chg % = - 0.0589 + 0.0968 * surprise	26,60%	42	25	>=0

*Source:* created by the authors

From table 5 can be seen that the values of the coefficients of the ML regression model differ from the base model. The effect on index returns remains the same - positive. In the ML model number of events is much smaller due to the data had to be broken down into training and testing sets. The coefficient of determination differs significantly between models. This indicates that even with smaller count of events, ML model can provide better explaining of EURO STOXX 50 price returns.

The results of this work confirm the theoretical assumption that better-than-expected news on industrial production has a positive effect on stock returns. Similar results were obtained by the researchers Gurgul and Wójtowicz (2014) and Harju and Hussain (2011), but the coefficients of determination cannot be compared because the researchers examined not one but several indicators.

Given how fast basic and machine learning is evolving, the regulatory framework should leave room to serve for further developments. Any changes should be limited to clearly identified problems for which feasible solutions exist. This kind of approach can be also found, for instance, in EU Commissions White Paper on Artificial Intelligence (COM 2020 (65) final, 19.2.2020), also in Executive order of USA President on “Maintaining American Leadership in Artificial Intelligence” (Issued 11.02.2019).

## Conclusions

From the scientific literature analysis, we see that researchers get quite different stock return results with different economic indicators. In some cases, surprises in economic indicators have a positive effect on stock returns, while in others they have a negative effect. It has been observed that the results are quite contradictory regarding the industrial production indicator. Researchers agree that, in theory, better-than-expected news on this indicator should have a positive impact on stock returns, but the results are contradictory. Therefore, this indicator was chosen for this analysis. Simple regression analysis (OLS), GJR-GARCH, ARMA-GARCH, SV, GJD, ES, BVAR methods are used to model the impact of economic indicators on changes in stock price returns. The most

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common of these are the least squares regression analysis method and the ARIMA-GARCH methods. The ARMA-GARCH model is usually used to analyze continuous time series when the model equation also includes fluctuations the values of a variable for a previous period. For this reason, this method is not suitable for this case because past stock price returns are not examined in this work. Therefore, one of the research methods chosen in this study was the least square method (OLS). The second method that the authors have chosen and that is innovative is the machine learning method. The use of these two methods will allow to choose and understand which, the model is better on this problem

A methodology includes three stages of data analysis and modeling. In the first stage, correlation matrices are developed that show the biggest relationship between the surprise indicator and the index price returns. In this way, it is possible to decide at which minute, after the announcement of industrial production, the surprise indicator and the index price return correlate the most. To make the models as accurate as possible, correlation matrices are created in five scenarios. In the second stage of this study, the regression models are created and tested to see whether they meet all assumptions. The remaining models are analyzed. In the third stage of the research, by applying the artificial intelligence method, we create new regression models based of the machine learning method, which are compared with the previously developed models.

Total 10 regression models were constructed. Of those, 2 met all assumptions. Model statistics shows that the coefficient of determination is respectively equal to 24.70% and 21.80%. Trying to evaluate the value of the coefficient of determination from a statistical point of view, this is a relatively small value, which explains approximately one quarter of the return on the EURO STOXX 50 index in specific 40 and 42 minute. However, from an economic point of view knowing that stock markets are multifaceted and affected by huge flows of information, events, moods, speeches, and so on. - this percentage is quite high and weighty. If a quarter and fifth of the return on an index can be explained by only one economic indicator, then by extending the research to include more indicators or factors, this percentage should increase. Correlation matrix show that the higher values of the coefficient of determination are visible in the last five minutes. This indicates that the surprise values of the indicators have lagged but longer impact on stock price returns over all period. Thus, the opportunity to take a profit raise. In the end of the research machine learning method was applied to create new regression models on purpose to compare with base models. Results show that the values of the coefficients of the ML regression model differ from the base model. The effect on index price returns remains the same - positive. In the ML model number of events is much smaller due to the data had to be broken down into training and testing sets. The coefficient of determination differs significantly between models respectively 33,22% and 26,60%. This indicates that even with smaller count of events, ML model can provide better explaining of EURO STOXX 50 price returns. Stock regulation in both the US and Europe is an evolving process that depends not only on economic factors and technological development, but also on political will. The development of artificial intelligence will certainly have a positive impact on the stock institute not only in economic, but also in legal terms. The rules for financial institutions which systematically internalise have become more detailed and the pre-trade and post-trade transparency obligations have been extended to financial instruments other than listed shares in EU. In USA on the contrary, the rules on the financial institutions have been relaxed in recent years. European and the US markets depend on how legal regulation affects the trading process. Although they are both intend to promote competition in markets, EU and U.S. adopt different provisions with respect to main that strongly influence the competition for order flow among trading venues.

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