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How to define macroeconomic announcement surprises? An example of the impact of US macroeconomic news on stock prices on the Warsaw Stock Exchange

1. Introduction

In an efficient financial market, only unexpected information leads to significant price changes. This is also the case with the publication of important macroeconomic data. Therefore, the unanticipated component of the announced macroeconomic data is crucial in the analysis of the impact of macroeconomic news on financial markets (e.g., stock or bond markets). This unexpected news (surprise) is usually defined as the difference between the observed and expected value of the published indicator:

$$Surp_{0,i} = A_i - E_i \tag{1}$$

where A_i is the value of the i-th announcement of the indicator, while E_i is the market expected value of the indicator. The more the released indicator value differs from market expectations, the higher the value of $Surp_{0,i}$ is. Thus, $Surp_{0,i}$ measures the size of the news surprise.

The vast majority of studies on the impact of macroeconomic data announcements on financial markets are based on the analysis and estimation of appropriate models in which there are dummy variables corresponding to an unexpected part of the announced news. This approach assumes a linear dependence of returns of

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the analyzed assets on the size of the information surprise, i.e. on the difference $A_i - E_i$ (see, for example: Balduzzi et al., 2001; Andersen et al., 2003, 2007; Będowska-Sójka 2010; Harju, Hussain, 2011; Kočenda, Moravcova, 2018; Kurov et al., 2019).

However, the question arises as to whether $Surp_0$ is a good measure of news surprises, i.e. whether it accurately reflects how surprising the published value of the macroeconomic indicator is for investors. For this reason, the properties of the differences $A_i - E_i$ should be examined. In particular, it should be verified whether this measure is robust to the occurrence of outliers. Additionally, the nature of the relationship between information surprises $Surp_0$ and returns should be carefully studied in order to determine the strength of the linear relationships between them. In addition, it is worth considering other alternative ways of defining and measuring the size of the unexpected part of news that will have the desired properties.

The aim of this paper is to analyze the properties of various surprises measures for the announcements of US macroeconomic news. The relationship between surprises and returns will also be studied based on the impact of announcements of macroeconomic indicators describing the US economy on the 5-minute returns of the WIG20 index (the main index of the Warsaw Stock Exchange). The analysis presented in this paper is based on data on announcements of 15 US macroeconomic indicators and 5-minute returns of WIG20 from January 2001 to February 2021.

Recent studies (for example, Będowska-Sójka, 2010; Suliga, Wójtowicz, 2013; Gurgul, Wójtowicz, 2014, 2020; Gurgul et al., 2016; Gurgul et al., 2021) indicate a significant and very strong impact of the publication of macroeconomic data from the US on the share prices of companies listed on the Warsaw Stock Exchange. Among the various indicators that describe the state of the US economy, the Nonfarm Payrolls (NFP) stands out. It is also one of the most important macroeconomic indicators for the US economy (Andersen, Bollerslev, 1998; Andersen et al., 2007). Therefore, a more detailed analysis presented in the first part of the paper is carried out on the example of NFP announcements. The application of NFP data also ensures that the results are not distorted by the impact of the publication of the other indicators.

In addition to the analysis of the properties of the $Surp_0$ distribution and distribution of the other measures of surprises, the linear relationship between surprises and WIG20 returns in the first five minutes after the announcements is examined. The analysis of correlation coefficients allows one to determine the strength of the linear relationship between surprises and returns. However, the analysis of such individual relationships may not lead to correct conclusions because sometimes more than one US macroeconomic indicator is released at the same time. Therefore, a study considering the possibility of the impact of the publication of individual indicators overlapping is also carried out with the use of an appropriate model in which surprises are explanatory variables.

The rest of the paper is organized as follows. In the next section, we describe the data used in the paper. In Section 3, we present the results of the analysis of macroeconomic news surprises distribution for NFP announcements. This study is extended in Section 4 to other US macroeconomic indicators. In Section 5, we briefly analyse the properties of linear models explaining WIG20 returns by news surprises. The final section concludes the paper.

2. Data

The analysis presented in this paper is based on data from the announcements of 15 macroeconomic indicators from the US economy and on 5-minute returns of the WIG20 index from January 2001 to February 2021. These indicators are: the Consumer Confidence Index (CCI), the Consumer Price Index (CPI), the Durable Goods Orders (DGO), the Existing Home Sales (EHS), the Real GDP (GDP), the Housing Starts (HS), the Initial Jobless Claims (IJC), the Industrial Production (IP), the ISM Manufacturing Index (ISM), Leading Indicators (LI), the New Home Sales (NHS), the Nonfarm Payrolls (NFP), the Philadelphia Fed Business Outlook Survey (PFBO), the Personal Income (PI), and the Retail Sales (RS). Almost all of them are released on a monthly basis and describe the economic situation in the US in the previous (or even in the current) month. The only exception is IJC, which is announced weekly and describes the labor market in the previous week, and GDP, which is released monthly but describes the GDP in the previous quarter.

As shown, for example, by the analysis of Będowska-Sójka (2010), Gurgul et al. (2021), Gurgul et al. (2016), Gurgul and Wójtowicz (2014, 2020), Suliga and Wójtowicz (2013) carried out with the use of various methods, there is a significant and very strong impact of the publication of US macroeconomic data on share prices of companies listed on the Warsaw Stock Exchange. The strongest reaction of investors is observed after the announcements of unexpected values of NFP, which is one of the most important American indicators.

NFP is one of the indicators published in the Employment Report of the Bureau of Labor Statistics. The others are: the Unemployment Rate, Average Hourly Earnings and Average Workweek. Each of them describes different aspect of the employment situation and its changes can lead to different investor reactions.

As Employment Reports are usually published on the first Friday of the month, the information they contain is one of the first macroeconomic data to describe the US economy in a given month. In addition, the reports describe the labor market, which is a very important part of the economy. As a result, information contained in Employment Reports is closely followed by investors around the world and has a very strong impact on bonds, exchange rates, and stock prices (Carnes, Slifer, 1991; Andersen, Bollerslev, 1998; Andersen et al., 2007). The NFP announcements are also one of the most important American data for investors on the Warsaw Stock Exchange (Suliga, Wójtowicz, 2013; Gurgul, Wójtowicz, 2014, 2020; Gurgul et al., 2016).

It should also be emphasized that, since the NFP is one of the first US macroeconomic indicators to be published during the month, its impact is not distorted by the announcements of other indicators, which usually are released a few days later. Therefore, the results of the examination of the properties of the various measures of unexpected part of NFP announcements are not distorted by the impact of other important information from the American economy. Hence, in the first part of the paper, particular attention will be paid to the analysis of the properties of surprise measures on the example of NFP announcements.

Determining the expected value of the announced macroeconomic indicator is also important for studying the relationships between surprise measures and WIG20 returns. The expected value E_i of an indicator is usually defined in two ways. First, it may be estimated from the previous values of the indicator with the use of an appropriate econometric model, for example an ARMA model. The second way of defining the expected value of the macroeconomic fundamentals is based on surveys. According to it, E_i is proxied by the median response (consensus) of managers and professional financial analysts. From these two approaches, the survey-based definition of the expected component of macroeconomic news announcement is more common in the literature (see, for example: Almeida et al., 1998; Balduzzi et al., 2001; Andersen et al., 2003, 2007; Będowska-Sójka, 2010; Harju, Hussain, 2011; Gurgul, Wójtowicz, 2014, 2015; Kurov et al., 2019). As shown by Pearce and Roley (1985), the application of surveys to the forecast announced value of macroeconomic fundamentals outperforms any forecast based on their historical values.

Forecasts of the announced value of the macroeconomic indicator obtained on the basis of surveys are quite easily available, because they are published by most economic data platforms a few days before the announcement date (for example, by Bloomberg, Yahoo, Trading Economics, Investing, koyfin, DeltaStock, Econoday, etc.). Furthermore, as shown by Pearce and Roley (1985), most of such forecasts are unbiased (i.e. in most cases the expected value of the difference $A_i - E_i$ is equal to zero) and have smaller mean squared errors than forecasts based on autoregressive models.

The vast majority of on-line financial data and analytics platforms provide only the announced value of the indicator and the consensus[1]. However, some of them (e.g., Econoday) also report additional information about the survey results. For example, they provide the smallest and highest values specified in the surveys. It allows one to calculate the range of analysts' forecasts. The range can be seen as a measure of analyst uncertainty about the future value of the indicator.

Professional users, for example, in the Bloomberg Terminal, have access to more detailed data on the survey statistics for each indicator. Before each announcement of an important macroeconomic indicator, Bloomberg Terminal not only provides the value of consensus, but also provides standard deviation of the survey results from which the consensus was calculated. This is a more precise measure of uncertainty, and, on this basis (after the announcement), the surprise value is defined. The surprise, which is equal to the difference between the announced and predicted value of the indicator divided by the standard deviation of the surveys, shows how large the surprise value when is compared to the variability of the forecasts.

The news surprises considered in this paper are calculated based on the reported value of the indicator and the survey median (consensus). We also take into account the lowest and highest values of the forecasts, as well as standard deviations of the surveys. All these values come from Bloomberg database.

The basic measure that describes how much the announced value of the indicator differs from the market expectations is surprise $Surp_0$ defined for each i-th announcement in (1) as the difference between the announced value A_i of the indicator and the survey expectation E_i. This difference is a natural measure of a news surprise and is of great importance to investors. This is because most analysts describing and interpreting macroeconomic data releases make two comparisons of the announced value: with its previous values from the last few months or with its market expectation. The problem with interpreting the $Surp_0$ difference is that it does not take into account the uncertainty about the true value of the indicator and the variation of the forecasts of the true indicator value among analysts. Furthermore, when measuring the size of the news surprise related to the current publication of the indicator, one should also take into account how the values of the surprise have changed in the past. Therefore, in this paper, we additionally consider the following measures of the magnitude of news surprises:

$$Surp_{1i} = \frac{A_i - E_i}{S_i} \tag{2}$$

[1] As shown by Wójtowicz (2015), application of data from various news websites leads to very similar conclusions regarding the impact of NFP publications on stock prices on the Warsaw Stock Exchange.

$$Surp_{2i} = \frac{A_i - E_i}{S_{12,i}} \tag{3}$$

$$Surp_{3i} = \frac{A_i - E_i}{H_i - L_i} \tag{4}$$

where S_i is a standard deviation of surveys from which the consensus E_i was calculated, H_i and L_i are the maximum and minimum values of the surveys, and $S_{12,i}$ is the standard deviation of surprises from the given announcement and the 11 previous announcements.

The above surprise measures differ in the way they take into account additional information that allows for a comparison of the difference $A_i - E_i$ with analysts' uncertainty ($Surp_1$ and $Surp_3$) or with the previous surprises ($Surp_2$). $Surp_1$ relates the difference $A_i - E_i$ to standard deviation of market forecasts. In this way, even a very large value of the difference between the announced and expected value of the indicator may be of little importance if the analysts were very heterogeneous in their forecasts. On the other hand, sometimes a small difference $Surp_0$ can become significant if the analysts' forecasts were very consistent and were characterized by a very small standard deviation. The same idea is behind the definition of $Surp_3$. In this case, however, the measure of the heterogeneity of market expectations is the difference between the largest and the smallest forecast value of the indicator. The range has some serious disadvantages because it depends only on two values of the data (maximum and minimum), and thus it is very sensitive to outliers. Standard deviation is also sensitive to outliers, but their impact on it is much weaker than the impact of minimum and maximum on the range. However, the obvious advantage of the range is its simplicity: the max and min values of surveys are generally available in some financial datasets, while it is much more difficult to find the values of the standard deviation of analysts' forecasts.

In the absence of more detailed information on the survey results, the earlier values of the difference $A_i - E_i$ may be used to assess the size of the surprise. It is quite a natural approach to measure the surprise because usually investors compare various current data with historical values looking for repeating patterns or trends. The large value of the difference is more important for investors if it is preceded by much lower values in the previous months. On the other hand, the second or third very high value of $A_i - E_i$ in a row does not lead to an equally strong reaction from investors.

When using the measures $Surp_1$, $Surp_2$ and $Surp_3$, it is important that they are standardized and that their values (which are calculated for different macroeconomic indicators) can be compared. Usually, this cannot be done when comparing the value of the $Surp_0$ measure itself, as different macroeconomic indicators are expressed in different units or have values of very distant levels.

3. NFP announcements

When analyzing reactions of investors on the Warsaw Stock Exchange to unexpected information contained in NFP announcements, it is worth paying attention to the values of this indicator itself. Comparing the NFP values published in the subsequent months of the period under consideration, the extreme values announced between April and August 2020 (that is, from the initial stage of the COVID-19 pandemic) clearly stand out. For this reason, in Figure 1, the published NFP values are presented in two graphs: before April 2020 (left graph) and after that time (right graph). These graphs also show the differences between the published NFP value and the market expectation measured by consensus. To illustrate the differences between the NFP and the surprise values before and after April 2020, both graphs show the values for the announcement on April 3, 2020 (the last value on the left graph and the first value on the right graph). To supplement this information, Table 1 presents more detailed data on selected NFP announcements in 2020.

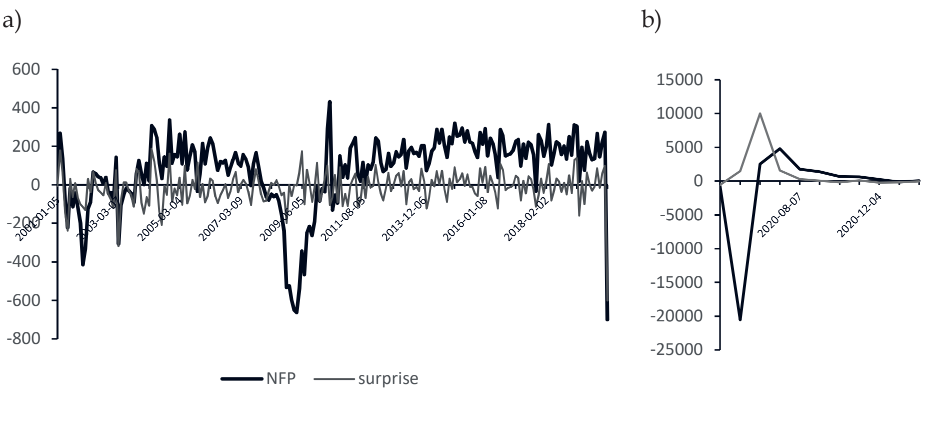

Figure 1. Announced values of NFP and values of surprises $Surp_0$ in the period 2001–2021

Note: This Figure presents announced NFP values (thick line) along with surprises $Surp_0$ values (thin line) form January 2001 to April 2020 (a) and from April 2020 to February 2021 (b).

Table 1

Details of NFP announcements in the initial phase of the COVID-19 pandemic

Date	Actual	Consensus	Survey High	Survey Low	Survey Std. Dev.
2020-03-06	273	175	249	132	21.72
2020-04-03	–701	–100	100	–4000	626.36
2020-05-08	–20 537	–22 000	–8600	–30 000	2928.31
2020-06-05	2509	–7500	–800	–12 000	2384.01
2020-07-02	4800	3230	9000	500	1493.19
2020-08-07	1763	1480	3210	–600	819.97

Note: This table presents announced values of NFP and some basic survey statistics for published between March and August 2020.

From January 2001 to March 2020, the published NFP values ranged from −663 (April 2009) to 431 (June 2010). NFP value announced on April 3, was –701. Then, in May 2020, the NFP fell to −20537. Analysis of Figure 1 shows that fluctuations of the $Surp_0$ values are much smaller than changes in NFP and the values of the difference $A_i - E_i$ are only to some extent related to the size of the published NFP. Before the COVID-19 pandemic $Surp_0$ ranged from −318 (March 2003) to 188 (April 2004). However, extreme values of NFP announced in 2020 associated with very high uncertainty of analysts led to extreme values of $Surp_0$ in the following months. $Surp_0$ in April 2020 (equal to −601) is the lowest value in the entire period. Similarly, the differences in the next four months are the four highest values over the whole period 2001–2021. These extremely high values significantly distort the distribution of $Surp_0$ values and have negative consequences for the analysis of the impact of the unexpected NFP value announcements on the stock prices on the Warsaw Stock Exchange. This negative effect is probably also observed in other markets.

At this point, it is worth commenting on the impact of the employment situation reports on the prices of shares listed on the Warsaw Stock Exchange in the first months of the COVID-19 pandemic, i.e., between April and August 2020. First, the investor reaction to the announcements in April and May was inadequate to the sign of the surprise. On April 3, we observe an increase in the WIG20 value by about 0.375% in the first 5 minutes after the announcement of the value of NFP lower than expected by 601. Similarly, the very high value of the surprise released on May 8 ($Surp_0$ = 1463) was followed by negative change in the WIG20 index ($R_t \approx -0.232\%$). Second, the changes in the WIG20 in the first 5 minutes after the NFP releases in the following months are not as large as the surprise values would suggest. This is evidenced by the comparison of the ranks of surprises and returns reported in parentheses in the respective columns in Table 2. The reason for these discrepancies may be the COVID-19 pandemic itself and the fact that at that time investors probably paid much more attention to information on the development of the pandemic in Poland and in other countries, in particular to information on the introduced restrictions and their possible impact on economies. On the other hand, the returns in the first 5 minutes after the NPF releases from April to August 2020 are significant when compared to their values in the three hours prior to the announcements[2].

Table 2

Values of surprise measures for NFP announcements in the initial phase of the COVID-19 pandemic

Date	$Surp_0$		$Surp_1$		$Surp_2$		$Surp_3$		R_t	
2020-03-06	98	(209)	4.51	(221)	1.70	(220)	0.84	(223)	0.183%	(170)
2020-04-03	−601	(1)	−0.96	(91)	−3.17	(2)	−0.15	(97)	0.375%	(204)
2020-05-08	1463	(225)	0.5	(148)	3.10	(226)	0.07	(143)	−0.232%	(37)
2020-06-05	10009	(227)	4.2	(219)	3.45	(227)	0.89	(224)	0.415%	(209)
2020-07-02	1570	(226)	1.05	(166)	0.54	(171)	0.18	(167)	0.265%	(187)
2020-08-07	283	(224)	0.35	(140)	0.10	(136)	0.07	(145)	0.149%	(164)

Note: This table presents values of surprise measures for NFP announcements published between March and August 2020. In the last column, values of WIG20 returns from the first 5 minutes after the announcements are reported. The numbers in parentheses indicate the rank of a given value of the surprise measure (or returns) in the entire sample.

The differences between the WIG20 returns and the values of $Surp_0$ can be partially explained by the values of the remaining surprise measures. In particular, the $Surp_1$ values indicate that if we take into account the heterogeneity of analysts' forecasts, only the NFP value published on June 5 was clearly different from market expectations. The analysis of the $Surp_3$ value leads to the same conclusion. Values of $Surp_2$ are very high for NFP announcements in April, May, and June 2020. This, in turn, is due to the fact that the absolute values of the differences $A_i - E_i$ increased in the following months. As $Surp_2$ compares the value of the difference from the given month with its historical values up to 11 months, the first large value of the difference $Surp_0$ appearing after a period of low values leads to a very large value of $Surp_2$. Successive, greater and greater values of $Surp_0$ also

[2] To verify the significance of the first 5-minute returns after a news announcement, we checked that they are within a 90% confidence interval constructed from 36 returns in the 3-hour period prior to the announcement.

imply high values of $Surp_2$. It is worth noting, however, that the announcement on July 2, 2020, although very different from expectations, does not caused such a high value of $Surp_2$ because it was preceded by a few even stronger surprises.

Table 3

Descriptive statistics of macroeconomic news surprises

	$Surp_0$	$Surp_0$ before April 2020	$Surp_1$	$Surp_2$	$Surp_3$
Mean	42.3	−11.8	−0.29	−0.13	−0.06
Std. dev.	685.5	74.9	2.50	1.04	0.47
Min	−601	−318	−8.19	−3.27	−1.82
1st quartile	−58	−57.3	−1.84	−0.87	−0.35
Median	−8	−8.5	−0.38	−0.07	−0.06
3rd quartile	33	32.3	1.17	0.54	0.21
Max	10 009	188	8.69	3.45	1.97
Skewness	13.8	−0.28	0.14	0.05	0.10
Kurtosis	203.3	4.12	3.38	3.65	4.74

Note: This table presents descriptive statistics of macroeconomic news surprises under study computed for NFP announcements in the period from January 2001 to February 2021. Due to extreme values of $Surp_0$ in 2020, its distribution before the COVID-19 pandemic period is described in the separate column ('$Surp_0$ before April 2020').

For a more detailed analysis of the values and properties of the surprise measures under study, several basic descriptive statistics of their distributions are presented in each column of Table 3. Due to the described-above extreme values of the differences $Surp_0$ between announced and expected values of NFP in the initial period of the COVID-19 pandemic, the characteristics of the $Surp_0$ distribution before April 2020 are presented in the separate column. The values of order statistics (confirmed also by the value of the skewness coefficient) indicate that distribution of $Surp_1$, $Surp_2$ and $Surp_3$ are symmetric. Moreover, the values of kurtosis close to 3 suggest that the $Surp_1$, $Surp_2$, and $Surp_3$ can be described by a normal distribution. As a confirmation of this conjecture, the Shapiro test does not reject normality of $Surp_1$ and $Surp_2$ at the 5% significance level, and of $Surp_3$ at the level of 1%. The skewness of $Surp_0$ before April 2020 also is very close to zero and kurtosis is close to 3. However, the extreme values of $Surp_0$ after April 2020 disturb the values of both measures suggesting a very strong asymmetry of the $Surp_0$ distribution.

Most of the models used to analyze the impact of announcements on stock prices considers linear relationship between returns and news surprises. Hence, it is worth analyzing in detail the strength of the Pearson correlation between surprise measures and the changes of the WIG20 in the first 5 minutes after the announcements of unexpected NFP values. Results of this analysis are summarized in Table 4. As before, we separately analyze correlations with $Surp_0$ before April 2020. The values in the first row ('Correlation') are calculated on the basis of data from the entire dataset. They show a similar strength of the dependence of the WIG20 returns on the size of macroeconomic surprises for $Surp_1$, $Surp_2$, and $Surp_3$. However, as can be concluded from the comparison of the results in the first two columns, the extreme values of $Surp_0$ from 2020 have a very strong negative impact on this linear dependence. They lower the value of Pearson correlation coefficient from 0.475 (before April 2020) to 0.119 when data from the whole period are analyzed together.

Investors do not always react to the releases of macroeconomic data. This applies in particular to those announcements that are not surprising enough, i.e., when the published value of the indicator differs little from the market expectations. In such a situation, the observed changes in WIG20 right after the announcement may seem random. Therefore, to describe the impact of only very unexpected news, the following rows of Table 4 report the values of the Pearson correlation coefficients calculated for announcements with a respective surprise measure greater in absolute value than the breakpoint indicated. In the second row ('Correlation – 1st Q'), 25% of announcements with the weakest surprises are removed. In the third row ('Correlation – me') we present correlations computed for the half of the strongest surprises. Analogously, the last row in Table 4 contains the correlation between the surprise measures and the WIG20 returns computed for the 25% strongest unexpected news about NFP.

Table 4

Correlations between macroeconomic news surprises and WIG20 returns

	$Surp_0$	$Surp_0$ before April 2020	$Surp_1$	$Surp_2$	$Surp_3$
Correlation	0.119	0.475	0.454	0.449	0.463
Correlation – 1st Q	0.133	0.523	0.499	0.494	0.513
Correlation – me	0.158	0.557	0.548	0.511	0.566
Correlation – 3rd Q	0.186	0.589	0.591	0.567	0.555

Note: This table presents values of Pearson correlation coefficients between surprise values and 5-minute WIG20 returns immediately after news announcements. The second, third and fourth rows report correlations computed only for announcements with an absolute value of surprises greater than the indicated breakpoints (1st quartile, median, and 3rd quartile, respectively).

From the comparison of the values in Table 4, it can be noticed that the restriction of the analysis to stronger surprises increases the correlation coefficients between the surprise measures and the 5-minute returns of the WIG20 right after the announcements. Moreover, correlations in each row are similar to each other except $Surp_0$ for the entire period. This means that the use of relative measures of macroeconomic news surprises (i.e. $Surp_1$, $Surp_2$, and $Surp_3$) gives very similar results about the strength of the linear relationship with WIG20 returns, regardless of whether we relate the difference $A_i - E_i$ to the dispersion of analysts' forecasts or to the variability of the previous surprises. However, the differences $Surp_0$ themselves, are very sensitive to the occurrence of outliers, which adversely affect the measurement of the strength of the linear relationship between $Surp_0$ and the WIG20 returns right after news announcements.

The period under study (2001–2021) is very long and includes both bull and bear market time periods. In particular, it covers two large financial crises: the global financial crisis in 2007–2009 (which originated in the USA) and the European debt crisis in 2010–2014. Therefore, it is important to analyze changes in the strength of the relationship between surprises and WIG20 returns in subsequent years. For this purpose, the correlation coefficients between the surprises and WIG20 returns are calculated in windows with a length of 48 months, shifted by one month. The first such window covers data from January 2001 to December 2004. The next one: from February 2001 to January 2005, etc. Figure 2 shows the Pearson correlation values in such windows for each of the surprise measures considered. The ends of the windows are marked on the X-axis.

As can be seen in Figure 2, for the greater part of the period 2001–2021, the values of the correlation coefficients for the surprise measures are very close. However, there are periods when they differ noticeably from each other. The largest discrepancy (before the pandemic period) is visible for data covering the beginning of the global financial crisis, i.e. from January 2004 to January 2008. For that period, the difference between the correlation coefficients is over 0.1 (correlation for $Surp_0$ is equal 0.5, whereas the correlation for $Surp_3$ equals 0.61). A large spread in the correlation values is also observed in the last few years before the COVID-19 pandemic. However, in that period, the lowest correlations are observed for $Surp_3$.

The most cases of the highest values of correlation coefficients occur for $Surp_0$, and the least for $Surp_1$. However, when we take into account the observed changes in the correlations and small differences between correlations computed for different surprises, it is difficult to unambiguously select the best measure of macroeconomic news surprises. Hence, when selecting the appropriate surprise measure, one can follow its simplicity. In this respect $Surp_0$ is the best. However, its sensitivity to outliers means that the models built on it may lead to inconsistent or erroneous conclusions about returns. For this reason, a more stable measure of surprises should be used for modeling purposes.

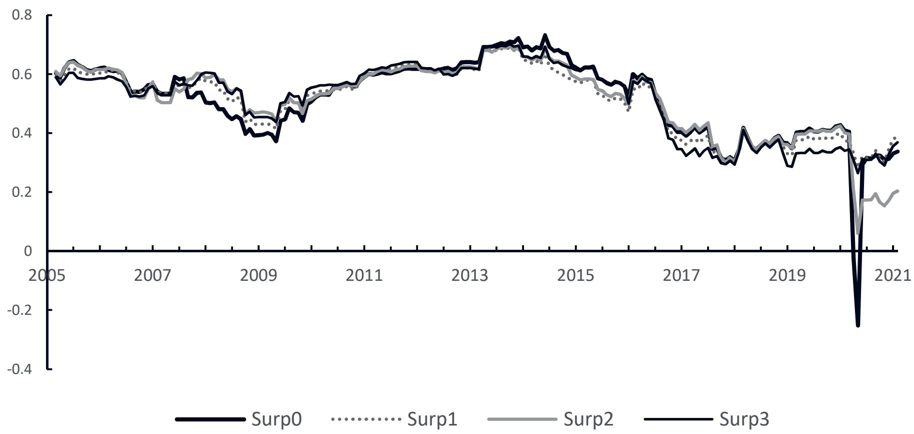

Figure 2. Pearson correlation coefficients between surprise measures and 5-minute WIG20 returns in 4-year windows

Note: The ends of the windows are marked on the X-axis.

4. US macroeconomic news announcements

A comparison of surprise measures on the example of announcements of only one (even the best) macroeconomic indicator may not give a complete picture of their properties. For this reason, the analysis of the distribution of surprise measures will also be carried out on the basis of the announcements of 15 macroeconomic indicators describing the US economy. In order to facilitate the comparison of the distributions of individual measures, in Figures 3–6 we present boxplots for these measures calculated for each of the indicators[3].

In general, distributions of surprise values computed for different indicators have a similar range for each of the surprise measures (except $Surp_0$). However, there are some outliers. The smallest number of outliers and the most symmetric distributions can be observed in the case of $Surp_2$, i.e. when the difference $Surp_0$

[3] As the indicators are expressed in different units, in order to compare $Surp_0$ for different indicators, all values of $Surp_0$ for each indicator are divided by their sample standard deviation.

is compared with its past values. On the other hand, the least stable are the $Surp_0$ distributions. In the case of some indicators (like DGO, IJC, NFP, PI, and RS), distributions of $Surp_0$ show a strong positive asymmetry caused by extremely large positive surprise values. A slight asymmetry can also be observed in the case of some distributions of $Surp_1$ and $Surp_3$, however in these cases the effect of outliers is much weaker than in the case of $Surp_0$. The analysis of the boxplots in Figures 3–6 confirms the conclusions about the distributions of surprises drawn on the basis of the analysis carried out previously on the basis of the NFP announcements only.

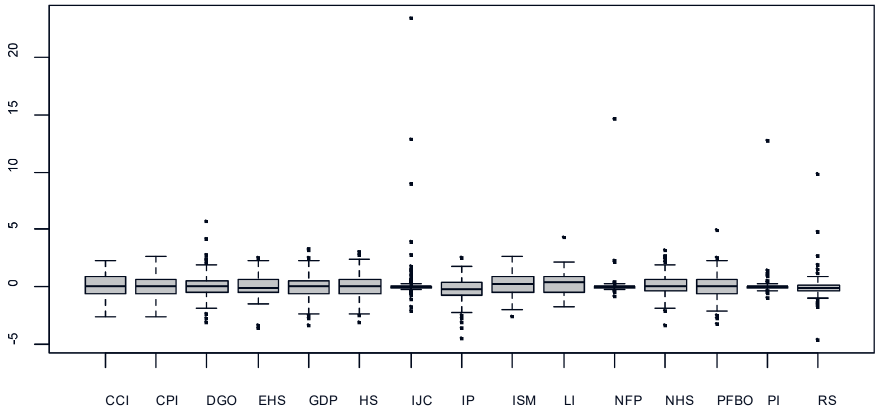

Figure 3. Boxplots of the $Surp_0$ values computed for the announcements of various US macroeconomic indicators

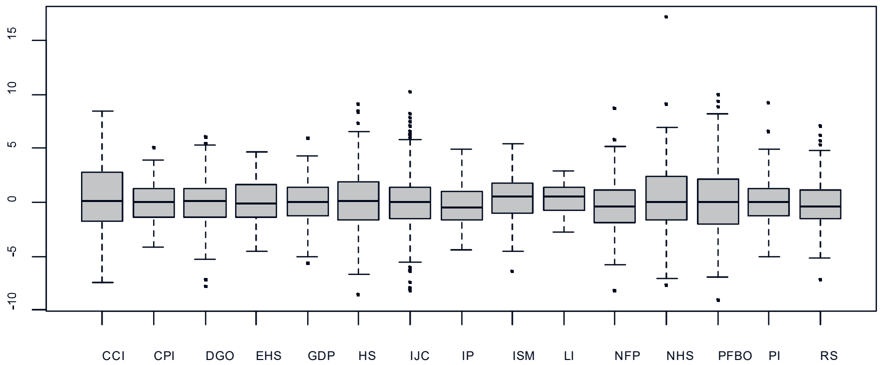

Figure 4. Boxplots of the $Surp_1$ values computed for the announcements of various US macroeconomic indicators

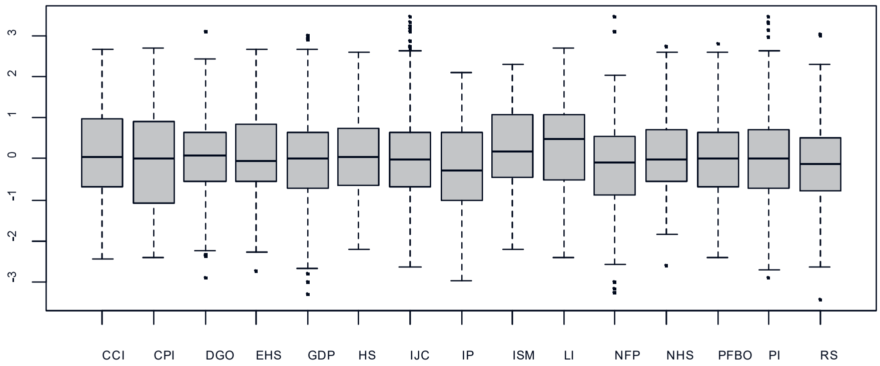

Figure 5. Boxplots of the $Surp_2$ values computed for the announcements of various US macroeconomic indicators

In contrast to the NFP, most of the considered indicators are published around the middle of the month or even later. Moreover, very often they are released at the same time. Therefore, the study of the Pearson correlation between the values of individual surprise measures and the WIG20 returns in the first minutes immediately after news releases may not give a true picture of the impact of unexpected information contained in the announcements of the indicators on stock prices on the WSE. As the impact of the publication of various indicators may overlap, the relationships between returns and surprises will be examined on the basis of appropriate models.

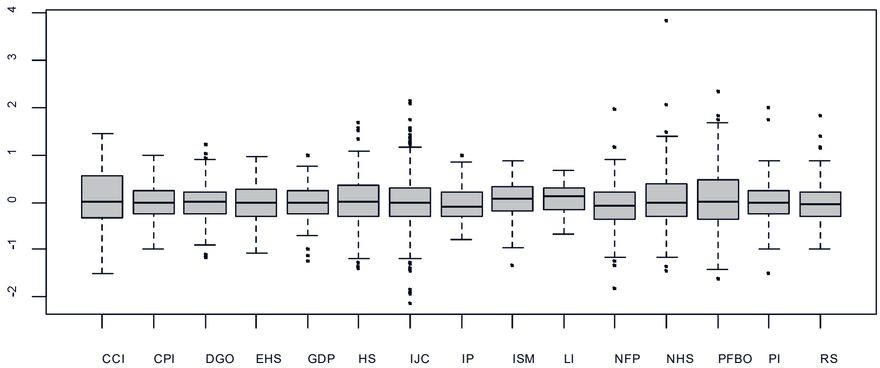

Figure 6. Boxplots of the $Surp_3$ values computed for the announcements of various US macroeconomic indicators

5. Linear models for WIG20 returns

Various models to describe the impact of unexpected macroeconomic news announcements on stock prices, futures, or bonds are considered in the literature. These are mainly various versions of linear models (VAR, ARMA, ARFIMA or AR) with dummy variables added (see, for example: Balduzzi et al., 2001; Andersen et al., 2003; Andersen et al., 2007; Hanousek, Kočenda, 2011; Harju, Hussain, 2011; Będowska-Sójka 2013; Kurov et al., 2019). Due to the possible heteroskedasticity of the residuals and the seasonal patterns observed in intraday volatility (for example, Harju, Hussain, 2011; Gurgul, Wójtowicz, 2020), residual variance in these models is described in an additional equation. Despite their diversity, all the above models assume a linear relationship between news surprises and returns (or their volatility).

To analyze how various definition of news surprises affect the results of such linear models we apply to the WIG20 returns the model presented by Andersen et al. (2007). In this model the conditional mean of the 5-minute returns is a linear function of their I lags and J lags of each of the K news announcements. This model is given by the formula:

$$R_t = \beta_0 + \sum_{i=1}^{I} \beta_i R_{t-i} + \sum_{k=1}^{K} \sum_{j=0}^{J} \beta_{kj} S_{k,t-j} + \varepsilon_t \tag{5}$$

where R_t are 5-minute WIG20 returns, $S_{k,t}$ are the news surprise for k-th indicator at time t ($K = 15$). To take into account only data strongly related to the announcements under consideration, estimates of the model parameters are based only on observations from days when the announcements were released[4]. More precisely, for each day of the announcement, we analyze fifteen 5-minute returns before the announcement and eighteen observations after it. The number of lags I and J are determined based on Schwarz information criterion.

Despite the fact that each of the surprise measures has similar values for different indicators, the range of values differs between the measures. To ensure the comparability of the regression results obtained for different surprise measures, we divide the values of each measure calculated for a given indicator by its sample standard deviation. This is a procedure similar to that applied to compute standardized news in Andersen et al. (2003) (and also in Andersen et al., 2007; Harju, Hussain, 2011; Kurov et al., 2019).

[4] Due to the fact that very often more than one indicator is released at the same time, in the entire period from January 2001 to February 2021 there are 2365 days on which the value of at least one of the analyzed indicators was published. As a result, the model (5)-(6) is estimated on the basis of 78045 5-min WIG20 returns.

Following Andersen et al. (2007), to improve the efficiency of the estimates of model (5), we use the weighted least squares estimation procedure with time-varying volatility approximated with the following model:

$$|\hat{\varepsilon}_t| = \sum_{i=1}^{I'} \delta_i |\hat{\varepsilon}_{t-i}| + \sum_{d=1}^{D} \gamma_d D_d + \sum_{k=1}^{K'} \sum_{j=0}^{J'} \gamma_{kj} D_{k,t-j} + u_t \tag{6}$$

where the first term (with $I' = 9$) takes into account the ARCH effect in the residuals. The second term accounts for the seasonal pattern in intraday volatility, and it contains dummy variables D_d for each of the 5-minute intraday intervals of data included in the model. The last term in the above regression models possible impact of news announcements on intraday volatility in a one-hour period after news release. For announcements of the k-th indicator, it contains dummy variables $D_{k,t-j}$ up to a lag $J' = 12$ (i.e. up to one hour).

Parameters of the model (5)–(6) are estimated separately for each surprise measure under study on the basis of data from the whole period January 2001 – February 2021. The results of these estimations are reported in Table 5 where, for simplicity, we present only the values of the model (5)[5]. The Schwarz information criterion indicates $I = 4$ (significant autocorrelation of 5-minute returns up to 20 minutes) and $J = 1$ (significant impact of unexpected news only in the first 5 minutes after the announcements) in model (5) for each surprise measure. These values are in line with the previous results from the literature indicating the very fast reaction of investors on the WSE to the announcements of US macroeconomic data (see, for example, Gurgul, Wójtowicz, 2014; 2020). As the vast majority of the news surprise variables $S_{k,t-j}$ are insignificant for $j = 0$, in Table 5 we report only the values of parameter estimates for $S_{k,t-1}$ describing the impact of news surprises right after news announcements. Additionally, we present the values of t statistics in the significance test.

A comparison of the results presented in Table 5 leads to the conclusion that in most cases the estimated parameters and significance of the parameters are similar for different surprise measures. The impact of unexpected news about CCI, CPI, DGO, GDP, HS, IP, ISM and RS on WIG20 returns in the first 5 minutes after news releases is significant at the 1% level in the case of each surprise measure. On the other hand, announcements of LI, PFBO, and PI do not lead to significant changes in stock prices on the WSE. The significance tests give mixed results about the impact of releases of unexpected values of IJC, NFP, and NHS. In most of these unclear cases, the difference is due to the results of the linear model estimation for $Surp_0$. The distinct behavior of this measure is most evident

[5] We do not present estimates of the intercept because they are insignificant and very close to zero in each case.

when unexpected IJC or NFP values are analyzed. When $Surp_0$ is applied in the model, the model parameters for IJC and NFP announcements are insignificant, whereas for the other news surprise measures, the values of t statistics strongly reject the null hypothesis about insignificance of IJC and NFP. These ambiguous results are due to very extreme positive values of $Surp_0$ reported in Figure 3 for both IJC and NFP.

Table 5

Response of WIG20 returns to US macroeconomic news surprises

Variable	$Surp_0$		$Surp_1$		$Surp_2$		$Surp_3$	
	Estimate	t statistics	Estimate	t statistics	Estimate	t statistics	Estimate	t statistics
R_{t-1}	-0.009^{**}	(−2.09)	-0.010^{**}	(−2.24)	-0.009^{**}	(−2.17)	-0.010^{**}	(−2.24)
R_{t-2}	-0.020^{***}	(−4.67)	-0.020^{***}	(−4.73)	-0.020^{***}	(−4.68)	-0.020^{***}	(−4.70)
R_{t-3}	-0.008^{**}	(−1.97)	-0.008^{*}	(−1.85)	-0.008^{*}	(−1.91)	-0.008^{*}	(−1.87)
R_{t-4}	0.014^{***}	(3.51)	0.014^{***}	(3.53)	0.014^{***}	(3.40)	0.014^{***}	(3.50)
CCC_1	0.056^{***}	(5.17)	0.050^{***}	(4.75)	0.049^{***}	(4.55)	0.048^{***}	(4.62)
CPI_1	-0.082^{***}	(−3.92)	-0.080^{***}	(−4.05)	-0.068^{***}	(−3.37)	-0.075^{***}	(−3.83)
DGO_1	0.092^{***}	(6.91)	0.120^{***}	(9.38)	0.098^{***}	(7.27)	0.120^{***}	(9.39)
EHS_1	0.024^{*}	(1.89)	0.025^{**}	(2.12)	0.021^{*}	(1.68)	0.024^{*}	(1.95)
GDP_1	0.113^{***}	(5.89)	0.091^{***}	(4.72)	0.106^{***}	(5.74)	0.090^{***}	(4.69)
HS_1	0.040^{***}	(4.16)	0.039^{***}	(4.34)	0.038^{***}	(4.17)	0.037^{***}	(4.08)
IJC_1	−0.006	(−1.01)	-0.041^{***}	(−7.64)	-0.042^{***}	(−7.75)	-0.039^{***}	(−7.4)
IP_1	0.048^{***}	(3.81)	0.040^{***}	(3.47)	0.039^{***}	(3.40)	0.040^{***}	(3.47)
ISM_1	0.079^{***}	(5.15)	0.078^{***}	(5.15)	0.074^{***}	(4.71)	0.077^{***}	(5.06)
LI_1	0.025^{*}	(1.70)	0.023	(1.62)	0.025^{*}	(1.77)	0.022	(1.59)
NFP_1	0.047	(1.61)	0.175^{***}	(6.89)	0.173^{***}	(6.87)	0.184^{***}	(7.30)
NHS_1	0.022^{**}	(2.08)	0.028^{***}	(2.70)	0.031^{***}	(2.89)	0.025^{**}	(2.36)
$PFBO_1$	0.016	(1.20)	0.025^{*}	(1.87)	0.018	(1.36)	0.026^{*}	(1.96)
PI_1	-0.007	(-0.52)	0.006	(0.70)	0.004	(0.50)	0.007	(0.73)
RS_1	0.089^{***}	(5.64)	0.098^{***}	(6.28)	0.108^{***}	(7.04)	0.097^{***}	(6.19)

Notes: This table presents the parameter estimates of model (5). Parameters are estimated by weighted least squares with residual volatility modelled by (6). *, **, *** indicate significance of a mean at 10%, 5%, and 1%, respectively.

It should be noted here that the differences in the results of the significance tests for various surprise measures lead to different conclusions about the impact of macroeconomic news announcements on stock prices. When $Surp_0$ is applied, the model suggests insignificant reaction of the WIG20 returns to IJC and NFP announcements. However, this conclusion is inconsistent with the results from the literature, which indicate a very high importance of information from the US labor market for investors in various stock markets.

A comparison of the parameter estimates leads to an interesting observation: results for $Surp_1$ and $Surp_3$ are very similar. This should come as no surprise as both measures of unexpected information follow a similar structure: the difference between the published and the expected value of the indicator is divided by a measure of variability of analysts' forecasts. For the same reason, the estimation results for $Surp_0$ are mainly similar to the results obtained with in the model with $Surp_2$ as an explanatory variable. Here, it is worth noting that $Surp_2$ does not have disadvantages that can be seen when using only the $Surp_0$ differences.

In addition to the analysis of the similarities and differences between the measures of surprise considered, the results in Table 5 also allow us to compare the strength of the impact of the US macroeconomic indicators announcements under consideration on stock prices. Investors on the WSE are most strongly affected by unexpected news contained in the monthly publications of the Bureau of Labor Statistics. This is definitely evidenced by the highest values of the NFP coefficients for 3 of 4 analyzed surprise measures. The GDP and DGO publications also have a very strong impact on the stock market in Poland, although the assessment of the strength of the impact depends on the measure of information surprises used.

6. Conclusions

In this paper, we analyzed the properties of the various measures of unexpected part of the announcements of macroeconomic news. The study was carried out based on data on announcements of 15 American macroeconomic indicators from January 2001 to February 2021. The most commonly used measure of news surprise is the difference between the announced and expected value of the indicator. However, it allows for the occurrence of extremely positive or extremely negative values, which distort its distribution. This, in turn, causes a noticeable weakening of the linear relationship between surprises and returns in the stock markets. For this reason, the difference between the announced and expected values of the indicator should not be used in linear models that describe returns. Therefore, we analyzed other surprise measures that took into account the heterogeneity of analysts' forecasts or the variability of previous surprises. The distributions of these measures are robust to the announcements of values that are far from market expectations. Additionally, each of these enhanced surprise measures is characterized by a similar strength of the linear relationship with returns. The choice of a specific surprise measure depends on the availability of the data. However, most can be calculated even on the basis of freely available data.

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Summary

The definition of a news surprise plays a crucial role in the analysis of the impact of unexpected macroeconomic news announcements. In this paper, we study the properties of the most commonly used measure of news surprise, defined as the difference between the announced and expected value of the indicator. Due to the high vulnerability of this measure to outliers, we consider alternative definitions of macroeconomic surprises. Based on the analysis of announcements of 15 American macroeconomic indicators, we show that taking into account the heterogeneity of analysts' forecasts or the variability of the previous surprises, noticeably improves the properties of the distribution of surprise measures. An additional study performed with the use of a dynamic model proves a strong linear relationship between surprise measures and WIG20 returns in the first five minutes after news announcements.

JEL classification: G14, E44

Keywords: *unexpected news, macroeconomic announcements, intraday data, Warsaw Stock Exchange*