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SUSTAINABILITY OF ELECTRICITY PRICES AND THE CONSEQUENCES FOR THE PRAGUE STOCK EXCHANGE

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Abstract. Sustainability of electricity prices hold an important part of the family budget, business operational costs, and vitality of the economy. Currently, multinational corporations are considered the main users of electricity and other energy recourses. For this purpose, we analyze the sustainability of electricity price and their impact equity stocks in the PX Index. The PX Index, which originates from Prague Stock Exchange is generally composed of firms in the financial and energy sector. This paper as well tries to predict the performance of these two variables in the 12 months ahead. The data cover the period from 1995 to 2022 standing on the monthly observations. The Vector Error Correction Model was used to detect the effect that electricity prices maintain on the PX Index. The estimated forecasts were conducted in the R program using Facebook Prophet and Auto ARIMA Model. The results indicate that non-sustainability of electricity prices negatively affect the equity stocks listed on the PX Index. Regarding predictions, the PX Index is expected to stay at almost the same levels while electricity prices increase. The results provide modest indications for investors, government, and regulators on the performance of these two indicators 12 periods ahead. Additionally, it is the first attempt to analyze the relationship between electricity prices and the equity markets since the liberalization of the Czech economy.

Keywords: Electricity prices; Equity Stocks; PX Index; VEC Model; Facebook Prophet; Auto ARIMA

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JEL Classifications: G15, G17

1. Introduction

The stock markets stand as an important element of the financial system that facilitates efficient allocation of national savings (Masood et al., 2017). The equity stocks of Central and Eastern European (CEE) exchanges barely reflect the financial and economic settings of the country (Sinicakova and Gavurova, 2017). At the same time, sustainable electricity prices and permanent supply are vital for well-functioning of the market economy (Belas et al., 2019; Rajbhandari et al., 2022). In many nations, energy efficiency is the focal point of energy policies, and it is also at the forefront of the discussion surrounding energy sustainability (Yao et al., 2022; Guo et

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al., 2022; Androniceanu et al., 2020; Simionescu et al., 2021). The work by Aliu et al. (2021) shows that due to financial literacy, macroeconomic and firm-specific factors are hardly priced into these exchanges. The structure of the firms in the PX Index is constantly changing while few of them exist since its foundation (PSE, 2022). Of the twelve blue chips that the index is constructed, four of them are local firms while the others are international. The index experienced an unprecedented downturn during the financial meltdown of 2008/09 and the Greek debt crisis of 2010/11. The outbreak of the COVID-19 pandemic was an additional shock for the global economy and the financial system in particular (Hassan et al., 2022; Batten et al., 2022; Kufel et al., 2022; Kinateder et al., 2021). At that time, the Czech economy shrank by 5.8% (WB, 2022), while the equity market grew by 30.2%. The speculative prices in the PX Index during the pandemic COVID-19 were mainly due to the excess liquidity formed in the Czech financial system. The Czech Central Bank relaxed lending activities but also gave a boost to the capital market by lowering the discount and Lombard rate (CNB, 2022). The identical speculative flow followed the Eurozone equity markets, where the European Central Bank (ECB) imposed QE measures of 1.8 trillion euros (Škare and Rochon, 2022; Škare and Sinković, 2021). Similarly, the Federal Reserve (FED) in the US confirmed once again that it is the guardian of the capital market artificial respiration (Ihrig et al., 2022). Even though the US economy was heading towards recession during COVID-19, equity markets were quickly recovering. Recently, the Russian invasion of Ukraine on February 24, 2022, placed the European capital markets into cardiac arrest (Ahmed et al., 2022) and sent Euro exchange rates into a free fall (Aliu et al., 2022). As a result of this conflict, commodity prices doubled while inflation began to accelerate quickly in the European Union (Mišík, 2022). From the investor's perspective, inflationary periods constantly raise concerns about the performance of financial instruments. On the other hand, unsustainable electricity prices accelerated enormous panic among financial investors. The empirical findings suggest that in the short run, equity stocks are not suitable anti-inflationary hedging instruments (Sellin, 2001; Kolcun and Rusek, 2018). The short-term negative relationship between stock returns and inflation is largely explained in standard macroeconomic textbooks. The inflationary periods beyond official targets, frequently go along with higher discounts and Lombard rates. In those moments, central bankers generally impose countercyclical monetary policy (raising interest rates), by smoothing the inflationary pressures and affecting stock returns (Pérez et al., 2020). The conflict in Ukraine has deteriorated inflationary issues in the Eurozone but also its growth potential. High and unsustainable inflation during this conflict brought also unemployment problems, known as stagflation. The intensity and duration of the crisis will depend on the shock that will be given to the economy and financial system in particular (Agarwal and Kimball, 2022). As this article is being written, uncertainties regarding gas supplies, electricity prices, and inflation in the EU remain in unknown territory. In addition to the macroeconomic factors and financial ones, equity stocks are as well affected by energy prices. The sharp increase in electricity prices and the expected gas shortages placed the Czech economy under scrutiny. The electricity prices are an integral part of the firm operational costs while constraining their capacity to invest. The association between electricity consumption and the uncertainties formed in the equity market is essential for the investor's positions in the marketplace (Bilan et al., 2017). We consider that this relationship is indirect where electricity prices first influence the firm's financial capacities and consequently their market prices. At that point, if the electricity prices are priced in equity stocks, it largely depends on the level of market efficiency. The stock markets in its majority consist of investors who recognize the limitations of the local environment (Kinateder et al., 2014; Choudhury et al., 2022). Thus, price changes depend on what investors foresee as a critical prospect for the domestic economy. Recognizing this fact, we have predicted the sustainability of electricity prices and PX Index for the 12 periods ahead and analyzed their causal relationship. The results are as expected, where the relationship between electricity prices and the PX Index is negative. Thus, higher electricity prices depreciate the value of equity-listed stocks listed. Meanwhile, forecasts indicate further acceleration of electricity prices in the Czech Republic while the stability period for the PX index.

In this paper, we analyze the association between the PX Index and changes in electricity prices. At the same time, our work tends to predict the performance of these two elements one year ahead. However, in the early 90s, the Czech economy was gradually transitioning to a market economy where the capital markets were non-existent. The difficult structural reforms both in the real economy and in the financial system enabled establishing capital markets. The early study by Vošvrda et al. (1998) show that the PX Index has gradually moved towards weak form efficiency. The inefficiency of that time was justified by regulatory deficiencies and the fact that the exchange was dominated by post-privatized firms. Many of the listed firms faced a lack of transparency and difficulty in adapting to a free market mechanism. From 1993 to 2000, the Prague Stock Exchange underwent many institutional changes but also enhanced the trading platform (Němeček and Hanousek, 2002). During that period, a considerable number of shares were transferred through the voucher scheme without respecting the listing requirements. This burdened the Czech equity market with information asymmetry and therefore influenced trading activities. The Czech Republic became part of the European Union in 2004, and from that year to 2008, the value of the PX Index doubled. This period of optimistic euphoria, Baxa (2007) describes as exaggerated expectations driven by common factors on the entire CEE exchanges. Later, Pošta (2008) analyzed the efficiency level of the PX Index by comparing it with that of the PX-GLOBAL Index. The results report that despite increased trade volume, the PX Index still stands within weak form efficiency. The equity stocks in the PX Index have continuously been detached from their intrinsic value and time to time prone to speculative issues. In this context, Aliu et al. (2020) investigated the fundamental value of firms listed on the Prague Stock Exchange based on the free cash flow allocated to investors. The results highlight that the market prices of domestic firms tend to be less speculative compared to international ones.

Sustainability of electricity prices stand as a significant part of household budgets, firms' profits, and the vitality of the entire economy. The energy sector is prone to permanent changes mostly due to geopolitical gravities, climate policies, and natural gas extractions (Brehm, 2019). These changes take place on a global scale, while investments in this field are often prone to strategic errors (Akimov and Simshauser, 2019). Small and medium-sized companies are permanent users of electricity, while corporations are considered the main ones. Therefore, higher electricity prices impose an extra burden on firms' financial performance and ultimately lower their stock prices. The economic reasoning leads us that higher electricity price dampens the market value of listed firms. The prices of equity stocks and those of electricity are subject to the market mechanism but with fundamental differences. The first is completely delivered from the market forces, while the second carries interferences from state regulators. Research on the relationship between the stock markets and electricity prices is limited. One of them is by Anwar et al. (2019) who explored the association between electricity consumption and stock market performance. Their findings could not identify any significant relationship between electricity consumption and changes in equity markets (on a related issue also Vochozka et al., 2021). The continuous supply of electricity is important not only for the country's economic growth but also for national security. Presently, the lack of sufficient diversification of energy sources is jeopardizing the entire economic prospect of the European Union (Gehring, 2022). In addition to other military risks, the dependence on Russian gas and oil is limiting their political actions as well (Vochozka et al., 2020). The CEE countries for a period were subject to a centralized system where the market was non-existent and the prices were the exclusivity of the central office. In the context of the former communist bloc, Bercu et al. (2019) declare that electricity consumption is an essential input of their economic growth and good governance. Our work used electricity prices and not consumption, since consumption trends are not always accompanied by price changes. The electricity prices partly rely on consumption level, while the rest on government regulation, competition, and the international context. In the end, changes in electricity prices are directly involved in the production costs and simultaneously on the equity stocks.

Market prices are necessary signals for investors as they efficiently orient financial recourses in the marketplace (Rowland et al., 2021). The low trade volume and the limited number of participants in the CEE exchanges are characteristic of markets with information asymmetry. Consequently, the equity stocks of the listed firms in the PX Index do not incorporate essential macroeconomic information. Aware of this problem, we analyze if the electricity prices are priced in the equity stocks of the listed firms in the PX Index. The Vector Error Correction Model (VECM) was applied to investigate this phenomenon, covering the period from 1995 to 2022. The significance of the paper increases since only one firm (such as ČEZ) maintains almost 20% of the market share within the index. Besides, it is a dominant firm in the Czech energy sector, whose profit doubled in 2022 mainly

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due to higher electricity prices. According to the Household Energy Price Index, Czech customers pay the highest electricity prices in the whole of Europe (HPI, 2022). On the other hand, the Czech Republic is one of the largest exporters of electricity in the world (Dvořák et al., 2018). The energy crisis that has gripped the European continent is unprecedented in recent decades (Bednář et al., 2022). In the meantime, the war in Ukraine has set security alarms for the EU but has also amplified the problems with gas supply. Facing these circumstances where gas and electricity prices are accelerating, forecasts are more than necessary. To this end, our work has predicted the performance and sustainability of electricity prices and the PX Index for the next 12 months. The work by Batten et al. (2022) considers that almost all investors apply out-of-sample as a forecasting tool. In our case, the Auto ARIMA and Facebook Prophet Model were used to generate these estimates. To the best knowledge, it is the first study that analyzes the influence of electricity prices on the Czech equity market. Recognizing the importance that electricity prices have for the listed firms in the PX Index, the following questions were asked.

RQ1: What is the relationship between electricity prices in the Czech Republic and the PX index?

On the other hand, the performance of the PX index and Electricity prices from June 2022 to June 2023 is too vague. The rest of the paper is structured as follows. The next section reviews the literature while the methodology is placed in section 3. The findings of this paper stand in section 4 while the concluding remarks on the fifth one.

2. Methodology

The methodology section is divided into two parts where 3.1 presents data collection while 3.2 methods are used.

2.1. Data

This work contains two objectives and for this purpose, two different methods were used. First, identify the causal relationship between changes in electricity prices and the PX index. Second, predicting the electricity prices and the performance of the PX index for the next 12 consecutive months. Figure 1 presents the performance of the PX Index and Electricity Prices (EP) in the Czech Republic from 1995 to 2022. The PX index originates from the most liquid companies listed on the Prague Stock Exchange (PSE). At the same time, the index is inefficient since prices do not reflect the macroeconomic settings and the performance of the listed companies. The weak form efficiency is limited by the low trading volume and the limited number of analysts. From 1995 to 2004, the price movements of the PX index remained almost at the same levels with minor variations. The brightest period for PX is between 2004 and 2008 when the growth was in the range of 143%. Due to financial deregulation and liberalization, the financial meltdown of 2008/09 hit the PX index hard. From September 2008 to June 2009, the index lost almost 60% of its market value. The next downturn appeared during the Greek debt crisis of 2010/11, where PX fell from 1175.2 basis points to 878.

Table 1 summarizes the descriptive statistics related to the PX index and Electricity Prices (EP) in the Czech Republic. The table indicates monthly raw data with 330 observations covering the period from January 1, 1995, to August 1, 2022. The standard deviation in the PX index is 14 times higher than for electricity prices (EP). Unlike the stock prices, a larger number of electricity contracts are futures traded, with a later delivery date, which explains the lower standard deviation. EP prices are also affected by the effective prediction of production and consumption, together with the limits of cross-border transmission networks.

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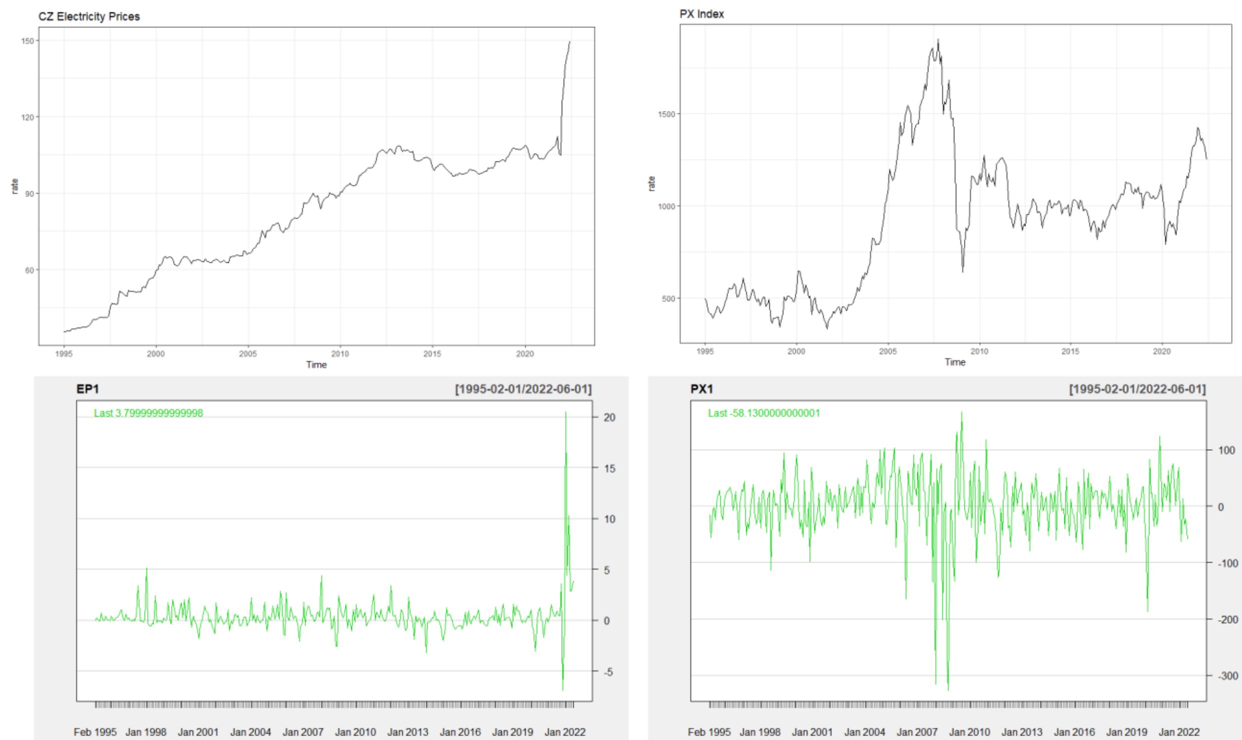

Figure 1. Indicates the Electricity Prices (EP) and performance of the PX index from January 1995 to August 2022
Source: own processing

Note: The figure 1 indicates the monthly closing prices of the PX index and Electricity Prices (EP) from January 1, 1995, to June 1, 2022. The PX Index stands as the main index of the Prague Stock Exchange (PSE) and is calculated in real-time. The index is constructed based on equity stocks of the most liquid firms, using a free floated weighted average price system. The plots are prepared in R studio using the "ggplot2" and "tidyverse" packages. The data on the other hand were collected from the Thomson Reuters Eikon database. The electricity prices are measured for wholesale customers while excluding collateral items, distribution fees, and other effects.

Table 1 indicates the descriptive statistics for the two variables used in our research, based on the raw data. For the time series to have a normal distribution, they must have a skewness of zero. We can conclude that the data are close to being symmetrical with a right light skewness for PX and a negative one for EP. On the other hand, the kurtosis should be three for the data to have a symmetric distribution. None of our data has a kurtosis of 3, where the value for EP is -0.74 while the PX stands at the level of -0.43. The maximum basis point for the PX index was 1908.3 while the minimum was 911.7. The maximum and minimum points for the PX correspond to the period before and during the financial meltdown of 2008. However, the maximum point (149.6 Kwh) of electricity prices is related to the recent European energy crisis.

Table 1. Descriptive statistics of the PX index and electricity prices in the Czech Republic.

	Dim	Mean	Median	Sd	Skewness	Kurtosis	Min	Max
EP	330	81.4	87.8	23.98	-0.20	-0.74	35.8	149.6
PX	330	911.7	956.5	367.73	0.35	-0.43	331.9	1908.3

Source: own processing

Notes: The table 1 indicates descriptive statistics with the raw data of the PX index and Electricity Prices (EP) in the Czech Republic. The table contains the number of observations (Dim), mean, maximum (Max), minimum (Min), kurtosis, standard deviation (Sd), and skewness. The summary statics was performed in the R studio with the "tseries" and "lessR" packages. The monthly data cover the period from January 1, 1995, to August 1, 2022.

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The raw data were not used to generate results from the Vector Error Correction Model (VECM) and Facebook prophet predictions. In the case of VECM, both variables are differenced (diff), while in the case of the Facebook prophet model log-transformation was used. In the construction of the VECM, it is required that the time series be stationary in the first difference. Unit root tests such as the Augmented Dickey-Fuller test, Phillip Peron test, and KPSS test, show that our data become stationary after first differencing. In the case of the Augmented Dickey-Fuller test, and the Phillip Peron test, our data (PX and EP) have a p-value smaller than 5%, while the KPSS is larger than 5%.

2.2. Methods

This section is divided into two parts, in 3.2.1. Vector Error Correction Model is analyzed, while in 3.2.2. Facebook prophet results are placed.

2.2.1. Vector Error Correction Model

The autoregressive model VAR analyzes the dynamic relationship among stationary time series variables. The VAR model is a system of equations where the endogenous variables are influenced by their lags and the lags of the other variables in the system. At the same time, the fan chart function within the VAR model is regularly used for prediction purposes. If the data are non-stationary, then differencing (diff) is usually applied to transform them into stationary. Unit root tests such as the Augmented Dickey-Fuller test, Phillip Peron test, and KPSS test are frequently used to test stationary problems. In the case of the Augmented Dickey-Fuller and Phillip Peron, the p-value must be lower than 5% while in the KPSS higher than 5%. The unrestricted VAR is a commonly used technique for assessing macroeconomic policies, financial crises, monetary shocks, etc. The formula below represents the VAR model with two endogenous variables and two autoregressive lags, known as Bivariate VAR.

$$y_t = b_1 + b_{11}y_{t-1} + b_{12}y_{t-1} + u_t \tag{1}$$
$$x_t = b_1 + b_{21}y_{t-1} + b_{22}y_{t-1} + v_t \tag{2}$$

The u_t and v_t stand for external shocks, while y_t and x_t indicate the endogenous variables in the system of equations. The VECM is a modified type of VAR model with a series that is stationary in its first differencing(diff I). As in the determination of the VAR model as well as in the VEC Model, the determination of the number of lags is important. The optimal number of lags in the R program is generated through three types of information criteria (IC). The optimal number of lags is recommended through Akaike Information Criterion (AIC), Hannan-Quin (HQ), Schwarz (SC), and Akaike Final Prediction Error (FPE). The last step before the implementation of the VECM Model is that the data must be co-integrated. The Johansen co-integration test (Engle and Granger, 1987) measures the long-term association of variables in the system. Co-integration is formed when two or more series maintain a long-run relationship. The formula for the Johansen test stands as follows.

$$y_v = A_1 x_{v-1} + e_v \tag{3}$$

Where:

$$\Delta y_v = A_1 x_{v-1} - x_{v-1} + e_v \tag{4}$$
$$= (A_1 - I)x_{v-1} + e_v \tag{5}$$

From above, the vectors within the equation are denoted by x_v and e_v while A_1 indicates the eigenvalue decomposition matrix. Based on the sequential tests, the ranking can take the form 0, 1, 2, 3, 4, 5.....n depending on the number of variables in the system. The rank of zero is considered the situation when no co-integration vector exists, one when we have one co-integration vector, and so on. In the case when we have three endogenous variables, then we can have a maximum of three co-integration vectors. For this purpose, VECM is a multiple-

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time series model where the data has a long-run stochastic trend. Finally, before testing the VECM, unrestricted VAR should be formed and the data should maintain long-run causality.

2.2.2. Facebook Prophet Package

The Facebook prophet is an open-source package generally applied to the time series variables that maintain seasonality issues. The prophet package was invented by two researchers who worked for Facebook (Taylor and Letham, 2018), currently named Meta Corporation. The foundation and the design of the prophet model stand on the specific characteristics of the Meta Corporation. The content of this algorithm consists of three core components, such as growth rate g(t), seasonality s(t), and error term ϵ_{-t}

$$y(t) = g(t) + s(t) + \epsilon_t \tag{6}$$

The g(t) indicates the trend function for the non-periodic values in the time series. On the other hand s(t), indicates the periodic changes that contain daily, weekly or monthly seasonality. The growth trend g(t) incorporates all data points that the package recognizes as "change points". The "change point" situation occurs when the series shifts direction due to particular events. The growth function in the R program can be built by choosing one of three parameters. The first is the linear growth model that involves linear equations with various slopes among changing points. Second, logistic growth for the series that are saturated and do not exceed the maximum and minimum (cap and floor). The formula for logistic growth is as follows.

$$g(t) = \frac{C(t)}{1 + x^{-k(t-m)}} \tag{7}$$

The growth trend in the logistic growth model includes carrying capacity (C) that varies as a function of time (t), growth rate (k) and offset (m). The flat trend stands as the third option in the prophet package with no growth over time but with seasonality issues. The fixed capacity (C) is always replaced with varying capacity over periods C(t). This metric justifies that innovations or unexpected events can completely change the growth trajectory. For this purpose, a trend change is incorporated by identifying the "change points" where the growth rate may alter. The changing points over time (t) are identified as s(j) and constrained with the rate (k) while completed with the adjustment rate k+ $\sum$ j:t>s_j. The whole process can be summarized with a defining vector.

$$a_j(t) = \begin{cases} 1, if\ t \geq s_j \\ 0, otherwise \end{cases} \tag{8}$$

The implementation of this prophet model stands as open-source software, available in R studio and Python. The prophet package is suitable for observations with hourly, daily, weekly, or monthly frequencies. It can also cope with the lack of reasonable missing data and seasonality such as the day of the week or month of the year. The packages used for the implementation of the prophet model in R studio are "tidyverse", "prophet" and "ggplot2". (The coding process and implementation of it in the R studio are available on request).

2.2.3. Auto ARIMA Model

The Auto ARIMA package in the R program uses the algorithm developed by (Hyndman and Khandakar, 2008). The function generates trials of the unit root test, minimization of the autocorrelation function (AIC), and applies the maximum likelihood estimation (MLE). The differencing executes attempts through the KPSS test where the range could be between 0 and 2 differencing. Thus, a maximum of two differentiations can be generated to return the series to stationery. The Auto ARIMA is classified as(p,d,q), where p stands for the number of autoregressive lag, d for differencing, and q for moving average lags. Although there are opportunities for intervention in Auto

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ARIMA to increase the number of autoregressive and moving average lags. In the R program, this type of intervention is done through the commands max.P = 3, max.Q = 3. In this case autoregressive and moving average lags have increased to 3 but higher coefficients can also be set. The fitted model is the one that has the lowest number of AIC, i.e. lags that exceed the 95% confidence band. The process is repeated until the Auto ARIMA model with the lowest number of AICs is found. The process can speed up using the command approximation=FALSE or the stepwise procedure stepwise=FALSE.

3. Results

The results section is divided into two parts, where in 4.1 stands the VECM results while in 4.2 the predictions with the Facebook prophet package.

3.1. VECM eesults

The partial autocorrelation function in Figure 2 indicates part of the correlation for time series that depends on its lag values. The function plays an important role in determining the number of lags in the autoregressive model. From the figure, we can see that the first lag is significant (exceeding the 95% confidence band) in the case of PX and EP. The PACF plots in Figure 2 indicate that the VECM model might be built with one lag in the system. Although the R program automatically suggests the number of lags through information criteria. Based on the Akaike Information Criterion (AIC), Hannan-Quin (HQ), Schwarz (SC), and Akaike Final Prediction Error (FPE) require the use of one lag in the model. Therefore, the VEC Model constructed in the R program for the PX and EP has used 1 lag in the system.

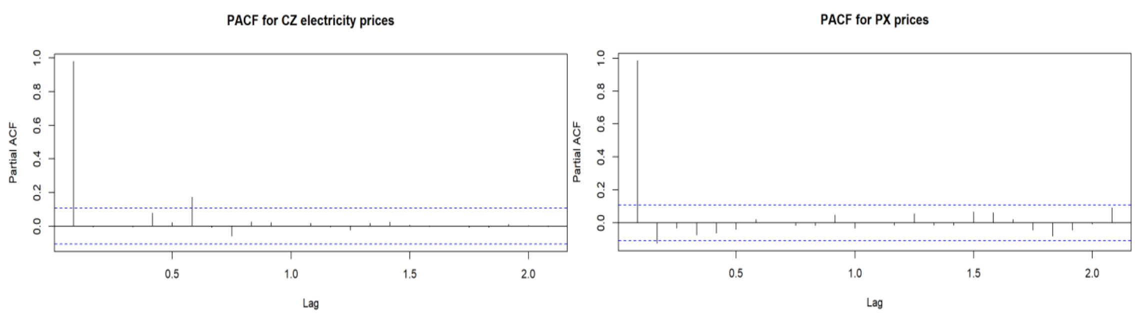

Figure 2. Partial autocorrelation function (PACF) for the electricity prices and PX index.
Source: own processing

Note: The figure 2 shows the plots of PACF function for the two variables used in our study (EP and PX). The variables are differenced (diff EP and diff PX) and cover the period from January 1995 to August 2022. The blue line represents the 95% confidence band, while the black bars stand for the number of lags.

Johansen Co-integration test in R studio was analyzed through the package "vars" and "tidyverse" while implemented through the function "ca. jo". Table 2 presents results from the Johansen test with trace statistics and maximal eigenvalue using 2 lags in the system. The test statistic is higher than the 10%, 5%, and 1% significance levels in the case of trace statistics, but also in the maximal eigenvalue. To this end, we can conclude that there exists long-run co-integration between electricity prices in the Czech Republic and the PX index. The reasons for a long-term association between EP and PX may be different, but the two are very important. First, the increase or decrease in electricity prices affects the operating costs of companies and at the same time their competitive position in the global market. As a result, the performance of listed firms can improve or weaken and this directly affects stock prices. Second, higher electricity prices put a burden on individual savings and as a result, less

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money is devoted to equity stocks. After all, high electricity prices create panic among investors and reduce their positions in the equity markets.

Table 2. Johansen Co-integration test based on trace statistics and maximal eigenvalue

Test type: trace statistic, without linear trend and constant in cointegration					
Eigenvalues (lambda):	[1] 0.314	[2] 0.245	[3] 0.000		
Values of the test statistic and critical values of test:					
	Test	**10%**	**5%**	**1%**	
r <= 1	91.96	7.52	9.24	12.97	
r = 0	215.49	17.85	19.96	24.60	
Test type: maximal eigenvalue statistic (lambda max), without linear trend and constant in cointegration					
Eigenvalues (lambda):	[1] 0.314	[2] 0.245	[3] 0.000		
Values of the test statistic and critical values of test:					
	Test	**10%**	**5%**	**1%**	
r <= 1	91.96	7.52	9.24	12.97	
r = 0	123.53	13.75	15.67	20.20	

Source: own processing

Notes: Table 2 highlights the outcomes from Johansen tests with trace statistics and maximal eigenvalue for the EP prices and PX index. The variables cover the period from January 1, 1995, to August 1, 2022. Each variable holds 329 observations based on their first differencing (diff EP, diff PX). The results are generated in R studio using the "urca", "tidyverse" and "vars" packages.

Table 3 shows the results of the VECM results linked with the electricity prices and PX index. Information criteria (AIC = 2, HQ = 2, SC = 2 and FPE = 2) suggest the using of 2 lags in the system. In this case, the formula requires the reduction of 1 lag in the model (n-1). The use of one lag makes our full sample size 329 as we lose one observation during the process. The VECM model in the R program is generated using the "tsDyn" package. Since VECM requires that the variables must possess co-integration, this is verified through the Johansen test in Table 2. The ECT findings from the VECM model confirm the long-term association between PX and EP. This indicates the correction from the disequilibrium is completed within one month. Moreover, both coefficients hold a negative sign which indicates a stable VEC Model. The situation is different in the short-run where the first lag (PX-1) does not hold short-run causality with itself but only with EP (at 10%). Alternatively, electricity prices show a negative short-run relationship with the PX index and itself at a 1% significance level. As expected, electricity prices in the Czech Republic negatively affect the equity stocks listed in the PX index.

Table 3. Results from the VECM Model

Model VECM		
Full sample size: 329	End sample size: 327	Number of variables: 2
AIC 3051.47	BIC 3085.579	SSR 1091117
Cointegrating vector (estimated by ML):		
	ECT	**Intercept**
Equation diff (PX)	-0.7507(0.0712)***	-1.2151(3.2147)
Equation diff (EP)	-0.0123(0.0022)***	0.0350(0.0998)
	PX1 -1	**EP1 -1**
Equation diff (PX)	-0.0528(0.0572)	-6.3447(1.5671)***
Equation diff (EP)	-0.0040(0.0018)*	-0.3805(0.0487)***

Source: own processing

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Notes: Table 3 highlights results from the Vector Error Correction Model for EP prices and PX index based on differenced series. The PX and EP cover the period from January 1, 1995, to August 1, 2022, standing on monthly series. The variables contain 330 observations, but one observation is lost in the system due to the use of one lag. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

3.2. Estimated Forecasts with the Facebook prophet

The forecasts with the prophet package contain two parts, where 4.2.1 are the estimates for the PX index, while 4.2.2 indicate the prediction for electricity prices.

3.2.1. The PX estimated forecasts with the prophet model

The study analyzes the impact of EP on the PX index, but also the performance of two variables in the 12 months ahead. The variables hold 330 observations and indicate the period from January 1, 1995, to August 1, 2022. The coding process of the prophet package in R studio requires that the date should be named with ds while the predicted variable with y. Figure 1 presents the forecasts and actual data for the PX index for the 12 ahead. As can be seen in the figure, the forecast starts from June 1, 2022, to June 1, 2023, using monthly observation.

The actual values are presented in black dots while the prediction is with the blue line. Based on the forecast, the PX index in the next 12 months does not have any upward or downward trend. As revealed in the figure, oscillations remain almost at the same levels. On June 1, 2022, the PX index was at the level of exp (7.13) = 1248.8 basis points. However, on June 1, 2023, is expected to be exp (7.1) = 1211.9, so for 37.2 basis points less than a year earlier. Recognizing the limitations of

this forecast, the highest point will be on September 22, 2022, when the index could reach 1881.8 basis points. Due to the low trading volume in the Prague Stock Exchange (PSE), the oscillations in the PX index are limited. The index holds four periods of downturns, one of which is the deepest (2008/09) and a clear upward trend that begins in 2004 and ends in 2008. Since the Greek debt crisis of 2010/11, the PX index has remained almost at identical levels without a marked upward or downward trend.

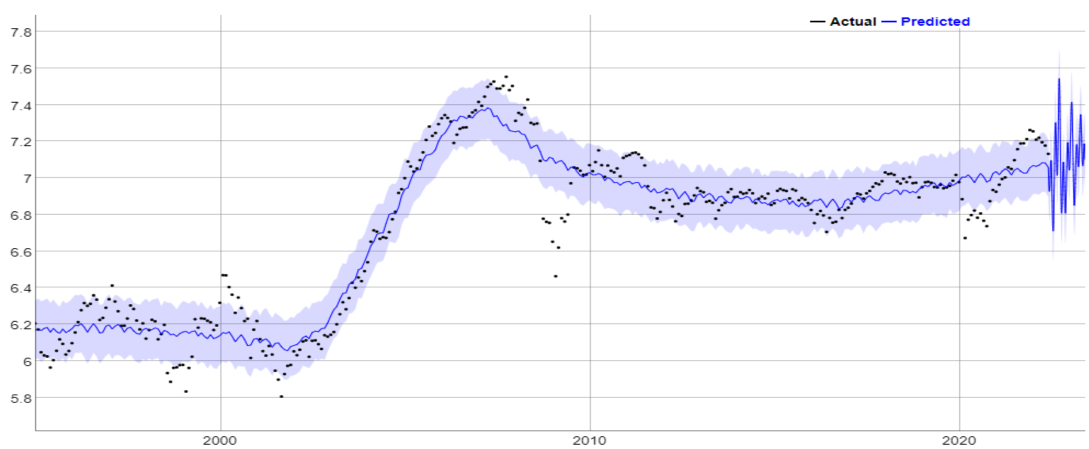

Figure 3. Presents the forecasts of the PX index for the 12 consecutive months.

Source: own processing

Note: Figure 3 plots the forecasts of the PX index from January 1995 to August 2022. The forecasts are made for the 12 months ahead from June 1, 2022, to June 1, 2023. The monthly data used for forecasting are log-transformed. Since the data contains 330 observations, forecasts for the next 12 months start from June 1, 2022. The shaded area with a violet color shows the error margin of the predicted one.

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Figure 4 is built from two components such as trend and seasonality patterns. The trend of the year reports the changes in the PX index from 1995 to 2023. Since the data are monthly, then the seasonality patterns are monthly as well. As can be seen, in spring and summer the activity of the PX index tends to decline. On the contrary, during the winter and autumn, the index tends to increase its activity. In January and September, it tends to reach its highest levels, while in August the lowest. The estimated forecasts of the PX index closing prices rely considerably on the structure of the listed companies. At the same time, these are only estimations while the future depends on many unknown events. The main uncertainty during this period is linked with the developments of the Russian-Ukraine war. The future is unpredictable since it depends on the decisions made by the market forces, government decisions, but also natural events.

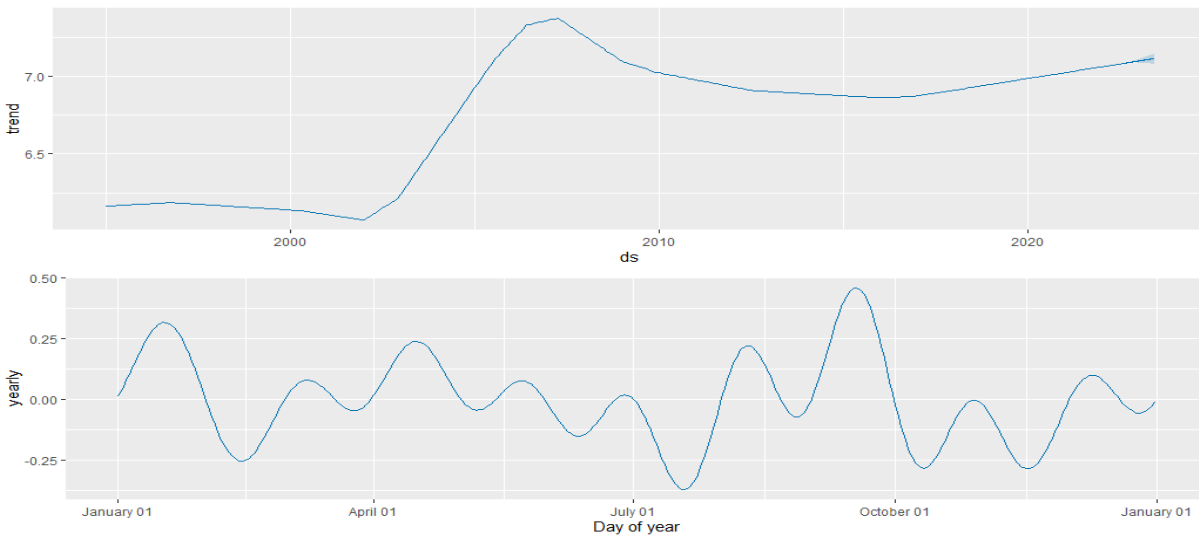

Figure 4. Presents the components of the PX index with day-of-the-year seasonality and trend patterns.

Source: own processing

Note: Figure 4 shows the seasonality issue of the PX index and the trend movements from January 1995 to August 2022. The observations present the trend and day-of-the-year seasonality with log-transformed series. Day of the year seasonality documents the periods when the PX index experiences an increase in activity, a decrease, or a stabilization period.

3.2.2. The EP forecasts using the prophet model

This section describes the estimated forecast of electricity prices in the Czech Republic for the next 12 months. The identical procedure was followed for EP prices as with the PX index. The monthly series is log-transformed indicating the period from January 1995 to June 2022. Figure 5 shows the actual data in black dots and the forecasts in the blue line, while the shaded part in violet highlights the error term. Actual data over the years show that electricity prices have been constantly rising with short periods of stabilization. The escalation period begins on September 1, 2022, until June 1, 2022, when prices jumped by 5.56%. According to prophet estimations, the electricity prices in CZ for the next 12 months indicate an increasing trend. The actual data highlight that the electricity prices on June 1 2022 were exp (5.01) = 149.9, while on June 1, 2023, are estimated to be exp (4.82) = 123.96 kilowatt-hours (kWh).

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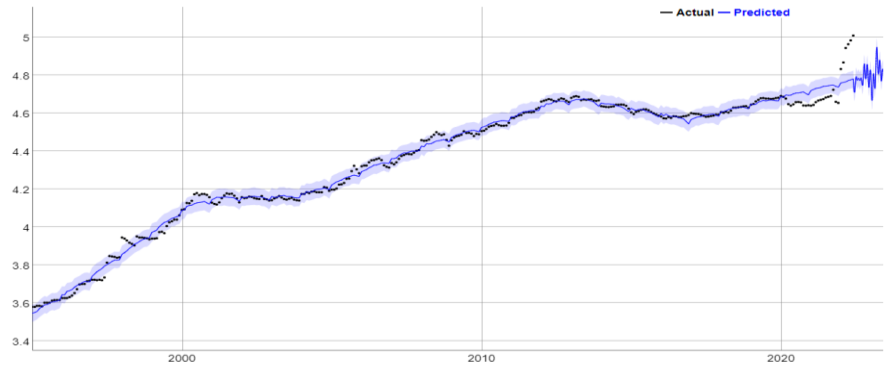

Figure 5. The prediction of electricity prices for the next 12 months with the Facebook prophet package.
Source: own processing

Note: Figure 5 indicates the forecasts for the 12 months ahead with monthly data from January 1995 to June 2023. The blue line represents the predictions, while the black dot represents the log-transformed data. The data for EP has 330 observations while the forecast for the next 12 months starts from June 1, 2022.

Figure 6 displays two related issues linked with electricity prices in the Czech Republic such as seasonality and trend. The trend of electricity prices is increasing, which is also confirmed by the estimations from the prophet package. As for monthly seasonality, electricity prices tend to increase during winter and autumn while they decline in spring and summer. Prices usually start their upswing in January and reach their peak in February and tend to fall in March. From March to June there is a downward trend, to experience a stabilization period from July to October. However, in October a slight increase, and then from December to January, there is another downturn. Electricity prices do not follow identical price patterns as equity shares. To this end, equity stocks are constructed under other intrinsic characteristics where price speculation is their main driving force. Stock prices are generally influenced by firm-specific factors and macroeconomic fundamentals, but at the same time fueled by psychological elements. The stock markets float under free fall principles where demand and supply determine their equilibrium. On the other hand, electricity prices are controlled by national regulators in addition to market forces. For this purpose, stock prices are prone to higher price instabilities compared to electric ones.

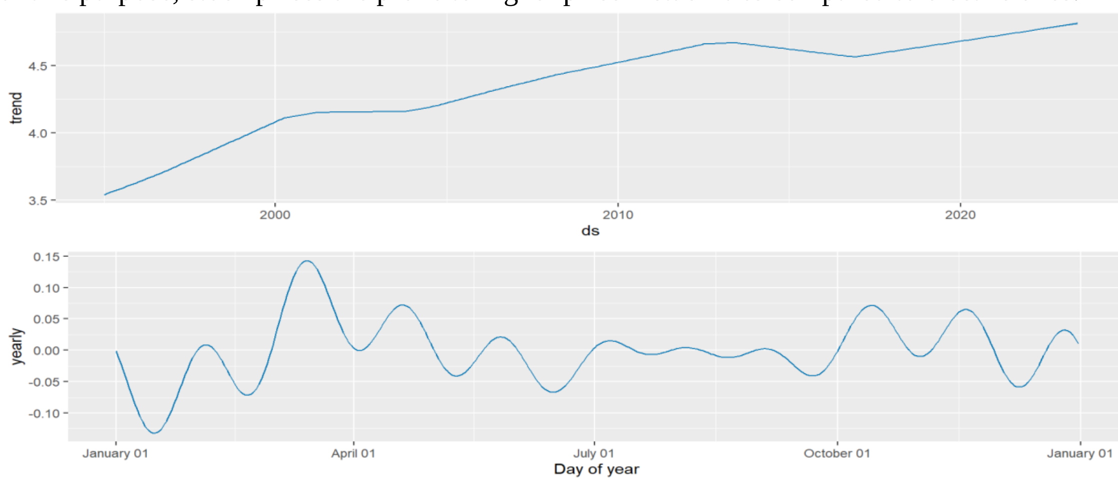

Figure 6. Indicates seasonality patterns and trend components for the Electricity Prices.
Source: own processing

Note: Figure 6 shows the components of electricity prices in the Czech Republic, such as the seasonality and trend. The observations are monthly from January 1, 1995, to June 1, 2022, where the data are log-transformed. The seasonality component is not presented daily since our observations are monthly. The data are collected from the Thomson Reuters Eikon database and processed in R through the "prophet" package.

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Figures A.1 and A.2 in the appendix highlight the deviation between actual data with the predicted ones. The red line shows the estimated forecast, while the black dots stand for the actual observations. The electricity prices in Figure A.2 display that actual data are very close to the forecasted line compared to the PX index. Thus, the estimated forecast is more accurate in the case of electricity prices than in the case of the PX index. This is also explained through the regression analysis in Table A.1 where R-square is higher for the electricity prices. For the PX index, 91.7% of the variations in the dependent variable (estimated forecast) are explained by the independent variable (actual data). In the case of electricity prices, the explanatory power stands at the level of 98.8%. The residual standard error is also lower in the case of EP (0.034) compared to the PX (0.117). Recognizing the characteristics of the two variables, we can conclude that the prediction accuracy is higher in EP than in PX.

3.2.3. Forecasting using Auto ARIMA Model

This section presents estimated forecasts with ARIMA (1,1,1) (0,0,1) [12] related to electricity prices and the PX Index. The results were generated in the R program using the "tidyverse", "forecast" and "tseries" packages. The first step was to declare the data for time series (ts) since they were in the "data. frame" format. To this end, one of the most powerful models for short-term forecasts is considered Auto ARIMA. The model is dependent on autoregressive lags (AR), integrated (I) or stationary issues of the series, and moving average lags (MA). The Auto ARIMA function automatically determines the number of autoregressive, moving average lags and solves for the unit root. In the case of electricity prices (EP), the R program suggested that the best fit model for the EP predictions is ARIMA (1,1,1) (0,0,1) [12]. The ARIMA or SARIMA model (since stands for the one seasonal moving average lag) includes one autoregressive lag, first differencing, and one moving average lag. The model fit is presented in Figure A.3 in the appendix where the model stability is defined through three plots. We can conclude that the model is stable since the data possess a white noise process, the lags are within the 95% confidence band and the histogram indicates unimodal distribution. Moreover, all the roots are within a unit circle and the results are available on request. Figure 7 shows the line of actual data and the projected one for electricity prices in the Czech Republic. As with the Facebook prophet package, the results of ARIMA (1,1,1) (0,0,1) [12] indicate an increase in electricity prices for the next 12 months. Since the forecast is for 12 periods, from 152 kWh (July 1, 2022) the electricity prices will reach the level of 171.3 kWh (July 1, 2023). In the 12 consecutive months, electricity prices in the Czech Republic will increase by 12.5%. Estimates with ARIMA predict that prices will be 152 czk/kWh on June 1, 2023, while Facebook prophet predicts a level of 123 czk/kwh. The ARIMA model predicts that electricity prices after 12 months will be 23% higher than the estimations with the Facebook prophet.

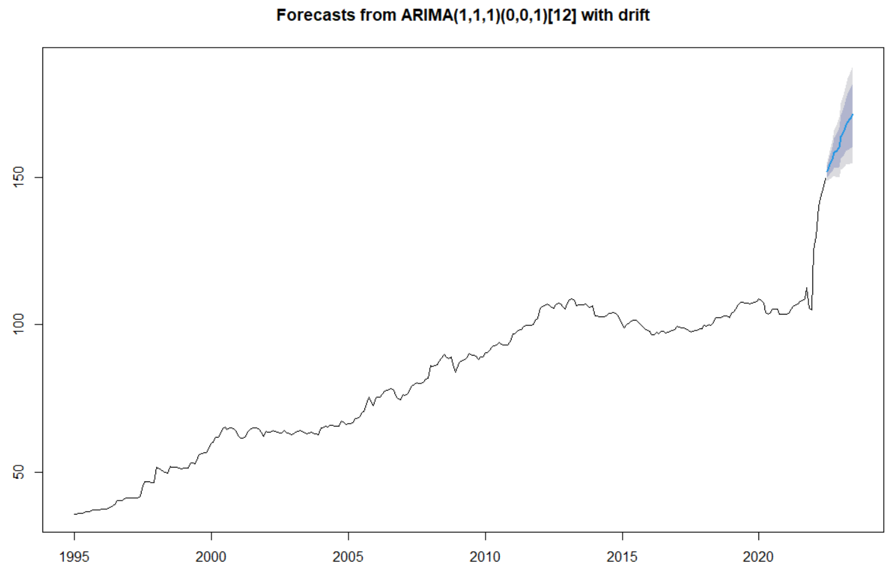

Figure 7. Estimated forecasts of electricity prices based on Auto ARIMA.

Source: own processing

Note: Figure 7 indicates estimated electricity prices for the 12 months ahead based on ARIMA (1,1,1) (0,0,1). The results of this forecast also exist in numerical form and are available on request. The forecast stand on one autoregressive lag, one moving average lag, the first differencing, and one seasonal moving average lag. The blue line represents the estimated forecasts, while the shaded area is the confidence band at 90 and 95%. The predictions start on June 1, 2022, and end on June 1, 2023.

Figure 8 presents the forecasts of ARIMA (0, 1, 1) of the PX index covering the period from January 1, 1995, to June 1, 2023. The estimations start on June 1, 2022, and end on June 1, 2023, with one moving average lag, one differencing, and no autoregressive lags. Estimations for the 12 months ahead are practically identical to those generated from the Facebook prophet. The PX index on June 1, 2023, according to ARIMA (0, 1, 1) will be in the range of 1244 basis points. The Facebook prophet predicted that on June 1, 2023, the PX index will be in the range of 1248.8 basis points. ARIMA (0,1,1) predicts that the index will be four basis points less compared to Facebook prophet estimation. Above all, both models estimate that the index will remain at almost unchanged levels.

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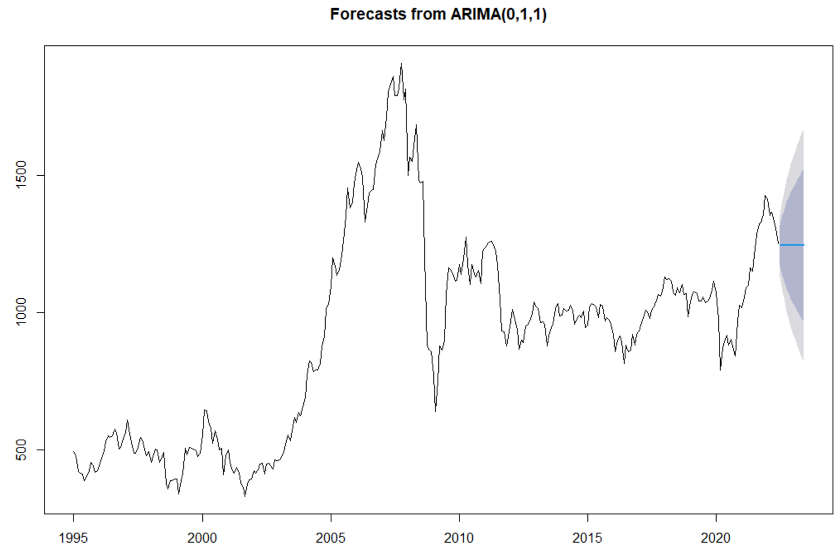

Figure 8. Estimated forecast of the PX index using ARIMA (0,1,1).

Source: own processing.

Note: Figure 8 indicated the full period for the PX index from January 1, 1995, to August 1, 2022. The data are collected from the Thomson Reuters Eikon database and processed in R with the "forecast" and "tseries" packages. The Auto ARIMA function in R has proposed ARIMA (0,1,1) where the variable has one differencing, one moving average lag, and no autoregressive lag. Numerical results of the tables for ARIMA (0,1,1) generated in R studio are available on request.

Conclusions

Sustainable electricity prices generate security for listed businesses and at the same time relax family budgets. Sustainability in this context means a regular supply of electricity but also reasonable prices. Equity markets are an important element of the financial system as they enable the efficient allocation of national savings. In the Czech Republic, banks play the primary role in financing individual consumption and national investments. The Prague Stock Exchange, from which the PX index originates, is a weak efficient form due to a limited number of analysts, low trading volume, financial literacy, market size, etc. Consequently, the market prices do not reflect all the events related to the local economy but also the international one. However, electricity prices are an integral part of the operational costs of publicly listed firms. Changes in electricity prices can improve but also harm the competitive position of firms in the marketplace. The Russian invasion of Ukraine produced unprecedented circumstances in international relations while causing serious consequences for the European economies. Since Russia declared a "special military operation in Ukraine" on February 24, 2022, electricity prices skyrocketed. Consequently, inflation in the European continent and especially in Eastern Europe experienced a continuous uptrend. This war is determining the course of the global economy, geopolitical state, and political relations among nation-states.

The results from the VECM model show that in the short-run, electricity prices negatively affect the PX index. Johansen test documents for long-term co-integration between PX and EP which is justified by the importance that electricity prices have for listed firms. The additional purpose of this paper was to forecast the electricity prices and the PX performance in the 12 consecutive months. The Facebook package predicts that electricity prices in the Czech Republic will have an upward trend until June 2023. The same phenomenon is estimated with the ARIMA model where electricity prices are higher by 23% compared to the Facebook prophet. The PX index

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according to the Facebook prophet will have minor fluctuations but it will remain almost at the same levels for the next 12 months. The ARIMA model predicts almost the same results with a 4 basis point difference. As for seasonality patterns, the situation is not the same in the two analyzed series. The PX index tends to increase during winter and autumn while declining during spring and summer. On the contrary, electricity prices experience upward generally during winter and autumn while decreasing in summer and spring. The study is constrained to only one country, which limits the generalization of this phenomenon. Moreover, the investigation with daily series would provide a broader overview of the Russia-Ukraine war and other external shocks imposed on PX and EP.

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Appendix

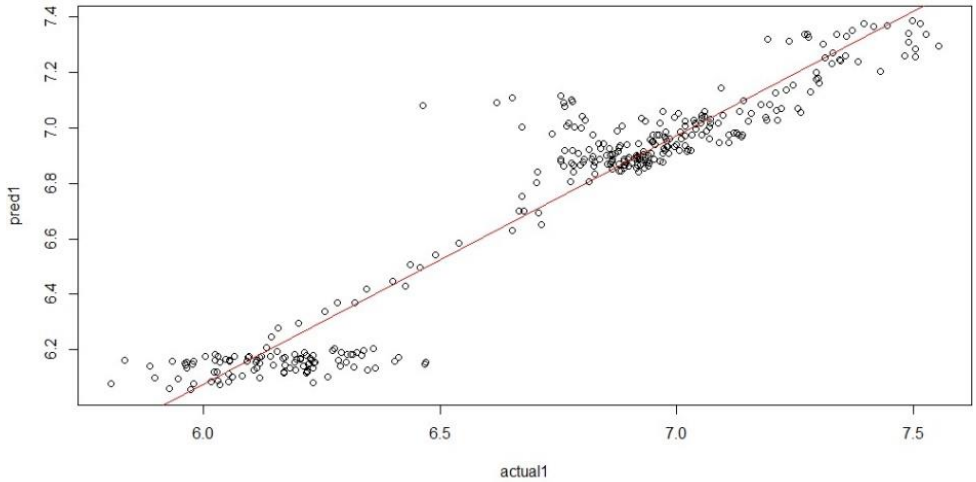

Figure A.1. Indicates the prediction line of the PX index compared with actual data.
Source: own processing

Note: Figure shows A.1. the prediction line (in red) compared to the actual data (black dots) with the linear model (lm). The data are log-transformed and represent the full-time period from January 1995 to August 2022. The results in the figure are explained through outcomes in Table A.1. (Model 1 - PX) placed in the appendix.

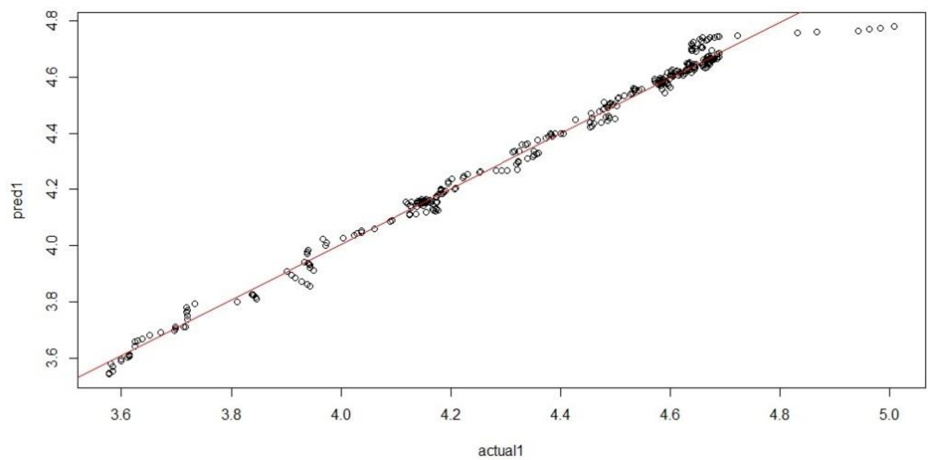

Figure A.2. Presents the forecasted line and the actual data for Electricity Prices in the Czech Republic.
Source: own processing

Note: Figure A.2. shows the prediction line (in red) and the actual data (in black) for the EP data based on the linear model. The data were collected from the Thomson Reuters Eikon database and processed in R studio through the ggplot2 package. The series are monthly and cover the period from January 1995 to August 2022.

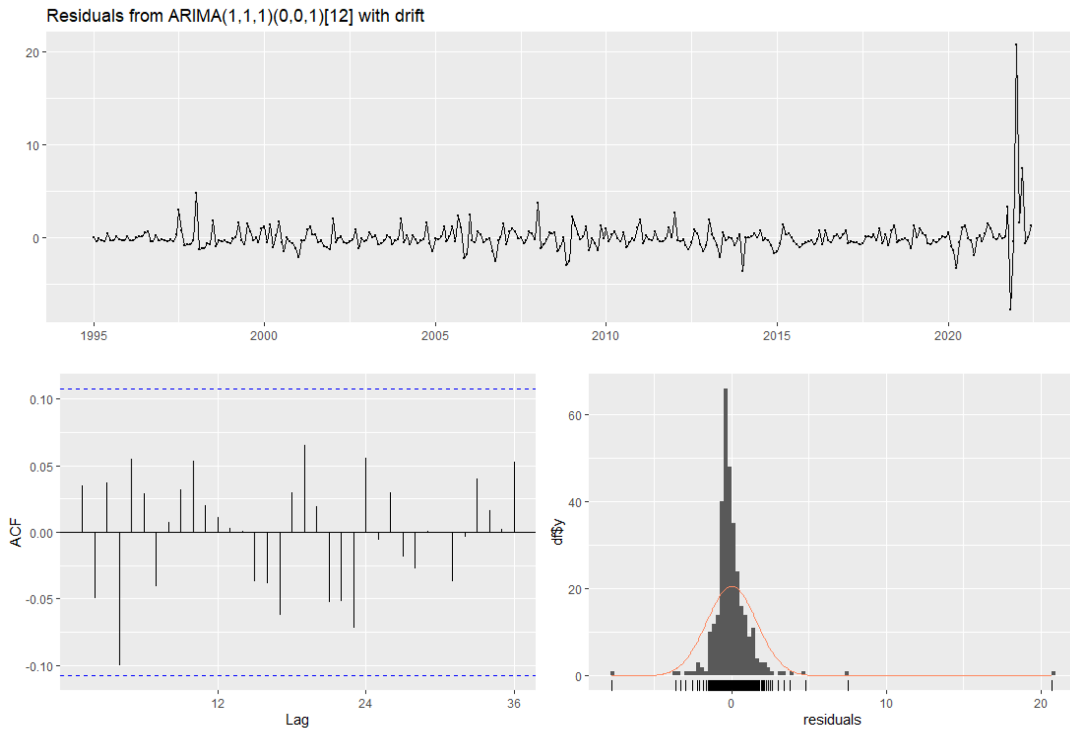

Figure A.3. The residual outcomes from the Auto ARIMA (1,1,1) (0,0,1) [12] in the case of electricity prices.
Source: own processing.

Note: Figure A.3 is composed of three EP plots indicating 1 autoregressive lag, 1 differencing, and 1 moving average lag. The fit of the model stands on the monthly series that covers the full period from January 1995 to August 2022. The residuals are close to indicating the white noise process except for the series lying in 2022. As for the Auto Correlation Function (ACF), all lags are within the 95% confidence band which indicates a stable model. The histogram shows that the residuals hold unimodal distribution and are close to being symmetrical.

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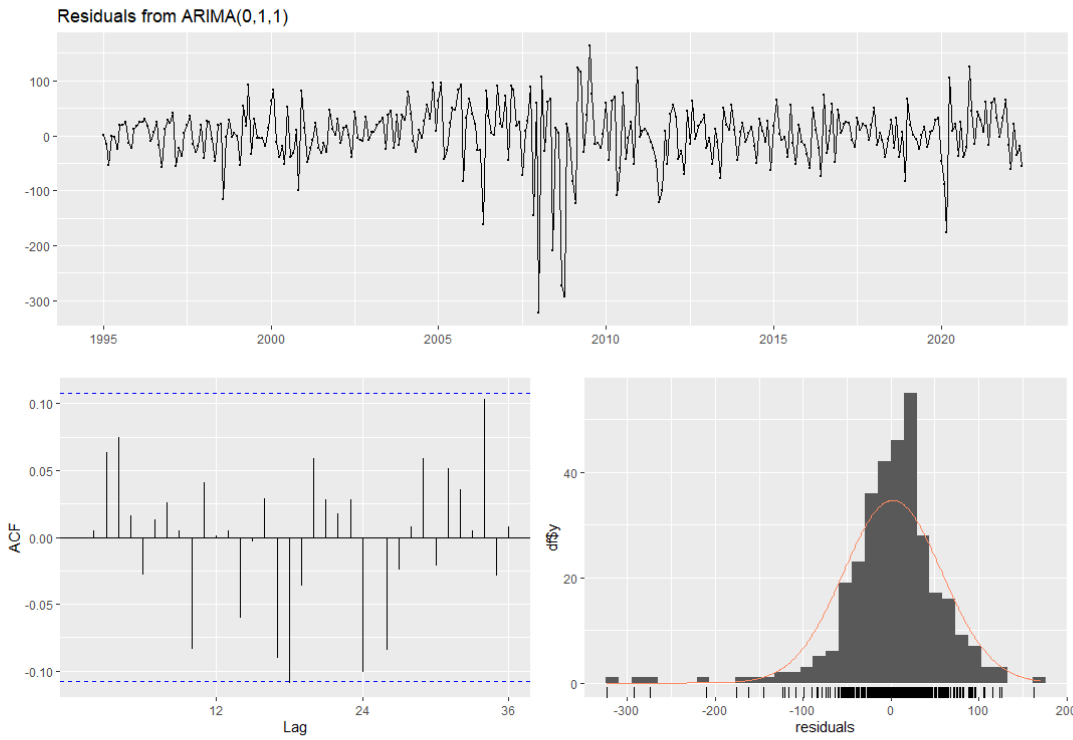

Figure A.4. Residual results for the PX index based on Auto ARIMA (0,1,1).

Source: own processing.

Note: Figure A.4 presents plots for the white noise process, the distribution of the residuals, and the autocorrelation function (ACF) for the case of the PX index. The series for the PX index contains a white noise process with exceptions during the crisis of 2008/09. The lags in the ACF plot stand within the 95% confidence band, while the histogram indicates that residuals are right-skewed.

Table A.1. Simple linear regression for the estimated predicted values and actual data in the case of PX and EP.

Coefficient (Model 1 - PX):			**Coefficient (Model 2 - EP):**		
	Estimate	**Std. Error**		**Estimate**	**Std. Error**
(Intercept)	0.69713	0.09974	(Intercept)	0.053939	0.025145
Actual (PX)	0.89636	0.01480	Actual (EP)	0.987599	0.005764
	t value	**Pr (>I t I)**		**t value**	**Pr (>I t I)**
(Intercept)	6.99	1.55e-11***	(Intercept)	2.145	0.0327*
Actual (PX)	60.85	<2e-16***	Actual (EP)	171.327	<2e-16***
Residual standard error: 0.117 on 328 degrees of freedom Multiple R-squared: 0.918, Adjusted R-squared: 0.9177 F-statistics: 3670 on 1 and 328 DF, p-value: < 2.2e-16			Residual standard error: 0.034 on 328 degrees of freedom Multiple R-squared: 0.988, Adjusted R-squared: 0.988 F-statistics: 2.935e+04 on 1 and 328 DF, p-value: < 2.2e-16		

Source: own processing.

Note: Table A.1 displays the simple linear regression for the electricity prices in the Czech Republic and the PX index. The data are long transformed and cover the full period from January 1995 to June 2022 with monthly observations. The independent variables stand for the actual data while the dependent one for estimated forecasts. The results are divided into two models (Model 1 and Model 2) where in the first model are placed regression outcomes from PX while in the second one for EP. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

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