buildings

MDPI

Article

Construction Price Forecasting Models in the Construction Industry: A Comparative Analysis

Lukáš Lederer [1,*], Helena Ellingerová [1], Silvia Ďubek [2], Jozef Bočkaj [2,*] and Marek Ďubek [1]

[1] Department of Building Technology, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského Street 11, 810 05 Bratislava, Slovakia; helena.ellingerova@stuba.sk (H.E.); marek.dubek@stuba.sk (M.Ď.)

[2] Institute of Judicial Expertise, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského Street 11, 810 05 Bratislava, Slovakia; silvia.dubek@stuba.sk

* Correspondence: lukas.lederer@stuba.sk (L.L.); jozef.bockaj@stuba.sk (J.B.); Tel.: +421-904-293-360 (L.L.)

Abstract: Construction prices rose rapidly during 2020 and 2021, making it almost impossible for contractors to adhere to agreed contract prices. For this reason, there was a request from contractors to adjust the contract price after signing a contract for work. During the implementation of the construction contracts, they were unable to comply with the fixed contract price. Forecasting the development of price indices could solve this problem by creating a reserve that would limit the adjustment of the contract price and the contractors' withdrawal from the contracts. The forecast could be enshrined in the contractual conditions before the start of construction, which would eliminate the risk of changing the agreed contract price for the investor and the possible occurrence of additional work. Data from statistical offices were used to create the price index forecast. In this article, four methods were used in the search for a more accurate forecast: regression analysis, exponential smoothing, the naïve method, and the Autoregressive Integrated Moving Average (ARIMA) model. From these methods, the most appropriate method was selected by multi-criteria decision-making, which was subsequently verified with actual published price index data. The main goals of this study are to determine the most suitable prognostic method for forecasting the development of the prices of construction materials and work and then comparing the forecasted data with the actual published data of statistical offices in the countries of Central Europe.

Keywords: series forecast; exponential smoothing; contract price

Citation: Lederer, L.; Ellingerová, H.; Ďubek, S.; Bočkaj, J.; Ďubek, M. Construction Price Forecasting Models in the Construction Industry: A Comparative Analysis. *Buildings* **2024**, *14*, 1325. https://doi.org/10.3390/buildings14051325

Academic Editors: Pramen P. Shrestha and Zhili Gao

Received: 4 March 2024
Revised: 25 April 2024
Accepted: 6 May 2024
Published: 8 May 2024

1. Introduction

Due to high unpredictability and a high level of risk, many contractors go bankrupt in the construction industry every year. Despite the large number of variables, usually the because of financial and budgetary factors [1]. More than 60% of contractor failures have financial causes. The inability to fulfill contractual conditions on the part of contractors in 77–95% of cases is caused by a lack of financial resources [2]. The decisive tool for the management of the entire construction and the starting point for the execution of the work is the contract for the work, which significantly affects the success of the final result. The contract for the work is often concluded, especially in the private sector, under pressure from the investor. In general, the terms of the contract, including the general contractual and commercial terms and conditions to the extent submitted by the investor cannot be commented on or changed by the supplier. Currently, based on our research, forecasting in the process of the creation of the contract price and its adjustment is used very rarely, if at all.

It can be concluded that in the procurement process of construction contracts, most often two types of contract prices are used in Slovakia and abroad:

1. Based on unit prices, when the contractor is bound to fulfill all conditions, provided that the actual incurred own costs and a reasonable profit are paid by the investor. This type of contract is usually used when the amount of work is not exactly known, or when changes in the amount of work actually performed are expected during construction (project documentation drawn up is of insufficient detail) [3].
2. A contract with a fixed price (fix price), which binds the contractor to carry out work and deliveries, regardless of his actual own costs incurred in connection with the delivery specified in the contract [4].

Considering the development of the prices of construction work and materials in 2021 and 2022, it was very complicated for contractors to comply with concluded contracts and contract prices, whether in the public or private sector. For this reason, there was a request from contractors to adjust the contract price after signing a contract for the work or during the implementation process. The difficult-to-predict development of the prices of construction materials from 2021 caused zero profitability for contractors and the unfeasibility of construction contracts under construction. This fact only led to disputes between contractors and investors because the contractors preferred to pay the contractual penalty and withdraw from such contracts rather than fulfilling them.

The main goals of this study are to determine the most suitable prognostic method for forecasting the development of the prices of construction materials and work and then comparing the forecasted data with the actual published data of statistical offices in the countries of Central Europe.

2. Materials and Methods

Based on data from statistical offices in EU countries, which monitor price developments and create indices of price developments for work, materials, and products consumed in the construction industry, it is possible to state an overall increase in prices in the monitored period from 2016 to 2023, as shown in Table 1. The Statistical Office of the Slovak Republic considers the prices of selected representatives, including built-in materials, at the level of own costs and profit markup for construction (object) and publishes indices of the development of the prices of materials and indices of the development of the prices of construction work separately. Other countries are represented by one index. The Czech Statistical Office publishes only one index which includes construction and assembly work as well as built-in material. The Austrian index of construction costs tracks 98 groups of construction materials and work. All monitored indices are taken on the basis of summary data—construction as a whole. Based on the data of the Statistical Office of the Slovak Republic about materials and products consumed in the construction industry, it is also possible to state an overall increase in prices in the period we are monitoring from the first quarter of 2015 to the second quarter of 2022, after which a slight market correction began, when the indices the prices of construction materials and work decreased slightly. The individual indices of statistical offices are calculated according to the Laspeyres formula, where the average price indices are weighted by the share of the value volume of the representative to the total value volume of production for the year 2015 [5]. Laspeyres Index:

$$\text{Laspeyres Formula} = \sum (\text{Observation Price} \times \text{Base Qty}) / \sum (\text{Base Price} \times \text{Base Qty}) \quad (1)$$

For the indices from 2015 and 2016, the Statistical Office published an index with a base in 2010, which was then recalculated according to the Laspeyres formula, with the considered base—an average of 2015. The same also applies to indices published after 2021, as they were published by individual statistical offices for the 2020 base.

Table 1. Comparison of the development of the price index in Slovakia and in nearby countries [6–8].

Year	Quarter	Construction Work in Slovakia	Construction Materials in Slovakia	Austria	Czech Republic
2016	Q1	100.8	98.4	98.2	100.8
	Q2	101.6	99.4	102.8	101.1
	Q3	101.2	99.7	102.0	101.4
	Q4	101.6	99.6	103.4	101.8
2017	Q1	103.4	102.4	104.7	102.2
	Q2	104.5	102.6	105.0	102.7
	Q3	105.0	102.8	107.6	103.2
	Q4	105.3	104.4	108.7	103.9
2018	Q1	103.4	102.4	104.7	102.2
	Q2	104.5	102.6	105.0	102.7
	Q3	105.0	102.8	107.6	103.2
	Q4	105.3	104.4	108.7	103.9
2019	Q1	111.3	110.6	112.1	110.0
	Q2	111.7	110.4	112.6	110.4
	Q3	112.5	111.2	111.6	112.4
	Q4	113.3	111.1	110.6	112.8
2020	Q1	114.7	110.3	111.1	114.6
	Q2	115.1	109.6	110.8	114.9
	Q3	115.4	109.9	110.8	115.8
	Q4	116.4	109.9	112.4	112.8
2021	Q1	111.7	113.6	115.9	117.4
	Q2	119.2	119.6	124.0	120.5
	Q3	124.6	129.9	126.0	123.5
	Q4	124.3	134.9	125.3	125.4
2022	Q1	140.4	133.0	134.2	131.5
	Q2	152.8	138.8	137.8	136.1
	Q3	154.6	144.5	136.2	139.1
	Q4	153.7	149.1	133.2	140.7
2023	Q1	156.3	155.0	134.8	142.8
	Q2	157.4	156.6	137.6	143.7
	Q3	155.6	157.9	136.6	144.4

When comparing the development of the price index of construction materials and work, their similarity can be noticed, as shown in Table 1. The Statistical Office in Slovakia and offices abroad recorded the largest increase in prices in the construction industry in the first half of 2021 and the beginning of 2022. During this period, the price development index in the construction industry rose in the range of 15.8–31.5 percentage points. In the previous period (from 2016 to 2020), price development indices in the construction industry expressed a "gradual growth" in the prices of construction work and materials in the range of 2 to 5 percentage points per year [6–8].

Data from the Slovak Statistical Office are used as a source for forecasting the time series of the development of the prices of construction materials and work. Individual data are represented by point values, which are expressed in percentage points, where the average of 2015 = 100 enters as the basis. Based on the data of the Slovak Statistical Office, which forms the indices of construction work, materials, and products consumed in the construction industry, it is possible to state an overall increase in prices. The monitored period begins with the first quarter of 2015 and ends with the third quarter of 2023, as newer data were not available at the time.

2.1. Forecasting Methods

When deciding on the most suitable forecasting method, four types of forecasting methods were used. These were subsequently compared between each other on the forecasting errors they showed. In this case we used time series forecasting methods: decomposition by regression analysis, exponential smoothing, the naïve method, and the ARIMA model [9].

- Decomposision by regresion analysis—reg
- ARIMA model—arima
- Exponential smoothing—ETS
- Naive method—naïve

2.1.1. Decomposition by Regression Analysis

Regression analysis was used as the first forecasting method of time series. Using this analysis relationships between individual variables—the values of the price index of building materials or the price index of construction work—were examined. The main purpose of regression analysis is to examine and characterize the inner relations between variables. Its task is to find a mathematical function called a regression function, or regression model, which should best describe the course of dependence between variables. Within the compared methods, a simple regression analysis was used for multi-criteria selection. A simple analysis is one where we deal with one independent variable, the dependent variable YY, will depend on the independent variable XX. A useful aid in the investigation of dependence is the graphic method using a point graph formed by points [xi,yi] [xi,yi], for i = 1, . . ., ni = 1, . . ., n in the plane, where xixi and yiyi are the values of the examined variables XX and YY. Based on the course of the point graph, we decide what type of dependence it is: linear, quadratic, hyperbolic, exponential, etc. [10].

2.1.2. Exponential Smoothing

Exponential smoothing is a method that has a self-correcting mechanism, as shown in Figure 1. This mechanism can adjust forecasts in a way that is inconsistent with past errors. It is a weighted moving average of current and past values, where the weights decrease exponentially, and therefore it can be used for smoothing and at the same time for making various predictions [11]. Using this mechanism, this model can achieve more accurate forecast data and demand for the last period, except for the smoothing coefficient. The exponential smoothing method seeks to eliminate various historical irregularities and elements in the current demand period and achieve optimal forecasting results [12]. This method is considered to be an evolution of the weighted moving average method, which calculates a time average that has a self-correcting mechanism. The weighted exponential average method aims to adjust the forecasts in a way that contradicts the previous deviations, through corrections that may affect the smoothing coefficient.

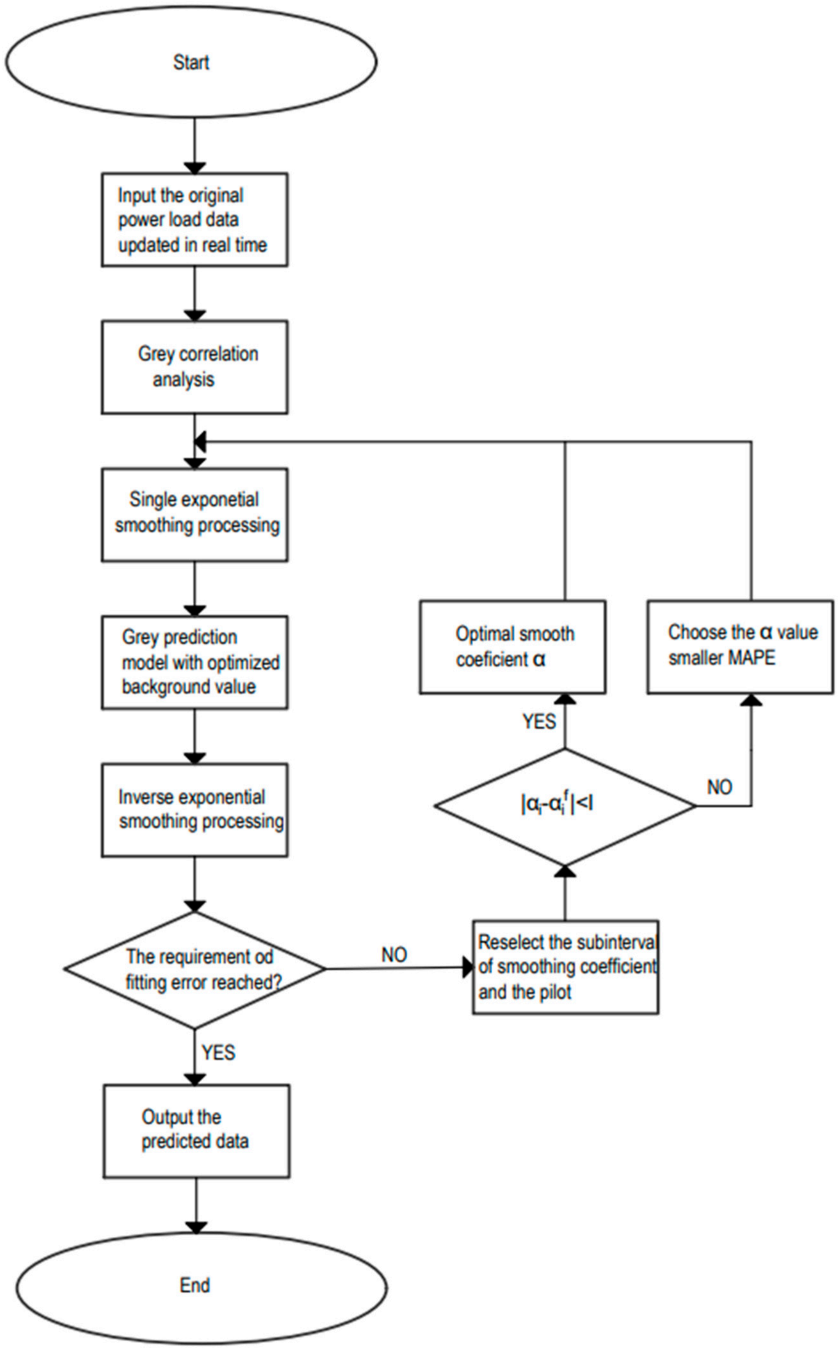

Figure 1. The flow diagram of the exponential smoothing [13].

2.1.3. ARIMA Model

ARIMA is a model of autoregressive integrated moving average, which serves mainly to offer a better understanding and prediction of individual points in the future [14]. The basic working mechanism of the ARIMA model is pictured in Figure 2. ARIMA models are applied in cases where the data show evidence of non-stationarity in the sense of the mean, but not the variance, where the initial differencing step can be applied one or more times to eliminate the non-stationarity of the mean function, i.e., the trend. When seasonality appears in a time series, seasonal differentiation can be used to remove the seasonal component [15].

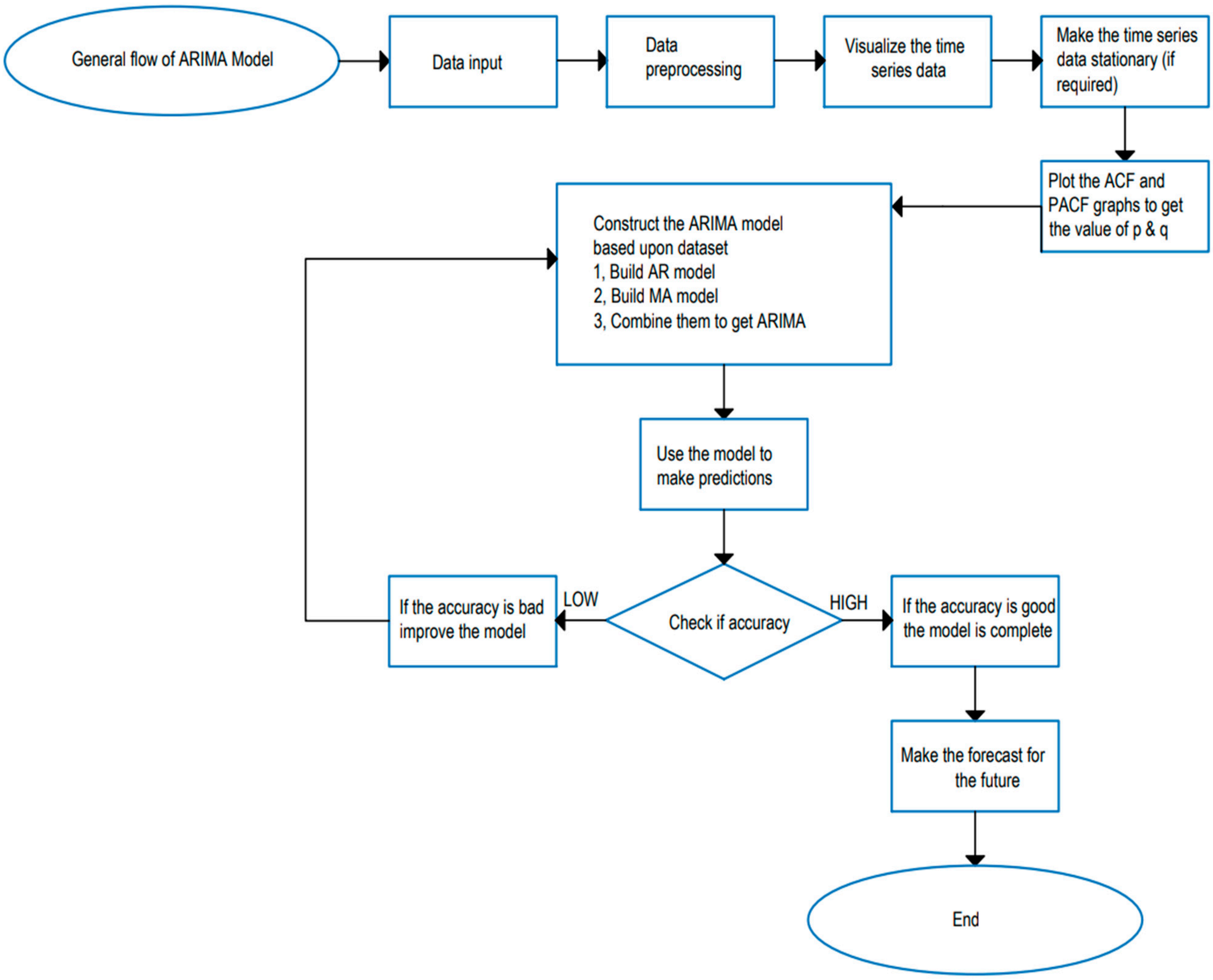

Figure 2. Flow diagram of ARIMA Model [16].

2.1.4. Naive Method

For naïve predictions, we simply set all predictions to the value of the last observation. Meaning

$$\hat{} RT + \mid h \mid T = RT \quad (2)$$

where:

- Rt—observed value of the time series;
- ∣h∣T—absolute value of the difference of the last observation.

Naive predictions based on the random walk model are equal to the last observation because future movements are unpredictable and equally likely to be up or down [17].

2.2. Classical Decomposition

The classical method of time series decompositions, which was used in this case, was created in the 1920s. It is a relatively simple procedure and forms the starting point for most other time series decomposition methods. In this case, additive decomposition using monthly data was used. The performed decomposition of time series serves to identify the strength of the mean and seasonality in the observed time series of prices of building materials and prices of construction work. With classical decomposition, we assume that the seasonal component is constant from year to year [18]. The seasonal component describes periodic changes in the time series, the period of which is equal to a certain standard unit of time (week, month, year, etc.) or its constant multiple. Thus, the seasonal component captures changes that regularly repeat each year [19].

2.3. Training and Validation

After performing a classical decomposition of the data, it can be said that the seasonal component is closer to zero than to one. Therefore, the time series of the prices of construction materials and work do not show too much seasonality. Also, after measuring the strength of the trend, it can be concluded that the degree of strength of the trend is relatively small and that the time series do not show a trend. Based on these facts, seasonality and trend strength will be ignored in further forecasting [20].

After classical data decomposition, the descriptive ability of each method was checked on the test sample. The results can be seen in Figure 3. As test samples used data from the period from 2015 to the end of 2020, part of the time series from 2020 to 2022 served as the validation part. After the data decomposition, the control of the descriptive ability of the individual forecasting methods was determined.

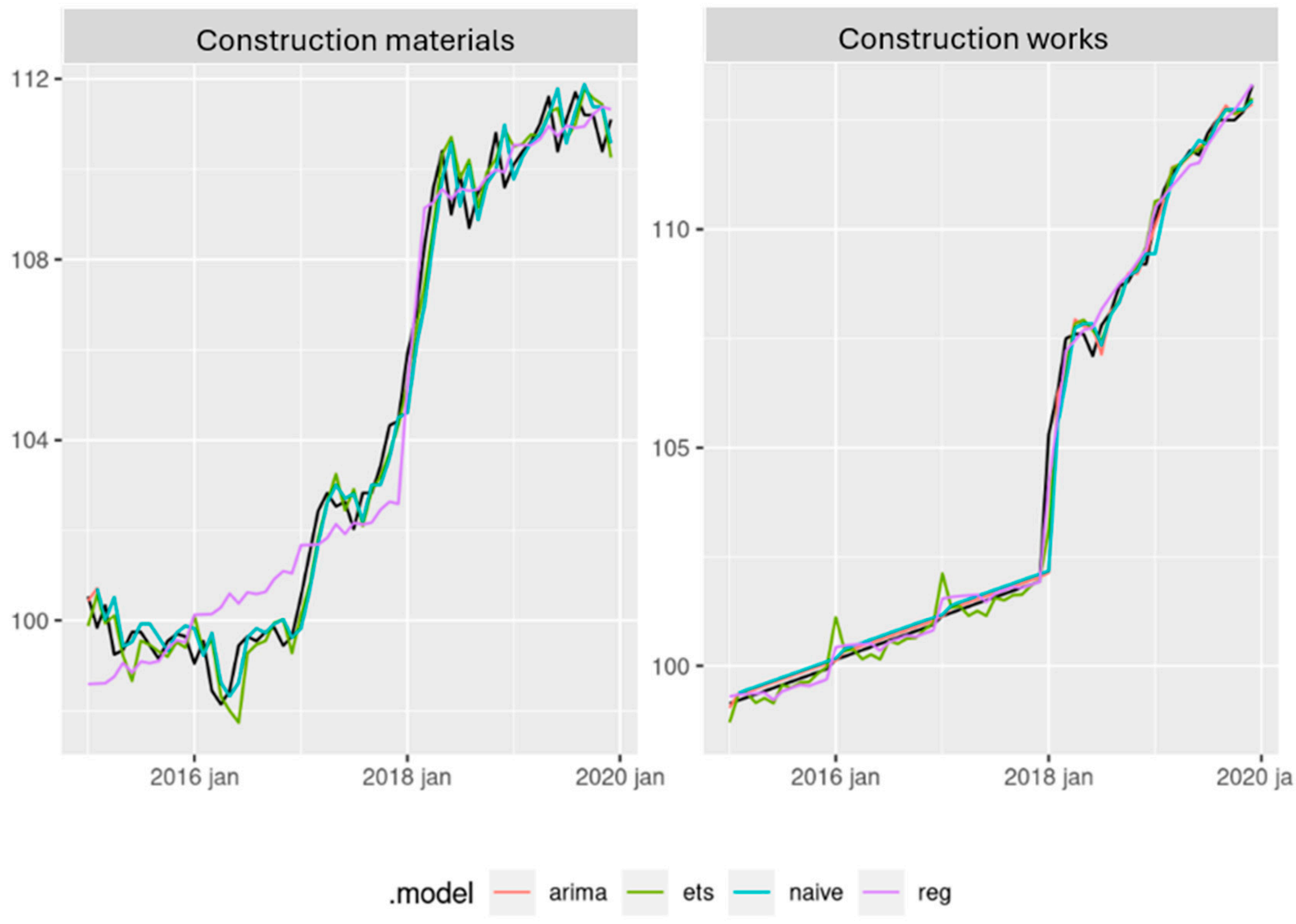

Figure 3. Descriptive ability check.

With individual forecasting methods, we subsequently examined how well the model can forecast time series within the validation period from 2020 to the end of 2021. The results of this comparison are shown in a graph in Figure 4.

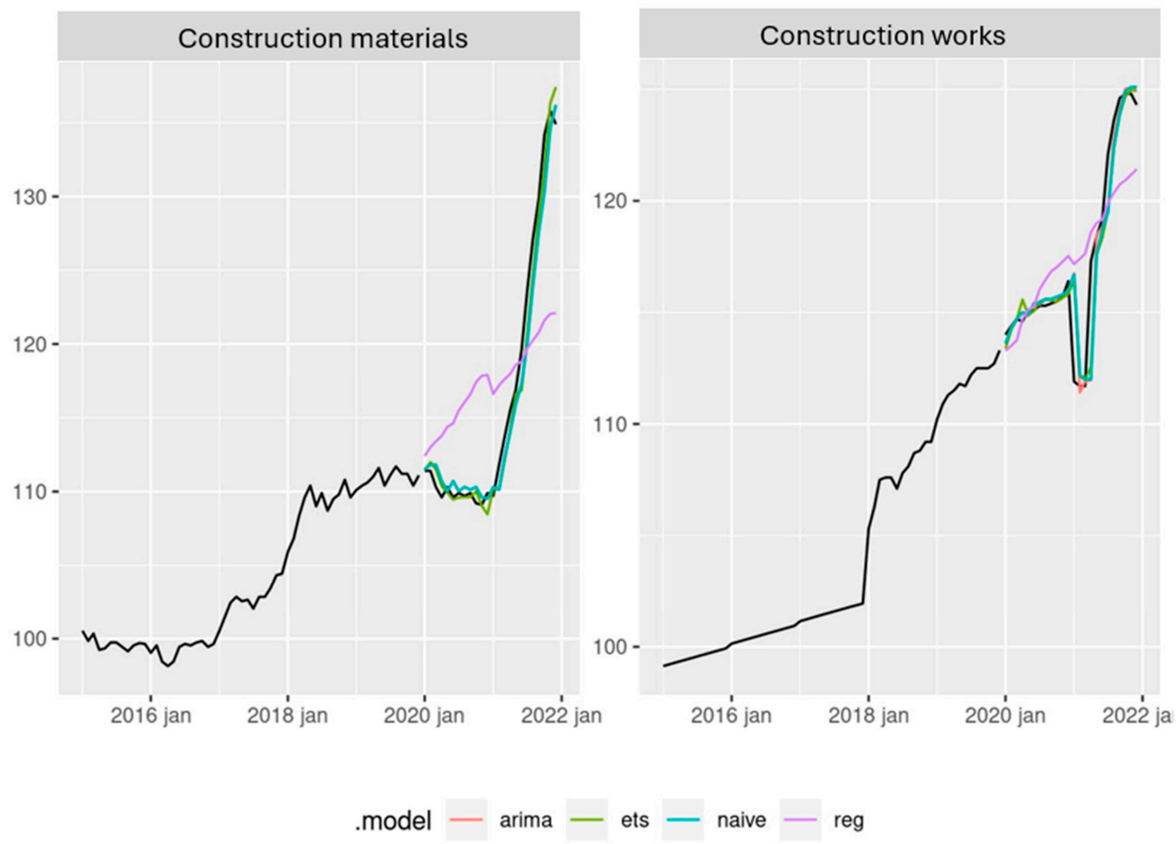

Figure 4. Single step forecast.

For the four prognostic methods, the mean square error (MSE) was subsequently determined—that is, the average squared difference between the estimated values and the actual value within the validation part of the sample. MSE is the risk function corresponding to the expected value of the squared loss.

3. Results

3.1. Multi-Criteria Selection

Multi-criteria selection was created for the time series of indices of building materials and the time series of indices of construction work. For multi-criteria decision-making, the minimization criterion is used in all of the aforementioned forecasting methods and errors. The results of multi-criterial selection are shown below in Table 2 for construction materials and Table 3 for construction work.

- Sigma—standard deviation
- MAE—mean absolute error
- RMSE—root mean squared error
- MAPE—mean absolute percentage error
- MASE—mean scaled error

Table 2. Multi-criteria selection of time series forecasts of construction materials.

Model	Sigma	MAE	RMSE	MAPE	MASE	MSE	Overall	Rank
reg	0.430	1.000	1.000	1.000	1.000	0.204	4.634	4
ARIMA	1.000	0.949	0.930	0.954	0.949	3.518	8.300	3
ETS	0.813	1.00	1.000	1.000	1.000	5.000	9.813	1
naïve	1.000	0.947	0.944	0.949	0.949	3.518	8.307	2
Weight	0.100	0.100	0.100	0.100	0.100	0.500		

Table 3. Multi-criteria selection of time series forecasts of construction work.

Model	Sigma	MAE	RMSE	MAPE	MASE	MSE	Overall	Rank
reg	1.000	0.981	0.957	0.994	0.986	1.576	6.494	4
ARIMA	0.429	0.841	0.925	0.829	0.842	4.567	8.433	3
ETS	0.447	0.926	0.925	0.938	0.927	5.000	9.162	1
naïve	0.395	1.000	1.000	1.000	1.000	4.444	8.839	2
Weight	0.100	0.100	0.100	0.100	0.100	0.500		

3.2. Forecast of Development Construction Price Indices

On the basis of multi-criteria selection and the nature of time series, it was found that the most accurate forecasting time series of prices of construction work and materials is possible using exponential smoothing—the ETS model. Two forecast intervals are used in the graphs shown below. The dark blue part shows the 80% forecast interval, which is predicted with 80% probability. The light blue part represents the 95% prediction interval, which shows the predicted value of the price index of construction materials and work with a probability of 95%. The dark blue line shows the average of the predicted values of the price indices of construction materials and work. The established results of the forecast of the ETS model are shown graphically in Figure 5 and subsequently processed numerically in Tables 4 and 5.

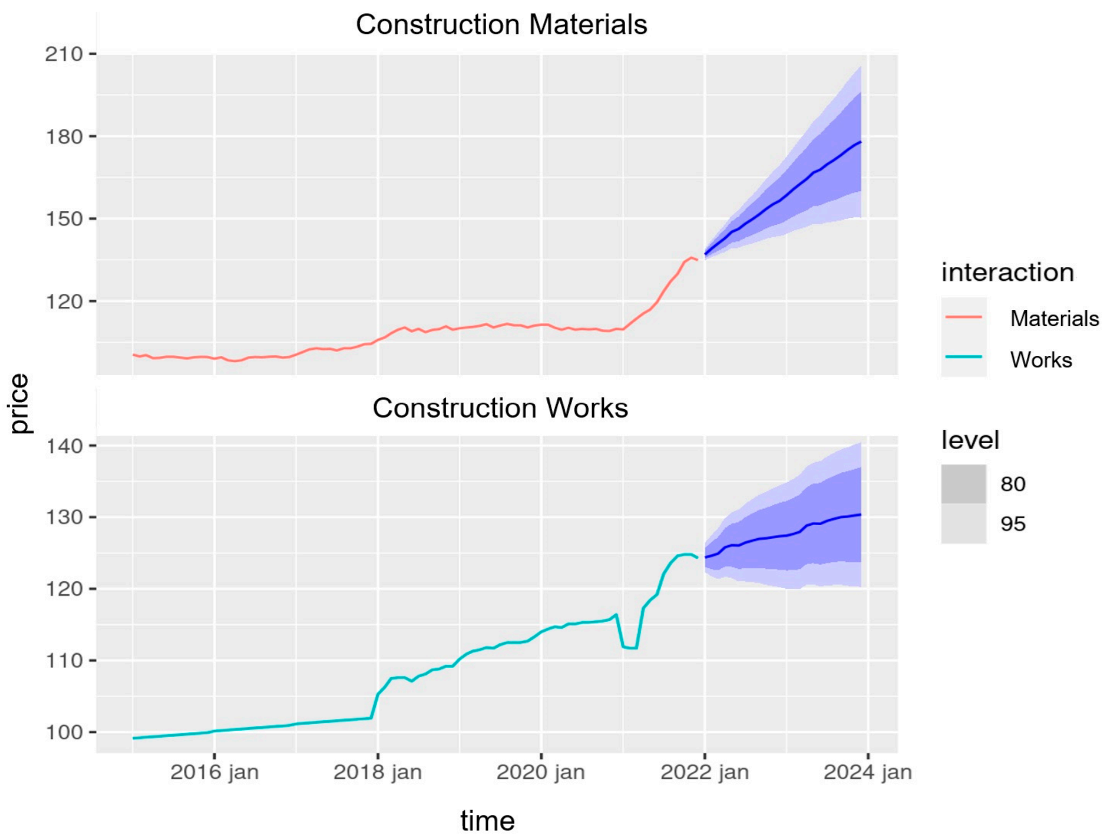

Figure 5. Forecast of the price development of construction materials and work.

Smoothing parameters:

- Alpha = 0.9849022
- Beta = 0.1359761
- Gamma = 0.001467

Table 4. Time series forecast of construction materials prices using the ETS model.

Time	Forecast Value	Lower Limit L80%	Upper Limit H80%
Q1/2022	140.97	138.31	143.64
Q2/2022	146.28	141.79	150.76
Q3/2022	151.55	145.15	157.96
Q4/2022	156.50	148.04	164.96
Q1/2023	162.54	151.87	173.20
Q2/2023	167.84	154.83	180.85
Q3/2023	173.11	157.62	188.60
Q4/2023	178.06	159.95	196.17

Table 5. Time series forecast of construction work prices using the ETS model.

Time	Forecast Value	Lower Limit L80%	Upper Limit H80%
Q1/2022	124.91	122.59	127.23
Q2/2022	126.04	122.76	129.33
Q3/2022	126.97	122.95	131.00
Q4/2022	127.34	122.67	131.99
Q1/2023	127.94	122.73	133.16
Q2/2023	129.08	123.36	134.79
Q3/2023	130.01	123.83	136.19
Q4/2023	130.37	123.76	136.98

A similar procedure was used for the time series of indices of building materials in the Czech Republic and Austria. The results of the development of prices of building materials using exponential smoothing can be seen below in Table 6 for Austria and Table 7 for the Czech Republic.

Table 6. Time series forecast of construction materials prices in Austria using the ETS model.

Time	Forecast Value	Lower Limit L80%	Upper Limit H80%
Q1/2022	124.91	122.59	127.23
Q2/2022	126.04	122.76	129.33
Q3/2022	126.97	122.95	131.00
Q4/2022	127.34	122.67	131.99
Q1/2023	127.94	122.73	133.16
Q2/2023	129.08	123.36	134.79
Q3/2023	130.01	123.83	136.19
Q4/2023	130.37	123.76	136.98

Table 7. Time series forecast of construction work prices in the Czech Republic using the ETS model.

Time	Forecast Value	Lower Limit L80%	Upper Limit H80%
Q1/2022	124.91	122.59	127.23
Q2/2022	126.04	122.76	129.33
Q3/2022	126.97	122.95	131.00
Q4/2022	127.34	122.67	131.99
Q1/2023	127.94	122.73	133.16
Q2/2023	129.08	123.36	134.79
Q3/2023	130.01	123.83	136.19
Q4/2023	130.37	123.76	136.98

At the end of this study, the forecasted data were compared with the actual published data of individual statistical indices. The exponential smoothing model was used in every series forecasting method. Table 8 shows a comparison of the forecasted values with the values actually published by the Slovak Statistical Office.

Table 8. Comparison of the forecast with the actual price development in Slovakia.

	Construction Materials in Slovakia			Construction Work in Slovakia		
Time	**Predicted Value**	**Index Value**	**Difference**	**Predicted Value**	**Index Value**	**Difference**
Q1/2022	140.97	140.4	0.57	124.91	133.0	8.09
Q2/2022	146.28	152.8	6.52	126.04	138.8	12.76
Q3/2022	151.55	154.6	3.05	126.97	144.5	17.53
Q4/2022	156.50	153.7	2.80	127.34	149.1	21.76
Q1/2023	162.54	156.3	6.24	127.94	155.0	27.06
Q2/2023	167.84	157.4	10.44	129.48	156.6	27.12
Q3/2023	173.11	155.6	17.51	130.00	157.9	27.90

Table 9 shows a comparison of the forecasted values with the values actually published by the Austrian and Czech Statistical Offices.

Table 9. Comparison of the forecast with the actual price development abroad.

	Czech Republic			Austria		
Time	**Predicted Value**	**Index Value**	**Difference**	**Predicted Value**	**Index Value**	**Difference**
Q1/2022	128.2	131.5	3.3	127.8	134.2	6.4
Q2/2022	130.7	136.1	5.4	131.2	137.8	6.6
Q3/2022	133.5	139.1	5.6	132.7	136.2	3.5
Q4/2022	135.6	140.7	5.1	133.9	133.2	3.1
Q1/2023	138.4	142.8	4.4	136.8	134.8	2.0
Q2/2023	140.9	143.7	2.8	139.8	137.6	2.2
Q3/2023	143.7	144.4	0.7	141.3	136.6	4.7

4. Discussion

In the first part of this publication, the goal was to determine the most suitable method for forecasting time series based on the errors that individual methods showed in the validation and test part of the sample. With the multi-criteria selection that was applied, we found out that the most suitable method for predicting time series is exponential smoothing—the ETS model. From the input data of the statistical offices from the years 2016–2021, a forecast of the development of the indices of prices of construction materials and work for the years 2022–2023 was subsequently made. While using exponential smoothing, we obtained the most accurate data compared to the ones published. Exponential smoothing is a method that has a self-correcting mechanism that is able to adapt forecasts. The exponential smoothing method seeks to eliminate various historical irregular elements and achieve optimal forecasting results. For this reason, the ETS model proved to be most appropriate during unpredictable deviations from the mean.

The regression model showed the greatest deviation from reality, with such characteristics as time series. The regression model was not able to eliminate extremes within the forecast nor describe the relationships between individual variables as well as the other models, and thus showed the largest forecast errors. The remaining two ARIMA and naïve methods appeared to be appropriate in the multi-criteria comparison of forecast errors, however, when using them, we did not achieve such close values with those published by individual statistical offices. Due to the fact that used time series did not show seasonality or a significant power of the trend, the ARIMA model was not sufficiently accurate.

Using the naïve method, it is not possible to record the decrease in the values of the real development and therefore it was not the most suitable for such an unstable period as the indices experienced.

Further research could deal with the refinement of the forecast or its adjustment, while creating a longer sample of the time series from which it would be possible to create more accurate forecasts. To forecast time series, it is also possible to use deep learning methods, Long Short-Term Memory (LSTM), or dynamic regression models, which were not used in this study.

Subsequently, after choosing the most suitable method, our intention was to determine its accuracy in the selected period—21 months from Q1/2022-Q3/2023—in Slovakia and abroad. At the time of the publication of this article, more recent data from statistical offices were not available. The difference between the predicted value and the actual value for the price index of construction materials in Slovakia was 17.51 percentage points. The difference when comparing the construction work price index was 27.9 percentage points. In the Czech Republic, the difference between the forecast and the reality after seven quarters was 0.7 percentage points. When comparing data from the Austrian Statistical Office with forecast values, the difference was 4.7 percentage points. We noticed the biggest deviation from reality in the data published in Slovakia, which reacted most strongly to market changes. Abroad, the price indices of construction costs did not show such a sharp increase.

5. Conclusions

When forecasting indices of prices of building materials and work in a period with large deviations from the norm, it is most appropriate to use the method of exponential smoothing. The forecasted values differed from the reality in the period we monitored by an average of 12.7 percentage points (average difference in Q3/2023, Tables 8 and 9) depending on the time series used and its character. The average difference between forecast and actual values is calculated in Central European countries (Slovakia, Austria, Czech Republic). Forecasting methods, such as exponential smoothing, could be used in the preparation of the work contract, either on the part of the contractor or the investor. The investor would have information about the expected increase in costs after the conclusion of the contract for the work. The contractor could manage the risk of the given construction contract by using the forecast. In this case, a reserve could be established in the contract for the work based on the forecast, which would divide the risk between the investor and the contractor. The forecasting model can be used in the preparatory phase of a construction project when a work contract is prepared, it would be considered a contractual condition that defines the expected percentage increase in prices over time. This could determine the optimal financial reserve of the project. The second method of application, in which price forecasting as a tool for adjusting the contract price could be anchored in the contract or its amendment, would be its use in the phasing of construction. Such a contractual condition would, in principle, ensure price indexation in real time, which would give the contracting parties the opportunity to plan their own resources in advance. This measure could reduce the proportion of contractors who are unable to continue with the construction contracts stipulated in the work contract. By processing additional data from other countries or by using a longer time series, it would be possible to refine and objectify our conclusions.

Author Contributions: Validation, J.B.; formal analysis, H.E.; resources, M.Ď.; data curation, L.L.; writing—original draft preparation, L.L.; writing—review and editing, S.Ď.; supervision, H.E. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Arditi, D.; Koksal, A.; Kale, S. Business failures in the construction industry. *Eng. Constr. Arch. Manag.* **2000**, *7*, 120–132. [CrossRef]
2. Russell, J.S. Contractor Failure: Analysis. *J. Perform. Constr. Facil.* **1991**, *5*, 163–180. [CrossRef]
3. Oleríny, M. *Řízení Stavebních Projektu: Ceny a Smlouvy v Zahraničí Praxis*; Beck, C.H., Ed.; Nakladatelství: Praha, Czech Republic, 2002; pp. 162–169. ISBN 80-7179-665-4.
4. Ellingerová, H. *Náklady a Ceny v Stavebníctve*; Tribun EU: Brno, Czech Republic, 2013; pp. 120–132. ISBN 978-80-263-0509.
5. Štatistický úrad SR. *Indexy Cien Stavebných Prác, Materiálov a Výrobkov Spotrebovávaných v Stavebníctve SR za 4. Štvrťrok*; Štatistický úrad SR: Bratislava, Slovakia, 2021.
6. Štatistický úrad SR. Available online: http://datacube.statistics.sk/#!/view/sk/VBD_SLOVSTAT/sp2063qs/v_sp2063qs_0_00_00_sk (accessed on 15 January 2024).
7. Statistik Austria. Available online: https://www.statistik.at/statistiken/industrie-bau-handel-und-dienstleistungen/konjunktur/baukostenindex (accessed on 14 January 2024).
8. Český Statistický úřad. Available online: https://vdb.czso.cz/vdbvo2/faces/cs/index.jsf?page=vystup-objekt&pvokc=&katalog=31786&pvo=CEN052&z=T (accessed on 18 January 2024).
9. Hyndman, R.J.; Athanasopoulos, G. *Forecasting: Principles and Practice*, 2nd ed.; OTexts: Melbourne, Australia, 2018.
10. Harrell, F.E. *Regression Modeling Strategies: With Applications to Linear Models, Logistic and Ordinal Regression, and Survival Analysis*, 2nd ed.; Springer: New York, NY, USA, 2015.
11. Gardner, E.S. Exponetial smoothing: The state of art—Part II. *Int. J. Forecast.* **2006**, *22*, 637–666.
12. Hyndman, R.J.; Koehler, A.B.; Ord, J.K.; Snyder, R.D. *Forecasting with Exponential Smoothing: The State Space Approach*; Springer: Berlin, Germany, 2008.
13. Mi, J.; Fan, L.; Duan, X.; Qiu, Y.Y. Short-Term Power Load Forecasting Method Based on Improved Exponential Smoothing Grey Model. *Math. Probl. Eng.* **2018**, *2018*, 3894723. [CrossRef]
14. Peña, D.; Tiao, G.C.; Tsay, R.S. (Eds.) *A Course in Time Series Analysis*; John Wiley & Sons: New York, NY, USA, 2001.
15. Hyndman, R.J.; Khandakar, Y. Automatic time series forecasting: The forecast package for R. *J. Stat. Softw.* **2008**, *27*, 1–22. [CrossRef]
16. Uppala, S.; Manjula, B.; Girija, A. Profit Prediction Using ARIMA, SARIMA and LSTM Models in Time Series Forecasting: A Comparison. *IEEE Access* **2022**, *10*, 124715–124727. [CrossRef]
17. Brockwell, P.J.; Davis, R.A. *Introduction to Time Series and Forecasting*, 3rd ed.; Springer: New York, NY, USA, 2016.
18. Cleveland, R.B.; Cleveland, W.S.; McRae, J.E.; Terpenning, I.J. STL: A seasonal-trend decomposition procedure based on loess. *J. Off. Stat.* **1990**, *6*, 3–33.
19. Dagum, E.B.; Bianconcini, S. *Seasonal Adjustment Methods and Real Time Trend-Cycle Estimation*; Springer: Berlin/Heidelberg, Germany, 2016.
20. Hyndman, R.J.; Koehler, A.B. Another look at measures of forecast accuracy. *Int. J. Forecast.* **2006**, *22*, 679–688. [CrossRef]