Household Electricity Prices on Europe

Python Programming Class Project

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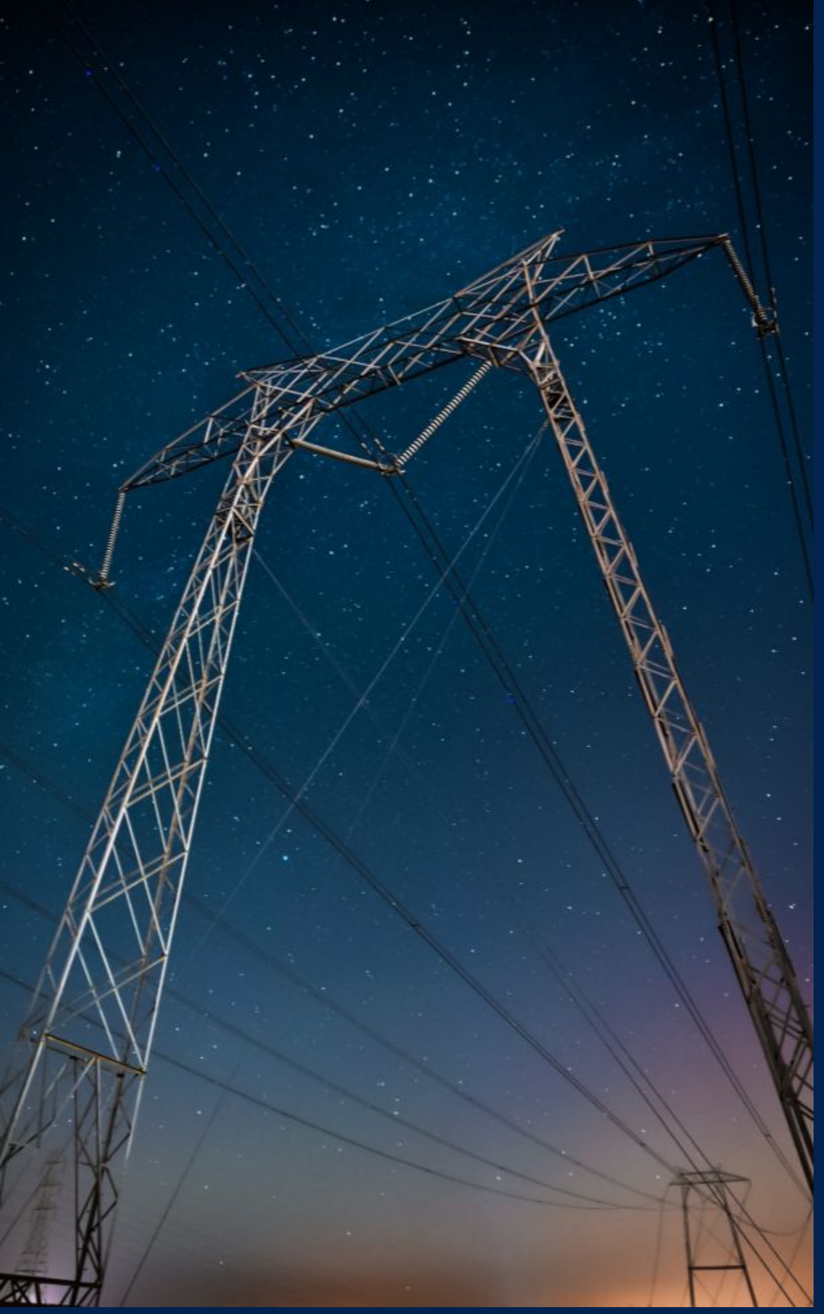


Project Scope

This project aims to analyze the evolution of retail electricity prices in Europe over an extended period.

Dataset: European wholesale electricity prices – monthly

The mentioned dataset contains the prices of electricity in Europe, which are centralised in a monthly configuration. However, these are not the end consumer prices as they do not include taxes, levies, network charges, subsidies, and supplier profits. These are prices on what is called the spot market. Unlike the previous dataset, which may be more relevant for this analysis, end-customer prices make a more relatable analysis.

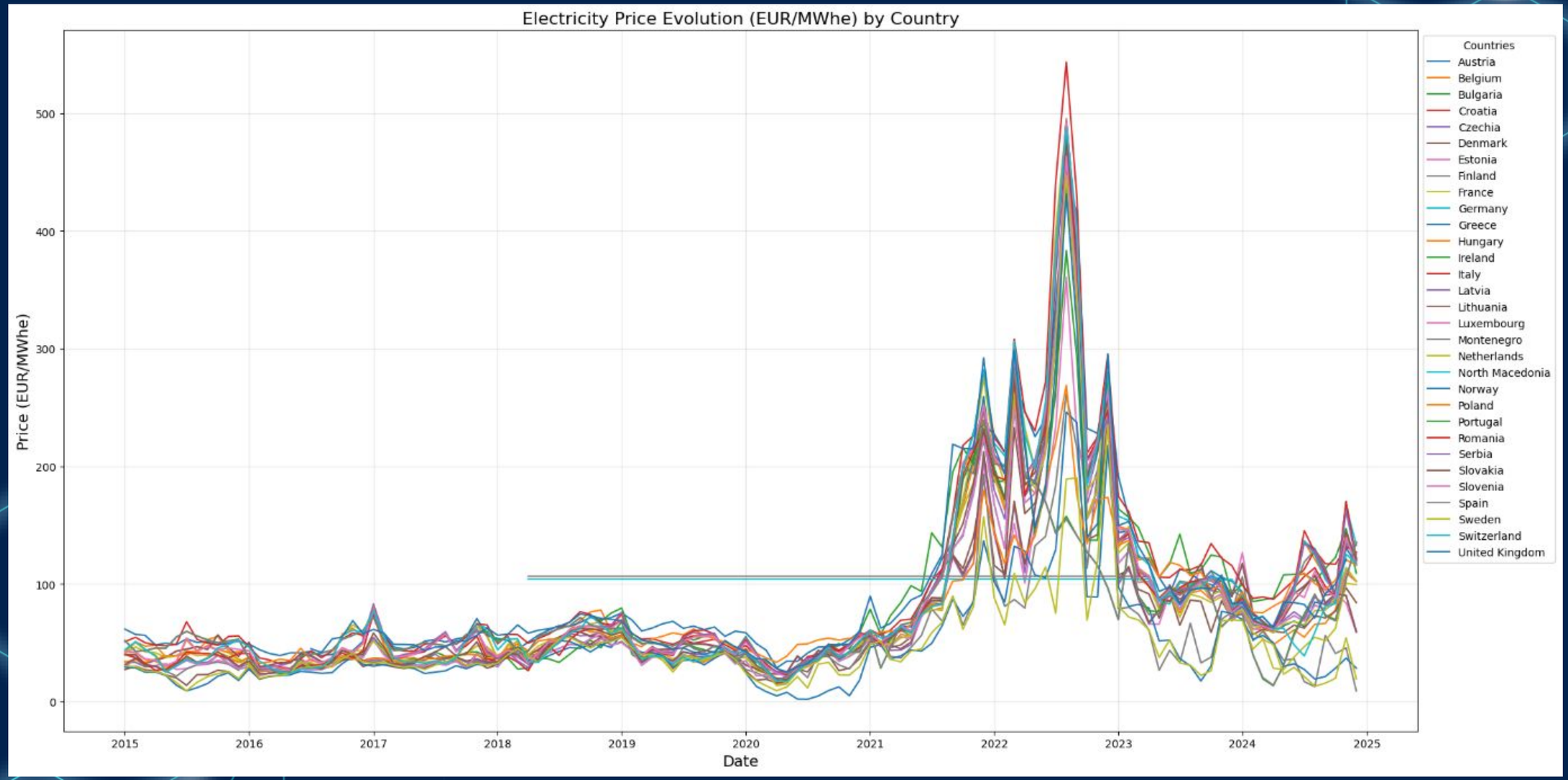
Data Cleaning

Country	ISO3 Code	Date	Price (EUR/MWhe)
Austria	AUT	1/1/2015	29.94
Belgium	BEL	1/1/2015	42.33
Czechia	CZE	1/1/2015	29.47
Denmark	DNK	1/1/2015	27.12
Estonia	EST	1/1/2015	33.84
Finland	FIN	1/1/2015	33.81
France	FRA	1/1/2015	40.94
Germany	DEU	1/1/2015	29.94

The datasets has 3504 observations, it contains monthly data for 31 countries starting with January 2015 and ending with December 2024.

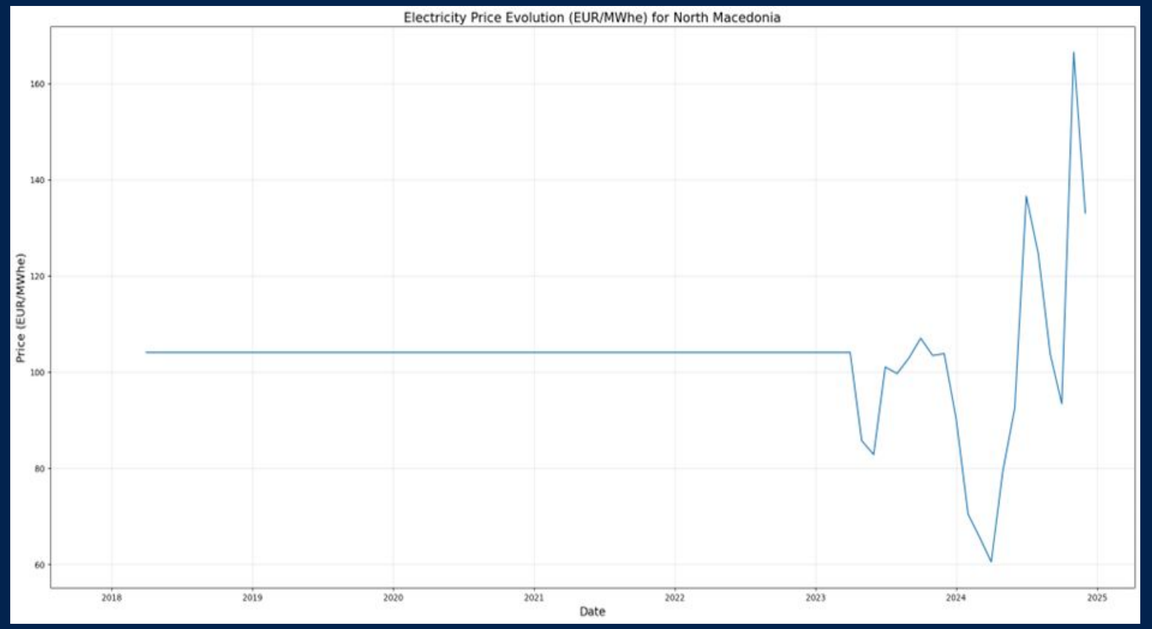
3504 observations

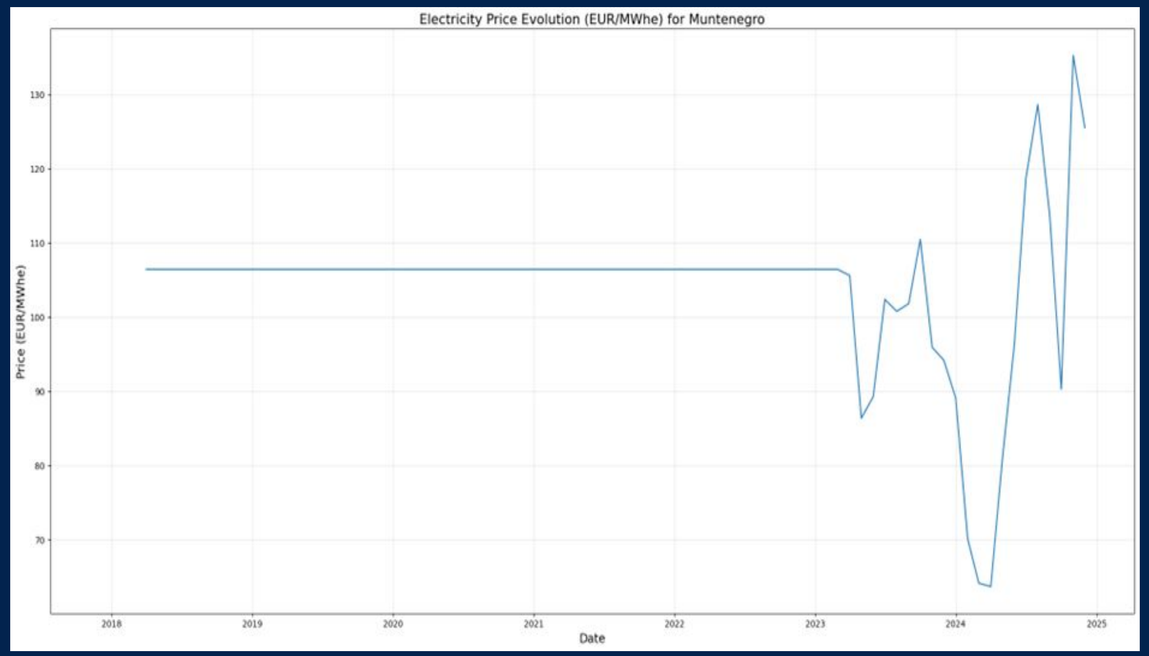
Data Cleaning



2 countries with inappropiate data were removed from the dataset.

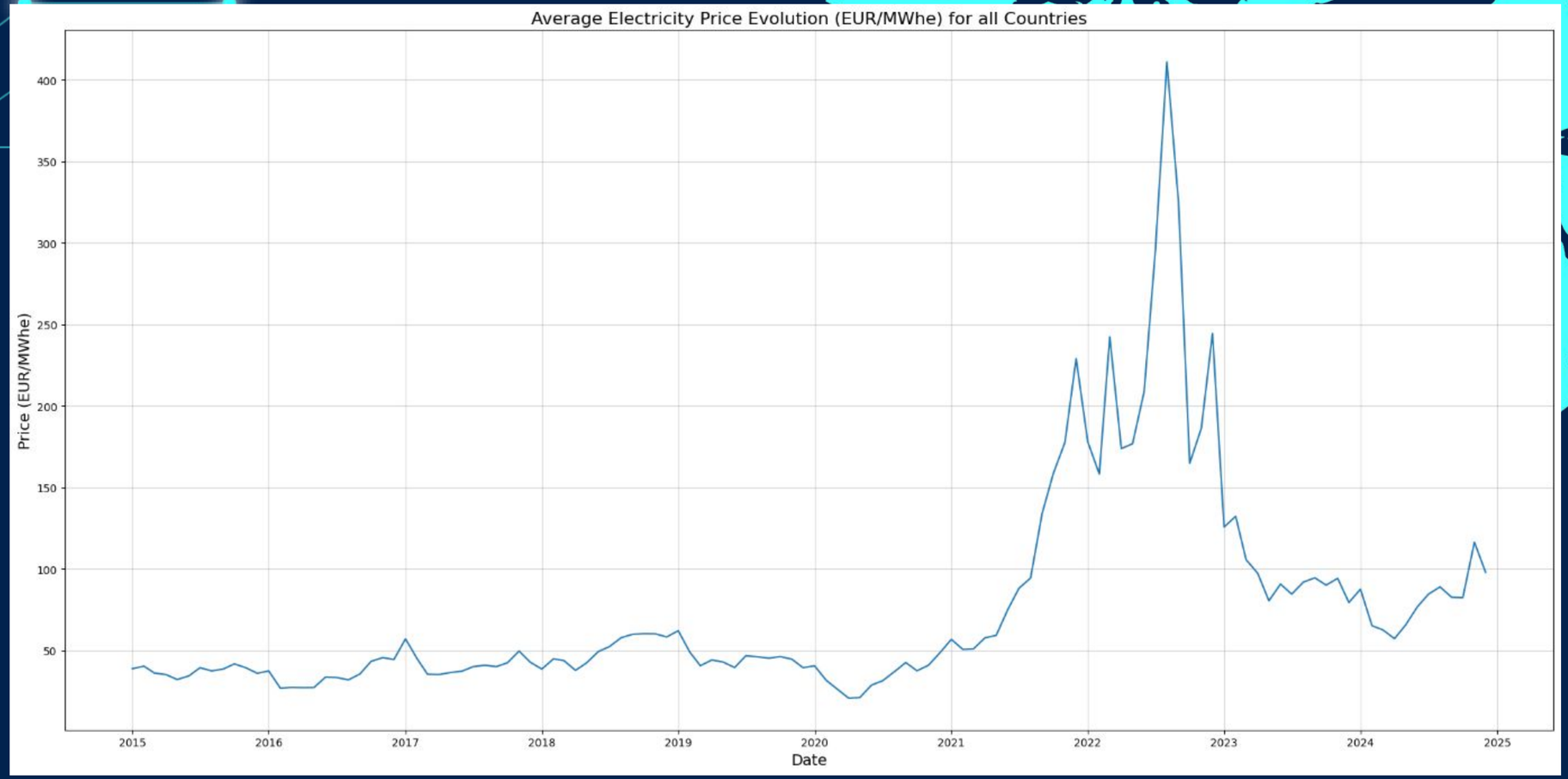
Four countries (Bulgaria, Croatia, Serbia, and the United Kingdom) were missing price values for the first part of 2015.



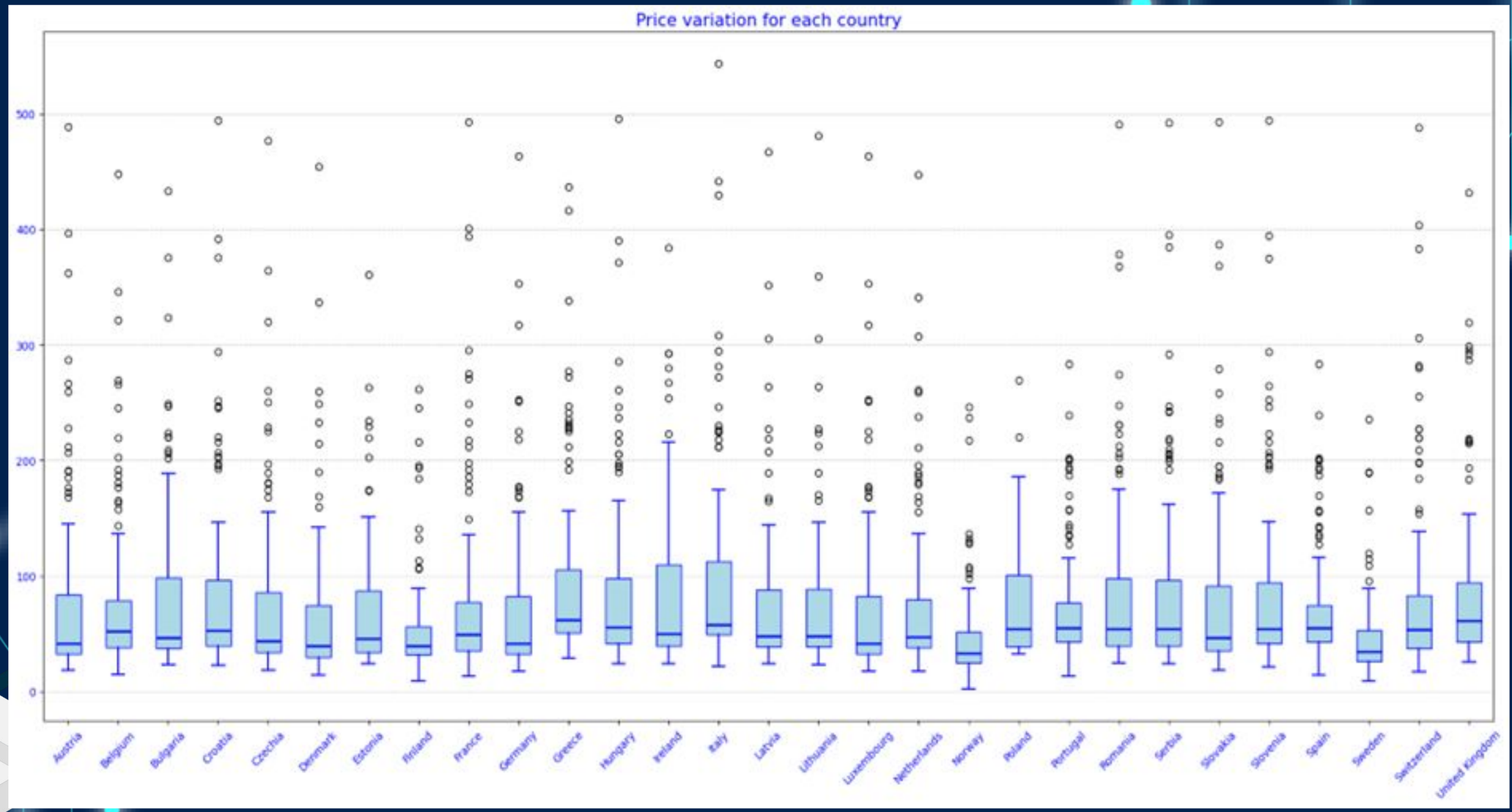


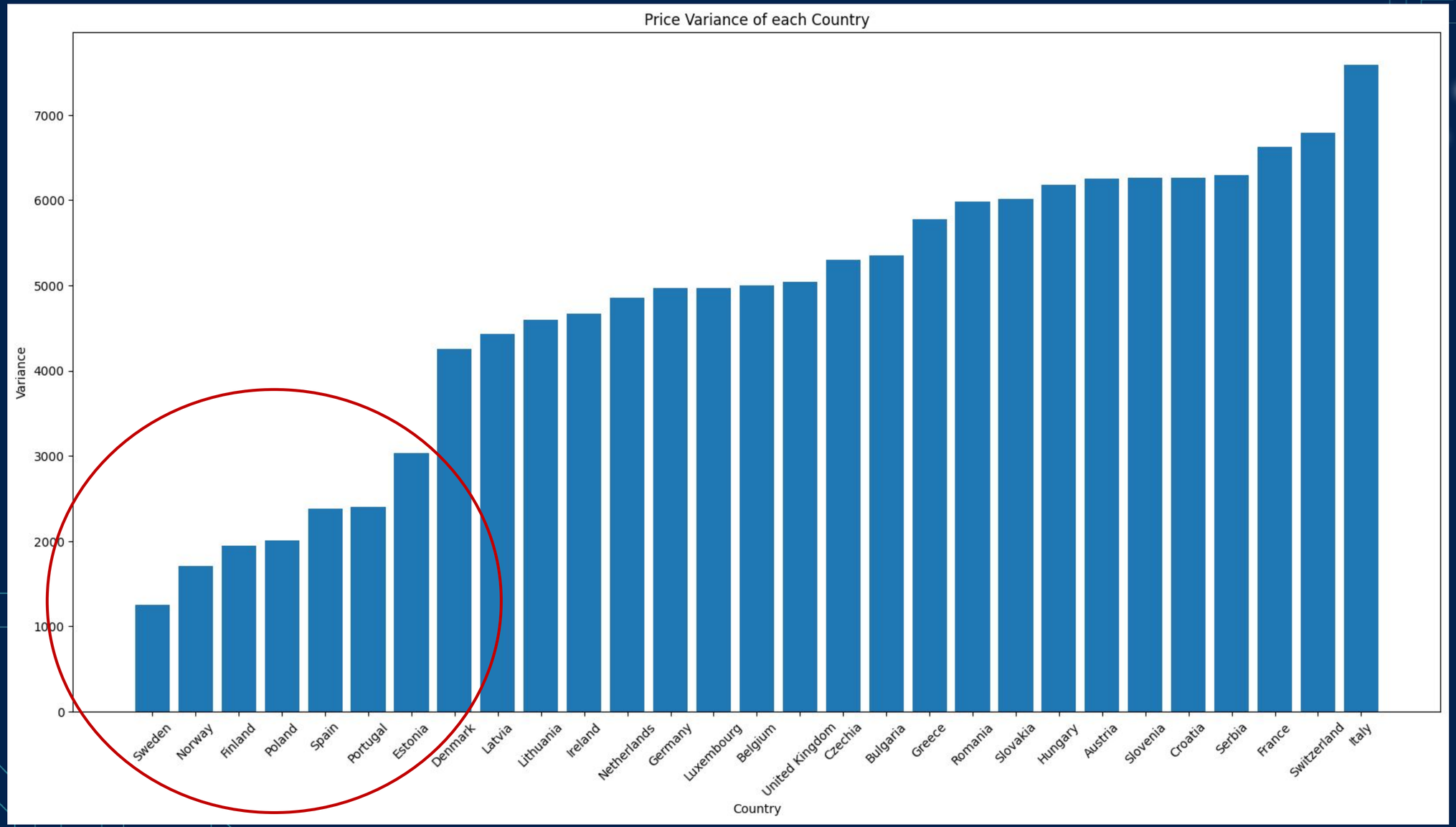
Data Analysis

Covid-19 Pandemic and **Russia's war on Ukraine**

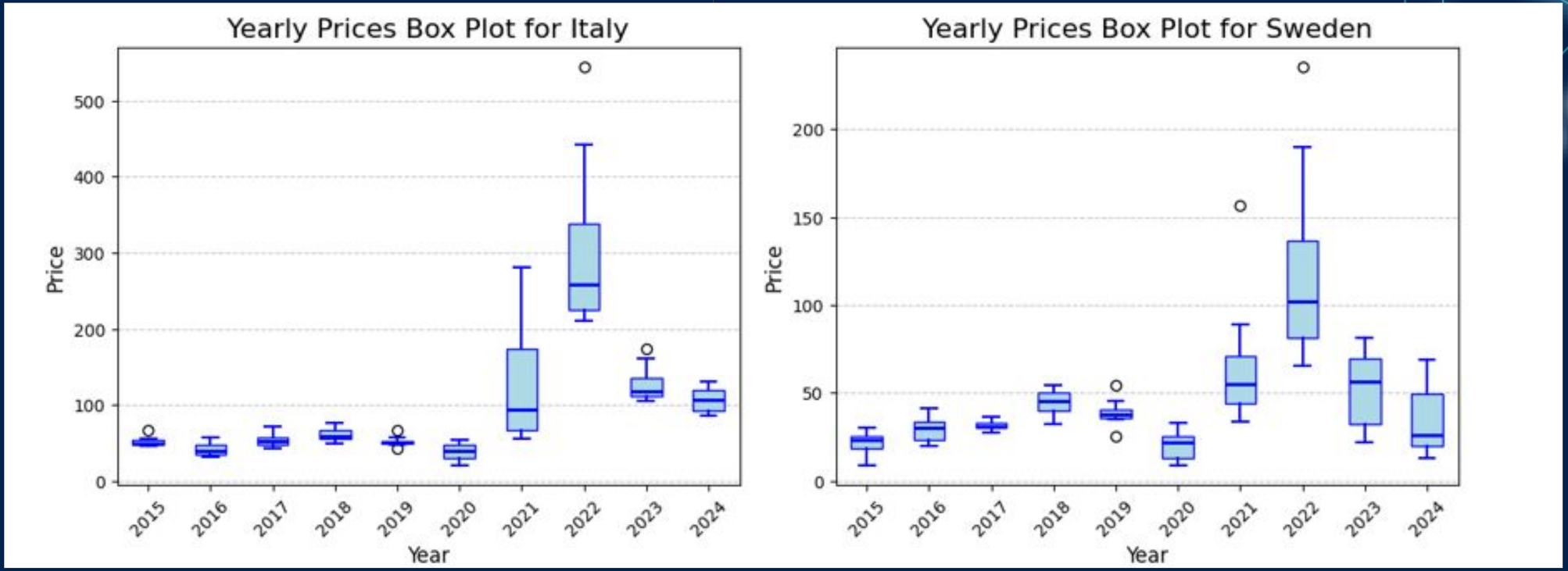


Price Variation




Price Variance of each Country
Variance
0
1000
2000
3000
4000
5000
6000
7000
Sweden
Norway
Finland
Poland
Spain
Portugal
Estonia
Denmark
Latvia
Lithuania
Ireland
Netherlands
Germany
Luxembourg
Belgium
United Kingdom
Czechia
Bulgaria
Greece
Romania
Slovakia
Hungary
Austria
Slovenia
Croatia
Serbia
France
Switzerland
Italy
Country

The difference can be best seen in the years 2021 and 2022 where the difference in prices is as much as 200 to 250 euros.



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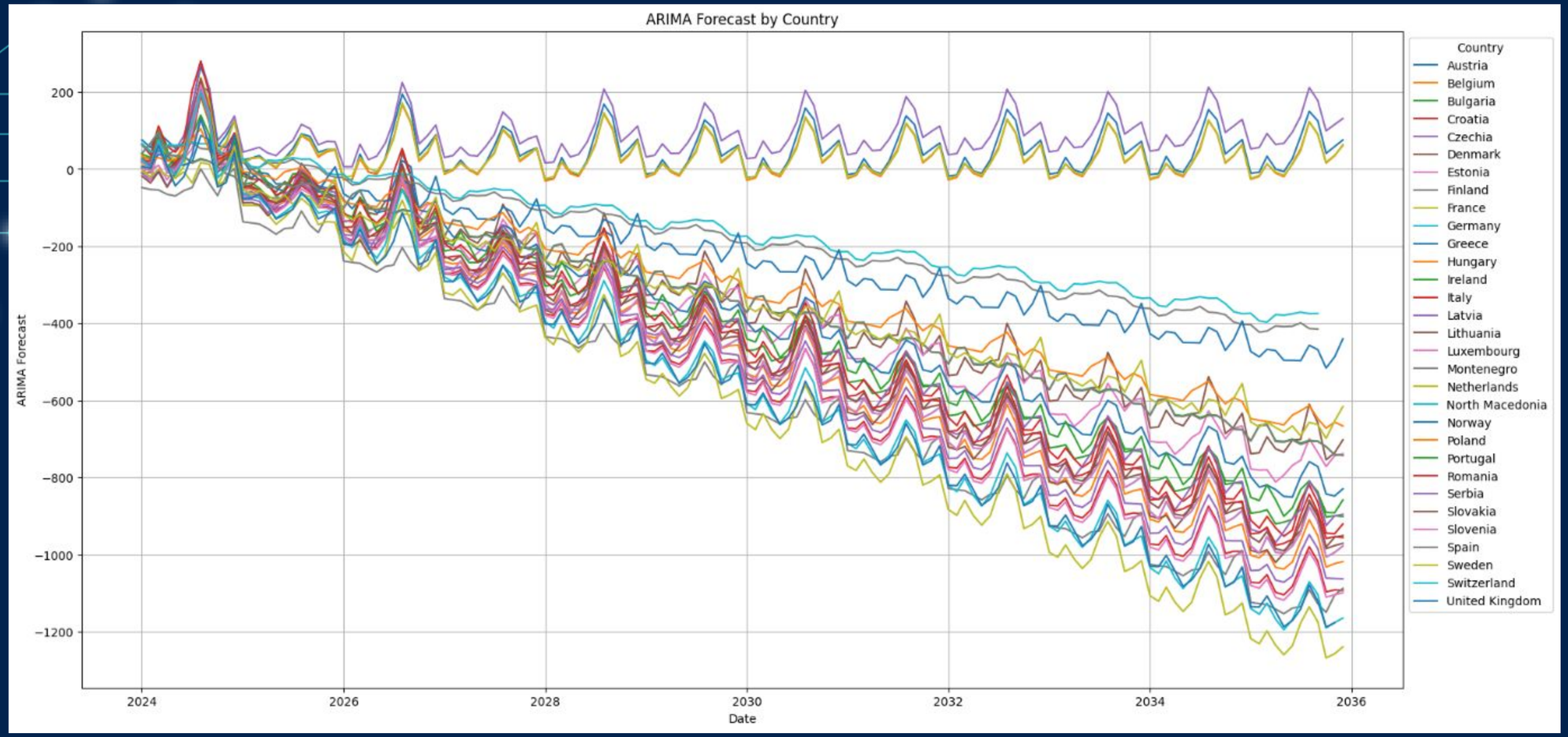
Data Prediction

Models used:

- **ARIMA** (AutoRegressive Moving Average);
- **LSTM** (Long Short-Term Memory) for **Hybrid Model** with ARIMA;
- **Linear Regression**

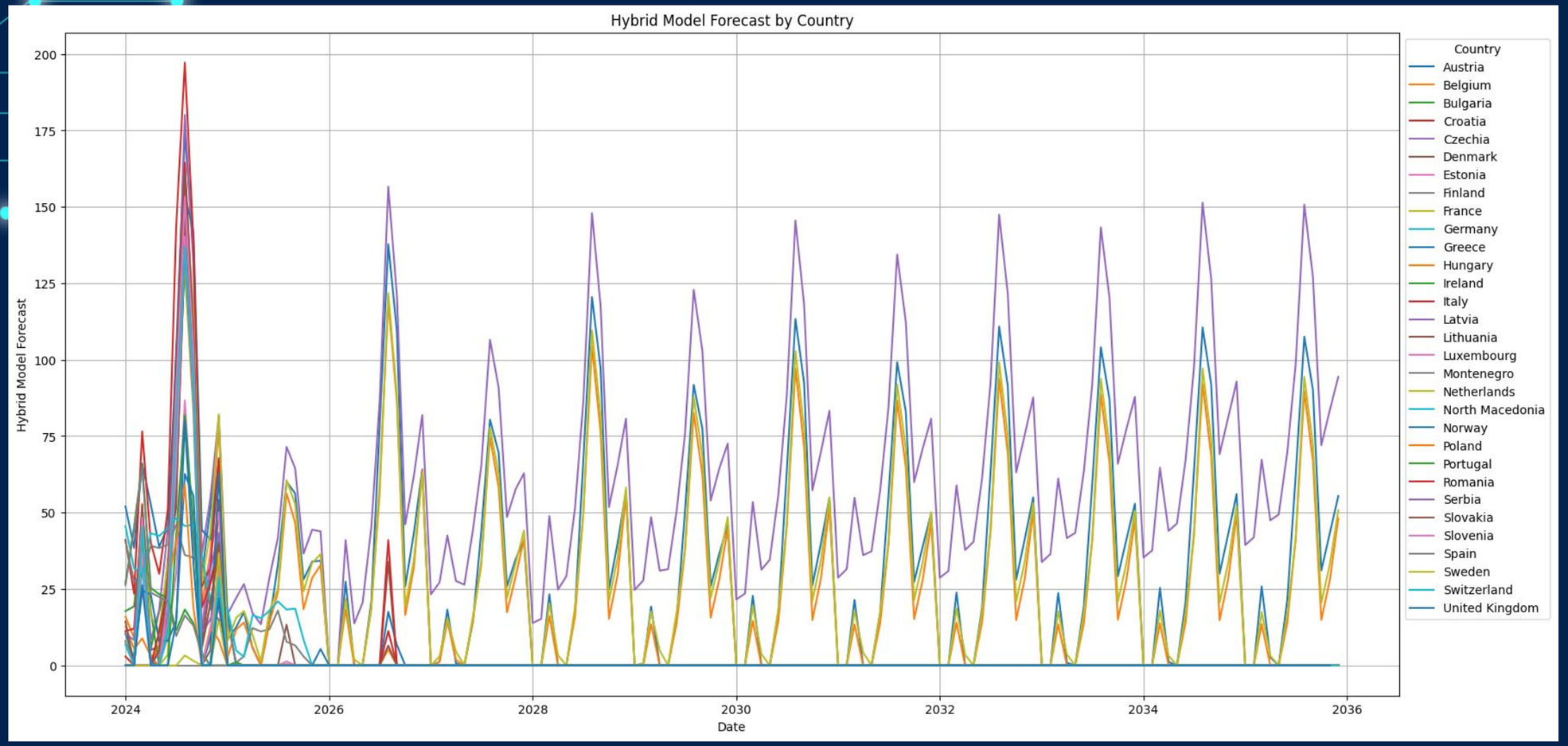
EaTemp

1. ARIMA



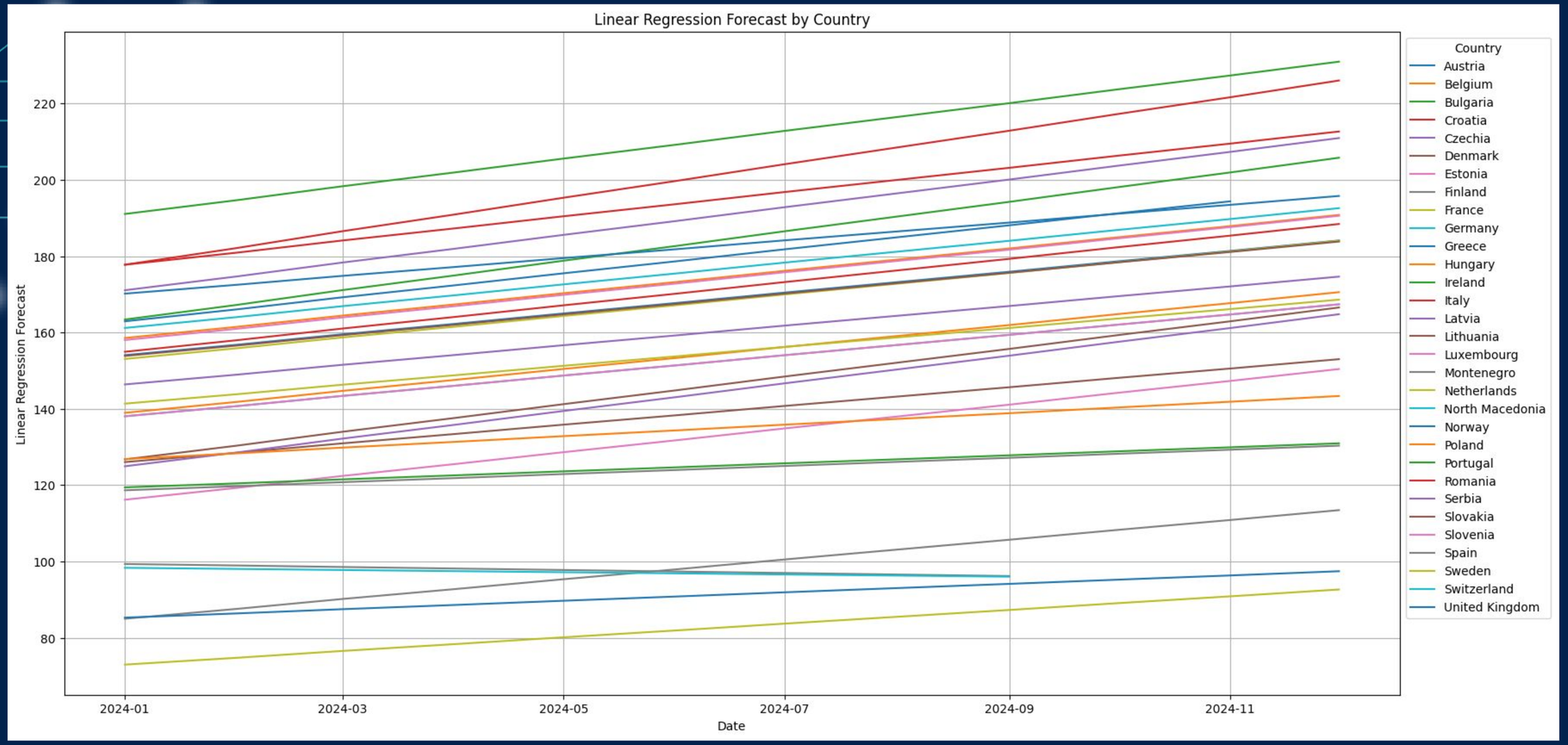
The results show a **decreasing projection** of the price and a **repetitive pattern** as well. One reason for this may be the inappropriate choice of ARIMA parameters, the large variability in the data caused by two disruptive events, or non-linearity in the data.

2. Hybrid (ARIMA & LSTM)



LSTM was prepared using the residual values of ARIMA. The combination between the two follows this function: `hybrid_forecast = alpha * arima_forecast + (1 - alpha) * lstm_predictions`, where **alpha = 0.7**

3. Linear Regression



Model Performance Comparison

Country	MAE_ARIMA	MAE_Hybrid	MAE_LR	MSE_ARIMA	MSE_Hybrid	MSE_LR	MAPE_ARIMA	MAPE_Hybrid	MAPE_LR
Austria	61.983	56.576	88.840	6383.839	3596.395	8145.227	81.187	72.860	121.313
Belgium	55.648	50.534	84.725	5079.431	2985.570	7382.206	83.876	74.781	131.982
Bulgaria	54.862	56.508	83.590	3841.798	4377.110	7565.018	54.388	57.642	97.835
Croatia	67.253	63.623	108.773	5608.334	5389.934	12074.013	72.219	69.955	128.124
Czechia	56.411	54.060	76.224	6014.487	3399.889	6063.563	69.854	65.396	98.878
Denmark	54.741	50.384	69.459	4738.767	3184.536	4894.224	76.697	71.176	102.729
Estonia	57.062	62.848	49.921	4193.317	4823.942	2865.419	68.768	73.816	65.882
Finland	86.006	43.158	59.586	9075.502	2481.734	4122.784	204.439	100.000	279.801
France	71.071	52.542	110.518	6424.827	3430.918	12625.815	126.625	90.210	238.253
Germany	69.584	58.152	75.214	5960.109	4249.632	5749.111	89.437	74.248	102.076
Greece	38.333	38.678	82.988	2267.674	2039.015	7327.661	36.798	37.326	94.937
Hungary	63.318	61.342	75.800	5285.712	5004.089	6322.103	65.246	63.950	90.581
Ireland	62.942	82.640	104.639	5702.153	7992.894	11065.293	56.693	76.464	101.429
Italy	62.020	55.711	87.431	5163.666	3705.261	7709.097	55.451	51.467	83.772
Latvia	67.740	57.668	60.052	5896.306	4205.632	4092.251	81.527	68.886	78.305
Lithuania	72.691	59.336	61.858	6618.215	4374.976	4315.168	87.471	70.820	80.575
Luxembourg	69.584	57.431	75.214	5960.109	4179.254	5749.111	89.437	73.195	102.076
Netherlands	52.625	48.462	78.203	4426.005	2844.518	6243.636	69.832	64.135	108.179
Norway	35.042	32.946	53.775	1589.294	1236.648	3223.927	117.109	97.901	184.847
Poland	54.424	79.989	38.396	3423.799	6733.590	1587.952	56.923	83.313	42.276
Portugal	58.205	54.571	60.660	5020.441	4343.703	4591.265	107.903	86.308	194.034
Romania	61.006	61.059	69.919	4866.345	4919.611	5568.072	61.507	62.181	83.371
Serbia	64.962	62.645	90.798	5561.916	5344.897	8726.874	65.695	64.714	104.175
Slovakia	66.565	58.622	78.192	5247.291	4506.454	6386.459	72.865	65.273	95.384
Slovenia	69.396	59.801	84.402	5655.853	4837.550	7362.970	76.810	67.189	103.270
Spain	57.801	54.305	60.455	4990.889	4340.177	4541.672	103.979	83.786	188.985
Sweden	46.019	33.570	48.697	2587.094	1464.381	2858.523	144.760	96.377	227.359
Switzerland	72.558	63.686	101.658	6649.662	4912.970	10787.545	103.978	86.352	159.153
United Kingdom	79.688	71.534	94.795	8433.256	5895.464	9108.516	91.866	83.887	118.336

The hybrid model **outperforms** ARIMA and Linear Regression in the majority of observations.

The **MAE**, **MSE** and **MAPE** values are big overall which implies further tuning of the model is needed or choosing another model or a larger dataset.

Conclusion and Recommendations

- Objective: Analyze European electricity prices (2015–2024) and predict future prices using advanced modeling techniques.
- Data Insights:
  - Price surges during disruptive events (COVID-19, Russian invasion of Ukraine) reached 4-5x increases.
  - Countries with high renewable energy showed greater price stability.
- Prediction Models:
  - ARIMA: Produced inaccurate results, including negatives.
  - Hybrid Model (ARIMA + LSTM): Achieved the best performance with precise forecasts.
  - Linear Regression: Acceptable results but weaker metrics.
- Performance Metrics: **Compared models using MAE, MSE, and MAPE; Hybrid model outperformed others.**

- Future Work:
  - Refine model parameters for better performance.
  - Explore larger datasets with hourly observations or alternative modeling techniques.

Thank you for listening!

Credit | Image: Unsplash