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Assessing EU Performance Toward Fit for 55: A Predictive Time Series Approach

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Predictive Analytics

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Abstract

This study assesses the progress of the ten most economically significant EU member states, as well as the EU as a whole, towards meeting the "Fit for 55" package's intermediate target of reducing CO_2 emissions by 55% by 2030 compared to 1990 levels. A hybrid predictive approach combining supervised and unsupervised methods was applied to generate country-level forecasts using the best-performing ETS and ARIMA models with optimized parameters. The results suggest that if current trends continue, the EU is expected to achieve a 46% reduction by 2030, which is 9 percentage points below the target. Only one country, Denmark, is currently on track to meet the target in full. The paper finally highlights major performance gaps among the considered member states, discussing potential strategies that the European Commission could adopt to close the remaining gap and reach the 55% goal, also in view of the long-term 2050 neutrality deadline.

Keywords: Fit for 55 – EU - CO_2 - Emissions – ETS – ARIMA – Time Series - Forecasts

1. Introduction

1.1 Context

According to the United Nations' *Sustainable Development Agenda*, the climate crisis is one of the defining challenges of our time. The ongoing emission of greenhouse gases (GHGs), particularly carbon dioxide (CO_2), is the main anthropogenic cause of this crisis.

The issue was first formally addressed at an international level in the 2015 Paris Agreement, where leaders from 196 countries presented and discussed their *Nationally Determined Contributions* (NDCs), which are intended to limit the increase in the global temperature to no more than 1.5°C above pre-industrial levels.

On that occasion, the EU member states signalled their intention to become the world's first climate-neutral economic block by 2050. This objective was later formalised by Ursula von der Leyen's European Commission through the *European Green Deal* (2019). To support this goal, an interim target was set out in a wider reform package known as *'Fit for 55'*: by 2030, the EU must reduce its greenhouse gas emissions by 55% compared to 1990 levels.

1.2 Research Question

This paper aims to use historical time series data on CO_2 emissions from several economically significant EU member states to estimate each country's contribution towards achieving the 2030 'Fit for 55' target using predictive models such as ETS and ARIMA.

Although there is no explicit sanctions mechanism for countries lagging behind in green policies, this analysis sheds light on internal EU dynamics. It enables us to identify the member states leading the way in climate action and those falling behind - an imbalance that could affect their reputation in EU negotiations.

1.4 Related Work

Although several studies have pursued similar predictive objectives in the context of emissions, only a few have focused in detail on the EU and its individual member states.

Marotta et al. (2023) forecasted GHG emissions for major European countries by training a multifactorial regression model that incorporated each country's GDP, population and renewable energy share (RES)[1]. Dritsaki & Dritsaki (2020) combined an ARIMA(0, 2, 1) model with an ARCH(1) and compared the results of the dynamic model with those of the static one, ultimately finding better performance in the latter. Unlike our approach, their work adopts a purely supervised modelling strategy and focuses solely on EU-wide emissions without considering individual member states. Finally, Duenas & Mandel (2024) used an ETS model to analyze emission variability across different European regions (not individual countries), paying particular attention to the dynamics of emissions *trading* among member states.

2. Data

2.1 Dataset Description

The data used in this study come from the *Global Carbon Budget*, a team of scientists who publish the most authoritative annual report on global CO_2 emissions. This report is regularly referenced at COP meetings.

The dataset, which can be downloaded via the Our World in Data portal, contains 28,137 observations of annual carbon dioxide emissions (in tonnes) from 1750 to 2023 (depending on data availability[2]), covering more than 200 countries. It was last updated in November 2024 and is subject to annual revision.

For the purposes of our analysis, we significantly streamlined the dataset. We only considered observations from 1900 onwards, focusing on the ten most economically relevant EU member states: Germany, France, Italy, Spain, Poland, the Netherlands, Belgium, Sweden, Austria and Denmark. In addition to these ten time series, we included two aggregate series - *EU27* and *World* - to compare Europe's commitment to climate neutrality with global trends.

2.2 Data Overview

2.2.1 EU vs. World

Before delving into the analysis and focusing entirely on the EU *'bubble'*, it is important to emphasize that, unlike in Europe, global carbon dioxide emissions are not decreasing - quite the opposite, in fact (see Fig. 1). Despite the

[1] Renewable Energy Share (RES) refers to the proportion of a country's total final energy consumption that is derived from renewable sources such as wind, solar, hydro, and bioenergy.

[2] For some countries data is not available from 1750 but begin later.

Paris Agreement, highly developed countries such as China (which accounted for 34% of global emissions in 2023) and developing nations such as India (+8% emissions in 2023) continue to record substantial annual increases in their emissions.

Figure 1: *EU vs. World % Change in CO_2 Emissions*

2.2.2 European Union

Deep diving into EU, Germany is by far the largest emitter, having consistently produced over one billion tonnes of carbon dioxide annually by the end of the last century - roughly 2% of the annual global emissions in those years. Other major economies, such as France and Italy, along with Poland - whose historically strong steel industry has contributed significantly to its emissions - follow behind (see Fig. 2).

As expected, the countries with the lowest emission levels are the smaller, less populous ones, such as Denmark, Sweden, Austria and Belgium.

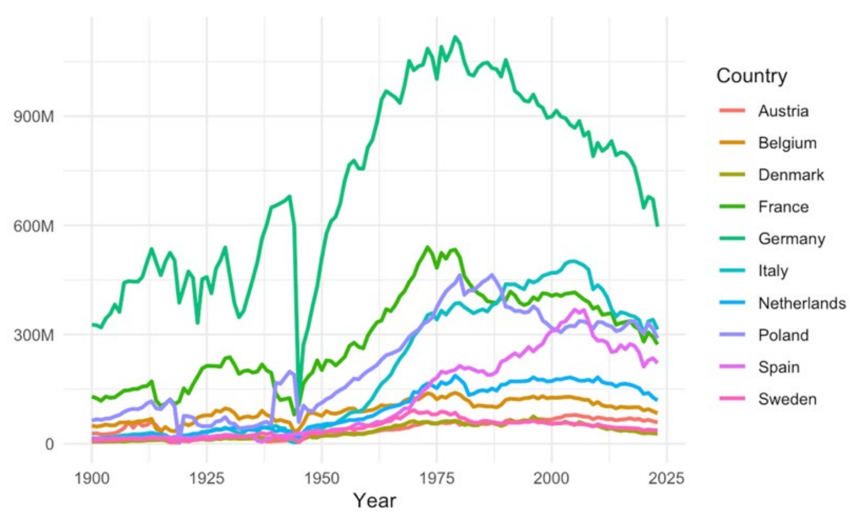

Figure 2: *CO_2 Emissions (in tonnes) of Top EU Countries*

3. Forecasts

To address the research question, we produced forecasts by combining both supervised and unsupervised approaches.

We identified the best-performing model - between *ETS* and *ARIMA* (both with optimized parameters, which are automatically found by R) - for each country using *RMSE*[3] as the evaluation metric. The training data covered emissions from 1900 to 2019, while the test data spanned the years 2020 to 2023.

After having applied these models using this time an unsupervised approach to generate annual forecasts for the period 2024–2030**,** we calculated the projected percentage reduction in emissions for each country by 2030 relative to 1990 levels. This allowed us to assess each country's progress towards the Fit for 55 target.

3.1 ETS vs. ARIMA: Which one to use?

There is not always a clear explanation of why one model outperforms another. Differences in performance are often due to unobserved factors or the statistical complexity of the time series. Nevertheless, the following section aims to provide a clear interpretation of the results of the ETS vs. ARIMA comparison summarized in Table 1.

Flag	Country	RMSE ETS	RMSE ARIMA	Best Model
	Austria	6.5M	6.1M	ARIMA (0,1,4)
	Belgium	13.4M	11.2M	ARIMA (1,1,3)
	Denmark	1.6M	3.1M	ETS (M,A,N)
	France	25.2M	25.3M	ETS (A,Ad,N)
	Germany	72M	77.3M	ETS (A,Ad,N)
	Italy	18.389M	18.386M	ARIMA (1,1,1)
	Netherlands	25.2M	26.5M	ETS (A,A,N)
	Poland	26.5M	21.4M	ARIMA (0,1,0) + drift
	Spain	35.7M	22M	ARIMA (3,1,0)
	Sweden	3M	4.3M	ETS (A,Ad,N)
	EU27	165.4M	192M	ETS (A,A,N)
	World	1.63B	1.59B	ARIMA (0,2,2)

Table 1: *Best Model for Every Country (using RMSE)*

[3] RMSE (Root Mean Square Error) is a standard metric used to measure the accuracy of a model's predictions; it represents the square root of the average squared differences between predicted and actual values.

3.1.1 ETS

The *ETS model (Error, Trend, Seasonality)* performed better in countries like Germany and France, where emissions follow a relatively stable and consistent downward trend. This likely reflects the impact of long-term, well-implemented environmental and industrial policies.

In countries with more rapid reductions, such as Denmark, the best model is an ETS with a *multiplicative* (M) error component which better handles sharp changes (see Fig. 3 - Denmark). Instead, countries with slower reductions were attributed an ETS model with an *additive damped* (Ad) trend that perfectly fits the declines that gradually slow down over time which forms an (almost invisible) elbow (see. Fig. 3 - France).

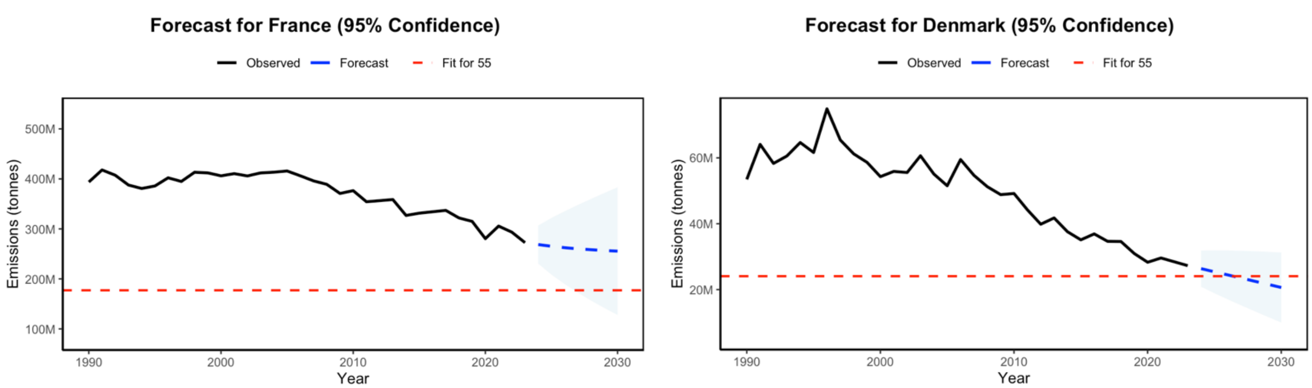

Figure 3: *2030 Forecasted Emissions for France and Denmark using Best Models (ETS)*

3.1.2 ARIMA

Thanks to its *moving average* (MA) component[4], the *ARIMA (p, d, q) model* delivered better results for time series with greater irregularity and volatility such as Austria (q = 4)(see Fig. 4 – Austria) and Belgium (q = 3)(see Fig. 4 - Belgium). These cases likely reflect the absence of stable, long-term strategies, with the partial exception of Italy (RMSE difference between the two models was minimal).

[4] It allows the model to absorb shocks and noise and take them into account for forecasting.

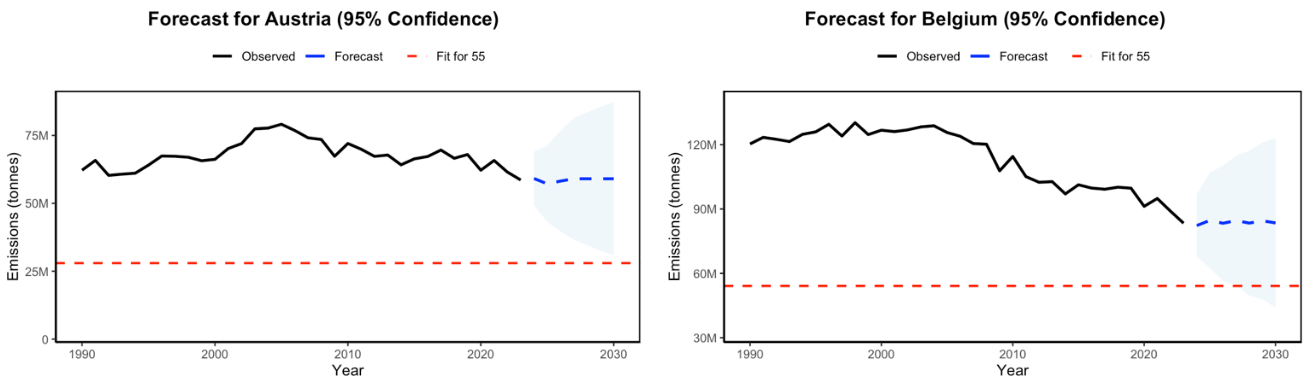

Figure 4: *2030 Forecasted Emissions for Austria and Belgium using Best Models (ARIMA)*

3.1.3 Flat Forecasts

One issue that arose during the forecasting process was the occurrence of *flat* forecasts. This typically arose when the selected model was ARIMA(0, 1, 0) or ETS(A, N, N). These models - a random walk without drift and a simple exponential smoothing model without trend, respectively - do not incorporate any dynamic components (neither trend nor seasonality). Consequently, their forecasts remain constant, equaling the last available observation.

As this behaviour was not realistic for the time series involved (Poland - predicted with ARIMA(0,1,0)), we adjusted the model to allow for a more expressive trajectory. This was achieved by adding a small constant negative *drift* term in the ARIMA model (see Fig. 5 – it looks like forecasts are still flat, but they're not).

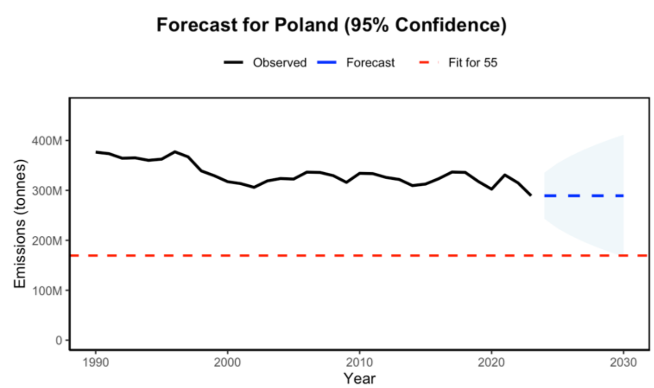

Figure 5: *2030 Forecasted Emissions for Poland (ARIMA + drift)*

3.2 Monitoring Fit for 55 Progresses

We have included selected projection graphs for 2030. The light blue shading represented the confidence interval, which widens over time due to the dynamic nature of the forecasts and the propagation of error. The red dashed line showed the threshold that must be crossed to meet the intermediate 'Fit for 55' target.

To summarize the results obtained, we compiled Table 2.

Flag	Country	1990	2030	% Change	Situation
	Austria	62.2M	59M	-5.1%	**CRITICAL** - heavy intervention
	Belgium	120.3M	83.5M	-30.6%	**BAD** - intervention
	Denmark	53.5M	20.6M	−61.4%	**EXCELLENT** - no intervention
	France	393.7M	255.5M	-35.1%	**OK** - moderated intervention
	Germany	1.1B	600.5M	-43.1%	**GOOD** - light intervention
	Italy	438.2M	283.7M	-35.3%	**OK** - moderated intervention
	Netherlands	162.8M	100.6M	-38.2%	**OK** - moderated intervention
	Poland	376.6M	302.1M	-19.8%	**VERY BAD** - strong intervention
	Spain	230.2M	219.1M	-4.8%	**CRITICAL** - heavy intervention
	Sweden	57.5M	35M	-39.1%	**OK** - moderated intervention
	EU27	3.9B	2.1B	-46.0%	**GOOD** - light intervention
	World	22.7B	40.7B	79.2%	**NOT** in the scope of Fit for 55

LEGEND
CRITICAL: 0% - 10%
VERY BAD: 10% - 20%
BAD: 20% - 35%
OK: 35% - 40%
GOOD: 40% - 50%
EXCELLENT: > 50%

Table 2: *EU's Top Countries Forecasted Performance Fit for 55*

As can be seen, none of the countries considered, except Denmark, are projected to break through the red dashed line. Each country's situation was classified using one of the following six labels: *Critical, Very Bad, Bad, Ok, Good and Excellent.*

The EU's overall situation is neither alarming nor particularly encouraging: projections estimate a 46% reduction in emissions by 2030 compared to 1990 levels. However, the outlook suggests that smart, targeted interventions in key countries could accelerate progress, bringing us very close to the 55% target.

At this point, the main question is how the European Commission should act to accelerate progress. Two main strategic options emerge:

1. Bring lagging countries up to speed through intensive, short-term green policy interventions.
2. Further strengthening climate policies in countries that are already relatively advanced in their transition.

The *second* option may be the more efficient choice, as it involves countries that already have the infrastructure and technical expertise to implement further green measures. However, this strategy could exacerbate disparities within the Union. Southern and Eastern European countries, such as Spain and Poland, may view it as neglect, which could undermine the EU's core principle of solidarity.

For this reason, it seems that the Union is leaning towards a hybrid strategy of accelerating progress in the most advanced countries while redistributing some of the resulting benefits to those that are lagging behind. This approach is consistent with the overarching goal of achieving climate neutrality across all member states by 2050. Leaving less advanced countries behind would be counterproductive, since all members will ultimately be required to meet this common goal.

4. Conclusion

In conclusion, the EU is not very well positioned with respect to the intermediate 'Fit for 55' target yet, as our projections indicate that emissions would be reduced by 46% by 2030 if current trends continue. Certain member states, such as Spain and Austria, show substantial gaps: -4.8% and -5.1%, respectively. Over time, these organical disparities could undermine the principle of solidarity and even threaten the cohesion of the Union itself.

Although the hybrid strategy of accelerating progress in more advanced states and redistributing gains to less advanced ones appears to be an effective way of achieving the collective target of reducing emissions by 55%, serious doubts arise as to whether such an approach will remain acceptable to the leading countries in the long term until 2050 when all member states are expected to be climate neutral.

4.1 Future Scenarios

As Duenas & Mandel (2024) suggested, future research could be expanded by identifying the key political and non-political factors that contribute to differences in emissions across countries. This would be particularly valuable in the context of studying the most effective ways to achieve climate neutrality by 2050.

Finally, as illustrated in Table 2 and Figure 1, the global scenario is following a markedly different trajectory. Projections indicate that emissions will increase by 80% by 2030 compared to 1990 levels. Unlike the EU, the global landscape is more fragmented as there are no shared deadlines. Conducting a similar analysis at the global level, focusing on major world powers and their respective Nationally Determined Contributions (NDCs), would be highly interesting. A comparable effort has been carried out by the YouTube channel *Kurzgesagt* in the video

“Who is Responsible for Climate Change? – Who Needs to Fix It?”, which notably sourced data by Our World In Data.

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