Analysis of National Electric Vehicle Targets in China, Japan, and France

Abstract: The automobile industry constitutes to about 23% of global greenhouse gas (GHG) emissions from fossil fuels. The GHG emissions are projected to grow to 50% by 2050 under business as usual scenario. The adoption of electric vehicles (EVs) remains the most effective measure in curbing the vehicular emissions and possibly mitigating exacerbating effects of climate change. Governments worldwide are setting ambitious goals to phase out fossil fuel powered automobiles. This paper aims to analyze the national targets of EV penetration for three of the major global EV players – China, Japan, and France – using various forecasting models to assess if they can meet their goals or not. This paper finds that State Space Models outperform other time series models for the purpose of long duration forecasting. None of the countries are predicted to meet their EV adoption goals under current policy, regulations, and incentives. However, it should be noted that 5 years of data is used to forecast 5 to 20 years ahead in the future. The short number of historical observations limit the forecasting capability and prevents the use of change-point analysis to incorporate different policy scenarios.

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1. Introduction

The global motor vehicle industry has historically been dominated by internal combustion engines. The industry's reliance on fossil fuels contributes 23% of energy-related greenhouse gas emissions globally (UN, 2015). Without significant technological advances, or government intervention, emissions from transportation are expected to rise close to 50% by 2050, more than any other sector. Currently, electric vehicles make up just over 2.5% of total sales (Teter, 2019).

In 2015, 195 countries came together to sign the Paris Agreement addressing climate change and outlining action to limit the planet's warming to under 2 degrees Celsius above pre-industrial levels (Denchak, 2019). While the world remains behind an acceptable trajectory on most of these action items, the International Energy Agency lists electric vehicles as one of the three technologies that has kept pace with the agreement's warming goals (Teter, 2019). Despite Electric Vehicles' small share of the total market, the global number of EVs rose 63% from 2017 to 2018, and the charging infrastructure to power this fleet increased by 44% (Paoli, 2019). Given this recent trajectory, electric vehicles do appear on their way to reaching the Paris Agreement's goal of comprising 20% of all vehicles by 2030 (Teter, 2019).

While on the surface the world appears on track to meet its general EV goals, the pace of adoption and the incentive structures vary dramatically from country to country (Paoli, 2019). Currently, EVs in China make up 45% of the global fleet, followed by Europe at 24% and the United States at 22% (Teeter, 2019). Countries such as France and Italy incentivize buying EVs by placing a "bonus malus" on traditional vehicles and reallocating the funds to subsidize EV buyers, while the United States and China rely on direct government expenditures (Paoli, 2019). Additionally, countries' incentive structures vary with their political and economic climates. For example, China, who had planned to terminate all EV subsidies by the end of 2020, reversed course during the economic damage brought on by the Coronavirus pandemic and extended their EV incentives and additional two years (Berman, 2020). There remains one consistency across these various policy climates: Government incentives toward EVs are rising (72% in 2018) and will likely continue to do so as countries look for avenues to make good on their Paris Agreement commitments (Paoli, 2019).

1.1 Study Objectives and Rationale

Unlike many broader, more complex aspects of the Paris Agreement, electric vehicles provide a more tangible metric to measure their success: Sales. Countries' electric vehicle sales provide an easily comparable way to measure their progress towards their sustainability goals. In addition to the global goal of 20% electrification by 2030, countries have set individual goals for EV sales with independent timelines and figures. This paper aims to analyze several examples of countries' EV goals and analyze their feasibility.

1.2 Literature Review

China, Japan and France's EV markets were chosen to investigate using appropriate time series models to assess the progress of their respective EV sales targets. The selection of countries was based on three criteria:

- Presence of an EV sales target
- Importance of the nation in global EV market
- Availability of EV market share data

China

China was chosen for our analysis as it provides the biggest market for electric vehicles. Recently, it has pushed for aggressive policies aimed at promoting clean transportation. Since 1980, China has witnessed 100 times increase in vehicle ownership. Increasing oil consumption from vehicles has exacerbated the concerns of public health and environmental consequences due to air pollution and greenhouse gas emissions (Lin and Wu, 2018). In order to combat air pollution, affirm its commitment to Paris climate accords and be a leader in the EV sector, China has used stringent policy reforms to incentivize expansion of its EV market share (Steer, 2018).

China has been providing subsidies to consumers for buying electric vehicles. Moreover, it financially penalizes car manufacturers for an absence of EV products in their product portfolio. For instance, in 2018, it released a mandate to sell 4.6 million electric vehicles by 2020 (Steer, 2018). Such aggressive policy reforms and incentives have increased the ownership of electric vehicles growing the sales by 62% in 2018. As of now, about 500 car manufacturers are registered to produce electric vehicles (MacDuffie & Shih, 2019).

As a step to long term goal of phasing out combustion engine vehicles, China has set a goal to increase EV sales to 25% of all domestic vehicle sales by 2025 (Sun & Goh, 2019). It also has specific goals for 2020 and 2030. This study uses the 2025 goal in order to assess whether China is on the track to fulfill its most salient EV commitment.

Japan

Japan is one of the largest hubs of global car manufacturers whose product sales constitute to about 30% worldwide. It is the third largest automobile manufacturer and exporter behind US and China (Mcllroy, 2017). Japanese OEM's were some of the first players in the automobile sector to introduce electric vehicles to the world. Moreover, Japan has also witnessed a technological commitment where an increasing number of OEMs are moving toward hybrid and hydrogen fueled cells and researching battery electric vehicles. However, in terms of market share, the country's adoption rate of electric vehicles has not been impressive (Hertzke et al., 2019). In Japan, while EVs only made up 1.13 percent of domestic vehicle sales in 2018, increasing EV demand in other major markets such as US, Europe and China is pushing Japanese car manufacturers to launch more electric offerings (Englemann, 2020).

In 2019, Japan mandated internal combustion engine (ICE) vehicles to be 30% more fuel efficient by 2030 in order to push the manufacturers towards EVs. Despite a low penetration of EVs in the automobile market, Japan hopes to increase EV market share to about 20-30% by 2030 (Nippon, 2019) And by 2040, Japan has set an ambitious target to phase out all ICE cars and, in doing so, has joined other nations in setting up goals for the future. Unlike China, Japan aims to promote electric vehicles through subsidies without penalizing internal combustion engine driven vehicles (Manthey, 2018).

Japanese OEMs can play a pivotal role in not just increasing the EV sales in their national market, but the international market as well under the context of increasing global demand of EVs in the developed world. Therefore, Japan was also chosen for our study to assess if the country would be able to meet its EV target by 2040 at current trends.

France

France is the largest EV market in Europe. It's EV sales have surpassed those of Norway which is a pioneer of clean transportation in Europe and are double the sales made in Germany, another country offering major subsidies and incentives for promoting electric vehicles. France has done so by providing fiscal incentives for consumers buying EVs and mandating, just like China, for all automobile manufacturers to have at least 1 EV product in their portfolio (Jacobs, 2017). Moreover, France plans to invest 700 million euros in researching and developing electric car batteries to reduce its reliance on essential components from Asian market (Rosa, 2019).

To become a carbon neutral country by 2050, France plans to ban vehicles powered by fossil fuels by 2040. In fact, this goal is one of the clauses of its new mobility law which also empower the people with the right to ask their apartment buildings to install EV charging stations (Clercq, 2019). In short term, it also plans to increase it charging capacity to 100,000 by 2022 under its charging station subsidy program (Randall, 2019) Despite its efforts, EVs constitutes to only 2% of car sales in France (Energía16, 2019). Therefore, this study also focuses on France's EV market to assess whether it will be able to meet its EV goals by 2040.

Table 1. Status of EV market and targets in selected countries

Country	EV Market Share (2019)	EV Goal
China	4.7%	25% by 2025
Japan	0.8%	100% by 2040
France	2.6%	100% by 2040

2. Dataset Information

Our dataset was in comma separated value (.CSV) format and comprised of monthly new energy vehicles sales in China, France and Japan from 2014 to 2019. The NEV sales included the sales of hybrid electric vehicles, plug-in hybrid electric vehicles, electric vehicles and fuel cell vehicles.

Since these data were from obtained from the database of Changjiang Securities, an investment bank in China, they were not open to the public. For China, we had all 72 measurements, but for France and Japan we only had 64 measures since we didn't find the data after May 2019.

Figure 1. NEV sales in China during 2015-2019

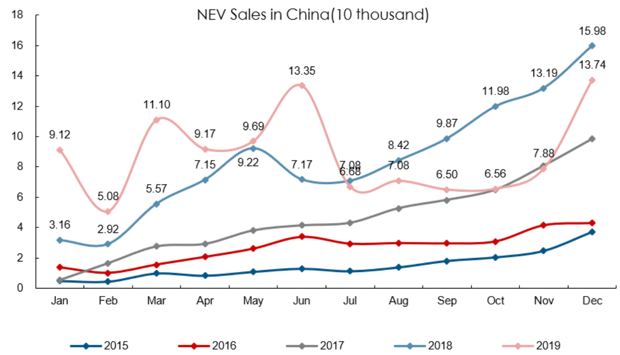


Figure 2. NEV sales in France during 2015-2019

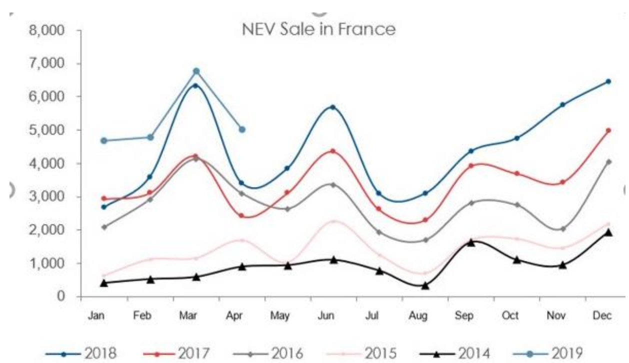


Figure 3. NEV sales in Japan during 2015-2019

3. Methods

Packages: We used the following R packages in our analysis: “dplyr”, “forecast”, “Kendall”, “tseries”, “smooth”.

Trend & Seasonality Analysis: The auto-correlation function (Acf()) and the partial auto-correlation function(Pacf()) were applied for each dataset to test the dependency or seasonality patterns. After that, we used decompose() function to decompose the datasets into seasonal, trend, and random components. If there is a clear seasonality pattern in the dataset, we will remove it in order to conduct ARIMA model. We also ran Augmented Dicky Fuller (ADF) test and Mann-Kendall test to determine the type of trend, stochastic or monotonic. Firstly, we removed the seasonal components if any; Secondly, we carried out ADF test to know whether there is a stochastic trend; Thirdly, if the series did not have a stochastic trend, we conducted MK test to know if it's a monotonic or stationary trend.

Forecasting models: We conducted forecasting based on several different models including ARIMA (Autoregressive Integrated Moving Average), SARIMA (Seasonal Autoregressive Integrated Moving Average), Exponential smoothing, Naive, Simple Moving Average and BSM (Basic Structural Model). After that, we use accuracy test to compare the models we conducted and choose the model with the highest accuracy level. In order to determine the EV market share, we assumed that total car sales remain unchanged from year to year. We used the total car sales for a country to calculate the proportion of EVs sold in the forecasting year.

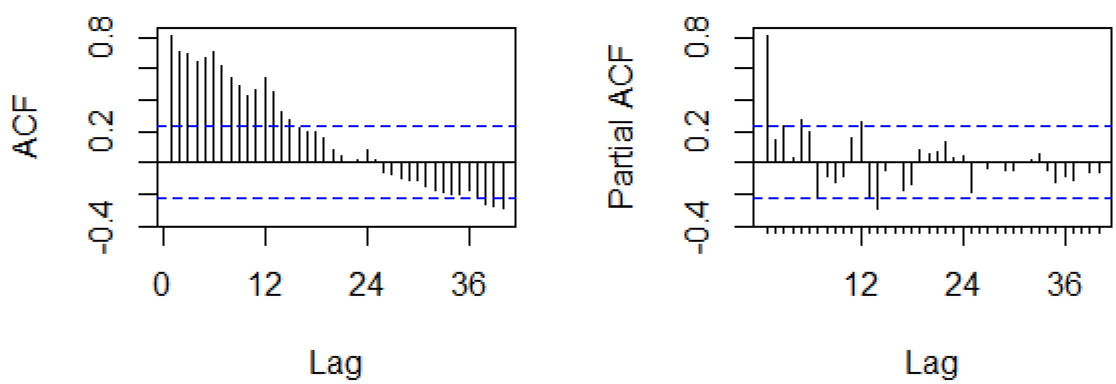
4. Results

4.1 China

Trend & Seasonality

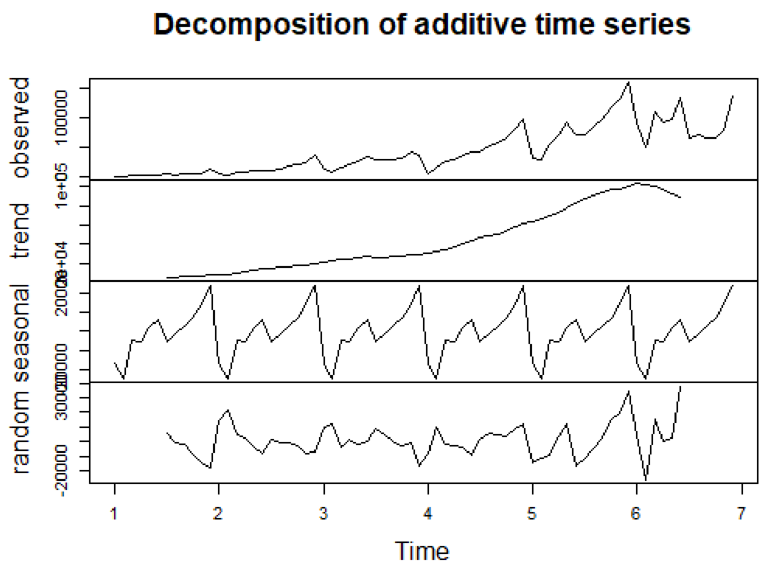
The ACF and PACF plots were plotted for China's NEV sales data. The slow decay of the ACF suggested that it was not a white-noise series. In contrary, the series was autoregressive and the value at a point was dependent on previous values. Besides, no seasonality has been observed based on ACF. For the PACF, there was a cutoff at the 1st lag.

Figure 4. ACF and PACF plots for China's EV Sales



The p-value from ADF test was 0.28, indicating there was a stochastic trend. According to trend component in the decomposition plots, it is worth noticing that there was an upward trend at first, but it decreased at the end of our data series. This tendency was caused by subsidy cut in the 2nd half year of 2019, which may influence the results of our models.

Figure 5. China's EV sales from January 2014 to December 2019 and its time series components



Forecast

We tried several models to forecast China's NEV sales in the next five years, including ARIMA(1,0,0), ARIMA(1,1,2)(0,0,2), BSM, simple exponential smoothing and seasonal naïve model. According to the accuracy test, the best model here was BSM model, which had the least MAPE value.

Table 2. Comparing forecast accuracy metrics of models predicting EV sales

Models	**ME**	**RMSE**	**MAE**	**MPE**	**MAPE**
ARIMA(1,0,0)	-27436.37	39579.37	34428.88	-44.38	49.56
BSM	5868.24	34475.97	26568.99	-1.91	29.26
ARIMA(1,1,2)(0,0,2)	18383.52	43028.83	35377.83	10.82	39.91
Simple exponential smoothing	-4419.35	27952.67	24251.58	-15.22	30.65
Seasonal naive	4200.27	37072.44	28269.55	-5.13	32.98

Based on the results from BSM model, we tried to answer the question we proposed: Can China meet its NEV goal (25% xEVs market share by 2025)? In order to calculate the NEV market share in 2025, we assumed that annual vehicles sales remain unchanged in 2025 (about 26mn in 2019). According to the BSM model, the NEV sales in 2025 would be 3,175,311, and NEV market share would be about 12%. As a result, we concluded that China cannot meet its NEV goal.

Figure 6. Forecast results from BSM model for China's EV sales

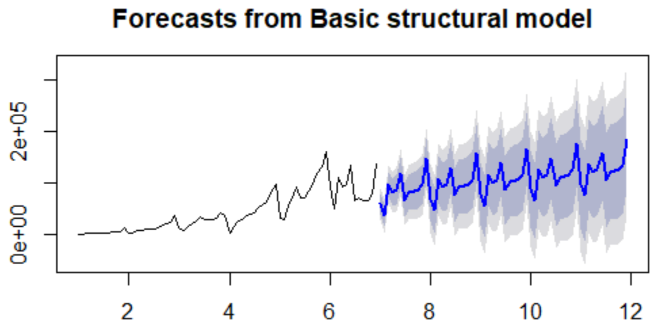
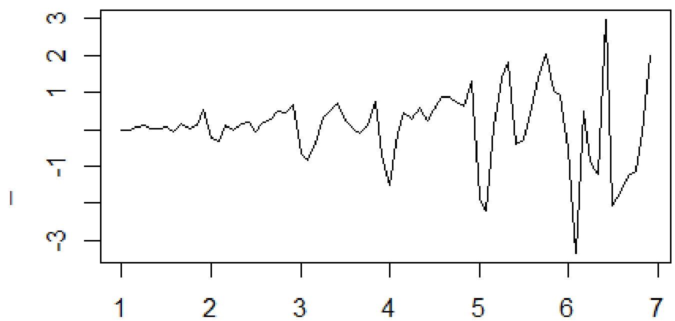


Figure 7. Residual plots from BSM model for China's EV sales



4.2 Japan

Trend & Seasonality

The autocorrelation (ACF) and partial autocorrelation (PACF) were plotted (Figure 9) for Japan's EV sales data from January 2014 to May 2018. The last year was left out for checking the accuracy of our forecasting models. After examining the ACF and PACF plots it was concluded that the time series did not have any autoregressive component or any seasonal component.

For performing trend analysis, the augmented Dickey-Fuller test (ADF) was used to identify the type of trend present in the time series, if any. The ADF test results ($p = 0.39$) came out to be non-significant, therefore, failing to reject the null hypothesis meaning that the series had a significant stochastic trend. This is also evident from the decomposition plot (Figure 8). The first half of the time series had a slight downward trend while the other half had a strong upward trend until it plateaued towards the end.

Figure 8. Japan’s EV sales from January 2014 to May 2018 and its time series components

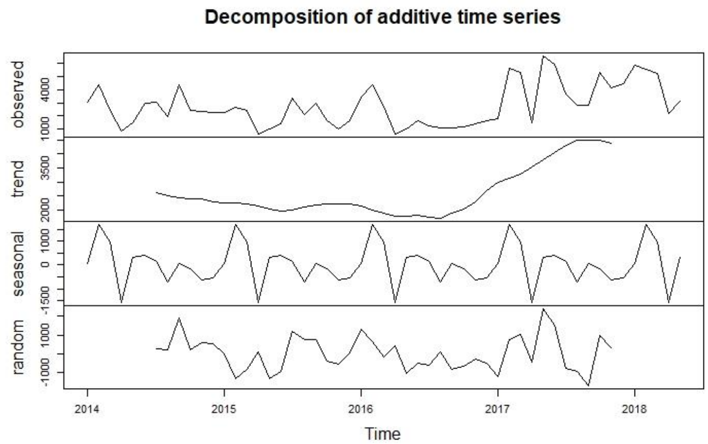
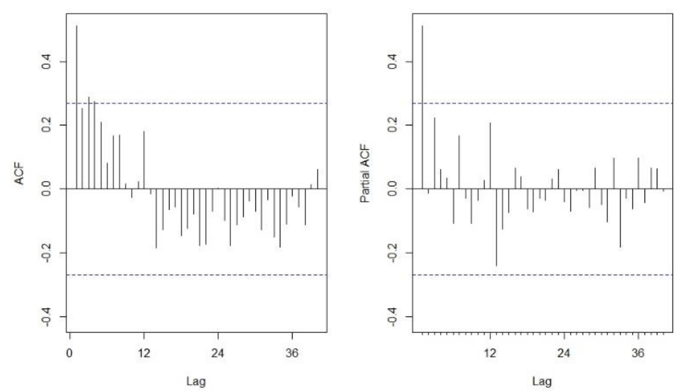


Figure 9. ACF (left) and PACF (Right) plots for Japan’s EV sales



Forecast

The market share of the EVs in Japan was forecasted using 2 State Space Models. The first model (SSM - I) was selected to minimize the mean absolute percent error when testing its accuracy with the test dataset from May 2018 to May 2019. However, the residual plots revealed an upward trend. Therefore, the second model (SSM - II) was developed to improve the randomness of the residuals around the zero line (Figure 11).

Japan had 5,195,216 car sales in the year 2019. Using the 2019 value, it was found that, based on the projections of SSM – I, on average the EV market share would constitute a mere 0.95% of the total automobile sector by 2040. Based on SSM – II, this number increased to only 5.09% percent of EV market share. Therefore, based on the State Space Models, Japan is unlikely to meet its goal of selling 100% electric vehicles by 2040.

Figure 10. Forecast results from the two State Space Models for Japan's EV sales by 2040

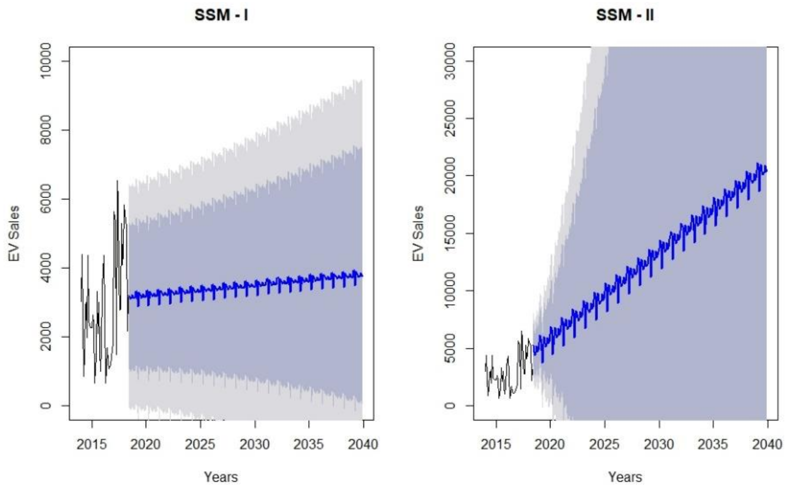
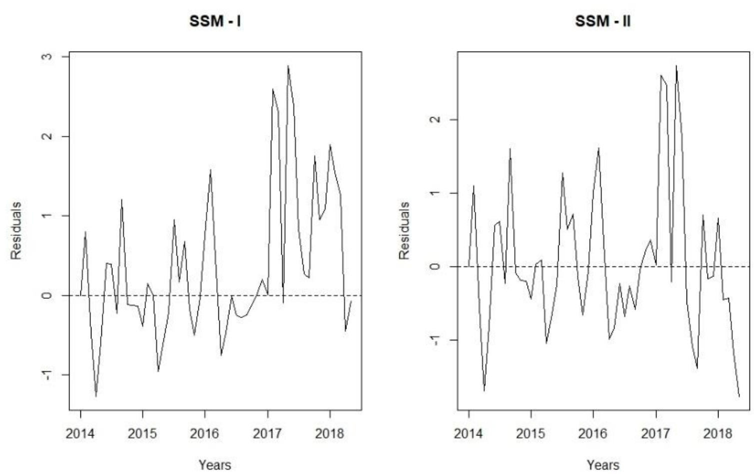


Figure 11. Residual plots for SSM – I and SSM – II

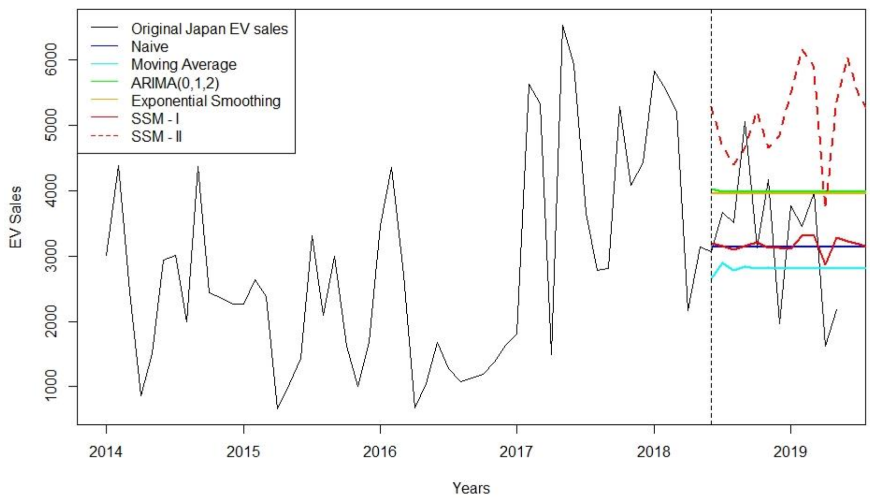


Naïve forecasting, simple moving average, ARIMA(0,1,2) and exponential smoothing models were also tested for their efficacy to predict the market share of EVs by 2040. However, due to the stochasticity of the short duration time series and the long future forecast, they did not perform well and converged to a constant mean value. The accuracy of each model is presented in table 3 and figure 12.

Table 3. Comparing forecast accuracy metrics of models predicting EV sales

Models	**ME**	**RMSE**	**MAE**	**MPE**	**MAPE**
Naïve	145.38	917.08	719.54	-5.04	25.71
Moving Average	476.67	1026.61	889.02	6.01	28.47
ARIMA(0,1,2)	-709.88	1151.02	901.21	-33.65	37.55
ETS	-673.05	1128.23	876.24	-32.42	36.59
SSM - I	116.25	942.15	731.35	-6.33	26.50
SSM - II	-1823.29	2233.28	1860.94	-73.56	74.51

Figure 12. Comparing accuracy of models predicting EV sales from June 2018 to May 2019

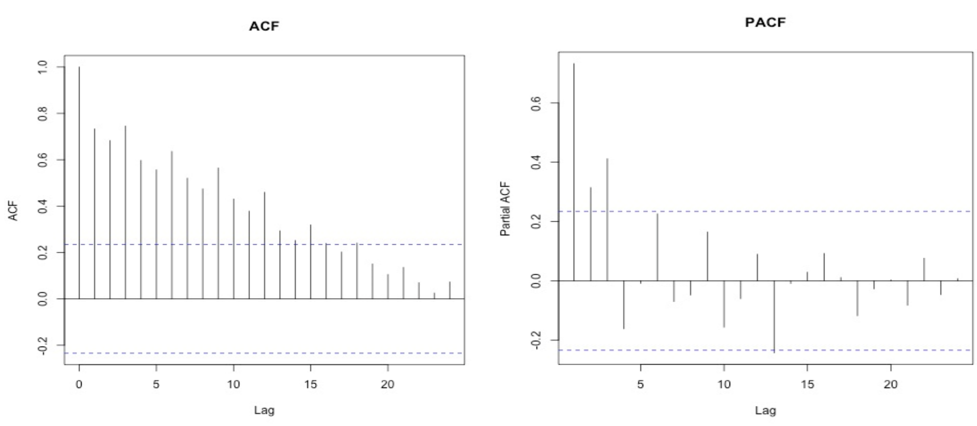


4.3 France

Trend & Seasonality

Below are the autocorrelation function and partial autocorrelation plots for France's EV sales from 2014-2019. The strong autocorrelation observed and gradually decay indicate the series is not white noise, but rather an autoregressive series. The three significant lags on the PACF, with a cutoff on the fourth, indicate the order of this autoregressive component to be 3. There is no seasonality observed in the data, but it does appear the autocorrelation consistently shows a spike every three months, suggesting some adjacent monthly sales are more dependent on one another than others.

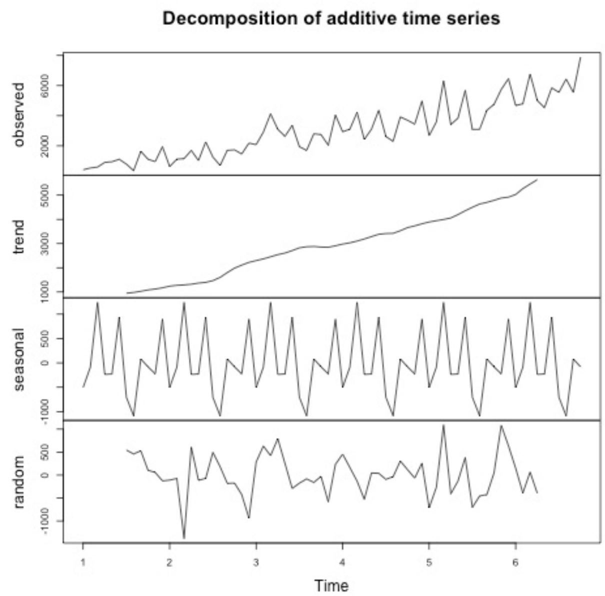
Figure 13. ACF (left) and PACF (Right) plots for France's EV sales



The Augmented Dickey-Fuller test for this time series yielded a p-value of 0.02782, meaning the series is stationary and independent of seasonality. This is likely because while the data is cyclical, the cycle does not appear to have consistent repetitiveness, and there for the time in which the series is observed cannot be used to predict its behavior. This stationarity means the data does not require any differencing before being used in ARIMA models. The Mann Kendall Test yielded a p-value of < 2.22e-16 and a tau of 0.747, meaning there is monotonic trend that is increasing.

The Decomposition of the time series below corroborates the observations in the ACF and PACF that this trend is not seasonal. The seasonal component of the trend assembled by the Decomposition function does show a somewhat cyclical rise and fall, but not pertaining to any possible seasonal patterns. This is likely a result of the function attempting to assemble a seasonal component from the random component. The trend appears gradually upward sloping, consistent with the Mann Kendall observations. There is a marked increase in the slope in recent years. While no significant policy shift occurred in later years, the increased slope is likely a result of the convergence of cheaper EV technology and France having a large enough charging infrastructure to make EV ownership practical.

Figure 14. France’s EV sales from January 2014 to May 2019 and its time series components



Forecast

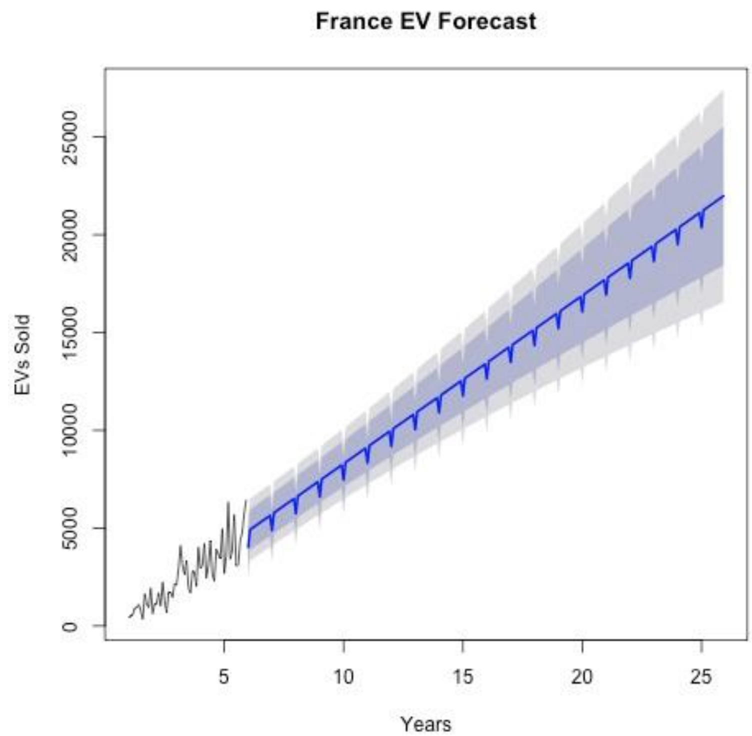
As seen below in the model comparison, the Basic Structural Model had the lowest MAPE and was therefore judged to be the best for forecasting France’s future EV sales. The ARIMA model showed similar promise as its residuals appeared to be white noise, but the MAPE has significantly higher than the BSM.

Models	**ME**	**RMSE**	**MAE**	**MPE**	**MAPE**
ARIMA (2,1,1)	-745.6462	1254.234	1147.013	-15.98957	21.68155
BSM	635.5569	1210.65	865.7372	8.591104	13.5425
Simple exponential smoothing	338.9209	914.4999	693.3613	2.88811	29.54499
Naive	-681.8182	1201.541	1000	-14.95871	19.111139

Below is the resulting State Space model used for forecasting France’s EV future. The projection looks relatively stable, given the extreme time horizon. One anomalous trend observed is the repeated decline in sales throughout the line. This may be an effect of consistently lower vehicle sales in France in the months of July, August (Statista, 2019). The decline in July and August is logical given new models of cars typically debut in the early fall, so consumers would be more hesitant to purchase immediately leading up to that. However, this decline is buffered on either side by typically high sales in May and September, likely accounting for consumers purchasing a car after tax rebates or purchasing the newest model of a given vehicle. These anomalies likely have a complicated interaction with EV sales as the options for EVs are more limited, and therefore we can expect to see more supply-side effects in their sales.

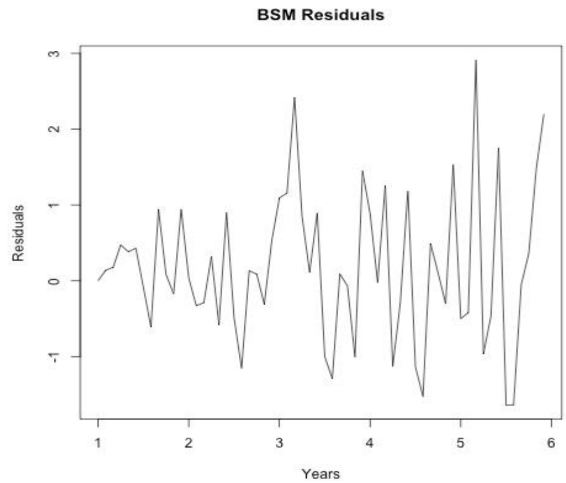
Under the BSM model, France will be far from fulfilling its goal of 100% EVs by 2050. This model predicts EV sales will be 299,677 annually by 2040, which would make up just 13.8% of the 2,173,481 cars sold in the country in 2018.

Figure 15. Forecast results from BSM State Space Model for France's EV sales by 2040



Below are the residuals for the BSM model, which appear to be largely white noise and show little remaining trend not captured.

Figure 16. Residual plots from BSM model for France's EV sales



5. Conclusion and limitations

None of the countries we forecasted for was on track to meet its EV sales goal. China and France are similarly behind their goal, as their projected EV sales are 12% and 13.8% of total market for their target years. Japan especially will need meaningful policy change if it expects to meet their 2040 goal. Our projections indicate their current trajectory will yield EVs as 5% of total vehicle sales in 2040, as opposed to their 100% goal.

A significant limitation to this paper was the limited dataset given the distant time horizon, especially with Japan and France. Because of the novelty of the electric vehicle market, several months of data can prove crucial in the trajectory of the market. Additionally, because of their dependence on government incentives, EV sales can be extremely volatile when policies shift. For example, in March 2020, China extended their electric vehicle subsidies program that was previously being phased out (Berman, 2020). We would expect to see a resurgence in EV sales for 2020 that would significantly affect our projections for their 2025 goal. Similarly, in December 2019, France raised the maximum price of incentives toward new EVs (Randall, 2019). This move, once manifested in early 2020 sales, would likely significantly impact our projections in a favorable way for France. Further data would have also given us the chance to preform change point analysis and better incorporate policy effects in our projections.

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