2024 Data Challenge: Electric Vehicles

Jess Brandvold, Chen Chen, Francesca Hillman

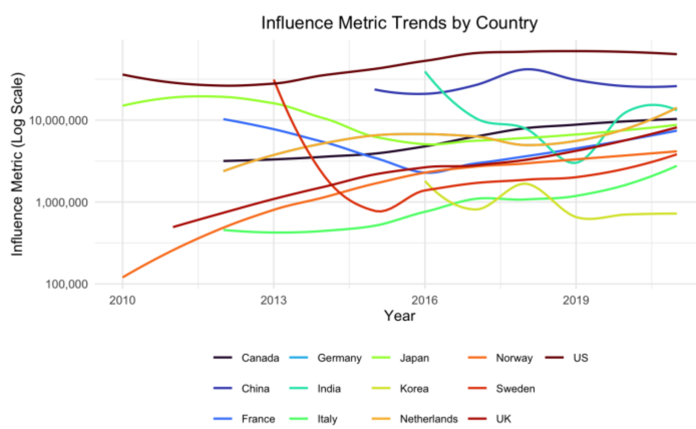
We are analyzing electric vehicle (EV) data, which measures the amount of EVs sold, electric vehicle charger data, which measures the number of slow and fast charging points, and energy production data, which measures total energy production in gigawatt hours, all by country, from 2010-2021. To answer the questions, "How might energy production trends be related to the adoption of EVs?" and "What factors are the best predictors of future EV adoption? Which countries are best positioned to embrace the transition to EVs?", we performed regression analyses, hypothesis testing, and visualized our findings by graphing the correlations between the different datasets.

The top 10 countries with the highest EV sales – specifically battery electric vehicles (BEVs) and plugin hybrid electric vehicles (PHEVs) – are China, the USA, Germany, the UK, France, Norway, the Netherlands, Japan, Sweden, and Canada; the top 10 countries with the highest EV stock being identical except for the rankings. Of these countries, energy production and EV sales were positively correlated in China (0.54), the Netherlands (0.46), Norway (0.32), Sweden (0.59), and the U.S. (0.08), with EV sales increasing as total energy production (in GWh) increases. This makes sense, as more energy is needed to support an increasing number of electric vehicles. The countries with a negative correlation between EV sales and energy production are Canada (-.59), France (-0.30), Germany (-0.53), Japan (-0.13), and the U.K. (-0.60), with EV sales decreasing as total energy production (GWh) increases. Electric vehicles typically consume less energy than vehicles powered entirely by gas and also waste less energy when in operation (Kirk). Thus, this negative correlation may be explained by the fact that EVs are more efficient, so these countries don't need to produce as much energy for EVs to get the same outcome as regular vehicles, and even operate for longer periods. Or else, EVs are indirectly saving energy in different ways. This indicates that North America, Europe, and East Asia are more accepting of green technology, and many countries are actively pushing towards higher rates of EV adoption and increased sustainability measures. For instance, the U.S. provides tax credits for households who buy or are planning on buying and EV (IRS). A factor that may need to be considered is the fact that, during the COVID-19 pandemic in 2020 and 2021, global energy demand declined, energy production decreased, and many countries had not fully recovered to pre-pandemic energy production, which is reflected in this data (Hoang et al.).

We theorized that the best predictors of future EV adoption would be a country's number of charging stations and their energy production: countries with infrastructure to support EVs, which need to be charged like regular cars need to be refueled, may be more likely to adopt more EVs, as charging is more convenient. Countries with higher energy production may be able to support the increased strain EVs may put on the grid, as they already have massive sources of energy. We performed a regression analysis and hypothesis test of the number of EVs against the number of charging stations and of energy production for each country in our top 10 EV sales list. Our null hypothesis was that there is no relationship between EV sale data and the other 2 datasets. Our alternate hypothesis was that there is a positive relationship. The countries with statistically significant regression analyses against energy production at alpha = 0.005 are Canada (p-value = 0.0002), Sweden (0.0003), and the U.K. (0.0001). This indicates that, for these countries, there is a relationship between the number of EVs sold and energy production. There were no countries with statistically significant regression analyses with regard to the number of charging stations. This method is somewhat limited, because we cannot predict how many charging stations will be built in the future, nor can we take other factors into consideration, such as policy and public perception of EVs. This method also doesn't take into account non-linear relationships; EV sales have grown much in the last few years.

To find the best predictor of future EV adoption (energy production vs EV charging points and energy production vs EV sales), we created a new dataset consisting of the world's total EV sales per year, the world's total energy production per year, and the world's total number of charging points per year, then calculated the correlation between total EV sales and total energy production and the correlation between total EV sales and total charging points. EV sales and charging points had a higher correlation (0.83) than sales and energy production (0.71). This is not necessarily what we expected based on the country-only data. We then performed another hypothesis test on this world data, with our null being that there wasn't a relationship between the datasets and alternate being that there was a positive relationship between the datasets. Based on a multivariate linear regression of total sales per year vs total energy produced per year and sales per year vs total number of charging points per year, we found that, at level = 0.01, only the number of charging points was statistically significant with respect to EV sales, with a p-value of 0.00030 (total electricity had a p-value of 0.072). So, we concluded that generally, the best predictor of future EV adoption is the number of charging points.

To determine which countries are best positioned to embrace the transition to EVs, we created a new metric by which to compare the countries. This 'Influence Metric' divided total electricity production per country by total charging points per country, which showed how much electricity was available per charging point. We then multiplied that number by total EV sales per country, which gave us an idea of how effectively a country's infrastructure supported EV adoption. The countries we tested by this metric were the 10 countries with the highest EV sales, as well as South Korea, India, and Italy, which all appeared somewhere in the top 10 countries with the highest energy production or most EV chargers. As seen in the graph to the right, the countries with the highest Influence Metric (as of 2021), and thus the countries we predict to be best positioned to embrace the transition to EVs, are the US, China, and the Netherlands. This indicates that these 3 countries are likely to adopt EVs sooner than other countries, and may lead the world in the amount of EVs adopted. These findings could be due to various reasons besides the number of chargers and increased energy production, such as government policy, public perception of EVs, and cost (Pamidimukkala et al.). This metric and graph are also somewhat limited, as it could turn out that EV vehicle growth becomes unexpectedly high or low.



Overall, we recommend that countries with high Influence Metrics first transition to EVs. If other countries want to transition to do the same, it may be useful to start building up EV infrastructure first. As of 2021, EV usage is not very common on a wide scale, so EVs don't make up much of a country's total energy production. However, energy production is still an important factor to consider in the future. As EVs become more popular, countries still need to account for this potential strain on the energy grid by strengthening their energy production infrastructure.

Works Cited

"Clean Vehicle Tax Credits." *Internal Revenue Service*, www.irs.gov/clean-vehicle-tax-credits.

Hoang, Anh Tuan et al. "Impacts of COVID-19 pandemic on the global energy system and the shift progress to renewable energy: Opportunities, challenges, and policy implications." *Energy policy* vol. 154 (2021): 112322. doi:10.1016/j.enpol.2021.112322

Kirk, Karin. "Electric Vehicles Use Half the Energy of Gas-Powered Vehicles." *Yale Climate Connections*, 13 Feb. 2024, yaleclimateconnections.org/2024/01/electric-vehicles-use-half-the-energy-of-gas-powered-vehicles/.

Pamidimukkala, Apurva, et al. "Barriers and Motivators to the Adoption of Electric Vehicles: A Global Review." *Green Energy and Intelligent Transportation*, vol. 3, no. 2, Apr. 2024, p. 100153, doi:10.1016/j.geits.2024.100153.