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What are the economics of electric vehicles? Although an electric vehicle (EV) costs more than an equivalent automobile with an internal combustion engine (ICE), a buyer benefits from federal and provincial subsidies that close the gap between the EV and its ICE equivalent. Of course, that is precisely the idea–to encourage people to purchase an EV rather than an ICE. When faced with the alternative of buying an EV versus an ICE, the purchaser will also have been influenced by government policy announcements to ban future sales of ICEs in the next decade, which casts doubt about the future serviceability of ICE vehicles.

The purpose of this paper is to examine some of the issues related to policy concerning electric vehicles. In particular, it is to demonstrate that a simple policy of subsidizing EVs can be much more complex than anticipated by policy makers.

The unanticipated cost of a simple consumer subsidy

Suppose the supply and demand curves for electric vehicles are given in Figure 1. Equilibrium occurs at point *e* where the price for an electric vehicle is P^* and the number sold is given by Q^*. If the government provides a per unit subsidy to consumers of amount $P^*–P_S$, the effective price facing the consumer is P_S thereby leading to an increase in demand to Q_S. The supply price (=marginal cost of production) to produce Q_S amount of EVs is given by c. Thus, to avoid the shortfall between demand and supply, given by $Q_S – Q^*$, producers will also need to be subsidized. In essence, the required subsidy will be much larger than anticipated; consumers will receive an anticipated subsidy given by the area bounded by P^*P_Sba, but producers will require a subsidy given by cP^*ad.

In practice, the subsidy provided manufacturers takes a variety of different forms. Some companies have been provided carbon offset credits that they can sell in carbon markets or directly to producers of ICEs. Sale of carbon offset credits to other automobile manufacturers facilitated the success of Tesla, for example. Other EV producers were provided subsidies to establish manufacturing facilities or develop battery production.

Finally, both subsidies will need to be increased if the demand function for EVs is shifted to the right because of changes in consumer tastes that favor electric vehicles. Government policies, social media, advertisement, and other factors have likely led to a shift from ICEs to EVs. If the per unit subsidy remains fixed, the cost to the treasury will increase, while the increase in the subsidy required at the manufacturing level depends on the elasticities of supply and demand.

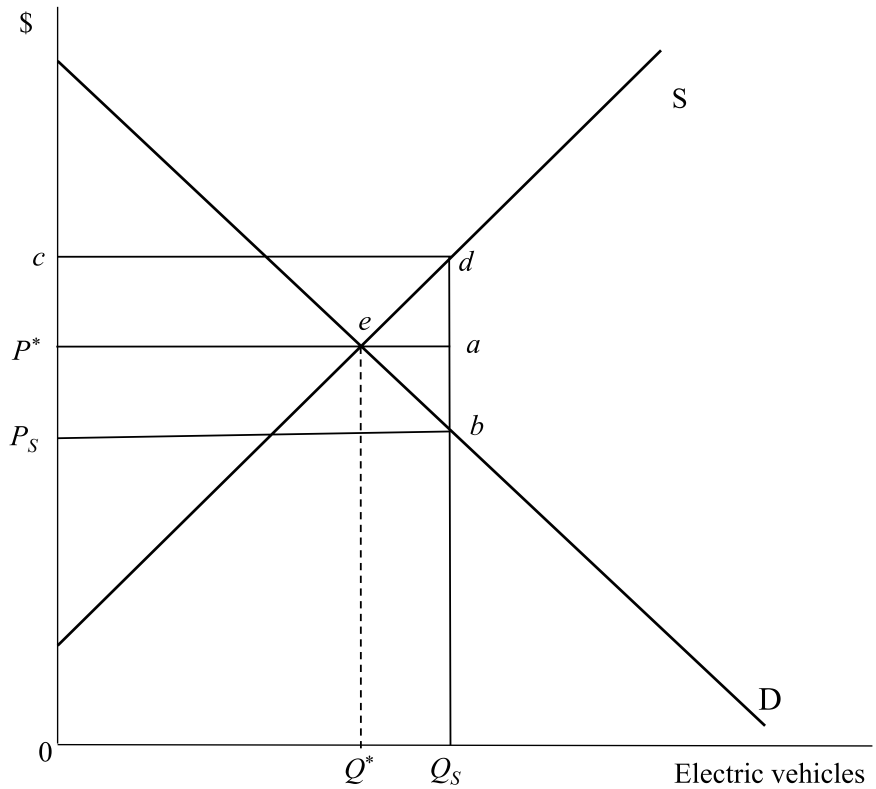

Figure 1: Economics of electric vehicle subsidies

What determines purchases of EVs?

Empirical research indicates that there are five major factors in determining whether buyers purchase an EV: per capita income, the price of gasoline, the availability of charging stations, the subsidy or actual price difference between the EV and its ICE alternative, and weather factors (e.g., how cold it gets). Research conducted by Xia (2024) examined the effect that different explanatory variables have on EV purchases across different cities within Canada. As indicated in the table below, after a person's income, the price of gasoline and rebates (subsidy) were found to be the most important determining factors, followed somewhat closely by the likelihood of very cold temperatures at the sales location and much less so the availability of charging stations. All five factors were found to be statistically significant determinants of EV purchases.

Explanatory variable	EV purchases
GDP	1.2406
Fuel price	0.2438
Rebate	0.2016
Minimum temperature	0.0811
# of charging stations	0.0006

Source: Xia (2024). Variables in standardized form, with other explanatory variables not indicated.

Direct effects on the economy

Now consider the costs that EVs impose upon the economy, in addition to the costs of rebates. In July 2023, the price of gasoline in Vancouver, British Columbia, was close to C$2 per liter, or about US$5.50 per US gallon. In Bellingham, a gallon of gasoline cost about US$3.95 per gallon. A major component of the difference between the Canadian and the American prices is attributable to a carbon tax, which is not imposed in the US, and (primarily) fuel taxes, some of which are meant to enhance and maintain transportation infrastructure; tax revenues are also used to pay for some of the costs of public transportation.

Fuel taxes are meant to incentivize people to drive less and rely more on public transportation, thereby reducing congestion as well as CO_2 emissions. The driver of an electric vehicle does not pay fuel taxes. EVs are exempt from fuel taxes, often benefit from low electricity rates (particularly in jurisdictions such as BC and Quebec that rely on hydroelectricity) and may benefit from unrestricted access to high-occupancy lanes (HOVs). Overall, these incentives increase driving distances and reduce reliance on public transportation and other forms of transport, including walking and cycling. Thus, government policies related to EVs generally lead to greater congestion and deterioration of road infrastructure due to an increasing number of heavier battery-powered vehicles.

Current policies that incentivize EV use lead to reduced tax revenues, increased per passenger costs of public transportation (as ridership goes down), and greater expenses to enhance and maintain transportation infrastructure. At the same time, it is the poorest in society that are hurt the most. The poor are least likely to purchase EVs, but they are the ones who are most hurt by higher taxes on gasoline, and especially carbon taxes, as transportation forms a larger component of their budget than those who are more well to do.

In addition to the forgoing local effects, EV policies have economy wide and international impacts. Canadian policies concerning electric vehicles constitute a subsidy to purchase a commodity produced in China, since China is the largest manufacturer and exporter of EVs. For example, China exports Tesla's model 3 and model Y vehicles to Canada. Canadian automobile manufacturers, which produce ICEs, experience a reduction in sales with accompanying job losses. This is illustrated in Figure 2. Based on the latest annual statistics for 2022, production of vehicles declined by 47.0 percent over the past decade. While the Covid-19 pandemic had some impact, vehicle production has lagged since the pandemic ended, with production down by 35.9% in 2022 compared to pre-pandemic (2019) production.

Although automobile manufacturers are encouraged to switch from ICEs to EVs, often requiring subsidies to make the switch, fewer workers are needed to produce EVs. In addition, the largest component of the manufacturing process, namely the battery, will likely need to be imported from China. Even if batteries are produced in North America, battery components will come from China as it has cornered the market for cobalt and lithium.

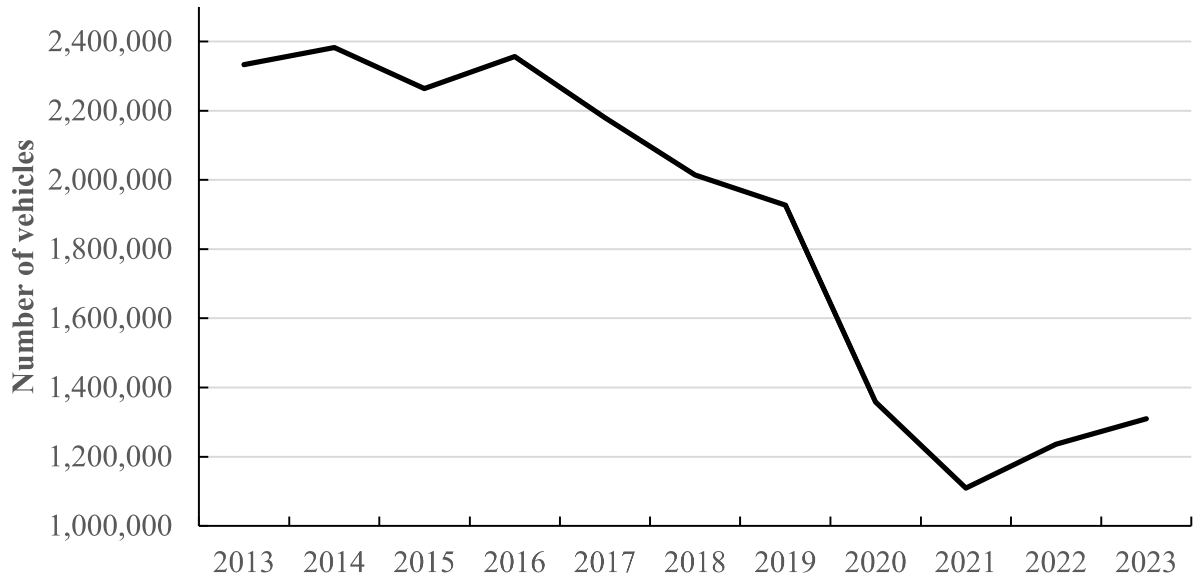

Figure 2: Light Duty Motor Vehicle Production, All Types, Canada, 2013-2022
[The total includes passenger vehicles and light commercial vehicles; 2023 projected.]
Source: https://www.cvma.ca/industry/stats/ and
https://www.statista.com/statistics/204346/comparison-of-canada-vehicle-production/

Canada currently subsidizes foreign production of electric vehicles and their components. Not only are there direct subsidies to purchasers of EVs, but there are many types of indirect subsidies that include loss of fuel-tax revenues, extra expenses for transportation infrastructure, enhanced congestion, and, perhaps, even subsidies to automobile manufacturers and/or their workers to enable them to transition towards a new reality in the automotive sector. Further, rising prices of gasoline and diesel fuel increase costs of moving freight, which result in higher prices for all kinds of products. The overall impact is a higher rate of inflation, which also tends to harm the poor more than those who are better off.

There remains a more insidious subsidy, however. One would expect the value of Chinese currency to rise relative to the Canadian dollar thereby making EVs more expensive and less likely to be purchased by Canadians. To maintain the value of the Canadian dollar and an exchange rate that keeps the prices of imports low (thereby mitigating inflation), it is necessary for Canada to export goods and services—other countries including China need to purchase something from Canada. Given the structure of the Canadian economy, the most important exports are energy goods (principally oil and coal, but also uranium), farm commodities (e.g., wheat, canola), and minerals (e.g., potash). While manufactures and services are also exported, the other 'goods' that might be desired by foreigners are Canadian debt, properties, and businesses (foreign direct investment). These constitute claims on future incomes generated by Canadians or, in the case of property, an additional contributor to current inflation.

Global impacts

And then there are the global externality costs. According to the International Energy Agency, EVs require 173 kilograms more minerals per vehicle than an ICE. They require more than double the copper, an increasingly scarce metal that is also needed for renewable electrical infrastructure, such as wind turbines and transmission lines. EVs also require some 9 kg of lithium, 40 kg of nickel, 12 kg of cobalt, and other rare earth minerals, which are not required for the construction of ICEs. Cobalt is mined by child laborers in the Congo, while vast amounts of water are required to mine lithium in South America resulting in severe environmental degradation.

If we consider the impact on global CO_2, we find mixed results. Chinese manufacturing employs electricity from coal to a much greater extent than is the case in Canada; indeed, Canada intends to eliminate coal-fired power in the very near future. Automobile production is likely more efficient in North America, requiring less energy, than in China—although this conclusion may no longer hold as China appears to dominate the production of EVs. Nonetheless, by importing EVs from China, more CO_2 enters the atmosphere compared to what would be the case if comparable, or even ICE, vehicles are produced in Canada. Offsetting this to some extent is the fact that EVs in Canada, particularly in BC and Quebec, rely on electricity produced from renewable sources, primarily hydraulics. To the extent that electricity continues to be produced from coal or natural gas, the benefits of switching to EVs would be much smaller. As it is, the global benefits of switching to electric vehicles are very small when considered in the context of total primary energy consumption.

Increased electricity generation

There is a dearth of studies that consider the effect on extant electricity grids from an increased demand from EVs. The results of one study are provided in Table 1. These indicate that large investments in generating capacity would be required. While it would be a simple task to build gas plants, the construction of hydroelectric facilities like BC's Site C could not be built in the next decade; after all, environmental and other opposition to Site C led to delays of some 40 or more years. Likewise, it might be difficult to construct sufficient wind turbines to meet the growing demand for electricity by EVs for various reasons, including 'not-in-my-backyard' (NIMBY) opposition to turbines and transmission lines, and the need for gas plants to backstop intermittent wind.

Conclusions

Research suggests that, based on lifecycle analyses and the makeup of the average grid, the benefit from EVs is smaller than anticipated. Compared to an equivalent ICE vehicle, an EV reduces CO_2 emissions by perhaps as little as 15% after 200,000 km, depending on the source of energy used to generate electricity. Savings of this magnitude could perhaps be realized through future improvements in ICE technology. When lifecycle emissions are counted, the emission-reductions benefits might be much smaller depending on where batteries and vehicles are built and how much fossil fuels are burned in mining cobalt, lithium, and other minerals. It also depends on lifetime emissions in rebuilding local electricity grids and producing the power needed to fuel EVs.

Table 1: Estimated impact EVs have on electricity loads and required increase in three types of generating assets for meeting projected future load, selected jurisdictions.

Item	Canada[d]	British Columbia	Ontario	Quebec
Hourly increase (MW)	1,280.95	152.38	492.72	310.09
Annual increase (GWh)	11,221.2	1,334.8	4,316.2	2,716.4
Hydropower dams[a]	10	1	4	2
500-MW capacity gas plants[b]	13	1	5	3
Wind power capacity (MW)[c]	17,381	1,956	6,517	4,195
Number of 3.5 MW turbines	4,966	559	1,862	1,199

[a] Number determined by dividing annual increase (GWh) by 5100 GWh projected annual output of Site C.
[b] Determined by dividing annual increase (GWh) by 3942 GWh assuming 500-MW capacity plant operates 8760 hours at 90% capacity.
[c] Assumes that wind turbines have a capacity factor of 25% but no account is taken of the effect intermittency has on other grid assets.
[d] Excludes Alberta, Nova Scotia, and Newfoundland and Labrador for which no information on EV sales is available.
Source: van Kooten and Clarke (2023)

Finally, there is increasing concern about battery fires and other problems with EVs that have concerned insurance companies. For example, as of late October 2023, there have been 204 confirmed Tesla fires with 71 fatalities (https://www.tesla-fire.com/). Further, when an EV is involved in an accident, the battery is frequently damaged requiring the vehicle to be 'quarantined'—stored away from other vehicles to prevent spread of a potential fire. This adds to repair costs. Insurance rates for EVs have been increased by approximately $1600 per year by the Insurance Corporation of BC (ICBC). Assuming a price of $2/liter for gasoline and an ICE efficiency of about 7.2 km per 100 km, an equivalent-size EV one would need to be driven more than 11,000 km per year before it would benefit from fuel-cost savings, and that assumes zero cost for electricity.

In conclusion, it might be useful to rethink the way in which the transition from fossil fuels to renewable energy occurs in the transportation sector.

References

van Kooten, G. Cornelis and Colton Clarke, 2023. Electric Vehicles and the Demand for Electricity. December. REPA Working Paper 2023-01. Department of Economics, University of Victoria, Victoria. https://web.uvic.ca/~repa/publications.htm.

Xia, Chenyang, 2024. Exploring the Determinants of Electric Vehicle Adoption in Canada: A Multi-City Study. REPA Working Paper 2024-02. Department of Economics, University of Victoria, Victoria. https://web.uvic.ca/~repa/publications.htm.