

EV Market Analysis Using Python and SQL

Kajal Darbe

Department of Science and Technology,

G. H. Rasoni Skill Tech University, Nagpur, Maharashtra, India

Abstract

I design a structural model of demand for electric vehicles and the supply of a public charging infrastructure by forward-looking local planners. Using Canadian data, I study the cost-effectiveness of electric vehicle incentives in this context. Subsidizing electric vehicle purchases almost doubled adoption in Quebec but had only a small impact on network provision. I conduct a rigorous cost-benefit analysis to study the environmental performance of Quebec's rebate program. I find that the marginal abatement cost of emissions is substantially higher than the social cost of carbon, suggesting that policymakers in Quebec over-invested on electric vehicle incentives.

KEYWORDS: *Electric Vehicles, EV Market Analysis, Data Analytics, Python, SQL, Time Series Analysis, Trend Analysis, Data Visualization, Predictive Modeling, Sustainable Transportation*

1. Introduction

Electric vehicles (EV) constitute one of the most promising innovations for lowering carbon emissions from the transportation sector, as long as clean energy production is available. Toulouse School of Economics, jean-francois.fournel@tse-fr.eu. I am grateful to Laura Lasio for her commitment and continuous support throughout this project. I would also like to thank Hassan Bencheikroun, Pierre Dubois, Isis Durrmeyer, John Galbraith, Andrei Munteanu, Kevin Remmy, Mathias Reynaert, Mario Samano, Katalin Springel, participants at the CIREQ Seminars, participants at the TSE Winter IO Workshop, participants at the Workshop on Policy and the Automobile Market Transition, and two anonymous referees at the Young Economist Symposium for their generous feedback. Above all, I would like to thank my friends Jean-Louis Barnwell, Léa Bignon, Julien Neves, and Laetitia Renée for their unwavering support. I acknowledge the financial support of the Fonds de Recherche du Québec Société et Culture (FRQSC), the Social Sciences and Humanities Research Council of Canada (SSHRC), and the European Research Council under grant ERC-2019-STG-852815 "PRIDISP". All remaining mistakes are my own.

Several barriers prevent the widespread adoption of this technology. The high initial purchase cost or the low availability of recharging sites may lead potential buyers to select internal combustion engines over electric ones, even if they place a high value on reducing their carbon footprint, factor in future fuel cost savings, or the lower maintenance costs associated with driving an electric vehicle. At the same time, if few people own and use an electric vehicle, there is little incentive for network operators to invest in local charging infrastructures. This slows down the transition to electric vehicles. Policymakers have introduced a wide range of incentives to convince consumers to adopt this new

technology. Perhaps the most common intervention is to subsidize the purchase of new electric vehicles directly. This narrows the price gap between internal combustion and electric vehicles, and leads to increased adoption. At the same time, financial incentives contribute to establishing a market demand for charging services. This encourages network operators to invest in charging station infrastructures, which yields additional electric vehicle sales through indirect network effects. While some jurisdictions leave the development of charging infrastructure to the private sector (often subsidizing new stations), others choose to provide charging services to electric vehicle owners in the form of a public good. This is the case of the Canadian province of Quebec, where county-level governments are responsible for the provision of local charging infrastructures. I propose a structural model that reflects this reality. Its key innovation compared to previous works¹ is that charging networks are provided by forward-looking local planners. I find that ignoring the forward-looking behavior of network operators over estimates the importance of network effects in electric vehicle markets. This result is important for the design of electric vehicle incentive programs as this would lead to over-estimating their performance. I study the introduction of the electric car in Canada and the cost-effectiveness of electric vehicle incentive programs. I gather a novel dataset of vehicle registrations and charging station installations in two Canadian provinces, Ontario and Quebec, for the period spanning 2012 to 2020. I start with a difference-in-differences analysis to study the direct impact of subsidies on sales, and their indirect impact on charging station provision. The identifying variation comes from changes to Ontario's rebate program that occurred in 2016 and 2018. Originally, Ontario and Quebec offered similar electric vehicle subsidies, between \$8,000 and \$8,500. The government of Ontario improved subsidies to \$14,000 in February 2016, and phased out its incentive program in late 2018

Subsidies are very effective at increasing electric vehicle adoption. The estimated intent-to-treat effect suggest that the improvements to Ontario's subsidies led to a 26.7% increase in electric vehicle adoption, while the abolition of the program reduced sales by 66.7% compared to baseline. I extend the analysis and estimate a continuous treatment effect model. I find that \$1,000 in subsidies is associated with a 7.7% increase in electric vehicle sales. This is qualitatively similar to findings by Muehlegger and Rapson (2022), who study an electric vehicle incentive program in California using a quasi-experimental setup. I also study the indirect effect of these subsidies on charging station deployment. The idea is that network supply might respond to shifts in the aggregate demand for charging services emanating from new electric vehicle owners.² I do not find evidence that the

policy changed the configuration of local networks in the short-run. Furthermore, I cannot find evidence that local networks changed along other dimensions. For example, I see no change in the number of charging points at each site or the share of fast charging stations available

1.1. The Canadian Market for Electric Vehicles

The transportation of passengers and freight accounted for 22% of all Canadian greenhouse gas emissions in 2021, ranking second behind oil and gas production.³ As such, the electrification of transportation has become a prime concern to both provincial and federal-level policymakers in Canada. I focus my analysis of electric vehicle incentives around the two largest Canadian provinces, Quebec and Ontario, which together account for two thirds of Canada's population. Both provinces offered generous rebates to new electric vehicle owners, starting as early as 2010. Moreover, electricity production in these provinces is almost exclusively emission-free. This provides a clean setup to study emission reductions resulting from the electrification of transportation.

I begin with a description of the various Canadian policies that are relevant to the analysis. I focus on three financial incentive programs offered by the provincial government of Ontario, the provincial government of Quebec, and the federal government of Canada. To paint the broadest picture possible, I discuss the financial and the non-financial incentives that are offered in each jurisdiction. I also describe how charging station networks are developed, as there are significant differences between the two provinces. Ontario relies on a more traditional model which leaves the development of local networks to the private sector. Meanwhile, the government of Quebec develops public networks in partnership with county-level governments, with little contribution from private operators.

1.2. Policy environment

Timeline. The transportation sector is one of the leading contributor to carbon emissions in Canada. Absent federal initiative, the provincial governments in Ontario and Quebec launched separate electric vehicle incentive programs in 2010 and 2012 respectively.⁵ The stated goals of the policies were to support the transition to electric vehicles, reward first adopters, and create a market demand for this new technology. Increasing adoption also creates a market demand for charging services, which encourages investments into charging stations from private and public operators.

While Quebec's Roulez Vert Program was maintained over time, the government of Ontario modernized its Electric Vehicle Incentive Program in February 2016.⁶ On that occasion, subsidies for battery electrics and long-range plug-in hybrids were significantly increased, from \$8,500 to \$14,000. For short-range plug-in hybrids, the rebate was slightly increased and made progressive in the capacity of the battery. Policymakers justified these improvements with Ontario's poor performance in terms of electric vehicle adoption compared to the rest of Canada.

The election of a conservative government in June 2018 led to the abolition of Ontario's cap-and-trade carbon tax in early October 2018. Since this carbon tax was the principal source of funding for electric vehicle subsidies, the Electric Vehicle Incentive Program was terminated at the same time. There is some anecdotal evidence in news reports that consumers were taken by surprise by this sudden change, as the government did not campaign extensively on these subsidies during the 2018 election cycle. With only a few weeks' notice, there was not a lot of time to capitalize on the rebate before the program expired, since ordering an electric vehicle usually took between 6 to 12 months at the time.

1.3. Network deployment

Presents the distribution of all charging stations by province and operating network. There are striking differences between the two provinces. The first one is the sheer difference in the size of the networks. In per capita terms, there are more than four times more stations in Quebec than in Ontario. Second, Ontario's network is predominantly operated and developed by private firms (even though most stations are installed on the street and are considered as public). In contrast, Quebec's market is dominated by the government provided platform, the Electric Circuit, with little competition from private firms.⁸ Network provision in Quebec does not follow a traditional model of demand and supply. Instead, the provincial government enters partnerships with regional governments, shopping malls, restaurant chains, and workplaces for the development of local charging station infrastructures. On one hand, the provincial government provides the platform (including the software infrastructure, the phone app, and billing services) and coordinates maintenance. It also regulates both the charging price paid by consumers and the whole sale energy price paid by the partner. On the other hand, the partner pays for the physical infrastructure (the actual station) and the installation cost. It then collects revenues from operating that station. Importantly, partners decide where and when to install stations, since they own property right on the land.

Network operators

	Ontario		Quebec	
	Nb. stations	Share total	Nb. stations	Share total
ChargeLab	18	0.02	1	4e-4
ChargePoint Network	219	0.20	70	0.03
<i>Electric Circuit</i>	29	0.03	1,960	0.70
Electrify Canada	4	4e-3	0	0
EV Connect	20	0.02	0	0
Flo	209	0.19	376	0.13
Ivy	23	0.02	0	0
Petro-Canada	19	0.02	7	2e-3
Shell Recharge	6	5e-3	0	0
SWTCH Energy	20	0.02	0	0
Tesla Destination	222	0.20	160	0.06
Non-networked	318	0.29	237	0.08
Total	1,107	1	2,811	1
Population, in 2020	14.22		8.44	
Nb. of counties	49		96	

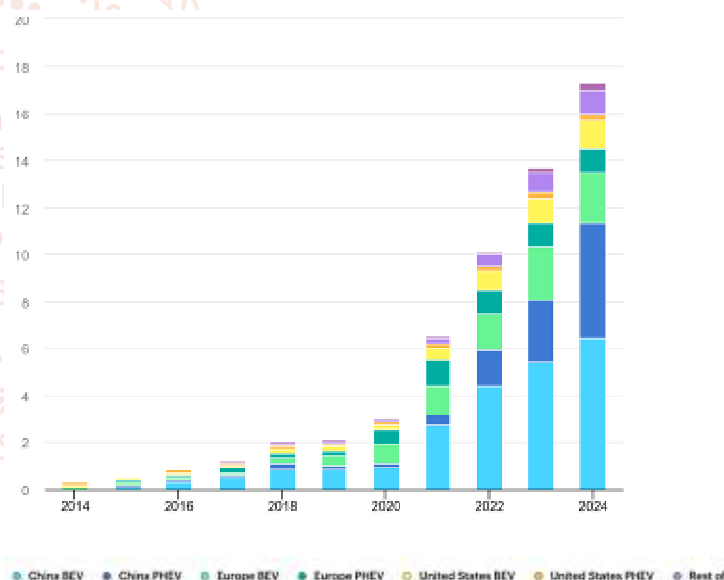
NOTE: The Electric Circuit is Quebec’s public platform. All other networks are operated by private firms. The network size is reported for year 2020. Population is in million.

2. Related work

Electric car sales topped 17 million worldwide in 2024, rising by more than 25%. Just the additional 3.5 million cars sold in 2024 compared to 2023 outnumber total electric car sales in the whole of 2020. China maintained its lead among major markets, with electric car sales exceeding 11 million – more than were sold worldwide just 2 years earlier. Global sales were slightly tempered by stagnating growth in Europe, as subsidies were phased out or reduced in several major markets, and as the EU CO₂ targets for cars remained the same between 2023 and 2024. Electric car sales continued to increase in the United States although growth was about one-quarter that of the previous year. Significantly, outside of these three major markets, there was a record increase in sales of nearly 40% to reach 1.3 million, closing in on the United States’ sales of 1.6 million electric cars.

The rapid growth in electric car sales over the past 5 years has had a significant impact on the global car fleet: At the end of 2024, the electric car fleet had reached almost 58 million, about 4% of the total passenger car fleet and more than triple the total electric car fleet in 2021. Notably, the global stock of electric cars displaced over 1 million barrels per day of oil consumption in 2024. Of course, the stock of electric cars is not spread evenly across the world – in China, for example, around one in ten cars on the road is now electric, whereas in Europe the ratio is closer to one in twenty.

Global electric car sales, 2014-2024



2.1. Almost half of China’s car sales were electric in 2024, representing almost two-thirds of electric cars sold globally

Electric car sales in China increased by almost 40% year-on-year in 2024, further driving up China’s share of global electric car sales. In 2021, China accounted for half of global electric car sales; this share grew to almost two-thirds in 2024. On a monthly basis, sales of electric cars have overtaken conventional car sales in the country since July 2024, bringing the share of electric car sales close to 50% for the full year. In China, 2024 marks the fourth consecutive year in which the electric car sales share grew by approximately 10 percentage points year-on-year.

The growth in China reflects in no small part the growing price competitiveness of battery electric cars with conventional cars in the country. In addition, China’s electric car market benefitted from the introduction of a trade-in

scheme in April 2024. The scheme, which is part of a wider economic stimulus package, applies to the purchase of conventional and electric cars alike, but with different levels of financial support. It offers CNY 20 000 (Yuan renminbi) (USD 2 750) for consumers that replace an older vehicle (conventional or electric) with a new electric car, and CNY 15 000 (USD 2 050) for replacement with a new conventional vehicle. In 2024, about 6.6 million consumers applied for the incentive, 60% of whom bought an electric car. As such, more than one-third of the over 11 million new electric car sales in the country benefitted from this incentive.

In recent years, sales of plug-in hybrid electric cars have been growing faster than sales of battery electric cars in China. The share of plug-in hybrid electric vehicle (PHEV) sales, excluding extended-range EVs (EREVs)², in China's total electric car sales has risen from about 15% in 2020 to nearly 30% in 2024. Meanwhile, the share of EREVs has more than quadrupled since 2020, surpassing 10% in 2024. The acceleration of PHEV sales in China led the share of electric car sales that are battery electric to fall from 80% in 2020 to below 60% in 2024, though in absolute terms battery electric car sales increased sevenfold over the same period, demonstrating their continued appeal to new customers.

3. Research Methodology

3.1. Demand

Consider consumer i living in county m . Each period t , this consumer chooses to purchase one of the $j = 1, \dots, J$ car makes available or to purchase nothing at all, denoted $j = 0$. In choosing which product to purchase, the consumer considers the net price of each product, $p_{jt} - \tau_{jt}$, where p_{jt} is the retail price and τ_{jt} a government subsidy on product j . It also considers observed product characteristics such as the horsepower, the driving cost, or the engine type. I denote the vector of observed product attributes by \mathbf{x}_{jt} . Furthermore, the consumer considers characteristics that are unobserved to the econometrician, summarized by the quality index ξ_{jmt}

For all models with an electric engine, the consumer cares about the opportunity of charging at home or on the network. Let N_{mt} be the charging network size in county m at time t , and define the indirect utility of charging as the deterministic function $v(N_{mt}, \theta_i)$, where θ_i is a consumer-specific preference parameter. For any product j , the associated indirect utility of charging is

$$v_j(N_{mt}, \theta_i) = \begin{cases} v(N_{mt}, \theta_i), & \text{if } j \in EV \\ 0, & \text{if } j \notin EV \end{cases}$$

I select the following functional form for the indirect utility of charging, $v(N_{mt}, \theta_i) = \theta_i \ln(1 + N_{mt})$,¹⁰ where N_{mt} represents the stations available to consumer i in his county of residence, and the "1" represents the opportunity to charge at home. This means that, when no stations are available in a region, consumers are assumed to have the option to charge at home. The function $v(N_{mt}, \theta_i)$ is increasing at a decreasing rate in N_{mt} for $\theta_i > 0$, such that each additional station is less valuable to the consumer than the previous one. I allow consumers to have heterogenous preferences in the observed product characteristics. Heterogeneity is introduced in two ways. First, the average taste for observed characteristics varies across regions through interactions with county-level average

demographics, denoted D_{mt} . Second, I allow for random coefficients to model the heterogeneity within county. Formally, the utility consumer i receives from purchasing product j is

$$u_{ijmt} = \beta_i^p (p_{jt} - \tau_{jt}) + v_j(N_{mt}, \theta_i) + \mathbf{x}_{jt} \beta_i^x + \xi_{jmt} + \epsilon_{ijmt}^d$$

where ϵ_{ijmt} is a consumer-specific disturbance. Consumers' taste parameters take the following form,

$$\beta_i^p = \beta^p + D_{mt} \Gamma^p + \sigma^p v_i^p$$

$$\beta_{ik}^x = \beta_k^x + D_{mt} \Gamma_k^x + \sigma_k^x v_{ik}^x$$

$$\theta_i = \theta + D_{mt} \Gamma^N + \sigma^N v_i^N$$

where k indexes the different product characteristics in \mathbf{x}_{jt} and the $v_i = \{v_i^p, v_i^x, v_i^N\}$ are jointly distributed as independent standard normal. The utility of the outside option is normalized to $u_{i0mt} = \epsilon_{i0mt}^d$ in each market. I rewrite the utility function in terms of a mean utility and a consumer-specific deviation,

$$u_{ijmt} = \delta_{jmt} + \mu_{ijmt} + \epsilon_{ijmt}^d$$

With

$$\delta_{jmt} = \beta^p (p_{jt} - \tau_{jt}) + ((p_{jt} - \tau_{jt}) \otimes D_{mt}) \Gamma^p + \mathbf{x}_{jt} \beta^x + (\mathbf{x}_{jt} \otimes D_{mt}) \Gamma^x + \xi_{jmt}$$

$$\mu_{ijmt} = \sigma^p v_i^p (p_{jt} - \tau_{jt}) + v_j(N_{mt}, \theta_i) + \sum_k x_{jt}^k \sigma_k^x v_{ik}^x$$

Assuming that the taste shocks ϵ_{ijmt}^d are independent and identically distributed as extreme value type I, the probability that consumer i purchases product j is given by

$$s_{ijmt}(\mathbf{p}_t, N_{mt}, \mathbf{x}_t, D_{mt}, v_i) = \frac{e^{\delta_{jmt} + \mu_{ijmt}}}{1 + \sum_{j'=1}^{J_{mt}} e^{\delta_{j'mt} + \mu_{ij'mt}}}$$

Taking expectation over all consumers yields the following aggregate demand for product j ,

$$s_{jmt}(\mathbf{p}_t, N_{mt}, \mathbf{x}_t, D_{mt}) = \int s_{ijmt}(\mathbf{p}_t, N_{mt}, \mathbf{x}_t, D_{mt}, v_i) dF(v_i)$$

3.2. Network supply

I consider the case of county-level governments (henceforth "local planners") responsible for supplying a public network of charging stations in their respective jurisdiction. Through out, I maintain the assumption that these local planners do not coordinate on a common deployment strategy, and that they control both the installation decision and the location of stations within their county. Furthermore, I consider local networks to be public goods, that is, they are non-excludable, non-rivalrous, and publicly supplied by local planners. Since I define each station as a charging site that can accommodate two to four drivers simultaneously, I consider the non-rivalrous assumption to be satisfied in most cases.

Law of motion: Before I define the local planner's problem, I consider the law of motion of the electric vehicle base. Let $Q_{mt}^{ev}(n)$ and $q_{mt}^{ev}(n)$ be the stock of electric vehicles in circulation and the sales of electric vehicles in county m and period t given a network of size n . The law of motion of $Q_{mt}^{ev}(n)$ can be written as

$$Q_{mt}^{ev}(n) = (1 - d)Q_{m,t-1}^{ev} + q_{mt}^{ev}(n),$$

where d is the fleet depreciation rate and $Q_{m,t-1}^{ev}$ includes only past sales, hence is pre-terminated and does not depend on n . The term $Q_{mt}^{ev}(n)$ can be recovered in each period by aggregating over market shares and multiplying by the market potential L_{mt} , that is,

$$Q_{mt}^{ev}(n) = L_{mt} \cdot \sum_{j \in EV} s_{jmt}(\mathbf{p}_t, n, \mathbf{x}_t, \mathbf{D}_{mt}).$$

Benefit function:-

I now describe the local planner's problem. In what follows, the index m represents both a local planner and its associated county. Each local planner m installs charging stations in its jurisdiction to maximize the aggregate value of the network to electric vehicle owners given the fixed cost of adding capacity

Recall that electric vehicle i derives a utility of $v(n, \theta_i)$ from a network of size n . I define as

$$B_{mt}(n) = \frac{Q_{mt}^{ev}(n)}{\text{Number of EV owners}} \cdot \left(\frac{\int \frac{v(n, \theta_i) - v(n-1, \theta_i)}{-\beta_i^p} dF(\nu_i)}{\text{Average gain in utility per EV owner from station } n} \right)$$

the local planner's contemporaneous benefits of increasing the network size from $n-1$ to n , where

$Q_{mt}^{ev}(n)$ and $v(n, \theta_i)$ are defined above, $-\beta_i^p$ is the marginal utility of income of consumer i (β_i^p is the price sensitivity), and γ is a local planner preference parameter.

The term in parenthesis represents the monetary equivalent of the expected gain in indirect utility that an electric vehicle owner receives when the network size increases from $n-1$ to n . The local planner's benefit, $B_{mt}(n)$, can therefore be seen as the aggregate gain in utility from all electric vehicle owners in county m and period t scaled by a preference parameter γ . The preference parameter is included to allow for the planner to value more or less charging on the network than electric vehicle owners themselves. To simplify the notation in what follows, I denote

$$\Delta v(n) = \int \frac{v(n, \theta_i) - v(n-1, \theta_i)}{-\beta_i^p} dF(\nu_i),$$

and I can rewrite the benefit function as

$$B_{mt}(n) = Q_{mt}^{ev}(n) \cdot \Delta v(n)^\gamma$$

I impose three assumptions on the local planners' benefit function. First, I assume that local planners are price-takers in the charging market. This prevents local planners from affecting consumers' utility via driving costs. This is easily satisfied as Quebec's provincial government regulates both energy prices and charging prices. Second, I assume that $\Delta v(n)$ is positive and weakly decreasing in n . This condition is sufficient to have a unique equilibrium in network size for a given stock of electric vehicles. This is trivially satisfied if $\frac{\partial v(n, \theta_i)}{\partial n} \geq 0$ and

$$\frac{\partial^2 v(n, \theta_i)}{\partial n^2} \leq 0, \forall n \in \mathbb{N}, \text{ and } \beta_i^p < 0, \forall i.$$

Finally, I assume that there exists a saturation point S , such that $\Delta v(n) = 0$ for all $n > S$. This last assumption is not absolutely necessary, but it simplifies the computation of counterfactuals.

4. Research Methodology

4.1. Summary statistics.

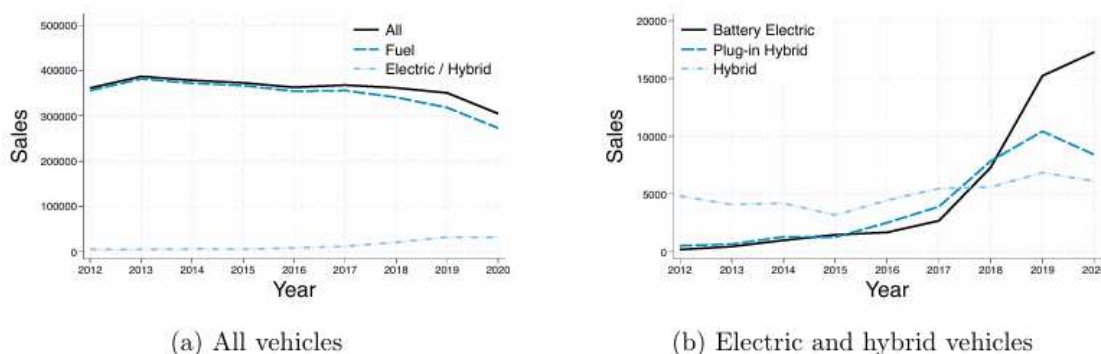
I estimate both the demand for cars and supply of stations at the county-year level. I focus on the province of Quebec, where stations are provided publicly (charging stations are provided by private firms in Ontario).

I define a product as a make-model-engine combination and I set the market size to be the number of households in each market. I present a summary of the characteristics of the available products. Battery electric vehicles are on average \$18,000 more expensive than traditional combustion engines while plug-in hybrids are on average \$6,000 more expensive.

The combined rebates seem to cover fully the price difference for plug-in hybrids, but not for battery electric vehicles. The evolution of vehicle sales in Quebec is depicted in Panel (a) shows that total sales are roughly constant until 2019, but then decrease due to supply chain disruptions and economic uncertainty caused by COVID-19. Panel (b) offers a breakdown by engine type for electric and hybrid vehicles. Sales of battery electrics and plug-in hybrids are rising steadily, with a sharp increase towards the end of the period. Sales of non-rechargeable hybrids are rising but slightly.

Several factors unrelated to the policy under study help explaining the sustained growth

Figure 2: Evolution of sales



In electric vehicle sales. One of them is the increasing electric vehicle offering, summarized in The number of battery electric and plug-in hybrid alternatives is rising steadily from 5 products available in 2012 to 31 in 2020. Meanwhile, the offering of internal combustion engines seems to decline slightly in 2019 and 2020, when sales of electric vehicles are highest.

The increasing availability of charging stations could also explain part of the growth in electric vehicle sales. The right side of the evolution of the charging station infrastructure over time. The number of stations available goes from 100

stations in 2012 to more than 2800 in 2020. Local networks are also densifying overtime. This is especially important in predominantly rural counties which have low population density. A large share of counties initially had no charging station network. In this case, electric vehicle owners are constrained to charging at home which act as a deterrent to the purchase of a fully electric vehicle. By 2020, 76% of counties had more than 10 stations available, 32% had more than 25 stations, and all counties had at least one open charging location.

Table 4: Evolution of choice set and charging infrastructure

Year	Number of products			Nb. stations	Share of counties with			
	Fuel	Electric	Hybrid		0 station	1-10 stations	11-25 stations	25+ stations
2012	165	5	9	100	0.69	0.25	0.03	0.02
2013	176	8	9	192	0.48	0.46	0.04	0.02
2014	187	11	9	339	0.29	0.62	0.04	0.05
2015	188	11	10	623	0.13	0.72	0.09	0.05
2016	186	13	10	914	0.03	0.69	0.22	0.05
2017	184	23	13	1,266	0.02	0.61	0.31	0.06
2018	184	26	13	1,616	0	0.57	0.30	0.14
2019	177	29	13	2,371	0	0.39	0.39	0.22
2020	173	31	13	2,811	0	0.24	0.44	0.32

Table 5: Demand estimation

	Estimate	Demographic interactions					σ
		Income	Age	Gender	Pop. density	Trend	
Price – Rebate	-0.802 (0.034)	0.027 (0.005)					0.143 (0.02)
$v_j(N, \theta_i)$	0.358 (0.028)	0.195 (0.033)	-0.116 (0.03)				
Power	0.943 (0.021)		0.182 (0.023)	0.040 (0.004)			
Weight	0.217 (0.034)					0.083 (0.004)	
Driving cost	-0.036 (0.004)						
Battery electric	-2.248 (0.079)	-0.670 (0.086)		0.173 (0.024)	-0.510 (0.053)		
Plug-in hybrid	-2.207 (0.071)	-0.745 (0.086)		0.149 (0.024)	-0.565 (0.052)		
Hybrid	-1.720 (0.021)		0.361 (0.045)	0.144 (0.015)			
Constant							-5.272 (2.783)
Observations	126,397						
Nb. of markets	864						
Objective function	3450.89						
Avg. own-price elasticity	-3.288						
Avg. own-price elasticity, EV	-3.131						
Nb. elasticity > -1	0						

NOTE: Includes brand, market segment, county, and year fixed effects. Robust standard errors in parenthesis.

4.2. Cost-effective policy

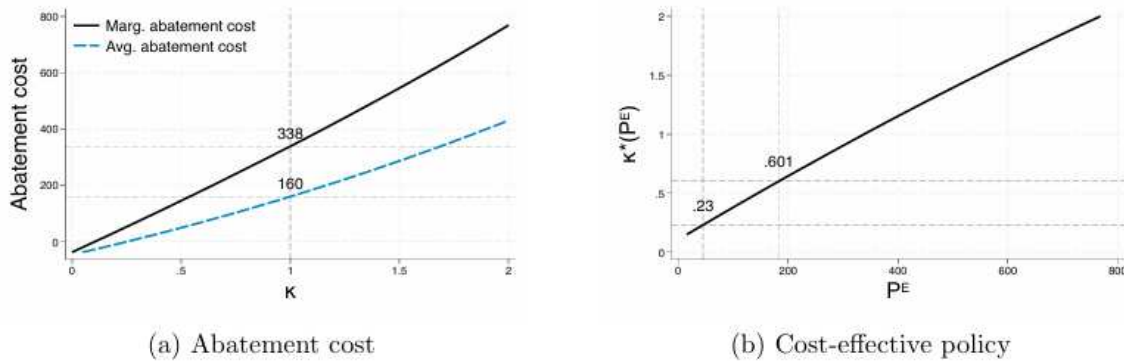
I study the cost-effectiveness of rebates by considering the social planner’s optimality condition. I compute counterfactuals on a grid $\{\kappa_1, \dots, \kappa_N\}$ using the forward-looking supply model, then I estimate the marginal abatement cost as

$$MAC(\kappa_n) = \frac{W(\kappa_{n+1}) - W(\kappa_n)}{E(\kappa_{n+1}) - E(\kappa_n)} - \frac{Cost(\kappa_{n+1}) - Cost(\kappa_n)}{E(\kappa_{n+1}) - E(\kappa_n)}$$

I collect the results to construct the marginal abatement cost curve as a function of κ . There are two interpretations to the social planner's first-order condition. On one hand, I can assume that it holds at the current rebates. In this case, equation provides an estimate for the cost of carbon, $PE = MAC(\kappa = 1)$. On the other hand, I can calibrate the cost of carbon to known estimates and recover the cost-effective policy $\kappa^*(PE)$. In what follows, I focus on the second interpretation.

Depicts the marginal abatement cost curve and the cost-effective policy curve for the chosen calibrated parameters. I observe that the marginal abatement cost is strictly increasing in the subsidy, which insures that a stable solution to the planner's problem exists and is unique at a given PE. In practice, I expect rebates to exhibit decreasing returns in term of emission abatement since the number of infra-marginal consumers increases with the rebate but emissions abated per new owner does not. I evaluate the marginal abatement

Figure 3: Abatement cost and cost-effective policy curves



Cost at current rebates to be \$338 per ton of carbon emissions. This is larger than current measures of the social cost of carbon. Figure 3 also reports the corresponding average abatement costs. A key observation is that the average abatement cost sits below the marginal abatement cost over the full policy space. This has important implications for policy design. Determining the cost-effective policy based on the average abatement cost systematically leads to an over-investment from the social planner. I invert the marginal abatement cost curve to recover the cost-effective policy curve. I evaluate the cost-effective policy for two separate estimates of the social cost of carbon. The chosen values are \$45 and \$183, which correspond to the average social cost of carbon and the 95th percentile of the distribution in 2018, according to the Government of Canada. For the lowest estimate, the cost-effective policy correspond to 23% of the current rebate programs. For the highest estimate, the cost-effective policy correspond instead to 60.1% of current rebates. In both cases, my analysis suggest that policymakers are over-investing on rebates

4.3. Alternative parametrizations

To paint the broadest picture possible, I redo the analysis using alternative sets of calibrated parameters. I start from the extreme case in which the policymaker cares only about government spendings and not welfare. This calibration is

$$AAC(\kappa_n) = \frac{W(\kappa_n) - W(0)}{E(\kappa_n) - E(0)} - \frac{Cost(\kappa_n) - Cost(0)}{E(\kappa_n) - E(0)}$$

Table 8: Alternative calibration results

Description	Calibration						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Parameters							
• Profit weight (ψ_1)	0	0	0	0.27	0.27	1	1
• Consumer surplus weight (ψ_2)	0	1	1	1	1	1	1
• Marginal cost of public funds (ϕ)	1	1.3	1	1.3	1	1.5	1.3
Cost estimates							
• Marginal abatement cost	873	600	338	552	290	595	420
• Average abatement cost	696	368	160	321	112	330	191
Cost-effective policy (Low SCC: \$45)							
• Policy (κ)	0	0	0.230	0	0.360	0.613	0.232
• Maximum provincial rebate	0	0	1,864	0	2,904	128	1,880
• Maximum federal rebate	0	0	1,165	0	1,815	80	1,175
Cost-effective policy (High SCC: \$183)							
• Policy (κ)	0	0.151	0.601	0.252	0.726	0.271	0.522
• Provincial rebate	0	1,208	4,808	2,016	5,808	2,168	4,176
• Federal rebate	0	755	3,005	1,260	3,630	1,355	2,610

NOTE: In all parametrization, we have $\rho = 0.95$, $T_j = 12.02$, and $\sigma_{\rho} = 22.083$. I compute two sets of cost-effective policies based on a social cost of carbon (SCC) of \$45 and \$183. Calibration (3) is the main specification. It is reproduced for comparability. Marginal abatement cost and Average abatement cost are in CAD per ton of carbon. Provincial rebate is computed by multiplying the cost-effective policy κ^* by \$8,000. Federal rebate is computed by multiplying the cost-effective policy κ^* by \$5,000. The federal rebate is available as of 2019.

Used widely in the literature related to the car market. In this case, the cost-effective policy is a corner solution: the marginal abatement cost is well above any conventional measures for the social cost of carbon for any level of the subsidy, hence the government chooses not to subsidize electric vehicles. I repeat the exercise for various combinations of the welfare weights and the marginal cost of providing public funds. I consider three cases for the welfare weights. In the first case, the policymaker takes into account consumer surplus but not profits. In the second case it takes into account consumer surplus and the taxable part of firms profits. The corporate tax rate in Quebec is a round 27% for large firms, hence I set the welfare weight on profits to 0.27. Finally, I consider the case where the policy maker cares fully about both consumer surplus and profits. I interact these three parameterizations with three different values for the marginal cost of public funds.

In all cases, the policymaker over-invests on subsidies. The cost-effective policy varies between 15.1% and 72.6% of the currently implemented rebate scheme (excluding the cases with a corner solution or very close to a corner solution) and the estimated marginal cost of abatement is between \$290 and \$876. Understanding the cost-effectiveness of environmental policies is crucial. With limited resources, policymakers need to choose where to allocate public funds to maximize the impact of their interventions on environmental outcomes.

5. Conclusion

The Canadian electric car market presents a unique opportunity to study the cost-effectiveness of subsidizing electric vehicle sales. Evaluating the environmental performance of such policies is important. With limited financial resources, policymakers should strive to reduce emissions at the lowest cost possible. My findings suggest that electric vehicle subsidies are an effective way to diffuse the technology and increase adoption. I find no evidence that these additional sales generate additional charging station installations in the short-run. In the long-run, I find that the program led to a small increase in network provision. This study provides a rigorous cost benefit analysis to evaluate the cost-effectiveness of rebate programs. I find in general that the marginal cost of abatement remains high compared to traditional measures of the social cost of carbon. This suggests that the provincial and federal governments in Canada over invest on electric vehicle subsidies compared to what is efficient. These results should be considered as part of a broader set of environmental policies. For example, investments into cleaner electricity production, reforestation, or the modernization of particularly polluting industries could abate emissions at a lower marginal cost. This study contributes to creating a unified framework to study and compare environmental policies and help policymakers make these crucial decisions.

6. References

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