Impact of financial incentives on the vehicle market in Norway

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Outline

Motivation

- Norway had the highest EV adoption rate (42.5% of total car sales) in Europe in 2019.
- Various incentives and policies, such as financial benefits (VAT exemption and Weight Tax reduction) and substantial investments in charging infrastructure.
- Due to said incentives, an ICEV may cost more than an EV of comparable characteristics.
- Implications of the proliferation of EVs are manifold for:
  - Individuals (Financial and Environmental),
  - Firms,
  - Government.

Research Questions and Preview of the Paper

1. Norway vehicle market structure?
   - Since 2010, there has been a consistent decrease in the sales of ICEVs, accompanied by a significant rise in the sales of EVs and PHEVs.
2. How do financial benefits (no VAT and Weight Tax) affect the demand for EVs?
   - Without VAT and WT incentives, overall EV sales would have been ca. 75% less, all other things held constant.
3. What are customers' benefits (financial and environmental)?
   - Up to 21.8 Billion NOK (1.85 Bn. Euro) financial benefits, with 0.1 tonnes CO2 per inhabitant (or ca. 500k CO2 tonnes) less for 2010-2019.
4. Who were the winners and losers among producers?
   - Tesla is the biggest winner with the best-sold model Model 3.
5. What did EVs replace?
   - The closest substitute for EVs are PHEVs.

Literature

- Literature:
  - Springel 2021 evaluates the effectiveness of direct purchasing price subsidies compared to charging station subsidies for EVs in Norway. However, it should be noted that the own-elasticities observed in this study are lower in magnitude with findings from published literature such as Huse & Lucinda 2014 (Sweden), Durrmeyer 2022 (France), Grieco *et al.* 2021 (USA), and others. These disparities raise questions regarding the true impact of financial benefits on EV adoption.
  - Xing *et al.* 2021 explore what EVs have replaced in the US. Their results suggest that EVs replace gasoline vehicles with an average fuel economy of 4.2 mpg above the fleet-wide average and 12 percent of them replace hybrid vehicles.

Contribution

- Analysis of the Norwegian vehicle market, with joint estimation of demand and supply, and with examinations of reactions under various scenarios
- Evidence of purchasing behavior when presented with wide range of benefits for buying new vehicles
- It helps policymakers to understand what EVs replaced and which vehicles are the closest substitutes of EVs in Norway
- It informs policymakers, industry stakeholders, and researchers alike about the winners and losers among producers in different scenarios

Institutional Background

All vehicles that are imported are subjected to different taxes/fees and among them are: *VAT*, *Weight Tax*, and *Scrappage Fee*. The Norwegian Government implemented the following financial incentives to promote the adoption of electric vehicles (EVs):

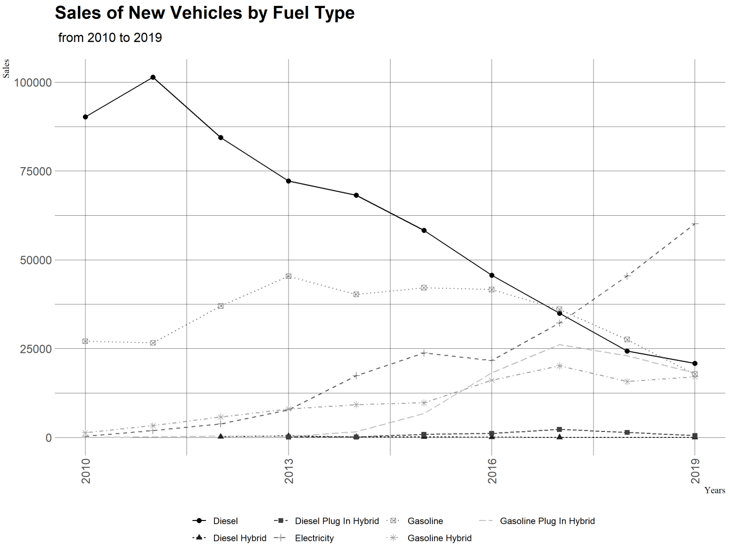
- The Weight Tax, which had been in effect since 1990. This tax is imposed on vehicles based on their weight. Details
- In 2001, a Value Added Tax (VAT) exemption for Battery Electric Vehicles (BEVs) was introduced. It means an exemption of a 25% increase in the base price.

Data Overview

- New all sales of vehicles data set:
  - quantities of all new vehicle sales at yearly level w/o prices sold
  - characteristics: brands, models, transmission, hp/kw, fuel economy, weight, drive train, no. of doors, and displacement
  - period: 2010-2019.
- Sample construction
  - a separate data set of prices of new vehicles
  - merge prices data to main sales data set by characteristics
  - aggregate to the best-sold model brand-model-fuel-transmission
  - sample represents 1.36 Mil. out of 1.5 Mil. of new vehicles sold

Summary Statistics

The Vehicle Market: An Overview



Demand Side

The consumer i chooses alternative j in the market t, iff the jth alternative provides the highest utility.

$$\mathcal{U}_{ijt} = x_{jt}\beta_{it} + \alpha_{it}p_{jt} + \phi_t + \Psi_{jt} + \xi_{jt} + \epsilon_{ijt} \tag{1}$$

where

$$\alpha_{it} = \alpha D_{it}, \tag{2}$$

$$\beta_{it}^{(k)} = \beta_0^{(k)} + \sigma_k \nu_{it}^{(k)}, \tag{3}$$

- x_{jt} - a (row) vector of K observed vehicle characteristics,
- p_{jt} - price of vehicle j in the market t,
- ϕ_t - market fe, Ψ_{jt} - vehicle fe's (model, body, fuel),
- ξ_{jt} - an unobserved vehicle attribute,
- D_i - demographic draws,
- $\beta_0^{(k)}$ - common to all consumers for the vehicles' characteristic *(k)*,
- σ_k - consumers' heterogeneity,
- ν_i - standard normal distribution $\mathcal{N}(0, 1)$,
- ϵ_{ijt} - idiosyncratic consumer-vehicle specific term (T1EV).

Supply Side

Firm f chooses prices in market t to maximize the profits of its products $J_{ft} \subset J$:

$$\pi_{ft} = \sum_{j \in \mathcal{J}_{ft}} (p_{jt} - c_{jt}) \, s_{jt} \tag{4}$$

In a single market, the corresponding multi-product differentiated Bertrand first-order conditions are, in vector-matrix form,

$$p - c = \underbrace{\Delta^{-1} s}_{\eta} \tag{5}$$

where the multi-product Bertrand markup η depends on Δ, a $J_t \times J_t$ matrix of intra-firm (negative) demand derivatives:

$$\Delta = -\mathcal{H} \odot \frac{\partial s}{\partial p} \tag{6}$$

Here, $\mathcal{H}$ denotes the market-level ownership or product holdings matrix in the market, where $\mathcal{H}_{jk}$ is typically 1 if the same firm produces products j and k, and 0 otherwise.
The functional form that I impose on the marginal costs is a log function

$$\ln(c_{jt}) = \sum_{k} x_{kjt} \gamma_k + \omega_{jt} \tag{7}$$

where ω_{jt} is the unobserved part of the product j in the market t, which might be the color of the vehicle, leather seats, and so on.

- Specification:
  - **D**: Prices over Income, Length, Acceleration, Transmission, Fuel Economy, Body Style, and Fuel Type.
  - **S**: Displacement, Weight, HP, and Trend.
- Demographics: Income deciles to build income distribution, and number of households to build shares.
- Instruments:
  1. Differentiation Instruments, cost shifters (Iron Ore), and Unit Labor Costs.
     Demand Instruments Supply Instruments
  2. Optimal Instruments.
- Two-Step GMM, 999 Halton Draws per market, uniform weights, and Algorithm (BFGS). All this run twice:
  1. With the first set of instruments,
  2. Used optimal instruments to improve the quality of instruments such that to have:

$$\mathbb{E}[Z^D \xi] = \mathbb{E}[Z^S \omega] = 0. \tag{8}$$

- Details of Two-Step GMM: Click here.
- PyBLP package.

Results

Variables	$\bar{\beta}$	σ	Demographics 1/*Income*
Demand Parameters			
Prices	-	-	-8.42
	-	-	(0.6)
Length	0.354	5.96	
	(4.41)	(2.38)	
Acceleration	-111	72.2	
	(19.7)	(9.32)	
Transmission	0.967	0.593	
	(0.27)	(1.63)	
Fuel Economy	0.372	0.0444	
	(0.0556)	(0.177)	
Supply Parameters			
Intercept	-8.37		
	(3.71)		
Displacement	1.15		
	(0.183)		
Log(Weight)	1.11		
	(0.04)		
HP	0.0038		
	(0.000188)		
Trend	0.00296		
	(0.00185)		

Table 1: *Note:* Controlling for market, brand, model, and body type.

Elasticities

Panel A:	Model 3	E-Golf	Leaf	e-tron	Outlander	Rav4	i3
Model 3 (EV)	**-4.78**	0.08	0.14	0.04	0.09	0.14	0.08
E-Golf (EV)	0.21	**-4.12**	0.17	0.16	0.57	0.23	0.16
Leaf (EV)	0.26	0.13	**-4.29**	0.10	0.12	0.17	0.14
e-tron (EV)	0.12	0.17	0.14	**-3.22**	0.12	0.15	0.19
Outlander (GPH)	0.05	0.12	0.03	0.02	**-1.70**	0.06	0.02
Rav4 (GH)	0.27	0.17	0.17	0.10	0.22	**-4.47**	0.13
i3 (EV)	0.13	0.09	0.11	0.11	0.05	0.11	**-3.31**

Panel B:

Fuel Type	Sales Weighted Mean Elasticities
Electric	-3.58
Gasoline	-4
Diesel	-4.24
GH	-3.82
DH	-4.27
GPHEV	-5.24
DPHEV	-5.51

Table 2: In Panel A: Own- and Cross-Elasticities for selected models in 2019. In Panel B: Mean Own-Elasticities by fuel type during the whole period 2010-2019. *Note: Gasoline Hybrid (GH), Diesel Hybrid (DH).*

Comment:

- Plug-In Hybrids have higher elasticities as they are the closest substitutes for EVs. They run mostly on batteries and charging of batteries is similar to EVs.

Change among fuel types. Share of the outside good.

Policy Simulations and Assumptions

Policy simulations:

1. What if no VAT exemption?
2. What if no Weight Tax reduction?
3. What if both were applied to EVs?

The following assumptions are made :

1. The equilibrium in all scenarios follows an oligopolistic Bertrand (Nash) Equilibrium.
2. VAT and Weight Tax are assumed to be endogenous.
3. The marginal costs would remain the same in all scenarios.

Financial Welfare

Panel A:	ΔCS	$\Delta \Pi$	ΔW
VAT	-15 Bn. (1.26 Bn. Euro)	-4.851 Bn. (418 Mil. Euro)	-19.851 Bn. (1.678 Bn. Euro)
WT	-14 Bn. (1.194 Bn. Euro)	-4.735 Bn. (408 Mil. Euro)	-18.735 Bn. (1.6 Bn. Euro)
VAT + WT	-21.8 Bn. (1.85 Bil Euro)	-7.31 Bn. (631 Mil. Euro)	-29.11 Bn. (2.481 Bn. Euro)
Panel B: Hypothetical Welfare Loss	Total	Average	
Removing all EVs	27.9 Billion (2.4 Bn. Euro)	130,093 (11,280 Euro)	
Removing Tesla	11.17 Billion (962 Mil. Euro)	227,809 (20,000 Euro)	

Table 3: In Panel A: Results of change in the welfare of customers and producers in different scenarios for the whole period 2010-2019. Currency is in Norwegian Krone (NOK) unless stated differently. Value-added Tax (VAT), Weight Tax (WT), Consumers surplus (CS), Profits (Π), Total Welfare (W). In Panel B: Welfare loss in hypothetical scenarios. *Note: Import prices (w/o VAT & Import Tax) are used to calculate PS.*

CS Calculation PS Calculation

Market simulations

	#Q	*EV*	*D*	*G*	*H*	*PH*
Actual	1,36 Mil.	214,379	600,473	341,368	107,183	100,569
VAT	1.32 Mil.	103,720	619,650	364,181	116,909	118,489
(Δ%)	(-2.9)	(-51.6)	(3.2)	(6.7)	(9)	(17.8)
WT	1.321 Mil.	113,073	619,466	361,966	115,591	115,593
(Δ%)	(-3)	(-47.2)	(3.2)	(6)	(7.8)	(14.9)
VAT + WT	1.3 Mil.	54,878	628,549	373,828	120,792	128,020
(Δ%)	(-4.4)	(-74.4)	(4.67)	(9.5)	(12.7)	(27.3)

Table 4: The "Actual" row reflects the overall sales figures, while the table provides insights into sales variations across different fuel types and scenarios throughout 2010-2019. All values are reported in units per vehicle. *Note: H is for Gasoline and Diesel Hybrid, and PH is for Gasoline and Diesel Plug-In Hybrid.*

Environment

	Total Cumulative $CO2$	Δ	Average per inhabitant
Actual	13,607,987	-	2.545
VAT	13,983,123	375,135	2.615
WT	13,984,064	376,077	2.615
VAT + WT	14,135,195	527,207	2.643

Table 5: All units are in tonnes and for the whole period 2010-2019. In the middle column is the difference between a scenario and the actual one.

Traffic Volume Distribution 1 Distribution 2 Distribution 3

Market Effects

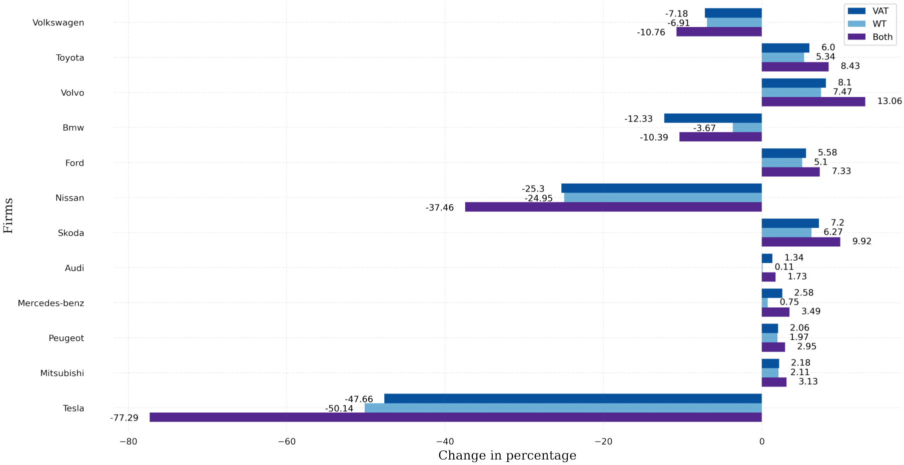


Figure 1: Winners and losers among producers in different scenarios.

Conclusions

- The crucial role of financial incentives in the diffusion of EVs, accounting for up to 75% of the EV car sale increase.
- Total financial welfare loss would sum up to 29.11 Bn NOK, with VAT and WT imposition.
- The closest substitutes of EVs are Plug-In Hybrid Vehicles. The highest increase (by percentage) would be for PHEVs.
- The environmental benefit for the whole period 2010-2019 is ca. 0.1 tonnes per individual.
- In 2019, the actual average (including EVs) CO2 emission per vehicle sold is 0.75 tonnes, compared to 1.1 tonne in case of VAT and WT for EVs.
- Firms that are focused on EVs would have been losers, especially Tesla with a 77% loss.

THANK YOU VERY MUCH FOR YOUR ATTENTION!

References

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Weight Tax Details

Table 6: Description of Weight Tax (*prices in NOK*) for selected years.

Year	Description
2010	35.67/kg for the first 1150 kg, 77.74/kg for the following 250 kg, 155.51/kg for the following 100 kg, and 180.85/kg the rest
2015	39.10/kg for the first 1150 kg, 85.25/kg for the following 250 kg, 170.52/kg for the following 100 kg, and 198.31/kg the rest
2016	0 for the first 150 kg, 35.67/kg for the following 1000 kg, 83.01/kg for the following 250 kg, 166.04/kg for the following 100 kg, and 193.166/kg the rest
2019	0 for the first 500 kg, 25.42/kg for the following 700 kg, 63.35/kg for the following 200 kg, 197.96/kg for the following 100 kg, and 230.23/kg the rest

Back

Summary Statistics

Variable	Min	Median	Mean	Max	SD
Prices (in NOK)	25,500	337,800	378,775	3,762,600	188,873
Length (in cm)	263	447	443.9	550	34.3
Transmission (0-1)	0	1.0	0.6	1.0	0.5
Weight (in kg)	780	1425	1430	3750	273.5
Displacement (in m^3)	0	1598	1647.1	6417	560.6
Fuel Economy (1L/100KM)	0	0.5	0.5	1.5	0.2
KW	30	97	105.2	568	46.4
HP	41	132	143.1	772	63
HP/Weight	0.0275	0.068	.072	.321	.0199

	Total
No. Obs:	7,005
No. Firms	43
No. Models	386
Period	2010-2019

Table 7: Summary statistics of new vehicles sold in Norway in the period 2010-2019.

Back

Demand Instruments

- **Demand Instruments**: exogenous characteristics in the linear part, local version of differentiation instruments, a cost shifter (iron ore), and exchange rates (Norwegian Krone (NOK) vs EUR, USD, KRW, JPY, SEK, GBP, and CNY. This is a column interacted with origin of the brand.).

$$Z_{jt}^{D,Own} = \left\{x_{jt}, w_{jt}, x_{jt}^2, w_{jt}^2, x_{jt} \cdot w_{jt}, \Theta\right\} \tag{9}$$

$$Z_{jt}^{D,Local} = \left\{ Z_{jt}^{D,Own}, \sum_{k \in \mathcal{J}_{ft} \setminus \{j\}} 1\left(|d_{jkt}| < SD(d)\right), \sum_{k \notin \mathcal{J}_{ft}} 1\left(|d_{jkt}| < SD(d)\right) \right\} \tag{10}$$

where d_{jkt} is the difference of characteristic of product j as $d_{jkt} = d_{jt} - d_{kt}$, and $SD(d)$ is the standard-deviation of d_{jtk}.

Back

Supply Instruments

- **Supply Instruments**: exogenous characteristics in the linear part, local version of differentiation instruments, and Unit Labor Cost.

$$Z_{jt}^{S,Own} = \left\{x_{jt}, \Phi, x_{jt}^2, \Phi_{jt}^2, x_{jt} \cdot \Phi\right\} \tag{11}$$

$$Z_{jt}^{S,Local} = \left\{ Z_{jt}^{S,Own}, \sum_{k \in \mathcal{J}_{ft} \setminus \{j\}} 1\left(|d_{jkt}| < SD(d)\right), \sum_{k \notin \mathcal{J}_{ft}} 1\left(|d_{jkt}| < SD(d)\right) \right\} \tag{12}$$

where d_{jkt} is the difference of characteristic of product j as $d_{jkt} = d_{jt} - d_{kt}$, and $SD(d)$ is the standard-deviation of d_{jtk}.

Back

General Moments

The objective function that we are looking to minimize is

$$\min_{\theta} q(\theta) = \bar{g}'(\theta) W \bar{g}(\theta) \tag{13}$$

where

$$\bar{g} = \begin{bmatrix} \bar{g}_D \\ \bar{g}_S \end{bmatrix} = \frac{1}{N} \begin{bmatrix} \sum_{j,t} Z'_{D,jt} \xi_{jt} \\ \sum_{j,t} Z'_{S,jt} \omega_{jt} \end{bmatrix} \tag{14}$$

and W is a weighting matrix, Z_D and Z_S, demand and supply instruments, respectively. To estimate the objective function, I use Two-Step GMM.

1. In the first step, the weighting matrix W has diagonals $(Z_D Z_D'/N)^{-1}$ and $(Z_S Z_S'/N)^{-1}$,
2. the weighting matrix is updated with the inverse of vectors g (see Eq. (14)), and the estimated parameters in the second stage are assumed to be asymptotically efficient. Back

Change among fuel types.

	EV	D	DH	DPH	G	GH	GPH
EV	**35.66**	23	22.6	35.1	26.15	25.3	34.4
D	7.9	**13.18**	18	13.5	9.5	10.4	13
DH	0	0	**0**	0	0	0	0
DPH	0.4	0.34	0.37	**0.44**	0.3	0.31	0.54
G	10.44	10.2	10	12.46	**10.69**	11	11.54
GH	8.7	10.1	10.44	12	9.9	**7.94**	11
GPH	**14**	11.3	12.8	18.6	9.75	10.15	**13.4**
Outside good	22.9	31.88	25.86	7.9	33.71	34.9	16.12

Table 8: Sales weighted average of consumers for the year 2019 who would leave a fuel type for another or remain in the same fuel type or go to the outside option in terms of percentage.

Back

Share of outside good

Model	Percentage
i3	50
e-tron	37
Leaf	22
Rav4	17
E-Golf	15
Model 3	7
Outlander	2

Table 9: In the face of a price increase, the percentage who would substitute for the outside good for the selected models in 2019.

Back

Road Traffic Volume by Fuel Type

Fuel	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Diesel	17,335	16,626	16,691	16,229	15,741	15,494	15,059	14,829	14,527	13,936
Diesel Hybrid	16,083	15,374	15,439	14,977	14,489	14,242	20,606	19,734	18,664	14,079
Diesel Plug In Hybrid	16,083	15,374	15,439	14,977	14,489	14,242	13,953	13,286	15,438	16,379
Electricity	6,806	6,427	7,612	5,692	7,729	11,380	11,788	11,818	12,171	12,631
Gasoline	11,106	10,729	10,365	9,990	9,695	9,502	9,309	9,210	9,034	8,809
Gasoline Hybrid	16,083	15,374	15,439	14,977	14,489	14,242	12,614	12,835	13,572	12,893
Gasoline Plug In Hybrid	16,083	15,374	15,439	14,977	14,489	14,242	9,652	11,375	14,353	14,074

Table 10: Average Road Traffic Volume by Fuel Type for Passanger Cars. *Source: Statistics of Norway.*

Back

CO2 Distributions

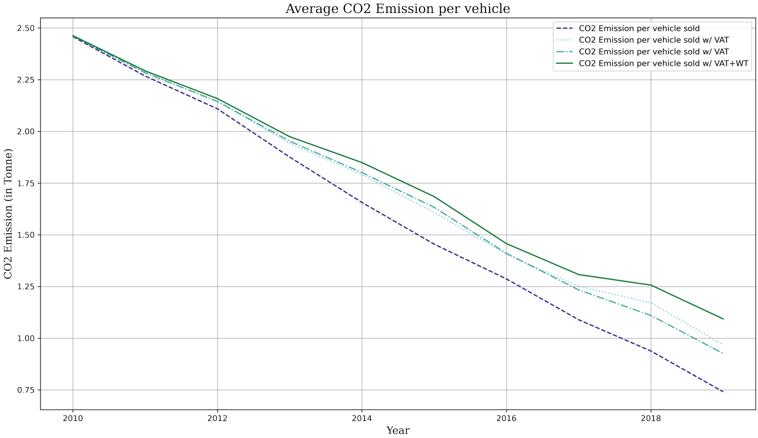


Figure 2: Average CO2 Emission per vehicle bought.

Back

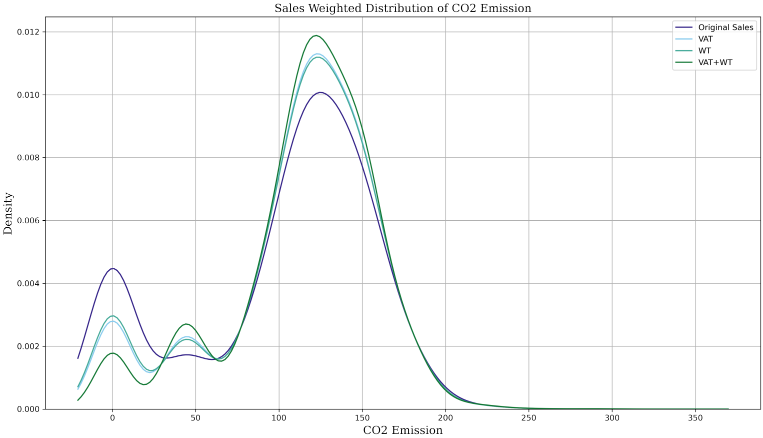
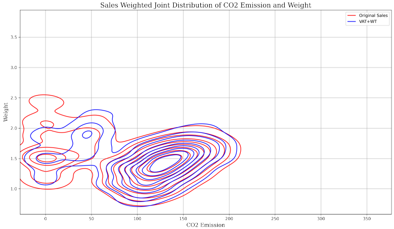


Figure 3: Distribution of CO2 Emission by using Gaussian Kernel Density and sales as weights.

Back

Weight, HP vs. CO2



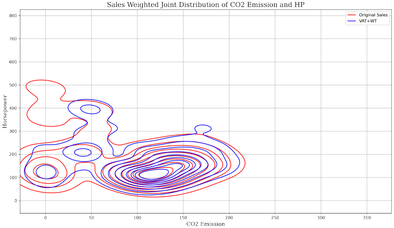


Figure 4: Joint Distributions of Weight and HP vs. CO2.

Back

CS

The surplus in market t is

$$CS = \sum_{i \in I_t} w_{it} CS_{it} \tag{15}$$

where CS_{it} is

$$CS_{it} = \log\left(1 + \sum_{j \in J_t} V_{ijt}\right) \Bigg/ \left(-\frac{\partial V_{ijt}}{\partial p_{jt}}\right) \tag{16}$$

Back

PS

- Import prices is the price without VAT and Import Tax (Weight Tax, CO_2, NO_x, and previously Engine Power Tax).
- To find the real profit, it is used:

$$\frac{p_{jt}^{import} - \tilde{c}_{jt}}{p_{jt}^{import}} = \frac{1}{|\epsilon_{jj,t}|} \tag{17}$$

- Then, we find marginal costs:

$$\tilde{c}_{jt} = p_{jt}^{import} - \frac{p_{jt}^{import}}{|\epsilon_{jj,t}|} \tag{18}$$

- Finally,

$$\tilde{\pi}_{ft} = \sum_{j \in \mathcal{J}_{ft}} \left(p_{jt}^{import} - \tilde{c}_{jt} \right) s_{jt} \tag{19}$$

Back