1ères Journées Analyse des Séries Temporelles, 23-24 juin 2025

The Influence of Macroeconomic Factors on Automotive Purchase Decisions in France : An Econometric Time Series Study

PhD Title: **Forecasts of the impact of changes in industry sectors at regional, national and European level**

By Claire Verdier[1,3], PhD Student CIFRE in applied maths,
PhD Supervisors : **Camelia Goga**[1], **Jihad Elnaboulsi**[1], **Yacouba Boubacar Maïnassara**[2]
Jean-Luc Marini[3]

[1] *Université de Marie et Louis Pasteur*
[2] *Université Polytechnique Hauts-de-France, INSA Hauts-de-France*
[3] *Openstudio*

Context

Context of the automotive industry

- European objective of '**zero CO2 emissions**' for vehicle use by **2035**.
- Carbon footprint of road transport:
  - ➢ 80% is linked to vehicle use.
  - ➢ 20% is linked to their manufacture and end-of-life management.
- Main identified drivers for **decarbonation** of car industry: **Replacement** of **combustion-powered vehicles** with **battery-electric and hydrogen-powered vehicles**.
- **Big upheaval on the powertrain ecosystem** :
  - ➢ More than 75% of internal combustion engines in 2020.
  - ➢ 10% of hybrid engines in 2020.

Objectives

Establish and predict trends based on consumer choices.

- **Aim**: Predict passenger car sales in France by examining economic indicators that influence consumer choices

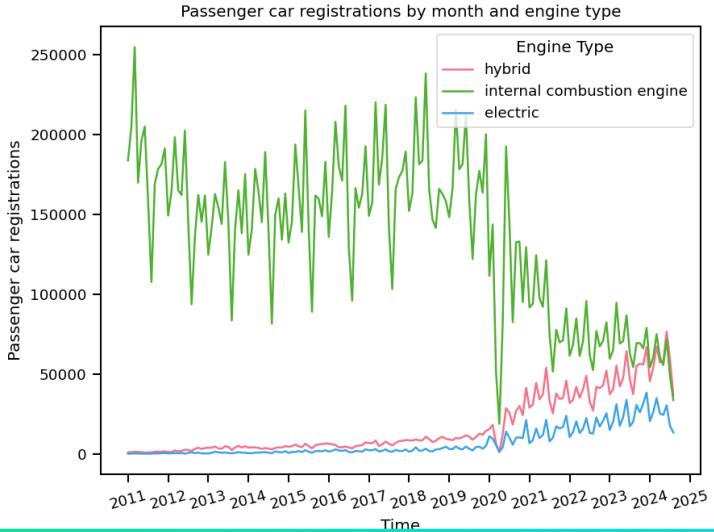
- **Explained variable y_t:** Number of new passenger car registrations by month (January 2011 to July 2024) and by engine type (electric, internal combustion, hybrid).

- **Explanatory X variables:**
  - ➢ GDP[(1)].
  - ➢ Savings rate[(2)] .
  - ➢ Motorbike, moped and electric buggy registrations[(3)].
  - ➢ Turnover index for long-term vehicle rental[(1)].
  - ➢ Fuel price mean[(4)].
  - ➢ etc.

[(1)] INSEE, [(2)] Banque de France, [(3)] Ministère de la Transition écologique et de la cohésion des territoires of France, [(4)] Data gouv

Times Series Approach

- **Descriptive components**
  - ➢ Seasonality
  - ➢ Trend
  - ➢ Dropping sales in April-May 2020.
- **Models combination:**
  - ➢ SARIMAX-GARCH.
  - ➢ Markov Switching Autoregressive models.



SARMAX model equation (Box, Jenkins et al. (2015))

The $SARMAX(p,q)(P,Q)_S$ model is defined as follows :

$$\begin{aligned} y_t =& c + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{i=1}^{q} \theta_i \epsilon_{t-i} + \epsilon_t - \sum_{i=1}^{p} \sum_{j=1}^{P} \phi_i \Phi_j y_{t-jS-i} + \sum_{j=1}^{P} \Phi_j y_{t-jS} \\ &+ \sum_{j=1}^{Q} \Theta_j \epsilon_{t-jS} - \sum_{i=1}^{q} \sum_{j=1}^{Q} \theta_i \Theta_j \epsilon_{t-jS} + \boldsymbol{\gamma}^\top \mathbf{x}_{t-1}, \quad t = 1, \ldots, T, \end{aligned} \tag{1}$$

where $\phi_i \in \mathbb{R}$, $p \in \mathbb{N}$, $\theta_i \in \mathbb{R}$, $q \in \mathbb{N}$, $\Phi_i \in \mathbb{R}$, $P \in \mathbb{N}$, $\Theta_i \in \mathbb{R}$, $Q \in \mathbb{N}$, $S \in \mathbb{N}$, $\boldsymbol{\gamma} \in \mathbb{R}^n$, $\mathbf{x} \in \mathbb{R}^n$, $\epsilon_t \in \mathbb{R}$

GARCH Model (Engle, R. F., & Ng, V. (1982) - Bollerslev, T. (1986))

The GARCH(s, r) model is defined as follows :

$$\begin{aligned} \epsilon_t &= \sigma_t \eta_t, \quad \eta_t \overset{iid}{\sim} \mathcal{N}(0,1) \\ \sigma_t^2 &= \omega + \sum_{i=1}^{r} \alpha_i \epsilon_{t-i}^2 + \sum_{j=1}^{s} \beta_j \sigma_{t-j}^2 \end{aligned} \tag{2}$$

where $\omega \in \mathbb{R}_+^*$, $\alpha_i \in \mathbb{R}$, $\beta_j \in \mathbb{R}$.

Markov Switching Autoregresive Model (Hamilton, J. D. (1989))

The $MS(s) - ARX(p)$ model is defined as follows :

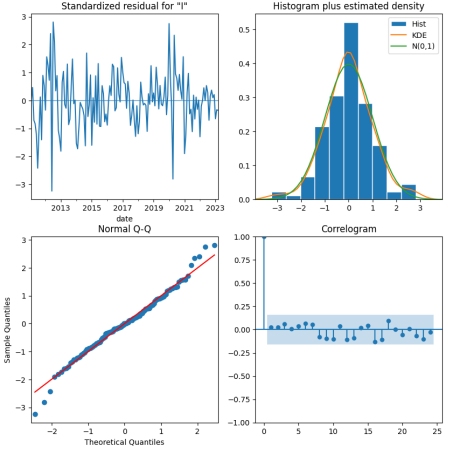
$$y_t = c^\top \xi_t + \sum_{i=1}^{p} \phi_i^\top \xi_t y_{t-i} + \gamma^\top \xi_t \mathbf{x}_{t-1} + \epsilon_t \tag{3}$$

$$\xi_t = \mathcal{P}^\top \xi_{t-1} + \nu_t$$

where $y_t \in \mathbb{R}$, $c \in \mathbb{R}^s$, $\phi_i \in \mathbb{R}^s$, $\gamma \in M_{s,n}(\mathbb{R})$, $\mathbf{x}_t \in \mathbb{R}^n$, $\xi_t \in \mathbb{R}^s$, $\epsilon_t \in \mathbb{R}$, $\mathcal{P} \in M_{s,s}(\mathbb{R})$, $\nu_t \in \mathbb{R}^s$.

Results: Electric vehicles

SARMAX-GARCH Model for electric vehicle



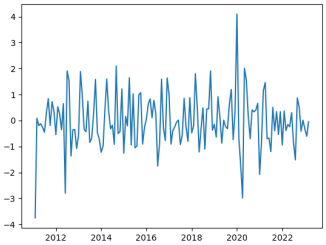
Variables	Coefficients	p-value
Motorbike, moped and electric buggy registrations	-0.0003	0.004
Turnover index for long-term vehicle rental	-0.0317	0.000
New vehicle price index	0.0617	0.005
Second-hand vehicle price index	-0.1603	0.000
Fuel price mean	-0.9794	0.000
savings rate	0.1652	0.000
GDP	2.5078	0.000
Registrations of hybrid passenger vehicle	0.5535	0.000
ϕ_1	0.2564	0.000
ϕ_2	-0.1330	0.077
ϕ_4	-0.1941	0.033
$\Theta_{1,12}$	0.1630	0.063

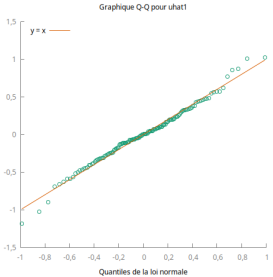
Table: Model's result of electric vehicle sales

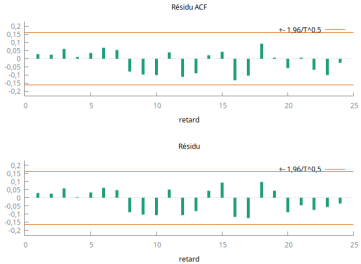
GARCH model for electric vehicle

variables	Coefficient	Error std.	z	p-value
ω	0.0947455	0.0947455	6.849	7.46e-12
α_1	0.245128	0.101241	2.421	0.0155

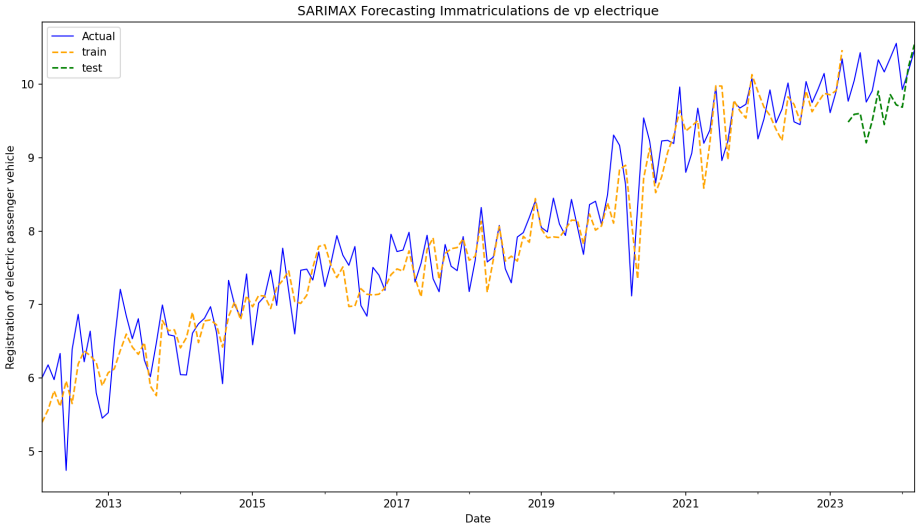
Table: GARCH Model's result of electric passenger car sales







Prediction of $SARMA(4,3)(1,0)_{12} - ARCH(1)$



Conclusion on SARMAX-GARCH model

Even with shocks, the SARMAX-GARCH model provides a **robust framework** to **understand** and **predict** the dynamics of electric vehicle registrations in the French car industry.

MS-AR model : Regime transition table and Recession plot

Switching parameters: the constant, exogenous variables and the autoregressive part.

Variables	Coefficients	p-value
$\mathbb{P}(s_t = 0 \mid s_{t-1} = 0)$	0.0372	0.000
$\mathbb{P}(s_t = 1 \mid s_{t-1} = 0)$	0.474e-20	1.000

Table: Regime transition parameters of MS-ARX model for electric vehicle

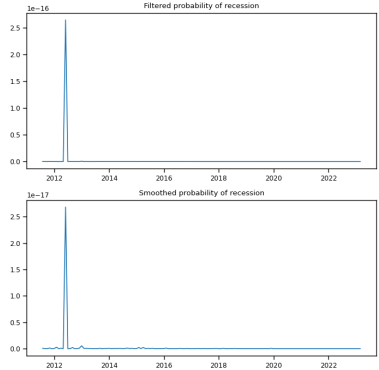


Figure: The filtered and smoothed probabilities of a recession for electric vehicle.

MS-AR model : Regime transition table and Recession plot

Switching parameters: the constant, exogenous variables.

Result for: Household debt, Saving rate, GDP.

Variables	Coefficients	p-value
$\mathbb{P}(s_t = 0 \mid s_{t-1} = 0)$	0.5380	0.000
$\mathbb{P}(s_t = 1 \mid s_{t-1} = 0)$	0.0877	0.005

Table: Regime transition parameters of MS-ARX model for electric vehicle

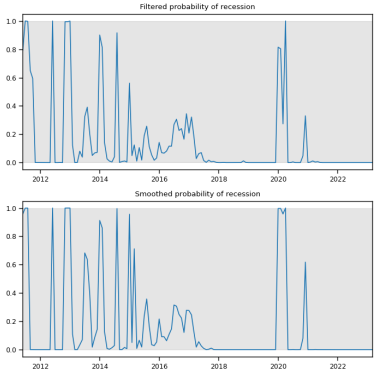
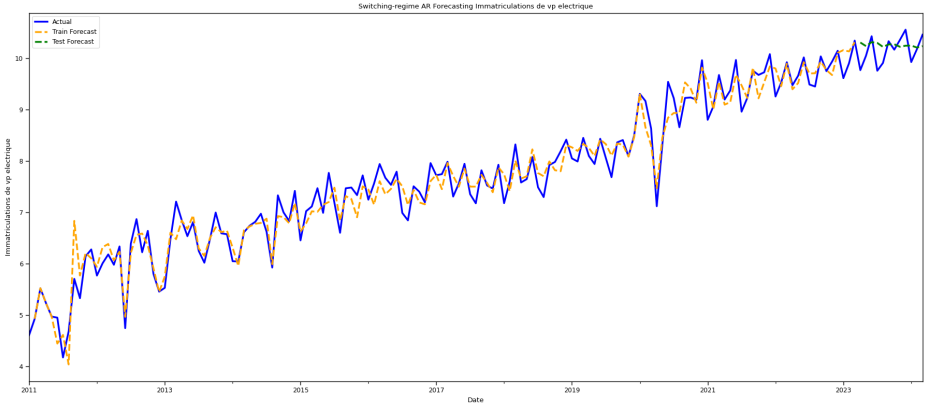


Figure: The filtered and smoothed probabilities of a recession for electric vehicle.

Prediction of $MS(2) - AR(5)$ for electrics vehicles sales



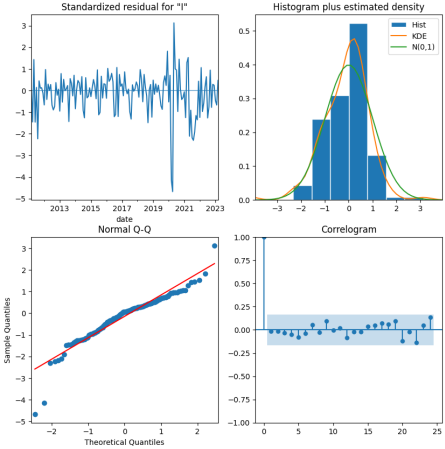
Conclusion on MS-ARX model

- Useful for analysing **time series shocks**.
- MS-ARX model is **irrevelant** in our case: Stay with a single regime.

- **Exogenous variables** are **sufficient** to **explain regimes changes** in times series.

Results: ICE vehicles

SARMAX-GARCH Model for ICE vehicle



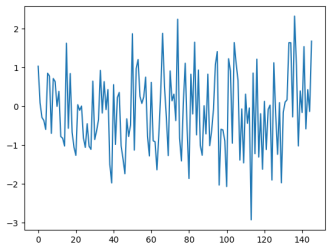
Variables	Coefficients	p-value
Turnover index for long-term vehicle rental	-0.0280	0.000
GDP	1.357	0.000
ϕ_1	-0.1730	0.019
ϕ_2	-0.5344	0.000
ϕ_4	-0.1552	0.029
θ_3	-0.2818	0.002
Φ_1	0.3292	0.000

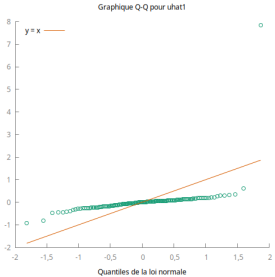
Table: Model's result of internal combustion engine vehicle sales

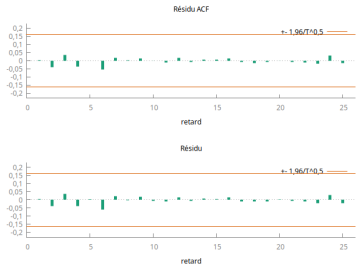
GARCH model for electric vehicle

variables	Coefficient	Error std.	z	p-value
ω	0.00656145	0.00270423	2.426	0.0153
α_1	0.507448	0.166637	3.045	0.0023
β_1	0.492552	0.102400	4.810	0.0000

Table: GARCH Model's result of internal combustion engine passenger car sales







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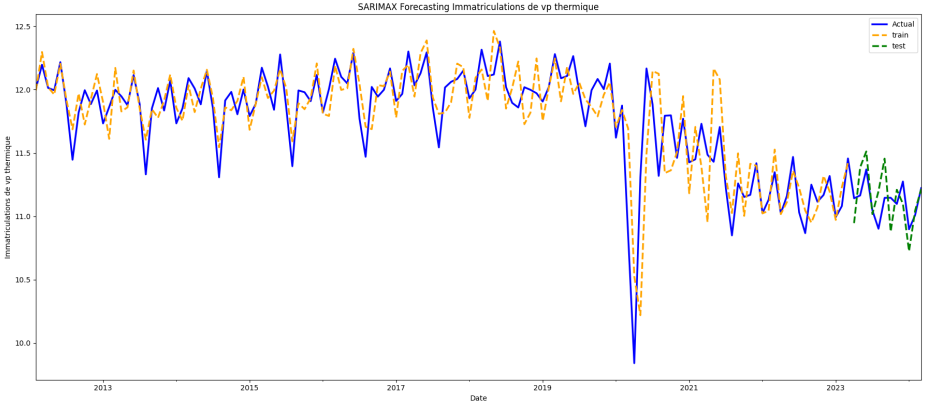

Conclusion on SARMAX-GARCH model

Even with shocks, the SARMAX-GARCH model provides a **robust framework** to **understand** and **predict** the dynamics of ICE vehicle registrations in the French car industry.

Conclusion

- **SARMAX-GARCH model** provides a detailed **understanding of the economic factors** (and conditions) influencing the registration of internal combustion engine vehicles, hybrid passenger vehicles and electric passenger vehicles in the French car industry.
- **MS-AR models** are useful to **analyse time series shocks**. In our case, **exogenous variables** may be **sufficient** to **explain regime changes in times series**.
- **Perspective**:
  - ➢ We assumed that the **residuals follow** a **GARCH model**. It would be interesting to **test** a **weak noise** to assess this hypothesis.
  - ➢ **Other indicators** can explain the consumers' choice : **psychological**.

Thank you for your attention !

Claire VERDIER - claire.verdier@univ-fcomte.fr

Variable descriptions

Variables	Mean	Min	25%	Median	75%	Max
Motorbike, moped and electric buggy registrations	1416.57	120	272	778	2054	5952
Turnover index for short-term vehicle rental	97.67	41.77	78.92	93.53	114.07	185.81
Turnover index for long-term vehicle rental	85.34	62.5	72.145	81.67	96.545	148.32
New car price index	102.52	91.22	98.415	101.25	104.14	118.49
Second-hand car price index	100.88	99.24	99.95	100.11	100.89	106.08
Fuel price mean	1.43	1.15	1.32	1.41	1.47	1.96
Unemployed number	2686.60	2079	2413.5	2708.33	3003	3111
Household debt	59.17	53.29	54.71	57.94	63.32	67.94
GDI purchasing power	0.26	-1.55	-0.081	0.21	0.58	3.32
Savings rate	15.69	13.29	14.06	14.71	16.86	25.75
GDP	5.858	5.126	5.371	5.717	6.107	7.263
interest rate	0.167	0.0	0.03	0.09	0.285	0.54
Business confidence index	92.91	80.0	86.5	93.0	99.0	109.0

Markov Switching Autoregresive Model

The Markov chains $\{s_t\}$ can be defined ξ_t as a vector with dimension $M \times 1$ where the i-th element is 1 if $s_t = i$ and 0 otherwise. In this way, the Markov chains follow a vector autoregression process of order 1, known as VAR(1) as follows:

$$\xi_t = P^\top \xi_{t-1} + \nu_t \tag{4}$$

where P is the transition matrix, ξ_t is the vector of unobserved states of the Markov chain and ν_t is a martingale difference sequence.

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- Hamilton, J. D. (1989). A new approach to the economic analysis of nonstationary time series and the business cycle. Econometrica: Journal of the econometric society, 357-384.