US gasoline demand function

Data on gasoline consumption (c_t), gasoline price (p_t) and real GDP (GDP_t) show an upward trend. c_t has also a clear seasonal impact (usually higher growth in the first quarter, peak at the end of the second, then a fall).
For this, model should contain time trend (t) and quarter dummies ($q1, q2, q3, q4$).
First two quarters of 2020 display a strong fall for each series, so I consider dummy for COVID outbreak (COV).

Transforming c_t, p_t and GDP_t in logarithm it is possible to interpret coefficients of model for the demand function as elasticities.

First attempt is a static OLS model without lags, but it has lots of problems: correlogram and residuals through time do not appear unpredictables, and Godfrey test up to order 8 rejects the null.

Adding filters for l_c_t, l_p_t and l_GDP_t (ADL (3,5) in the script) there are no more autocorrelation problems, but several parameters are insignificant.
Specification tests lead to the following ADL model (3 Information Criteria and Adjusted R^2 increase):

$$\begin{aligned} l\_c_t = {} & 0.052 - 0.023q1 + 0.036q2 + 0.022q3 - 0.001t - 0.244COV + \\ & + 0.622l\_c_{t-1} - 0.13l\_c_{t-2} + 0.19l\_c_{t-3} - 0.018l\_p_t + 0.004l\_p_{t-1} + \\ & + 0.716l\_GDP_t - 1.173l\_GDP_{t-1} + 1.176l\_GDP_{t-2} - 0.419l\_GDP_{t-3} + \varepsilon_t \end{aligned} \tag{1}$$

Then, I verify potential endogeneity problems for gasoline price.
European Oil price (Brent) and US Oil price (WTI) could be two possible instruments, both correlated with gasoline price and uncorrelated with the error term (consumption shocks).
Trying several TSLS regressions with and without lags, with one and both instruments, Hausman test do not reject H_0 (consistency of OLS), so I keep ADL (ref. 1). Possible reasons could be that another relevant variable (GDP) was just inside OLS, or maybe are necessary other kind of instruments.

Since variables are in logarithm, short and long run elasticities can be computed through the dynamic multipliers (in particular, δ_0 and LRM).
For a direct examination of δ_0 and LRM of price and income on gasoline consumption, I convert ADL (ref. 1) into an ECM.

- Price elasticity: always negative, lower magnitude in the short run (-0.019, but coefficient not significant), growth in the long term (-0.047).
  So, it confirms negative relation between demand and price (apparent contrasts with scatterplot among c_t and p_t, where it seems being an odd growing relation; but plot do not take account\keep stable through time important underlying factors, such as developments in vehicle efficiency,

new electric cars, costs to extract oil, ...).
So, consumption is less price elastic in the short term. Reasonable because an increase in price can't change too much people's habits\means of transport. Only permanent variations can push toward important changes (such as buy an efficient car, ...).

- Income elasticity: with GDP as indicator, higher in absolute value with respect to price elasticity (short term = +0.716, in the long run it increases to +0.952).
  As a whole it make sense: although there are some swings in the initial quarters, both δ_0 and LRM are positive, but the latter is bigger (maybe because permanent high income can push people to buy bigger cars, to travel more, ...). Even in this case, relevant changes take time.