Externalities estimate to 2030 in Italy under different hydrogen fuelled car fleet development scenarios

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The main target of this work is to draw a comparison between the magnitudes of the light duty vehicles fleet externalities under different hydrogen fuelled car fleet scenarios. The conclusions it reaches might be useful to understand if the savings coming from this green option can balance the investments it needs. The time span is to 2030 and it concentrates on Italy.

1. Introduction

Externalities coming from road transport system have been gathering attention from many stake holders in the last years. Both the passengers and the goods transportation have been following the same constantly growing path of the Italian economy. This complementary phenomenon, somehow cause and effect, has raised issues about its sustainability in a context where the economy needs to grow to improve people's standard of living. Consequently, the challenge is not to constrain mobility but limiting or reducing the bad effects coming from it. This issue holds peculiar importance for Italy since the two main reasons by which it is violating Kyoto's commitment on CO_2 emissions are power generation and transport sector itself. In particular, taking into account the introduction of alternative fuels it is likely to have a lower average impact of the vehicles fleet.

This paper focuses on the implementation of a hydrogen fuelled cars fleet in Italy up to 2030. The basic intuition is that this kind of cars have the opportunity to reduce externalities, mainly in terms of GHGs gases, local gaseous pollution and noise emissions. Therefore, the outcome the researcher would like to accomplish is to have a glance to the monetary gains, in terms of avoided externalities, by introducing this technology in the coming years. This estimate might be useful for further investigations using different methodologies.

First of all, a forecast of the Italian cars fleet will be carried out. The results of this part are the basis for the following, core section that deals with the externalities evaluation. Here two scenarios are drawn: the first one assumes that the hydrogen technology will not have any technology breakthrough at all. Instead, in the second scenario there will be a gradual spread of hydrogen fuelled cars till to reach a 15% share to 2030. Other assumptions are better explained in those paragraphs. At the end the modeler can compare the two outcomes. The scope of this work has to be taken into account accordingly to the difficulties faced in his construction. Therefore, the final remarks are weighted by the limits encountered during the forecasting phase.

2. Italian cars fleet forecast to 2030

2.1 Econometric theory and economic rationales

When asked to provide a solid prediction of this variable, the researcher might choose different paths to do it. For instance, it might be interesting to find out if there is a relationship between this trend and population or income. Basic single equation regressions were tested to prove the supposed underlying correlation but econometric outcomes showed it was not the most effective way to explain it. The coefficients did not pass the T-statistic significance test. A reason for that might be the connection between micro and macro responses in terms of car purchases triggered by an income increase. Individuals would tend not to buy extra cars in case of an increase of their incomes. Instead, they will likely substitute the previous car with another and better one. Only big increase in personal earnings would lead to purchase a new, additional car. Pictorially, it looks like horizontal straight lines whose steps are far each other when incomes lie on the horizontal axis and number of purchased vehicles on the vertical axis.

Another strategy would be using Vector Auto Related or Vector Error Correction Model. In this case, the effort drives to exploit the links existing between the different fuels share in order to provide a global forecast of the fleet. The problem faced with this strategy was that the main variable, the overall fleet, had a homogeneous path while the single shares (i.e. gasoline, diesel and gas) did not. The data were the same, since the first one is just the sum of the others but the information you can obtain differed substantially. This was probably caused by the price gap, taxes on gasoline and diesel and Government incentives on gas fuelled vehicles. The total need was fulfilled in any case but differently from time to time. Hence, it was ineffective to build a model that was supposed to exert leverage on the mutual relationships among the variables. A better way to do it was to concentrate on the fleet time series itself.

Two considerations led the construction of the final model. The first one was that this is a phenomenon that should have a ceiling. The reasons for that are, mainly, urban congestion and air pollution, mainly. Secondly, it is reasonable to say that there might be a higher growing rate in the first phase, slowing down after it reaches the half of its evolution.

2.2 The model

The logistic curve has exactly the above mentioned features. Formally it can be represented in this way:

$$L(t) = [A+B]/ [1+b_0*\exp(-b_1*t)]+B \qquad (1)$$

Where A is the ceiling and B represent the floor (zero in this case). Then it has been implemented a regression on the cars fleet time series from 1941 to 2002. The series goes back so far in time because the modeler wanted to check if the logistic curve could explain the data from the beginning. And so it was. Using a non linear estimate of the parameters b_0 (how fast it gets the ceiling) and b_1 (where the flex point is located) gives always better results than the linear estimate. The R^2 outcome of this model is very high: it ranges from 97,6% to 99,3% depending on the assumed ceiling. In fact, the model doesn't suggest to select a particular saturation point. Therefore, the researcher decided to build an alternative technique to support the choice.

2.2.1 Choosing the proper saturation point

The regular way the R^2 is built means that all the errors (i.e. differences between the fitted and the actual data) are weighted equally. But in this case it is more useful to choose models that better explain recent dynamics than older ones. So, it has to be highlighted that errors that are at the end of the series should be weighted more than the ones, say, 40 years ago. The total sum of squares would award models with different saturation points that, *coeteris paribus*, better perform recently and they, therefore, have a stronger forecast potential.

Since with the regular R^2 the underlying assumption is that the weight given to errors is always the same, the researcher had only to relax this hypothesis. Consequently, weights had to grow, approaching the end of the series, using different pattern: linear, squared and exponential ones, among others. The closer the "right" model got to the recent days, the less errors it was allow to do. This makes great sense if the final aim is to have a projection for the future, as it was.

The results coming from this particular technique showed that the 35 millions private and light duty vehicles ceiling was the best ones. Most of the above mentioned models led to this conclusion comparing the computed total sum of errors.

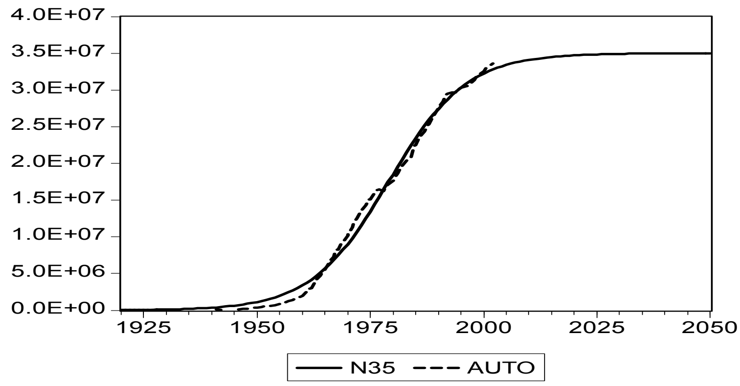
2.3 The results

The 35 millions cars fleet ceiling has a (regular) R^2 of 99,4% and has given the following result:

$L(t) = [35.000.000]/ [1+ 1018,056*\exp(-0,117*t)]$ (2)

Pictorially it looks like this:

Figure (1):



The dotted line represents the actual data; the solid line is the final logistic curve.

3. Externalities under different scenarios

The previous section model gives the researcher the basis to build an economic evaluation of externalities. Using these data it will be implemented a model that gives outlooks of the private cars fleet impact under different hydrogen fuelled vehicles penetration assumptions.

3.1 Model structure and underlying assumptions

The way results are computed is a typical bottom-up example. It starts from disaggregated data combining them after to get a final, representative outcome.
The modeler employed 1998 ExternE Transport estimates about monetary impact in term of car/kilometer driven for each fuel and at different journey speeds (urban, extra-urban and highway). Estimates about the journey speed share were kindly provided by Italian APAT. The chosen mileages for each fuel was only the mean of the last 30 years since their variance showed to be reasonably low. The assumed shares (sorted by fuel) evolution was based on the observation of the present trends and EU predictions. Diesel cars sales reached, in 2003, the gasoline vehicles sales after a constant growth in the last 10 years. The fleet ratio between these two fuel is still 9/2 but, by 2030, it might be claimed that it could get close to parity. Referring to biodiesel, natural gas and hydrogen the researcher took the EU commitment to favor these fuels. By 2020, an intermediate step here, biodiesel should represent 5% of the total fleet, natural gas 10% and hydrogen 5-7%. So, hydrogen was supposed to achieve a 15% share in the second, optimistic scenario.
Most of the literature in this field agrees on the prediction that steam methane reforming will be the first technology introducing the "supposed to be" hydrogen economy. But there are not, at present, reliable "well-to-wheel" evaluations about the externalities of this technology. So a trick would be to assume that the hydrogen cycle is perfectly clean, i.e. without any external effects in terms of emitted gases and noise. This hypothesis implies, basically, that renewable sources are employed in the hydrogen production. This is not too far away from reality, taking into account the time span and the fact that it has to stress the optimistic side of the scenario in contrast with the pessimistic one.
Hence, the yearly externalities are simply the weighted average of these and the previous data. Each year total externality is the sum of the single fuel fleet externalities. The number of cars by year is the product between the total fleet forecast (see paragraph 2) and the assumed share evolution. Combining these data with the mileage it gives the total car/kilometer per year. Then the ExternE Transport estimates allow to work out the annual result.
There are two results for each year: the one belonging to the first pessimistic scenario (no hydrogen vehicles at all) and the second, optimistic one (15% of hydrogen fuelled cars to 2030). To compare these two it has been adopted the Net Present Value discount technique since financial amounts far away in time each other can not be barely put side by side. Consequently, the two nominal values rows have been discounted using the interest rate curve when it was calculated (October 2003).

3.2 The results

Here follows the table that shows the results sorted by year and scenario:

Table (1):

Year	A scenario: 0% share of hydrogen	B scenario: 15% share of hydrogen	Year	A scenario: 0% share of hydrogen	B scenario: 15% share of hydrogen	Year	A scenario: 0% share of hydrogen	B scenario: 15% share of hydrogen
2004	2.267.520.175	2.267.520.175	2013	1.634.993.136	1.532.357.229	2022	1.184.643.550	1.050.729.258
2005	2.244.297.946	2.226.936.627	2014	1.579.471.048	1.470.641.689	2023	1.141.532.455	1.006.813.766
2006	2.145.498.657	2.112.751.089	2015	1.525.273.044	1.411.055.647	2024	1.099.772.228	964.630.324
2007	2.110.303.600	2.062.629.312	2016	1.472.432.965	1.353.574.844	2025	1.059.341.534	924.123.435
2008	2.074.322.198	2.012.658.732	2017	1.420.974.061	1.298.167.169	2026	1.020.216.678	885.237.518
2009	1.923.490.462	1.852.939.978	2018	1.370.910.638	1.244.794.340	2027	982.372.107	847.917.291
2010	1.870.437.462	1.789.162.787	2019	1.322.248.976	1.193.412.874	2028	945.780.737	812.107.990
2011	1.817.922.799	1.726.926.049	2020	1.274.988.791	1.143.975.484	2029	910.414.351	777.755.654
2012	1.766.055.688	1.666.283.986	2021	1.229.123.959	1.096.431.790	2030	876.243.796	744.807.227
						Total sum	40.270.583.043	37.476.342.266

Externalities estimates are expressed in 2003 Euros. All values have been already discounted.

These outcomes seem to show that the monetary advantages introducing the hydrogen option in the coming years are not remarkable. A little bit than 3 billions Euros over a time span of 27 years could be not that advantageous since here it has not be considered the huge amount of investments it needs. In fact, to get a more comprehensive view it should be computed the money necessary to build the infrastructure to produce and to supply hydrogen. Moreover, it is worth to be highlighted that assuming less optimistic conditions in the second scenario the gap would be further reduced.

On the other hand, the modeler can find two reasons to explain the dimension of the gap. The first one relates to the discounting mechanism itself. The farther in time amounts of money are, the smaller weight they will have in present terms. All different fuel shares evolve linearly to arrive to their assumed levels in 2030. Consequently, as time goes by low emissions fuel gains weight, in relative terms, and this is reflected in the nominal gap between the two scenarios. But as nominal gaps grows, discount factors decrease compressing benefits that would seem to exist. The NPV technique has a solid theorical basis by the way it is built and it does not change the overall meaning of these results. But these considerations allow us to look at and interpret them under a different light.

The second reason that should clarify the magnitude of the difference in the two scenarios is strictly connected with the diesel fuelled cars fleet. Diesel cars have a way greater impact on environment than other engines. A first glance at the disaggregated values sorted by type of fuel would reveal that as diesel increases its share the total amount of externalities is by far explained by the diesel cars fleet itself. A mighty leverage that drives the absolute level of externalities is, therefore, the share of diesel fuelled cars. The way by which the researcher change her/his assumptions about it can modify also the size of the gap between the two scenarios.

3.4 Strengths and weaknesses of the model

Using easily available data and an easy model structure it has been provided a brief description of the possible perspective, in terms of environmental impact, taking into account the introduction of hydrogen fuelled cars. This is a useful starting point for further researches aimed at building a more complicated model. For example, there is the opportunity to relax individual assumptions to get a model that is closer to reality.

The drawbacks that this work shows are first of all related to the lack of data dealing with hydrogen cars. The additional problem is that even if these data were available it has to be drawn a prediction of them. Without any doubt, it is difficult to forecast on events in their early stages of development.

Moreover, some assumptions might have added uncertainty on the final outcomes. For instance, movements in the interest curve in the coming months or years can substantially change the results. But this is also a common issue when a discount method is involved.

The time span is long. The work focuses on a phenomenon that is supposed to have remarkable effects in the long run. But the longer is the time horizon, the lower it gets the prediction likelihood.

Finally, this is a quantitative work but qualitative variables might have a determinant weight in driving the success of the above mentioned fuels. In particular political developments traditionally have had a strong influence in choosing the allocation of research and infrastructure investments. These factors are honestly difficult to predict also because of the time span.

4. Conclusions

The question the modeler would have liked to answer is: is hydrogen a realistic option? This work has showed that there is not a strong evidence in this sense. The two scenarios differ substantially by the posted assumptions but the final gap between these two is narrow. Moreover, further investments would be needed to build the infrastructure. This gives an idea of the obstacles faced to introduce hydrogen car fleet.

Coming back to the initial problem, the noise and gases emissions, maybe other ways would be more viable. For instance, a natural gas fuelled vehicles infrastructure would be way easier to be built. In addition, it would be ready in few years, instead the hydrogen one. The issue is, therefore, how to balance the fuel mix taking into account also these considerations.

5. References

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