A SUSTAINABLE MARKET NICHE FOR HYDROGEN IN THE TRANSPORT SECTOR ?

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Overview

Mobility is one of the hard to abate sectors, and in particular, heavy-duty mobility is the one which concentrates both challenges – long range, need for quick refuelling, large payloads, etc. The current solution for heavy-duty transport, e.g. trucks, buses, delivery vehicles, etc. is based on comparatively high efficiency diesel engines, with lowest fuel costs, ensuring the lowest overall OPEX, despite higher maintenance costs than other engine types. Several solutions are evolving to decarbonate heavy-duty transport, e.g.: battery-electric vehicles (BEV), fuel cell electric vehicles (FCEV), bioLNG, bioNGV, etc. On the one hand, BEVs use technology that is becoming more mature, have a total cost of ownership (TCO) increasingly approaching that of diesel vehicles but remain limited by range and charging time. On the other hand, FCEVs have a greater range, are less limited by charging time and require a smaller battery than BEVs, that is smaller amounts of critical materials. Nevertheless, this technology is not very mature, has a relatively high TCO, and will need a supportive public framework, to ensure the delivery of low-carbon hydrogen. The main question in uncertain future is how the different solutions will position themselves with respect to each other, and which parameters will play the main role to ensure success. Assuming that fuel costs include all issues related to the refueling infrastructure, we focus on analysing the cost-benefit ratio related to the TCO of vehicles. In order to tackle this issue, existing research addressed the cost-benefit ratio of a green technology versus a reference carbon emitting technology, and pointed out the importance of anticipating investment in order to benefit of the learning effects (Grimaud and Rouge , 2008; Goulder and Mathai, 2000).

In this paper two green technologies compete with different cost advantages on two market segments. The learning-by-doing for each technology benefits from the total production on the two segments., This work explores which parameters play the main roles in the different scenarios and on the end-results, i.e. the technologies that are expected to succeed under given conditions. For instance, if the hydrogen market segment is too small or the potential cost reduction of FCEVs not sufficient, inducing a late launching deployment, it could be optimal to deploy BEV on both segments. Characterizing the conditions under which there is a sustainable niche for FCEV is the core issue discussed in the paper.

Methods

To address this issue, we consider a partial equilibrium model with two competing low-carbon technologies and one-carbon-based technology which is an extension of the model of Creti et al. (2017). Compared to mature carbon-based technology, unit production cost of low-carbon ones involves convexity and learning-by-doing. To plan sustainable green mobility, the social planner minimizes private cost of production and also the social cost of carbon (SCC) in the case of carbon-based technology, growing exogenously at the social discount rate.

In a first step, we use optimal control and dynamic optimisation tools to characterizean optimal deployment path for both technologies. We found preliminary theoretical results on the arbitrage between convexity and learning-by-doing, in accordance with the results highlighted by Bramoullé and Olson (2005).

In a second step, we introduce horizontal differentiation through two market segments: a large segment and a small segment (i.e. the niche). BEVs are better suited for the large segment and FCEVs for the small segment. A cost penalty is added to the TCO of electric vehicles that are used in the niche market, corresponding to the opportunity cost or the cost of additional vehicles. In the absence of cost convexity, only two strategies are optimal. The first strategy, called "B-B", is to maximise learning by focusing on a single technology, the cheapest and the one with the largest market size, that is battery. The second strategy, called "B-FC", is to develop each technology in its respective better segment, i.e. BEVs for the large segment and FCEVs for the small segment.

Results

The optimal strategy balances the amount of emissions prior to full sector decarbonization with the total discounted cash cost for the transition. Considering the B-FC strategy, due in particular to a higher initial TCO for FCEVs compared with BEVs, the transition to FCEVs on the small segment would take place later than the one of BEVs on the large segment. Using the B-B strategy changes these dates, thus influencing emissions prior to full decarbonization, but increasing the discounted cash cost since it promotes BEV on the short-distance segment. To provide a numerical application of our model, we consider the mobility segment of buses for the European geographical area. Simulations with parameters calibrated on public reports data and interviews with mobility experts characterize how parameters interact in the choice between the B-B and B-FC strategies.

Based on these calibrated parameters, it is shown that B-FC strategy dominates, i.e hydrogen mobility has a sustainable niche on the small segment of bus mobility. Considering the B-FC strategy, it is optimal to minimize the total discounted cost of transition to launch FCEVs on the niche market when the social cost of carbon reaches 160€/tCO_2. Sensitivity analysises also show how three key parameters favor the B-FC strategy: the size of the niche market, the level of the absolute cost advantage of FCEV over BEV in that niche and the time to TCO parity with diesel for FCEB formalized through the learning-by-doing rate of FCEV. A sensitivity analysis provides some ground to assess the robustness of our conclusion. In all of our scenarios, given the current level of the SCC, battery-electric vehicles must be launched immediately in the short-distance segment market.

Further attention should be given to the drivers of these three parameters: a reassessment of the FCEB target cost and learning rate, new solutions allowing fast-charging of heavy-duty transport at low cost or a new generation of battery could challenge the sustainability of a hydrogen market niche in the bus sector, but also in the heavy-duty mobility sector. Our simulations also show that an extension of the transition duration required for phasing out the carbon-based technology favors the B-B strategy to the detriment of the B-FC strategy. Given that the duration of the transition depends mainly on the amounts of investment available to decarbonize the economy, proactive climate policies will help develop a hydrogen market niche in the bus transport sector.

Conclusions

Contributions of the paper are twofold. Firstly, it clarifies the impacts of learning-by-doing, convexity and horizontal differentiation on the optimal transition path when several green competing technologies are available to decarbonize a given mobility segment. Secondly, the analysis is applied to the case of fuel-cell electric and battery electric buses to decarbonize the European park of diesel buses. Based on out current set of calibrated parameters the existence of a sustainable niche for FCEB is validated.

Our model can be extended in several directions. It would be possible to include other competing low-carbon technologies, such as biomethane and e-fuel. The model may also be adapted to other market segments, such as trucks, coaches, light duty vehicles, trains, or boats. However a more relevant extension would be to encompass all mobility segments into a larger sector model so as to link the market niches in these segments with the learning rates in the respective common cost components (fuel cells, tanks, monitoring systems). Additionnally, a more detailed study of the environmental impacts of the different low-carbon technologies must be carried out. In particular, the issue of indirect emissions from low-carbon vehicles needs to be addressed.

References

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