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Geodemographic analysis and estimation of early plug-in hybrid electric vehicle adoption

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HIGHLIGHTS

- Adoption of hybrid electric vehicles is analysed in demographically distinct areas.
- Several demographic characteristics strongly correlate with the HEV adoption ratio.
- We discuss the applicability of the results to estimation of early plug-in hybrid adoption.
- We demonstrate the use of public data in this context.

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ABSTRACT

Electric vehicles and hybrids are expected to become increasingly common in the coming years. The implications of growing adoption depend on its geographical extent. For instance, vehicles that are chargeable from the electrical grid, such as plug-in hybrids, can introduce problems for the distribution network especially if the vehicle adoption is spatially concentrated. In this paper, the adoption of hybrid electric vehicles is analysed in heterogeneous areas. The main purpose is to study the interrelationships between early hybrid electric vehicle adoption and different demographic and socio-economic characteristics of the areas. It is further discussed how the results can be applied to estimate the upcoming plug-in hybrid adoption. As there is a vast amount of information in the various registers of the society, slowly being opened for free usage but not fully utilised so far, it is also of interest to study and demonstrate the usability of public register data in this context. Our analysis suggests that certain characteristics of the areas strongly correlate with the hybrid electric vehicle adoption. The results of this study could be relevant, e.g., for electric distribution network planning, targeting policies to support cleaner vehicle adoption, marketing hybrid vehicles and locating charging stations.

1. Introduction

The worries over green house gas emissions and limited oil resources have led to a global attempt to increase the energy efficiency and the share of the renewables. According to World Resources Institute, in 2005 the transportation sector produced 14.3% of the global greenhouse gas emissions [1]. Electric vehicles (EVs) and hybrid electric vehicles (HEVs) are expected to improve the situation by increasing the fuel efficiency and by presenting a serious alternative to the use of fossil fuels.

The batteries used in electric vehicles and plug-in hybrid electric vehicles (PHEVs) are charged from the grid, and thus, substantial adoption of such vehicles can cause problems for the power-distribution networks. A situation where the adoption of EVs and PHEVs is regionally concentrated and the charging is unmanaged, has been considered especially risky in several studies (e.g. Lopes et al. [2] and Shao et al. [3]).

In the coming years, power-distribution networks are expected to be capable of handling various distributed energy resources (DERs) intelligently. As a result of the increased automation, the so called smart grid will potentially improve the efficiency, reliability and security of the electricity distribution. The grid connected vehicles can also be regarded as energy resources, as they do not only cause new increased loads while being charged, but can potentially be used to feed the battery stored energy back to the grid by providing vehicle-to-grid services (V2G). The possible use cases vary from serving the grid with more power during the peak hours to providing ancillary services, such as frequency regulation.

All in all, there is an increasing need for tools to help the planners and policy-makers to assess the diffusion of environmentally friendly technological innovations, such as the electric vehicles. Apart from that, there is a vast amount of data in the various registers of the society, slowly being opened for free usage, but not

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fully utilised so far. For privacy and practical reasons such data is often constrained in spatial resolution and might lack in coverage. Thus, methods are needed which can deal with the aforementioned constraints.

The general problem in assessing the diffusion of innovations is that proper data, collected from real market transactions, simply does not exist yet or its quantity is low. To deal with the absence of data, it is in some cases possible to relate the new product to another one, which has been in the market for a longer period of time, by analogy. Analogous products have certain similarities, and yet, such distinct features that they cannot be classified just as different generations of the same product. The method is used especially when attempting to predict the sales performance of new products. For instance, Bass et al. [4] used an analogy between a new satellite television product and cable TV.

The market for electric vehicles and hybrids is still in its early days. Several models of HEVs have been sold for years but the adoption has been slow. The additional price premium, the limited model selection and the hybrid technology's unfamiliarity are possible culprits for the slow adoption. The hybrid car market is still marginal compared to the conventional car market. As for the PHEV models, several car manufacturers have planned to start selling them during 2012. Pure EVs are still very rare and the adoption is expected to be slower compared to HEVs and PHEVs. This is thought to be the result of their short driving range before having to recharge, slow charging and the high cost of batteries. Because of the range and recharging issues the use cases for an EV are limited at the moment compared to the conventional internal combustion engine vehicles (ICEVs), HEVs and PHEVs. Thus, as concluded by Tamor et al. [5], a PHEV is much more plausible replacement for a conventional vehicle than an EV.

One thing that all the electric vehicle technologies certainly have in common is the capability to partly or entirely substitute the fossil-based fuel by electricity. Therefore the technology's selling points could be considered as being environmental friendliness and fuel (cost) savings. Moreover, some consumers seem to perceive the hybrid and EV technology as more advanced and technologically more interesting than the conventional ICEV technology [6]. Turrentine and Kurani [7] recognized that car buyers in the US market are not tracking their fuel consumption accurately. According to the study, a decision to buy environmentally friendly vehicle is more probably based on symbolic value and the perceived efficiency rather than on well calculated fuel savings.

As the penetration of HEVs is still very low, the current owners constitute of innovators or early adopters. They have demonstrated their willingness to pay premium price for environmentally friendly or fuel saving vehicle technology. The same consumer traits should be also applicable to the owners of PHEVs and possibly to the owners of EVs. Moreover, the possible use cases between the current PHEVs and HEVs are mostly similar. Either one of them can be a direct replacement for a conventional vehicle, in contrast to EVs which impose additional restrictions, such as the limited driving range. In comparison to HEVs, PHEVs introduce the additional issue of requiring a place for charging. Even though PHEVs can be charged from a normal electrical wall socket, for instance in urban setting, it might be sometimes difficult to find one that is available on a parking lot. Moreover, specialised charging stations might still not be common enough to depend on. In Finland however, it is commonly thought that the vehicle charging will happen mostly at home, as that is where the vehicle is parked for longest continuous period of time during the day. Also, many of the Finnish apartments and work places already have the infrastructure necessary for vehicle pre-heating. The same vehicle pre-heating infrastructure can be utilised as it is or with small modifications to charge the vehicles [8]. As such, at least in the Finnish setting, the availability of vehicle charging infrastructure is less of an issue and we do not consider it as a big differentiating factor between the adopters of HEVs and PHEVs. Thus, it could be assumed that HEVs and PHEVs are analogous products and the adoption would mostly happen among the same consumer groups.

The literature on the factors affecting the willingness to adopt EVs and hybrids is extensive. A large portion of it is based on stated preference surveys, while those based on revealed preferences, i.e. actual market transactions, are fewer. A large portion of the studies also consider the adoption on a countrywide scale rather than regionally, thus not analysing the phenomenon spatially. Furthermore, the use of already existing and publicly available registers, such as census data has been largely unexplored in this context.

In this paper, we have analysed the adoption of HEVs in distinct area types, characterised by different demographic and socio-economic attributes, by making use of public census data. A big motive for the analysis is in the potential to utilise it for estimating the upcoming PHEV adoption. As predicting the diffusion of new (or still non-existent) products is very difficult, the hypothetical analogy between HEVs and PHEVs could be used to predict the upcoming PHEV adoption in different geographical areas. The emphasis here is on the early adoption, as that is what the HEV adoption data available for this study really represents. This could have useful applications e.g. in policy-making, electric distribution network planning and locating charging stations.

The rest of the paper is structured as follows. Section 2 introduces the used data and methods. Section 3 contains analysis of the data both from temporal and regional perspectives. The results are presented and further discussed in Section 4. Finally, Section 5 concludes the work.

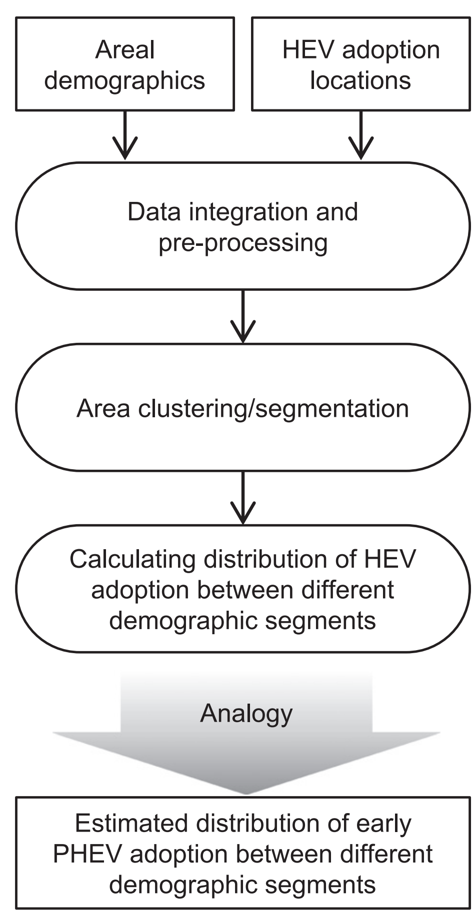

Fig. 1. The main elements of the performed analysis.