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Total cost of ownership and market share for hybrid and electric vehicles in the UK, US and Japan

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HIGHLIGHTS

- Ownership costs are compared for Electric, Hybrid, petrol and diesel vehicles.
- Total Cost of Ownership (TCO) is compared for UK, USA and Japan from 1997 to 2015.
- Hybrids are relatively cheaper in 2015 than the year of introduction.
- Market share of hybrids is strongly correlated with their relative TCO.
- At current low fuel prices in the UK, hybrids reach cost parity at 16,000 miles.

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ABSTRACT

New powertrain technologies, such as Hybrid Electric Vehicles, have a price premium which can often be offset by lower running costs. Total Cost of Ownership combines these purchase and operating expenses to identify the most economical choice of vehicle. This is a valuable assessment for private and fleet purchasers alike. Studies to date have not compared Total Cost of Ownership across more than two vehicle markets or analysed historic costs. To address this gap, this research provides a more extensive Total Cost of Ownership assessment of conventional, Hybrid, Plug-in Hybrid and Battery Electric Vehicles in three industrialized countries – the UK, USA (using California and Texas as case studies) and Japan – for the time period 1997–2015. Finally, the link between Hybrid Electric Vehicle Total Cost of Ownership and market share is analysed with a panel regression model.

In all regions the incremental Total Cost of Ownership of hybrid and electric vehicles compared to conventional vehicles has reduced from the year of introduction and 2015. Year on year Hybrid Electric Vehicles Total Cost of Ownership was found to vary least in the UK due to the absence of subsidies. Market share was found to be strongly linked to Hybrid Electric Vehicle Total Cost of Ownership through a panel regression analysis. Financial subsidies have enabled Battery Electric Vehicles to reach cost parity in the UK, California and Texas, but this is not the case for Plug-in Hybrid Electric Vehicles which haven't received as much financial backing. This research has implications for fleet purchasers and private owners who are considering switching to a low-emission vehicle. The findings are also of interest to policymakers that are keen to develop effective measures to stimulate decarbonisation of the fleet and improve air quality.

1. Introduction

Electrification of the transport sector offers the opportunity to utilise the increasing share of renewable energy generation whilst reducing national oil dependency. Urban air pollution is also a serious concern for residents in many cities across the world. Poor air quality claims the lives of over seven million people annually worldwide [1]. Different types of electric vehicles such as Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs) and Hybrid Electric Vehicles (HEVs) emit lower levels of carbon dioxide and air pollutants than conventional petrol and diesel vehicles [2,3], contributing to the decarbonisation of road transport and improving urban air quality. Growing the fleet share of these low-emission vehicles is therefore of interest to policymakers.

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With a larger battery and features such as regenerative braking, engine stop-start and a novel transmission system [4], hybrid and electric vehicles have a higher manufacturing cost than conventional vehicles [5]. Conversely, running costs are often lower stemming from cheaper annual fuel costs, taxes and maintenance. Many countries have offered subsidies or reduced taxes for low-emission vehicles to stimulate adoption: for example the Plug-in vehicle grant in the UK [6], the Clean vehicle rebate project in California [7] and the Green vehicle purchasing promotion measures in Japan [8]. Total Cost of Ownership (TCO) calculations can determine whether subsidies and lower running costs can offset this price premium. Vehicle ownership costs are important in vehicle adoption choice for both private and business purchases. This is evidenced by stated and revealed preference surveys (for example see Ozaki et al. [9]). Over the past decade there has been a rise in the number of vehicles bought through finance especially in the UK [10], however, the amount paid through a typical three year finance model is comparable to the vehicle depreciation (see Section 3.2).

The Toyota Prius was one of the first hybrid cars developed. It was released exclusively to the Japanese market in 1997 [11]. The diversity of the hybrid market has grown such that nearly fifty different models are available in the US vehicle market from a range of brands [12]. In countries such as the UK and Japan, plateauing Prius market share may be attributed to the greater availability of different hybrid models such as the Auris, Yaris and Aqua. Evidence for this is the success of the Toyota Aqua in the Japanese market [13].

This study contributes to the literature in three key areas: investigating how TCO has changed historically, examining how TCO varies across different geographic regions and analytically assessing the relationship between hybrid vehicle TCO and adoption. By building a comprehensive TCO model for several different geographic periods over a time period of 16 years (the period when data was available for all geographic areas), a panel regression model is used to assess the effect of changing ownership costs on market share. The conclusions from the HEV TCO/market share analysis aim to inform how policies can be introduced to stimulate HEV, PHEV and BEV uptake. To assess the robustness of the cost model a sensitivity analysis is conducted for variation in mileage, fuel price, depreciation rate, ownership period and discount rate.

2. Literature review

Many TCO calculations have been published to assess the cost effectiveness of new vehicle technologies such as electric commercial vehicles (e.g. Falcão et al. [14]), electric buses (e.g. Li et al. [15]), plug-in hybrid trucks (e.g. Vora et al. [16]) and vehicle automation (e.g. Wadud [17]). As early as 2001 Lipman & Delucchi [18] compared the cost of different degrees of hybridizations across multiple vehicle segments. Since then, many other publications (see Table 1 for review of key studies in TCO literature) have compared the ownership costs of battery and hybrid electric vehicles. Many of the studies focus on a full spectrum of PHEVs with different battery sizes; to assess whether the cheaper costs of running a PHEV with a higher battery storage capacity offsets the larger initial battery price (for example Al-Alawi and Bradley [19] and Hutchinson et al. [4]). The studies in the literature largely conclude that without government support hybrid and electric vehicles are still more expensive than petrol or diesel cars.

Previous published TCO calculations usually only consider vehicle ownership costs in one country of geographic region (e.g. Gilmore and Patwardhan [23] considers passenger vehicle TCO in India, and Diao et al. [24] consider private car TCO in China). Hutchinson et al. [4] is the only study which compares hybrid vehicle TCO across more than one geographic region concluding that the high fuel price leads to a shorter pay back of less than 2.6 years for HEVs in the UK compared to 6.7 years in California. HEV TCO can vary substantially over different countries and American states as a result of varying fuel price, availability of low-emission vehicle incentives and region dependent

Table 1
Total cost of ownership literature summary.

	Lipman & Delucchi [20]	Thiel et al. [21]	Al-Alawi & Bradley [19]	Hutchinson et al. [4]	Wu et al. [22]	This paper
Vehicle class	Compact or mid-sized large car, pickup, minivan, SUV	Compact car	Compact car, Mid-sized car, Mid-sized SUV, Large SUV	Mid-sized car	Small, Medium and Large cars	Mid –sized car
Powertrain type	Five degrees of hybridization	BEV, PHEV, HEV	HEV, PHEV 5–60	Mild, HSD, Two-Mode, Inline Full, Plug-in HSD, Plug-in Series	BEV, PHEV, HEV	BEV, PHEV, HEV
Purchase year	2000	2010	2010	2013	2015	1997/2000–2015
Economic yr	2000$	2010€	2010$	2013$	2015€	2015£
Economic country	USA	Europe	USA	USA and UK	Germany	UK, USA (California, Texas), Japan
Annual vehicle miles travelled	Not specified -decreasing with age	15,000 km	12,000 miles/yr for cars decreasing with age	130 000 miles over lifetime	Three cases: 7484 km, 15 184 km and 28 434 km	10,400, 11,071, 15,641, 6213 miles/yr for UK, California, Texas and Japan.
Vehicle life	15 years	(payback time)	5 and 13 years	130,000 miles	6 years	3 years (ownership period)
Fuel economy	EPA adjusted	NEDC European average	EPA adjusted	Fuel saving tests for urban and highway	Literature.	Spritmoniter
Gasoline price model	1.46 ($/gallon)	Assumed 60% tax on top of European oil price projections	Forecasted over vehicle life	3.20, 7.70 for USA, UK ($/gallon)	Own forecast	Forecasted over vehicle lifetime
Incremental cost model	MSRP used	Yes	EPRI, 2001; Kalhammer et al., 2007	Brooker et al. 2010; Clearly et al. 2010	Yes, derived.	MSRP used
Salvage	None	None	Vehicle resale	Vehicle resale	Yes	Vehicle resale
Maintenance	Yes	None	Yes	None	No	Yes
Insurance	Yes	None	Yes	None	Yes	Yes
Tax model	Yes	None	Yes	None	Yes	Yes
Discount rate	None	5%	6%	None	4.1%	3.5% (UK, Japan) 4% (US states)