Transportation Research Part A 73 (2015) 96–112

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Will subsidies drive electric vehicle adoption? Measuring consumer preferences in the U.S. and China

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A R T I C L E   I N F O

Article history:
Received 2 December 2013
Received in revised form 9 January 2015
Accepted 11 January 2015
Available online 14 February 2015

Keywords:
Vehicle electrification
Discrete choice modeling
Conjoint analysis
Federal subsidy policy
China
Willingness-to-pay

A B S T R A C T

We model consumer preferences for conventional, hybrid electric, plug-in hybrid electric (PHEV), and battery electric (BEV) vehicle technologies in China and the U.S. using data from choice-based conjoint surveys fielded in 2012–2013 in both countries. We find that with the combined bundle of attributes offered by vehicles available today, gasoline vehicles continue in both countries to be most attractive to consumers, and American respondents have significantly lower relative willingness-to-pay for BEV technology than Chinese respondents. While U.S. and Chinese subsidies are similar, favoring vehicles with larger battery packs, differences in consumer preferences lead to different outcomes. Our results suggest that with or without each country's 2012–2013 subsidies, Chinese consumers are willing to adopt today's BEVs and mid-range PHEVs at similar rates relative to their respective gasoline counterparts, whereas American consumers prefer low-range PHEVs despite subsidies. This implies potential for earlier BEV adoption in China, given adequate supply. While there are clear national security benefits for adoption of BEVs in China, the local and global social impact is unclear: With higher electricity generation emissions in China, a transition to BEVs may reduce oil consumption at the expense of increased air pollution and/or greenhouse gas emissions. On the other hand, demand from China could increase global incentives for electric vehicle technology development with the potential to reduce emissions in countries where electricity generation is associated with lower emissions.

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http://dx.doi.org/10.1016/j.tra.2015.01.002
0965-8564/

1. Introduction

1.1. The confluence of two trends in the global automotive industry

Motor vehicles consume one third of all oil used globally, two thirds of oil used in the U.S., and half of oil used in China (Davis et al., 2013; Ma et al., 2012). Together, China and the U.S. consume approximately one third of all oil consumed globally each year (U.S. EIA, 2014). In the U.S., passenger cars are responsible for 20% of annual greenhouse gas (GHG) emissions as well as 40% of volatile organic compound (VOC) emissions, 77% of carbon monoxide (CO) emissions, and 49% of nitrogen dioxide (NO_x) emissions (U.S. EIA, 2011). In China the emissions levels are comparable, with even higher portions of CO and NO_x emissions attributable to passenger vehicles (Lang et al., 2013). In addition, increasing China and U.S. dependency on foreign oil poses significant security implications, since both countries currently import nearly half of their annual oil consumption (see Fig. 1) (U.S. EIA, 2014).

At the same time that concerns about oil use are growing, the composition of the vehicle market is rapidly evolving. While vehicle ownership rates within developed countries are nearly static, transitional economies are rapidly adopting personal transportation. Of all the emerging markets, China has the largest growth rate in the world. Chinese passenger car ownership has had an average annual growth rate of 29% over the past two and a half decades (see Fig. 2). China is now the world's largest passenger vehicle market, a title held since 2009 after surpassing the U.S. (Liu et al., 2010; CATARC, 2009). This growth path should not be expected to stop soon. Currently, with 20% of the world's population, China has 60 vehicles per thousand people, compared to 800 vehicles per thousand people in the U.S. (National Bureau of Statistics of China, 2013; U.S. FHWA, 2013).

1.2. Implications of vehicle electrification for emissions and oil consumption

In the context of this study, we define vehicle electrification to include both gasoline HEVs and plug-in PHEVs/BEVs. HEVs take net propulsion energy from gasoline but utilize a small battery pack and electric motor to improve fuel efficiency, mostly through regenerative braking, engine downsizing, engine shutoff at idle, and power management. PHEVs are similar to HEVs, except they typically have a larger battery pack that can be charged by plugging into an electrical outlet. PHEVs can be driven for short distances (usually less than 40 miles) using only or mostly electricity before switching to gasoline for an extended range. BEVs run purely on electricity and do not use gasoline. They have large battery packs and large electric motors and must be plugged into an electrical outlet to charge. Table 1 summarizes these three technologies.

Each vehicle electrification technology offers some potential to reduce air emissions and oil consumption compared to conventional vehicles. While HEVs continue to rely on gasoline, they reduce both air emissions and oil consumption. PHEVs use grid electricity to displace additional gasoline, and BEVs displace gasoline entirely, but air emissions implications for plug-in vehicles depend on battery manufacturing and the mix of sources used to generate electricity (Samaras and Meisterling, 2008; Elgowainy et al., 2010; Michalek et al., 2011). Seventy-five percent of China's electricity and 42% of U.S. electricity is generated by burning coal, with its greenhouse gas and air quality implications (Liu et al., 2010; Lang et al., 2013; Ji et al., 2011; U.S. EIA, 2011). While plug-in vehicles are less effective at reducing GHGs in China due to higher life cycle electricity emissions intensity, they are on average still expected to reduce GHGs relative to CVs by as much as 17% (depending on adoption rates) with even more substantial reductions in the south, central, and north-west regions (Zhou et al., 2013). Fig. 3 summarizes this effect and shows the average emissions intensity of electricity generation in the U.S. and in China. Importantly, emissions vary by region and time of day within each country, and marginal emissions intensities relevant for added electric vehicle charging load are typically higher than average emissions intensities shown in Fig. 3 because dispatchable plants tend to be fossil fuel plants (Siler-Evans et al., 2012; Graff Zivin et al., 2014). Plug-in vehicles

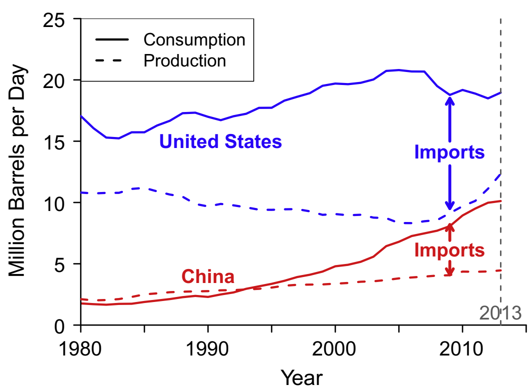

Fig. 1. Growth in U.S. and China dependency on foreign oil (U.S. EIA, 2014).