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Willingness-to-pay for infrastructure investments for alternative fuel vehicles

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ABSTRACT

This study investigates potential demand for infrastructure investment for alternative fuel vehicles by applying stated preference methods to a Japanese sample. The potential demand is estimated on the basis of how much people are willing to pay for alternative fuel vehicles under various refueling scenarios. Using the estimated parameters, the economic efficiency of establishing battery-exchange stations for electric vehicles is examined. The results indicate that infrastructural development of battery-exchange stations can be efficient when electric vehicle sales exceed 5.63% of all new vehicle sales. Further, we find a complementary relationship between the cruising ranges of alternative fuel vehicles and the infrastructure established.

1. Introduction

Alternative fuel vehicles (AFVs) are expected to play a role in reviving the automobile industry, as well as in mitigating carbon emissions in the transportation sector. This is reflected in the US American Recovery and Reinvestment Act of 2009 that provided tax credit for plug-in electric vehicles (EVs) and in the UK, where from 2010, purchasers were required to pay an excise duty when buying an average new gasoline vehicle (GV) while those purchased EVs in 2011 received a one-time exemption from the duty, received a rebate, and were exempt from annual vehicle taxes and showroom taxes. Similar incentives are being offered by other countries in Europe, and in 2010, Japan also began providing subsidies for EVs.

Nevertheless, the demand for AFVs is still relatively small. One of the reasons is the lack of investment in infrastructure for recharging/refueling these vehicles. The number of establishments for refueling EVs and fuel cell vehicles (FCVs) is insufficient. However, a few attempts have been made to resolve this problem. For example, London is planning to set up 1300 charging points by 2013. The "Source London" project provides a network of 400 recharge points that enable individually owned recharge equipment to be shared as of March 2012. In the US, a California-based venture company, Better Place, proposed that establishing rental battery stations, where drivers can replace a depleted battery with a fully charged battery within minutes, could serve as an effective solution. Shown evidence of consumer willingness to pay (WTP) for this sort of infrastructure, governments would be more inclined to approve investment in such infrastructure. A stated preference survey is a useful way to predict such potential demand under hypothetical scenarios in which circumstances can change dramatically.

This examines the potential demand for infrastructure investment by applying a stated preference survey conducted in Japan for hybrid electric vehicles (HEVs), EVs, and FCVs. Japan is selected as a case study because several auto manufacturers are competing to establish mass production technology for AFVs.

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Table 1
The attributes and levels of choice experiments.

Attributes		Levels			
Fuel type		GV	HEV	EV	FCV
Body type		Base 1	Base 2		
Manufacturer	GV	Base 3			
	HEV/EV/FCV	Toyota	Honda	Nissan	Mitsubishi
Cruising range (km)	GV	800			
	HEV	1000			
	EV	50	100	150	200
	FCV	300	400	500	600
Refueling rate	GV/HEV/FCV	5 min			
	EV	5 min (Exchange)	30 min	8 h	
Carbon dioxide (% reduction of a present average car)	GV	5%			
	HEV	40%	60%		
	EV/FCV	100%			
Fuel availability	GV/HEV	All existing service station			
	EV	10% of existing service stations (Exchange)	50% of existing service stations (Exchange)	Home	Home and supermarkets
	FCV	10% of existing service stations	50% of existing service stations		
Purchase price (including tax)	GV	Base 4			
	HEV	Base 4 + 20%	Base 4 + 40%	Base 4 + 60%	
	EV/FCV	Base 4 + 40%	Base 4 + 60%	Base 4 + 80%	
Annual fuel cost	GV	Base 5			
	HEV	Base 5 – 10%	Base 5 – 20%	Base 5 – 40%	
	EV/FCV	Base 5 – 20%	Base 5 – 50%	Base 5 – 80%	

Note: Base 1, Base 2, Base 3, Base 4 and Base 5 are specified by respondents respectively and differ between respondents.

2. Survey design

We select nine vehicle attributes, based on the focus of our study and the findings of previous studies. Attributes connected to refueling, refueling rate, and fuel availability are important factors that influence vehicle choice (Potoglou and Kanaroglou, 2007). Table 1 indicates these attributes and levels in detail. The characteristics of the attributes are as follows:

Fuel type: To compare the benefits of establishing infrastructure for EVs and FCVs, we considered the following four fuel types: conventional GVs, HEVs, EVs, and FCVs. Conventional GVs are treated as the base alternative that respondents were willing to purchase.

Body type: We asked respondents to choose two vehicle body types from nine alternatives that they would consider when making their next purchase decision, and used these two body type preferences to create respondent profiles. The following nine categories of vehicle body types were included in our survey: subcompact, compact/hatchback (hereafter compact), coupe, sedan, convertible, wagon, minivan, SUV/pickup truck, and truck/bus. The body types are unrelated to fuel types.

Manufacturer: We asked respondents to choose one automobile manufacturer, from a list, that they would definitely consider when making their next purchase decision, and used their preferences to create profiles for GVs. The list comprised 30 manufacturers, including foreign companies. It was assumed that only the following four representative automobile manufacturers in Japan produce HEVs, EVs, and FCVs: Toyota Motor Corporation, Honda Motor Company, Nissan Motor Company, and Mitsubishi Motors Corporation.

Cruising range: These are set as 800 km for GVs, 1000 km for HEVs, between 50 km and 200 km for EVs,[1] and between 300 km and 600 km for FCVs.

Refueling rate: The time taken to refuel all AFVs, other than EVs, is 5 min; EVs usually take longer to recharge, unless battery-exchange stations are available when the recharge time is comparable.

Carbon dioxide: By choosing an AFV, drivers can reduce the emissions of CO_2. The fuel type being used determines the CO_2 levels for all vehicles, with the exception of HEVs. Only HEVs have two levels of CO_2 emissions, and their emission levels have been reduced by 40% and 60% from the current levels.

Fuel availability: Depending on the type of FCV, either 10% or 50% of existing service stations offer the new fuel. When the battery-exchanging scenario is assumed, depending on the type of EV, either 10% or 50% of existing service stations provide

[1] The cruising range of Nissan's EV model, Leaf, is between 100 km and 220 km, depending on the speed, climate, road, and so on (Source: Nissan Leaf website: www.nissanusa.com/leaf-electric-car).

the facility. When a battery-recharging scenario is assumed, drivers of EVs can recharge the batteries at their home and/or at a supermarket.

Purchase price: The purchase price for GVs is based on respondents' answers regarding the amount they are willing to spend on their next purchase opportunity. The purchase prices for AFVs are indicated by the increase in the price that the customers are willing to pay for their next purchase of a GV.

Annual fuel cost: The annual fuel costs for GVs are the respondents' current number of refuels per month multiplied by the amount spent per refuel times 12 months. The annual costs for AFVs are indicated by comparing the decrease in the annual fuel costs of AFVs by the annual fuel costs of GVs. In the choice experiments, the respondents were instructed to assume that the annual fuel costs include the cost of replacing batteries for recharge-type EVs. The attributes of fuel types, refueling frequencies, and refuel stations are correlated, owing to common technologies among vehicles.

Respondents were also asked to consider all the non-listed attributes as identical for all vehicles. If respondents required information regarding vehicle attributes while answering questions, they were permitted to obtain that information.

Fig. 1 provides an example of a choice set. The profile for Vehicle 1 (GV) is created on the basis of the respondent answers regarding their next purchase opportunity. Thus, Vehicle 1 remains fixed throughout the choice sets for each of the respondents.

We made profiles for all types of AFVs using orthogonal arrays for nine attributes and four levels. Maintaining the orthogonality, the EV profiles that contradicted the scenarios regarding the refueling rate and fuel availability were modified. Under the battery-exchanging scenario, the refueling rate becomes 5 min and fuel availability is indicated by the percentage of current service stations offering the new fuel. Under the battery-recharging scenario, drivers can recharge the batteries at homes and/or supermarkets.

We constructed 64 profiles for each AFV, making 192 profiles in all. We randomly selected two from three AFVs and matched them with the GV profile. In this way, we created 128 choice sets. Thus, the profiles of GVs are the same across choice sets. There were 16 versions of the questionnaire and each respondent answered eight choice sets.

We conducted a web-based survey in February 2010. The clarity of the questions was examined using a pre-test that was conducted in December 2009. We sent emails to invite registered monitors to participate in the online survey, and 1531 people aged between 19 and 69 responded to this questionnaire, representing a response rate of 23.6%.[2]

Table 2 presents the summary statistics. Although the distribution of the genders and ages of our sample is similar to those of the census population in each prefecture, there were relatively fewer households with low incomes and more households with high incomes as compared to the census.

3. Discrete choice models

Vehicle choice behavior was analyzed using discrete choice models, which assume that consumers' choice behaviors are based on the random utility theory. We applied the nested multinomial logit (NMNL) model to avoid the restriction of independence from irrelevant alternatives, usually known as the property of independence from alternatives (IIA), which is assumed to exist in a multinomial logit (MNL) model.

We define ten specific constants (ASC) to avoid multicollinearity among the attributes of fuel type, fuel availability, and refueling time. The conventional GV is treated as the base alternative. We consider three types of tree structures, determined by fuel types, refueling times, and fuel availability. The tree structures were nested by the four branches of GV, HEV, EV, and FCV, which were further grouped according to whether they were zero-emission vehicles (EVs and FCVs), and whether they were conventional GVs or "green" vehicles. After comparing the estimated inclusive value (IV) parameters among the tree structures, we settled on a tree structure with the smallest Bayesian information criterion (BIC) (Fig. 2).

4. Results

We estimate two MNL models and one NMNL model (Table 3). In MNL 2 and NMNL, we analyzed the interaction effects between cruising ranges and the establishment of infrastructures. Using a one-tailed asymptotic *t*-test at a 1% significance level, the IV parameter of NMNL is significantly less than one, so the hypothesis that the true model is MNL is rejected. Therefore, MNL is an unacceptable model, and the parameter estimates are biased. The results for each coefficient are:

Alternative specific constants: The difference between the coefficients of HEV1 and HEV2 indicates the utility difference between the CO_2 emission levels of the two types of HEVs. Although the magnitude of the relationship between HEV1 and HEV2 indicates that, as expected, the reduction in CO_2 emissions is beneficial to consumers, the simulated confidence interval ranges between −¥134.5 and ¥477.9 thousand, including zero. Since the attribute level of the cruising range is constant in GV and HEV, the ASC for each of these vehicle types includes the utility of each fuel type and the utility of each constant cruising range and so cannot be evaluated separately.

[2] Poorly designed web-based surveys can cause sample selection bias. While some studies show that there are noteworthy differences between mail and web-based surveys, these differences are considered to be of minor importance when the goal of the survey is estimating WTP (e.g., Olsen, 2009). We attempted to mitigate selection bias by recruiting randomly sampled survey monitors and by not telling them the detailed contents of the survey in the recruiting process.

	Vehicle 1	Vehicle 2	Vehicle 3
Fuel type	Gasoline	Fuel cell	Electric battery
Body type	Coupe	SUV	Coupe
Manufacturer	BMW	Honda	Nissan
Cruising range	800 km	600 km	50 km
Refueling rate	5 minutes	5 minutes	8 hours
Fuel availability	All existing service stations	50% of existing service stations	Home and supermarkets
Carbon dioxide	5% less	100% less	100% less
Purchase price	¥1.2 million	¥1.44 million	¥2.16 million
Annual fuel cost	¥18,000	¥3,600	¥9,000
	⇩	⇩	⇩
Choose one vehicle			

Fig. 1. Example of choice set.

Prices and annual maintenance costs: The signs of the coefficients of price variables and annual fuel costs are as expected. These values indicate that car users' WTP for reducing annual fuel costs by $11.1 is approximately $128.[3]

Fuel availability: The difference between the coefficients of EV1 and EV2, EV3 and EV4, EV5 and EV6, and FCV1 and FCV2 represent the utility difference in the reduction in refueling time or in the extent of infrastructural support for EVs or FCVs. The magnitude relationship between these coefficients is in line with expectations.

Cruising range: The coefficient and the squared term of the cruising range represent the marginal utilities only in the utility function of EVs and FCVs. As expected, the coefficient and the squared term of the cruising range between refueling/recharging are positive. The coefficient of the squared term of the cruising range is negative. These results indicate that consumers' maximum WTP for the cruising range is represented by a certain value. We also estimated the parameters of the cross terms between a few ASCs and the cruising range. The coefficients of these cross terms represent the difference in the maximum WTP for the cruising range.

Body types: The coefficients of the body types relative to the small types, both subcompact and compact cars, have either positive or negative signs. The vehicle types of SUV/pickup truck, sedan, wagon, and minivan offer consumers significantly higher utilities when compared to the subcompact, compact, coupe, convertible, and truck/bus types. The coefficients of the cross terms between household size or age and body type indicate that: larger households significantly prefer coupes to the subcompact/compact type; younger people significantly prefer convertibles and sedans to the subcompact/compact types; and males significantly prefer coupes and trucks to the subcompact/compact types.

Fig. 3 provides the calculated WTP for the infrastructures for EVs and FCVs. The definition and interpretation of each item follow.

Quick recharge at home: "Quick recharge" implies that an EV battery requires 30 min for recharging. We define the WTP for a quick recharge at home is the difference between the WTP for EVs with batteries that are rechargeable at home for 30 min and those that are rechargeable at home for 8 h.

Normal recharge at the supermarkets: "Normal recharge" implies that EV batteries require 8 h for recharging. We define the WTP for normal recharges at supermarkets for two cases: (1) the consumer has normal recharge equipment at home (C1); and (2) the consumer has quick recharge equipment at home (C2). The WTP for C1 is the difference between the WTP for EVs with batteries rechargeable at a supermarket for 8 h and the WTP for those rechargeable at home for 8 h. The WTP for C2 is the difference between the WTP for EVs with batteries rechargeable at a supermarket for 8 h and the WTP for those rechargeable at home for 30 min.

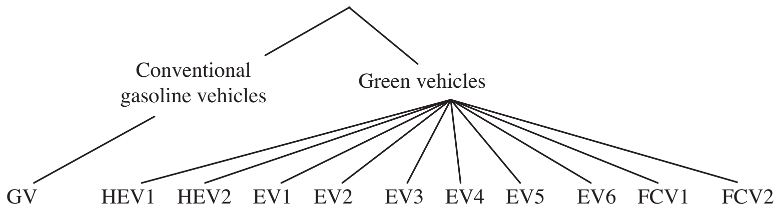
Quick recharge at the supermarkets: We define the WTP for a quick recharge at supermarkets for two cases: (1) the consumer has normal recharge equipment at home (C1); and (2) the consumer has quick recharge equipment at home (C2). The WTP of C1 is the difference between the WTP for EVs with batteries rechargeable at a supermarkets for 30 min and the WTP for those rechargeable at home for 8 h. The WTP of C2 is the difference between the WTP for EVs with batteries rechargeable at a supermarket for 30 min and the WTP for those rechargeable at home for 30 min. Our results indicate that, if an EV user possesses a quick recharge instrument, his/her WTP for a quick recharge at a supermarket decreases.

[3] During the period of the survey the average exchange rate was ¥90.28 per $.

Table 2
Summary statistics of respondents' characteristics.

		Sample (%)	Census (%)
Gender (Census data is as of 2010)	Females	43.42	49.93
Age group of respondents (Census data is as of 2009)	19–30	13.23	18.85
	<40	22.46	21.81
	<50	22.66	19.40
	<60	22.66	19.70
	<70	18.99	20.23
Household income (¥10^3) (Census data is as of 2008; the samples of no response are 9.55%)	<3,000	18.99	34.73
	<5,000	22.99	27.10
	<8,000	28.88	22.65
	<15,000	24.62	13.59
	<20,000	2.49	1.18
	20,000⩽	2.03	0.75
Number of household vehicles (Census data is as of 2008)	Average	2.43	1.10

Notes: The average of household vehicles owned by respondents is 2.17.



GV: Conventional gasoline vehicle	EV4: EV with battery rechargeable at home and supermarkets for 8 h
HEV1: HEV reduced by 40 % from the current emission level	EV5: EV with battery exchangeable at 10% of service stations
HEV2: HEV reduced by 60 % from the current emission level	EV6: EV with battery exchangeable at 50% of service stations
EV1: EV with battery rechargeable at home for 30 min	FCV1: FCV refueled at 10% of service stations
EV2: EV with battery rechargeable at home for 8 h	FCV2: FCV refueled at 50% of service stations
EV3: EV with battery rechargeable at home and supermarkets for 30 min	

Fig. 2. Tree structure of NMNL.

Battery-exchange stations: The WTP for establishing battery-exchange stations for EVs is given by the difference between the WTP for EVs with batteries exchangeable at 50% of current service stations and the WTP for EVs with batteries exchangeable at 10% of current service stations.

Hydrogen stations: The WTP for establishing hydrogen stations for FCVs is given by the difference between the WTP for refueling FCVs at 50% of current service stations and the WTP for refueling FCVs at 10% of current service stations.

Passenger vehicle sales in Japan were about 2.6 million in Japan. At the same time, there were approximately 40,000 domestic service stations (Web source: Agency for Natural Resources and Energy). Access to the infrastructure is a public good. Therefore, all purchasers of EVs or FCVs can share the benefits derived from any infrastructural establishment. The construction costs of battery-exchange stations for EVs range between $554,000 and $1,108,000 as of 2009.[4] Thus, the annual depreciation expenses, assuming an 8-year depreciation period, ranged from $69,000 to $138,000.

This result indicates that infrastructural development of battery-exchange stations can be efficient when the percentage of annual EV sales exceeds 5.6% of vehicle sales (11.26% for higher construction costs), regardless of the amount of infrastructure. This in turn suggests that the cost of a battery-exchange station can be covered by the increase in the purchase price of an EV. However, it is difficult to make hydrogen stations efficient, because the construction cost is expected to be higher than battery-exchange stations. The WTP for installing recharge stations in supermarkets was found to be negative in all cases.

[4] The costs of building battery-exchange stations are based on the articles by Galbraith (2009) and Schwartz (2009).

Table 3
Results using MNL models and NMNL model.

Variables and notations of coefficients	MNL 1 coeff.	MNL 2 coeff.	NMNL coeff.
HEV reduced by 40 % from the current emission level (HEV1)	0.162***	0.152***	−0.009
HEV reduced by 60 % from the current emission level (HEV2)	0.244***	0.223***	0.106**
EV with a battery rechargeable at home for 30 min (EV1)	−1.034***	−0.562***	−0.660***
EV with a battery rechargeable at home for 8 h (EV2)	−1.111***	−0.558***	−0.706***
EV with a battery rechargeable at home and supermarkets for 30 min (EV3)	−1.069***	−1.821***	−1.950***
EV with a battery rechargeable at home and supermarkets for 8 h (EV4)	−1.258***	−1.394***	−1.515***
EV with a battery exchangeable at 10% of service stations (EV5)	−1.522***	−1.674***	−1.801***
EV with a battery exchangeable at 50% of service stations (EV6)	−1.084***	−1.220***	−1.378***
FCV refueled at 10% of service stations (FCV1)	−1.225***	−1.029***	−1.143***
FCV refueled at 50% of service stations (FCV2)	−1.014***	−2.418***	−2.513***
Range $\times$ 10^{-3} [km] if EV or FCV, and 0 otherwise	2.786***	4.523***	4.477***
Range^2 $\times$ 10^{-5} [km] if EV or FCV, and 0 otherwise	−0.214***	−0.716***	−0.007***
Range $\times$ 10^{-3} [km] if EV1 or EV2, and 0 otherwise		−5.433***	−5.278***
Range $\times$ 10^{-3} [km] if EV3, and 0 otherwise		4.594**	4.733**
Range $\times$ 10^{-3} [km] if FCV2, and 0 otherwise		3.759***	3.732***
Price $\times$ ¥10^{-7}	−6.020***	−5.884***	−6.221***
Annual cost $\times$ ¥10^{-7}	−59.909***	−57.263***	−56.950***
Coupe (Dummy)	−0.608***	−0.564***	−0.547**
SUV/Pickup truck (Dummy)	0.309***	0.327***	0.345***
Convertible (Dummy)	−1.354**	−1.406**	−1.396**
Sedan (Dummy)	0.516***	0.562***	0.588***
Large type if Wagon or Minivan (Dummy)	0.123***	0.130***	0.147***
Truck/Bus (Dummy)	−0.898***	−0.892***	−0.869***
Toyota (Dummy)	0.176***	0.174***	0.177***
Honda (Dummy)	0.042***	0.045***	0.045***
Nissan (Dummy)	−0.010***	−0.011***	−0.011***
Mitsubishi (Dummy)	0.563***	0.563***	0.566***
Household size $\times$ Coupe	2.054***	2.136***	2.117***
Age $\times$ Convertible	−0.370***	−0.395***	−0.438***
Age $\times$ Sedan	−0.302***	−0.286***	−0.335***
Gender $\times$ Coupe (Gender = 1 if female, and 0 otherwise)	−0.326***	−0.284***	−0.333***
Gender $\times$ Truck	−0.585***	−0.569***	−0.627***
IV parameter of green vehicle nest			0.911***
Log likelihood	−11708.1	−11672.4	−11663.7

* Significance at 10%.
** Significance at 5%.
*** Significance at 1%.

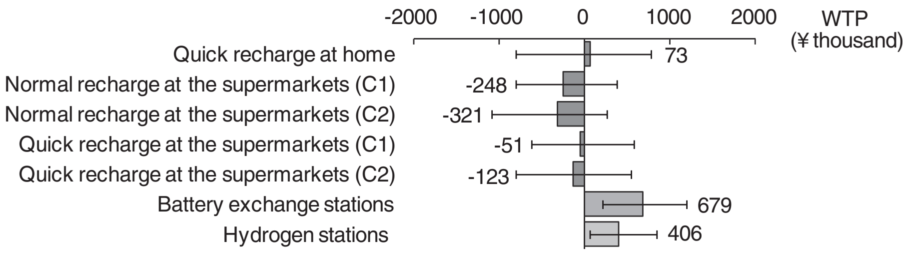


Fig. 3. WTP for establishing each infrastructure. *Notes*: The horizontal line on each WTP is the 95% confidence interval calculated using the Krinsky and Robb's (1986) procedure for 1000 draws of estimated parameter vector. C1 and C2 are the reference points where the consumers only have normal recharge or quick recharge equipment at their homes.

5. Implications

To understand the implications of our results we consider two scenarios of market shares, differing in whether there are alternatives to exchangeable-battery EVs. In Scenario 1, the infrastructure of recharge equipment allows drivers to fully recharge their EVs at home or at a supermarket for 30 min, and refuel their FCVs at 10% of service stations. Under Scenario 2, battery-exchange stations is possible at 10% of service stations is added. HEVs under both scenarios can reduce CO_2 emissions by 40% from the current level. Table 4 describes the results for the scenarios for the market share of Toyota's compact or subcompact cars. We assume that the prices of a GV, HEV, and FCV are ¥1.5, ¥1.8, and ¥10 million, and that the cruising ranges of a GV, HEV, EV, and FCV are 800, 1000, 200, and 600 km. The annual fuel cost of a GV is the sample mean, with the annual fuel cost for an HEV, EV, or FCV assumed to be respectively 28%, 50%, and 50% less than a GV. The means of age, gender, and household size are also used for computations. These forecasts demonstrate that the infrastructural development of battery-exchange stations for EVs will increase the market share of EVs, and that the market share for GVs will decrease most, followed by HEVs. Though there will be decreases in the share of EVs with a rechargeable battery (EV3), EVs using exchangeable batteries will not suffer a decrease.

The Ministry of Economy, Trade, and Industry (METI) of Japan published its report of the *Next-Generation Vehicle Strategy 2010* (NGVS2010) in April 2010. The government aims to meet the following targets by 2030: between 30% and 40% for HEVs, between 20% and 30% for EVs and PHEVs, up to 3% for FCVs, and between 5% and 10% for clean diesel vehicles. Our scenario forecasts suggest that a subsidy of $2770 for EVs on a price of $44,400 increases the market share of EVs by 1.81% in Scenario 1. Furthermore, the government targets set by METI for the market share of EVs can be achieved by a subsidy policy of $11,100 and $5540 for each EV in Scenarios 1 and 2.

Investment in infrastructure directly and indirectly increases benefits in the following two ways. The first is the utility from the infrastructure itself. Since infrastructure is a public good, AFV users can derive benefits from its use. The second is the indirect effect that the establishment of infrastructure increases the vehicles' cruising ranges. Therefore, the WTP for cruising ranges changes according to the extent of infrastructural establishment. Fig. 4 illustrates the interaction effect between cruising range and infrastructure. Infrastructure development moves the maximum WTP for cruising ranges to the right. These results indicate that consumers' WTP for certain cruising ranges increases with an increase in infrastructural development.

Since infrastructure improvements and increases of cruising ranges reduces the time to recharge or refuel AFVs, and increases the free time of the consumer, there would be substitution between them. Thus, it might be intuitively predicted that the WTP for the cruising ranges decreases as the infrastructure improves. However, our estimation results are not consistent with this prediction. A possible reason for this is the influence of a change in the distance respondents travel in their cars.

Table 4
Scenario forecasts of market shares of Toyota's subcompact/compact cars.

Price of EV (¥ million)	GV (%)		HEV (%)		EV with rechargeable battery (%)		EV with exchangeable battery (%)		FCV (%)	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
2	33.51	29.54 (−3.97)	32.23	27.90 (−4.33)	33.10	28.65 (−4.45)	–	12.91	1.16	1.01 (−0.16)
2.25	35.04	31.25 (−3.79)	33.92	29.75 (−4.17)	29.82	26.15 (−3.67)	–	11.78	1.22	1.07 (−0.15)
2.5	36.47	32.89 (−3.58)	35.52	31.54 (−3.98)	26.73	23.73 (−2.99)	–	10.69	1.28	1.14 (−0.14)
2.75	37.80	34.45 (−3.35)	37.02	33.27 (−3.75)	23.84	21.43 (−2.42)	–	9.65	1.34	1.20 (−0.14)
3	39.02	35.92 (−3.10)	38.41	34.91 (−3.51)	21.18	19.24 (−1.93)	–	8.67	1.39	1.26 (−0.13)
3.25	40.14	37.29 (−2.85)	39.70	36.45 (−3.25)	18.73	17.20 (−1.53)	–	7.75	1.43	1.32 (−0.12)
3.5	41.15	38.55 (−2.60)	40.87	37.88 (−2.98)	16.51	15.30 (−1.21)	–	6.89	1.48	1.37 (−0.11)
3.75	42.06	39.71 (−2.35)	41.93	39.21 (−2.72)	14.50	13.56 (−0.94)	–	6.11	1.51	1.42 (−0.10)
4	42.88	40.77 (−2.11)	42.88	40.42 (−2.46)	12.69	11.96 (−0.73)	–	5.39	1.55	1.46 (−0.09)

Notes: With Toyota the manufacturer, the columns of S1 and S2 demonstrate the forecasts of market shares in Scenarios 1 and 2. Under Scenario 1 there is no alternative of EVs of exchangeable battery type. Scenario 2 adds the alternative of EVs of exchangeable battery type to Scenario 1. The values in parentheses denote the change in market share from Scenario 1 to 2.

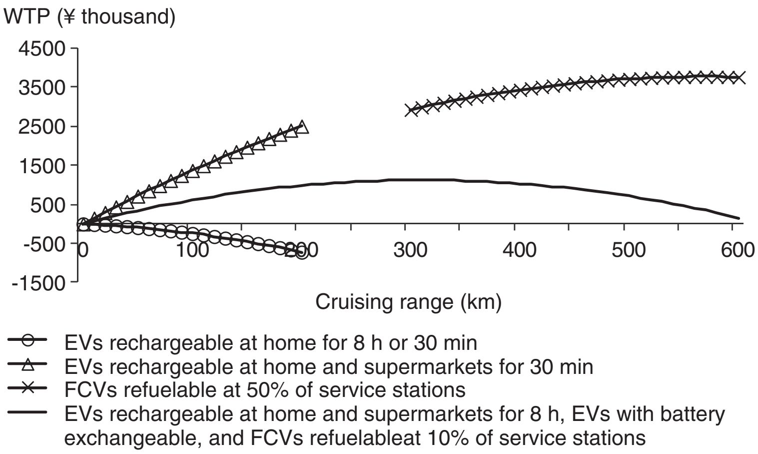


Fig. 4. WTP for cruising range of EVs and FCVs.

While we assume that the attributes omitted in the choice experiments are the same between the alternatives, some respondents might assume a distance between alternatives. If the infrastructure for an AFV is so inadequate that the consumer will switch to public transportation, the distance traveled in the AFV decreases, as does the value of the vehicle. In this case, the substitute relationship between cruising range and infrastructure improvement changes to a complementary relationship as cruising range increases. If the cruising range is longer than the travel distance per month, there would be a substitute relationship between them, because infrastructure improvement only reduces the time consumers take to recharge or refuel there AFVs, but does not cause a switch from AFV transportation to public transportation.

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