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Harnessing Motorists' Potential Demand for Hybrid-Electric Vehicles in Lebanon:

Policy Options, CO_2 Emissions Reduction and Welfare Gains

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The Climate Change and Environment in the Arab World Program aims to understand the climate change and environment policy process in the region and define the most appropriate policy recommendations by linking development in applied sciences on issues related to climate change and environment to social sciences.

Alexandra Irani [a] and Ali Chalak [b],[1]

a. Department of Agricultural Sciences, Faculty of Agricultural and Food Sciences, American University of Beirut, Lebanon; ac22@aub.edu.lb
b. Department of Agricultural Sciences, Faculty of Agricultural and Food Sciences, American University of Beirut, Lebanon; afi04@aub.edu.lb

1 Corresponding author. Tel.: +961-1-350000 ext. 4502. Fax: +961-1-744460

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Abstract

Public concern over deteriorating air quality and the associated local and global impacts has grown significantly in the past decade. Air quality degradation is linked first and foremost to the transportation sector in the Arab region with about 90% of total emissions of carbon monoxide resulting from transportation activities. In Lebanon's capital, Beirut, current levels of ozone and smog measured are several times higher than the world norms. In this paper, motorists' preferences for, and propensity to purchase, hybrid-electric vehicles (HEVs) and their readiness to switch to them are elicited by means of a choice experiment and hence indirectly estimates the value that they place on air quality. In addition, the paper investigates and monetizes net financial, welfare and environmental benefits resulting from this shift through the reduction in CO_2 emissions. Results are analyzed by means of a generalized multinomial logit model which accounts for both taste and scale heterogeneity. Simulations of aggregate switching behavior revealed that under a scenario which assumes that HEVs are exempt from customs and excise duties (following the 2010 suggested tax amendments by the Ministry of Finance), car buyers would actually be saving $5,100 by buying a hybrid-electric instead of a conventional gasoline vehicle and would enjoy a 30.5% reduction in fuel consumption and 20.5% CO_2 emission reduction per car per year putting the yearly net benefit at a high of $5,684 per brand new car sale. This would lead to total fuel cost savings amounting to $16.016 million and 19,600 tons of reduced CO_2 emissions per year. Accordingly, endorsing the suggested tax amendments is crucial to develop an HEV market in Lebanon and to achieve the consequent emission reductions and savings.

Key words: Choice experiment; CO_2 emissions; generalized multinomial logit; hybrid-electric vehicles; purchasing behavior.

1. Introduction

Mounting public concern over deteriorating air quality in recent years has incited governments, mainly in industrialized countries, to formulate environmentally-friendly policies and implement mitigation measures to reduce air pollution to acceptable levels. This has also motivated various studies in the fields of economics, environment, health and transportation, of which recent syntheses can be found in Stern (2007) and IPCC (2007). Chaaban (2008) indicates that the annual cost of all aspects of air quality degradation is substantial and could constitute up to around 2% of GDP in developed countries and more than 5% in developing countries. These costs comprise "mortality, chronic illness, hospital admissions, lower worker and agricultural productivity, IQ loss, and reduction of visibility". Due to its intensive use of fossil fuels leading to 22% of total carbon emissions (IEA, 2012), the transportation sector is also considered a main driver of global warming, reinforcing the anthropogenic character of climate change.

Energy conversion sectors, and specifically the transportation sector, are considered worldwide as the major sources of air pollution and the consequent air quality degradation. The effects of this pollution go beyond environmental problems, such as climate change and ozone layer depletion, and are linked to adverse long and short term health effects including an increase in mortality and morbidity rates (Chaaban et al., 2001). In the Arab region, air quality degradation is linked first and foremost to the transportation sector with about 90% of total emissions of carbon monoxide (CO) resulting from transportation activities. Between 70% and 80% of total hydrocarbon emissions originate from the transportation sector, and play an important role in the formation of photochemical oxidants (Chaaban, 2008).

In Lebanon, measured levels of ozone in the capital Beirut and smog are several times higher than the world norms with the transportation sector being the main contributor of CO, NO and non-methane volatile organic compounds (NMVOC) emissions (MoE et al., 2011). In addition, levels of particulates and sulfur oxides were found to be several times higher than international standards (Chaaban, 2008). The culprit is the country's transportation sector which is the main source of energy consumption and its associated greenhouse gas (GHG) emissions and air pollution impacts. Lebanon had an estimated 1.55 million registered vehicles in 2007, of which 1.25 million are passenger cars (MoE et al., 2011), and a relatively elevated car ownership rate of around 1 car for every 3 persons (MoE et al., 2012). The transport share of total energy consumed is at 54% which is relatively high compared to other countries like France (30%) and Egypt (23%) (Chaaban et al., 2001). As for particulate matter, motorists along the highway north of Beirut are exposed to air concentrations of 22 $\mu g/m^3$ of fine particulate matter (PM2.5), twice the acceptable level set by the World Health Organization (WHO), increasing the probability of death by 20%. Therefore, getting stuck in traffic for hours is not only stressful, but detrimental to human health (Baalbaki et al., 2013). In Beirut, the concentration of PM2.5 and PM10 can reach up to 20.7µg /m3 and 74.69 $\mu g/m^3$ respectively. Both measures surpass by far the acceptable levels of air pollutants set by the WHO at 10µg/ m^3 and 20µg/ m^3 respectively (MoE et al., 2012). According to Chaaban et al. (2001), a reduction of 10 µg/m3 in particulates (PM10) could save 80 lives per year. It could also reduce 3000 hospital admissions, 400 of which represent respiratory and cardiac conditions, 2,800 emergency room visits and 14,160 days of restricted activity. Overall cost reductions are estimated at around $10 million of which $5.4 million are pure medical costs.

The Lebanese public sector has not been totally oblivious to all these problems. In an effort partially to mitigate air quality degradation, the Lebanese government enforced law 341 in 2003 which banned the use of industrial diesel for transportation, and also banned leaded fuel. However, the need to consolidate and enforce programs and policies associated with Law 341/2001 on reducing air pollution from the transportation sector is not being seriously addressed. In its 2010 budget proposal (MoF, 2010), the Ministry of Finance (MoF), under the suggested tax revenue amendments, included article 83 which states that hybrid-electric vehicles (HEVs) would be exempt at imports from custom duties and excises for a period of three years. It is on this basis that some car dealers were encouraged to import and market HEVs in the hope that these exemptions be enforced, giving HEVs a competitive edge. According to the MoF, the imported cars are taxed as follows: 5% customs tax followed by either 15% excise tax if the value of the car is below LBP 20 million or 45% excise tax if the value of the car is above that bracket and finally a 10% value-added tax (VAT). Since, according to anecdotal evidence from car dealers, HEVs typically come at a price premium of around LBP 10 million over their conventional gasoline counterparts, they often face the higher customs tax bracket. In addition, new cars are subject to car registration fees which amount to around 7% of the car's value after adding customs, excise and VAT (the 7% rate includes the MoF's officially reported rate of 4% plus various other expenses). However, based on anecdotal information obtained from various car dealers, the car registration fee is higher for HEVs due to the presence of two engines in the vehicle. All of the above increases the absolute, and often the relative, price premium of hybrid with respect to conventional cars, rendering them unattractive without the MoF promised tax revenue amendments that are yet to be implemented.

In neighboring countries, Jordan offers a good example of tax incentives to encourage purchasing HEVs. Indeed, Jordan offers its HEV buyers tax cuts that contributed to increasing the ranks of the HEV fleet to 33,000 (Obeidat, 2014). Therefore without tax incentives, Lebanon's HEVs are unlikely to capture much market share. To add insult to injury, measures such as the use of alternative fuels (natural gas) and catalytic converters are still non-existent. In fact, catalytic converters are considered luxury goods and thus face additional import taxes (MoE et al., 2011). Yet a potential mitigation measure to rampant air quality degradation, although not sufficient on its own, is the promotion of zero- and/or low emissions clean-fuel vehicles, of which HEVs are a prominent example, that could contribute to the restoration of air quality in Beirut and Lebanon as a whole.

The aim of this study is to assess the preferences of motorists residing in Beirut for HEVs and their readiness to switch to them. Of the range of available clean-fuel vehicles, HEVs were selected as they are the closest to conventional gasoline cars, and hence motorists' decision to switch to them would be a smooth and straightforward affair. HEVs combine an electric motor and battery pack to the internal combustion engine found in conventional vehicles. They do not require additional infrastructure investments or changes such as electrical grid modification or special fuelling stations. Key advantages of HEVs over conventional and comparably clean and efficient technology (clean diesel, CNG) include: 1) reduced emissions of air pollutants; 2) substantial decreases in fuel consumption; 3) in most cases, lower cost of purchase, fuel and maintenance despite their higher initial costs and 4) being stepping stone technologies to the large-scale electrification of fleets and the subsequent reduction of road transport CO_2 emissions (UNEP, 2009). Motorists' preferences for, and propensity to purchase, HEVs and their readiness to switch to them are elicited by means of a choice experiment (CE). This CE therefore indirectly measures the value that they place on air quality. In addition, the study aims to investigate and monetize net financial, welfare and environmental benefits resulting from this shift to HEVs through the reduction in CO_2 emissions.

The results of this study would guide policy-makers in formulating at once cost-beneficial and environmentally-friendly policies aimed directly at the transportation sector, and indirectly public and environmental health. The study also aims to pave the way for further research related to quantifying the reduction in other air pollutants and greenhouse gas emissions and the improvements in public health through decreased morbidity and mortality rates, amongst others.

2. Materials and Methods

Choice Experiment

A choice experiment (CE) was designed to elicit the car preferences of motorists residing in Beirut and assess their willingness to purchase brand new hybrid instead of conventional cars. In the absence of real market data, CEs can be useful in understanding consumers' purchasing behavior as it closely simulates market choice situations. When carefully designed, CEs can yield credible estimates of willingness to pay (WTP) and market share gains for new products, new features in existing products, or changes in the level of provision of one or more attributes of existing products. This has made CEs and related stated preference methods a tool of choice among many marketing researchers and practitioners since the 1960s (Louviere et al., 2000, p. 283).

CEs are part of a wider set of stated preference methods known as attribute-based methods (ABMs). In the context of food choice, ABMs present survey respondents with a number of meal or portion attributes (e.g., portion size, safety certification, location) that can be provided at different possible levels. In addition, the costs of the various proposed changes to product attributes are usually proposed by means of changes of a price attribute. Consumers are asked to choose their most preferred product from a set of options differing in terms of their attribute levels as described in choice cards or sets presented to them. Repeated choices by consumers from a set number of choice cards reveals the trade-offs customers are willing to make between the attributes (Hanley, Mourato, & Wright, 2001). From the resulting choice data, the preference parameters of the various attributes of the good can then be estimated using the appropriate econometric tools, as will be detailed in the next section. In the field of transportation, various studies such as Ewing and Sarigöllü (2000), Högberg (2007), Potoglou and Kanaroglou (2007), and more recently Achtnicht (2012), have used CEs to assess motorists willingness to switch to, and pay for, clean-fuel vehicles.

Survey Design

The CE survey was developed based on an earlier pilot study conducted amongst students enrolled at the American University of Beirut. Based on the students' feedback, the survey instrument was refined. Modifications included creating several survey versions to cater for the respondents' preference for categories of car size, luxury and price. Absolute values, as opposed to the relative values used in the pilot study, were used to describe car attributes' levels, since in the pilot survey the respondents' feedback was that they struggled to translate attribute levels expressed as percent change from status quo into meaningful values.

The survey was divided into five sections that consisted each of questions dealing with the following: 1) screening criteria; 2) car preferences; 3) choice exercise; 4) attitudes and preferences; and 5) socio-demographic characteristics. In section 1, respondents who did not reside in Beirut, did not drive, did not intend to buy a car within the next year and did not have a valid driver's license were screened out of the survey. In section 2, respondents were asked about the various characteristics of the car they currently drive and the one they plan to buy in the next year such as purchase price, fuel consumption, car category, mileage, etc.

In section 3 (choice exercise), the core section of the survey, respondents were briefed about the hypothetical choice scenarios they would be presented with and how each would include three car options that they may or may not be willing to purchase in the next year. These car options would be described in terms of a set of attributes that aim comprehensively to describe the hypothetical car to be purchased, namely purchase price (in USD), car type (hybrid, gasoline), fuel consumption (km/tank) and financial incentive (car registration fee exemption for HEVs). The attributes and their corresponding levels are described in Table 1. All presented car options only differed with respect to the presented attributes but were otherwise identical (in terms of vehicle size, luggage space, color, options, safety and other specifications). Based on feedback received from the pilot survey and to be able to depict a real life car purchase scenario and cater for respondents' preferences, the choice sets were developed based on six car categories that take account of size, luxury, purchase price and fuel consumption (km/tank). Respondents were provided with an overview of the six car categories (small, small luxury, medium, medium luxury, SUV and luxury SUV) and were given examples of each to make sure they adequately select their preferred car type. Accordingly, the interviewer proceeded with the corresponding survey version.

Respondents were asked to choose the one option they like best in each of the ten choice sets or scenarios presented to them, or none if they are not satisfied with any of them or think they are too expensive for what they offer. An example of a choice set is shown in Figure 1. Before delving into the choice tasks, respondents were presented with a 'cheap talk' script to describe the propensity of respondents to inflate their stated WTPs in this type of surveys. Both opt-out options and cheap-talk scripts have been advocated in the stated preference literature as tools to help reduce the problem of hypothetical bias and align stated WTP with 'true' WTP (Hensher, 2010). Once done with the choice tasks, respondents were asked debriefing questions about the difficulty they faced in answering them as well as their attendance to each attribute while stating their choices.

An experimental design with an information structure maximizing a D0-optimal criterion (Ferrini & Scarpa, 2007) was employed to generate 20 choice sets. These were further divided into two blocks of ten choice sets each that were randomly administered to respondents. The design was adapted to each of the six car categories. This resulted in the development of a total of 12 survey versions. In section 4, respondents were probed about their attitudes and opinions towards the environment and air quality and their preferences for various car attributes. Finally, section 5 of the survey consisted of a number of socio-economic and demographic questions.

Household Interviews and Sample Description

The data were collected over two weeks in January and February 2014 through face-to-face interviews in Central Administrative Beirut targeting respondents aged 18 years or above. This study was approved by the American University of Beirut's Institutional Review Board (IRB). In order to ensure the anonymity of the respondents, no personal identifiers (e.g., names, addresses, and phone numbers) were collected. The study was completely voluntary, and participants were also given the choice to quit at any time, and refrain from answering any question(s). When necessary, items in the questionnaire were explained to ensure accurate responses.

The questionnaires were distributed proportionally to the number of registered voters in the areas to be covered. A multi-stage probability sampling was adopted to ensure a random, representative sample for identifying households and main respondents. The first stage consisted of selecting neighborhoods inside each selected area in a way to represent the make-up of the areas, the second stage consisted of selecting households based on a systematic random sample in each selected neighborhood according to the estimated number of buildings in the neighborhood, and finally the third stage consisted of sampling a primary respondent within each household based on the most recent birthday. The interviewer asked about the total number of adults aged 18+ years living in the household, and chose the one with the most recent birthday (at the date of the interview) to be the main respondent. If the selected person was not at home, a follow-up up to two times was conducted before declaring a nonresponse. This method ensured that everyone has an equal chance of inclusion, with no one allowed to self-select into the sample. If the selected respondent accepted to participate in the survey, the respondent was briefed about the objectives of the survey and the interviewers re-assured the respondent that the questionnaire is voluntary, anonymous and confidential. The questionnaire underwent two days of field testing prior to conducting the poll.

Sample characteristics are presented in Table 2. A total of 450 respondents completed the survey out of the 749 approached, of whom 93 refused to participate and 206 did not meet the eligibility criteria. The six survey versions corresponding to each of the car categories were distributed as follows: 26.9% for the small cars category, 21.7% for medium cars, 18.6% for medium luxury cars, 12.6% for SUVs, 12.0% for small luxury cars and 8.0% for luxury SUVs. This roughly corresponds to the current car type distribution pattern of the survey respondents. Of the 450 respondents, around 69.1% were males and 30.9% females and the majority (60.9%) were below the age of 40. A big portion of the sample (43.0%) holds a university undergraduate degree compared to a mere 9.3% that only completed elementary/ intermediate education. In terms of income, 35.8% of respondents mentioned having monthly household incomes of less than $2,500 and the majority (50.9%) had a monthly personal income of less than $2,000.

The majority of respondents (76.4%) own a car while only 14.7% share the car with family members. This underlines the country's relatively elevated car ownership rate of around 1 car for every 3 persons (MoE et al., 2012). Most respondents (73.0%) bought used cars and 37.8% mentioned they were planning to buy a used car in the next year. Motorists' inclination to used cars can be explained by the incentives this car market has to offer which include the availability of car loans and the lower road-usage fees. These conditions explain the country's aging car fleet that is comprised in its vast majority (90%) of passenger cars that are older than ten years (MoE et al., 2012). In terms of fuel expenditures, 42% of respondents spend between \$101 and \$200 on fuel per month which is equivalent to between \$1,212 and \$2,400 annually. This is considered relatively high compared to the monthly personal income of less than \$2,000 reported by 50.9% of respondents and gives a rough idea about the high percentage of income dedicated to covering fuel costs. Switching to HEVs can contribute to increasing fuel efficiency and thus directly decrease fuel consumption (and expenditures).

The Generalized Multinomial Logit Model

The mixed logit (MXL) has become one of the most widely used discrete choice models that aim at relaxing the behavioral limitations of the standard multinomial logit (MNL) specification, most notably the assumption of independence from irrelevant alternatives (IIA) and taste homogeneity (Hensher & Greene, 2003; Train, 2009). However, many researchers have argued that much of the response variability typically assumed to be caused by taste heterogeneity is actually more a result of scale heterogeneity; that is, the tendency for choice to be more random for some respondents than for others (Louviere & Eagle, 2006; Louviere et al., 2002; Louviere et al., 1999; Louviere et al., 2008). Formally, this is reflected by a larger variance of the stochastic error term of the utility function for some respondents (or choice tasks) compared to others. In intuitive terms, this will mean that, to the extent that scale heterogeneity occurs, preference parameters will proportionately be scaled up or down across respondents.

Recently, the generalized multinomial logit (GMNL) (Fiebig et al., 2010) operationalized these concerns by nesting both types of heterogeneity into one modeling framework. This model has been further investigated and its superiority to models, which only account for preference heterogeneity, such as the MXL and latent class (LC) models, seems to be a recurrent finding in the literature (Greene & Hensher, 2010; Keane & Wasi, 2013; Kragt, 2013). Authors have interpreted this scale variation as reflective of 'ability to choose' (Christie & Gibbons, 2011), 'preference certainty' (Li et al., 2014) or 'choice uncertainty' levels differing between respondents. Yet Hess and Rose (2012) argue that too much is being made of the ability of the GMNL model to separate scale from preference heterogeneity, as they claim that this ignores the "scale/taste sensitivity confound" imposed by the very form of the utility function assumed by the multinomial logit or its variants. While not dismissive of scale heterogeneity altogether, they argue that GMNL models "simply allow for more flexible distributions, thus uncovering from the data particular correlation structures within the heterogeneity that is being modeled whilst maintaining the scale/taste sensitivity confound". It is in this spirit that we apply the GMNL model; conditioning the mean of the random scale term on car category provides more room for (heterogeneous) attribute preferences, (fixed) price sensitivity, and WTP values to vary across six car categories while keeping the model parsimonious. This model also has the desirable property of treating the price coefficient as de facto random across respondents even when its sensitivity is being 'fixed', all the while ensuring that its sign is always negative in keeping with the expectations of economic theory.

The MXL model assumes a continuity of preferences over a range of parameter values. In this model, a person n faces a choice among J alternatives in each of T time periods (e.g. choice experiments). The indirect utility derived from alternative j and period t (U_{njt}) can be expressed as:

$$U_{njt} = V_{njt} + \varepsilon_{njt} = \beta_n' X_{njt} + \varepsilon_{njt}$$

Where V_{njt} is the deterministic component of utility, βn is a K×1 vector of preference parameters, and X_{njt} a K×1 vector of explanatory variables – in our case the attributes of the alternatives. The error terms ε_{njt} are often assumed to be independently and identically distributed (iid) with Type I Extreme Value distribution.

Preference heterogeneity is introduced by allowing β_n to vary randomly across respondents. The random parameters can be written as:

$$\beta_n = \beta + \Sigma v_n = \beta + \eta_n$$

where β is the K×1 vector of mean preference parameters; v_n a K×1 vector of random variables with zero means, unit variances and zero covariances; Σ a lower triangular Cholesky matrix; and η_n a resultant K×1 vector of random variables that is multivariate normal, MVN(0,ΣΣ'). η_n represents the stochastic heterogeneity of the random parameters. Since η_n is the same in the utility equations of all CEs for a given individual, the panel effect arising from unobserved correlation between the utilities in different CEs for a given individual is accounted for. Scale heterogeneity is introduced by modifying the preceding as follows:

$$\beta_n = \sigma_n \beta + \left[\gamma + \sigma_n (1-\gamma)\right]\eta_n$$

where σ_n is the individual-specific scale of the error term, and γ is a weighting parameter that determines how the variance of random preference parameters is scaled. Though (Fiebig et al., 2010) and (Greene & Hensher, 2010) imposed 0≤ γ ≤1 by using the logistic transformation $\gamma = \exp(\gamma^*)/(1+\exp(\gamma^*))$ and estimate γ* instead of γ, in this paper we follow (Keane & Wasi, 2013) and (Gu et al., 2013) who impose no such constraint, arguing that γ<0 and γ>1 still permit valid behavioral interpretations. In extreme cases, γ=1 will mean that the variance of random preference parameters is independent of the scaling of β, while γ=0 will mean that this variance is proportional to σ_n.

Three special cases of the GMNL model are noteworthy: (1) the MXL model when σ_n=1∀n, leading γ to fall out of the model; (2) the scaled multinomial logit (SMNL) model when var(η_n)=0 (i.e. Σ=0); and (3) the standard MNL when β_n=1 ∀n, σn=1∀n, and Σ=0. Finally, the scale term is specified as, where ω_n is a random variable drawn from the standard normal distribution truncated at ±2, τ the coefficient of the unobserved scale heterogeneity to be estimated, and $\bar{\sigma}$ a normalizing constant required to ensure the identification of β, and set to so that $E[\sigma_n^2]=1$ Observed heterogeneity in the mean of the scale term can be accommodated by setting it to $\sigma_n = \exp(\bar{\sigma} + \theta' z_n + \tau\omega_n)$, where z_n is a L×1 vector of individual-specific variables, and θ a L×1 vector of coefficients to be estimated.

Let y_{nt} denote the option chosen by respondent n on choice occasion t, and Ω the vector of parameters underlying the distribution of β_n, which includes β, Σ, θ, τ and γ (to be estimated). For a given value of β_n, the probability of this choice being made will be given by the multinomial logit formula:

$$P_{nt}\left(y_{nt} \mid \Omega, X_{nt}, z_{n,} v_n, \omega_n\right) = \frac{e^{\beta_n' X_{ny_{nt}t}}}{\sum_j e^{\beta_n' X_{njt}}}$$

As for the sequence of choices over T time periods, yn, the probability would be the product of these logit functions:

$$L\left(y_n \mid \Omega, X_n, z_n, v_n, \omega_n\right) = \prod_t \frac{e^{\beta_n' X_{ny_{nt}t}}}{\sum_j e^{\beta_n' X_{njt}}}$$

Since β_n is unknown and is drawn from a multivariate normal distribution, the unconditional probability becomes the integral of L(yn|β_n) over all possible values of β_n weighted by the density of β_n induced by v_n and ω_n:

$$P_n\left(y_n \mid \Omega, X_n, z_n\right) = \int \left(\prod_t \frac{e^{\beta_n' X_{ny_{nt}t}}}{\sum_j e^{\beta_n' X_{njt}}} \right) f\left(\beta_n \mid \Omega\right) d\beta_n$$

with f(·) denoting the continuous density function (such as the normal) of β_n conditioned on Ω. The unconditional probability P_n is the product of multinomial logit probabilities mixed over a density of preference and scale parameters. Estimation of the parameters is performed by means of simulated maximum likelihood methods detailed in Train (2009), as there is no closed-formed solution for equation (6). Finally, once the model is estimated, individual-specific preference parameters can be derived following the procedures described in Train (2009, Chapter 11).

Policy Simulations

To better understand the implications of motorists' willingness to switch to HEVs in terms of motorists' welfare, reduced CO_2 emissions, and policy-making, we first use the probabilistic model outputs to simulate the share of motorists who would purchase an HEV. From these probabilities, we simulate the average fuel consumption reduction, CO_2 emissions reduction, net financial benefits composed of the monetized fuel consumption savings minus the additional cost of purchasing an HEV, social benefits from reduced CO_2 emissions and the resulting total net benefits, all expressed per year and per brand new car sale. To motivate this exercise, we simulated these impacts under four scenarios that we felt cover reasonably well the space of feasible policy permutations:

1. Scenario 1 – this scenario assumes that an HEV market exists in Lebanon where both hybrid and conventional gasoline cars face the same current custom and excise tax system. Motorists are perfectly informed of all customs/taxes that apply to purchasing HEVs, the higher maintenance costs they face and their lower emissions. They are however unaware of their higher fuel efficiency.
2. Scenario 2 – The same conditions as Scenario 1 apply except for the fact that motorists are aware of the higher fuel efficiency of HEVs.
3. Scenario 3 – HEVs are exempt from custom and excise taxes, as per the MoF's promised tax revenue amendments.
4. Scenario 4 – HEVs are subject to a 50% discount on combined custom and excise taxes and are exempt from car registration fees.

For each scenario, the probability P of purchasing a hybrid (Hyb) car given a choice between it and a conventional gasoline (Gas) car was derived using the multinomial logit probability equation evaluated for each individual n and averaged out over respondents:

$$P_n(Hyb) = \frac{e^{V_n(Hyb)}}{e^{V_n(Hyb)} + e^{V_n(Gas)}}$$

where, given a policy scenario s and car category c:

$$V_n\left(Gas\right) = \beta_{n1} type_{Gas} + \beta_{n2} fuel_{Gas,nc} - \beta_{n3} price_{Gas,ncs} / 10000$$

$$V_n\left(Hyb\right) = \beta_{n4} type_{Hyb} + \beta_{n2} fuel_{Hyb,nc} - \beta_{n3} price_{Hyb,ncs} / 10000 + \beta_{n4} fi_s$$

Fuel consumption levels and purchasing price per car category are listed in Table 3. Fuel consumption (km/tank) figures were adapted from Frisman (2004). City mileage (mpg) figures were adopted and converted to km/tank units by multiplying each figure by 1.61 mile/km and dividing it by 3.79 L/gallon to convert it to km/L, and then multiplying this number by 20L/tank to convert it into km/tank. The report's fuel consumption figures for compact cars were assumed to apply to our small and small luxury categories; midsize to medium and medium luxury; and the average of midsize and full-size SUV to our SUV and luxury SUV categories. Note that under Scenario 1, the effect of no fuel consumption information was simulated by setting fuel levels to zero in both utility functions.

As for price levels (exclusive of registration fee and inclusive of customs and excise taxes and VAT), the average price of a gasoline car for each category was assumed to be the mid-point of the price levels' range for that same category (see Table 1). HEV prices for scenarios 1 and 2 were assumed to be 20% more expensive than their gasoline counterparts, as is typically the case (Bedel, 2014; Edmunds, 2013). For the purchasing prices of HEVs per car category under scenarios 3 and 4, firstly, pre-tax prices were deducted for all six categories by dividing them by 1.10 to deduct VAT (10%), and then by 1.20 for the small category, and 1.50 for the remaining five categories, to deduct the combined custom (5%) and excise (15% for small; 45% for the rest) taxes. Secondly, for Scenario 3 (no custom or excise tax), purchasing prices were obtained by multiplying the categories' respective prices directly by 1.10 to re-include VAT, while for Scenario 4 they were first multiplied by 1.10 for the 'small' category and 1.25 for the remaining categories (i.e. 50% reduction in combined custom and excise taxes), and then by 1.10 to re-include VAT.

After purchasing probabilities are estimated, we also estimated the proportion of fuel consumption reduction r by averaging out individual-level reductions, r_n, across respondents. r_n is calculated as follows:

$$r_n = P_n \times \frac{d_n}{15000} \times \frac{lpkm_{Gas,nc} - lpkm_{Hyb,nc}}{lpkm_{Gas,nc}}$$

where d_n is the average yearly travel distance (km/year) derived from the self-reported travel distance and normalized to an average of 15,000 km/year, the national average (MoE et al., 2012), by setting $d_n = d_n^* / \bar{d} \times 15000$, being the average of over the sample of respondents, and lpkm referring fuel efficiency (L/km), derived from Table 3 figures as $lpkm_{type,c} = 20 / fuel_{type,c}$. Indeed the term serves to weigh individual n's contribution to r by distance travelled. As for the yearly reduction R of fuel consumption per brand new car sale, this was calculated as the average of individual-level Rn terms calculated as follows:

$$R_n = P_n \times d_n \times \left(lpkm_{Gas,nc} - lpkm_{Hyb,nc}\right)$$

Similarly, the proportion CO_2 emissions reduction e was calculated as the average over sample respondents of en:

$$e_n = P_n \times \frac{d_n}{15000} \times \frac{ef_{Gas,nc} - ef_{Hyb,nc}}{ef_{Gas,nc}}$$

where $ef_{type,c}$ is the emission factor (g/km) for a given car type and car category c. Like R, the CO_2 emissions reduction E (t/car sale) is the average of individual-level En which is calculated as follows:

$$E_n = P_n \times d_n \times \left(ef_{Gas,nc} - ef_{Hyb,nc}\right) / 10^6$$

The average net additional cost, NC_{Hyb}, of buying an HEV; net benefit, NB_{fuel}, from fuel savings; and net social benefit, $NSB_{CO2,}$ from CO_2 emissions reduction, were all derived in $ per year per brand new car sale and as the respective sample's averages of their individual-level counterparts, $CH_{yb,n}$, $NB_{fuel,n}$, and $NSB_{CO2,n}$, derived as follows:

$$NC_{Hyb,n} = P_n \times \left(price_{Hyb,nc} - price_{Gas,nc}\right)$$
$$NB_{fuel,n} = P_n \times R_n / 20 \times \$1.1 / \mathrm{L}$$
$$NSB_{CO_2,n} = P_n \times E_n \times SCC$$

where $1.1/L is the typical price of a liter of gasoline in Lebanon, and SCC the social cost of carbon, taken to be $17/ tCO_2, as per El-Fadel et al. (2013).

3. Results and Discussion

Selecting the Best Model Specification

Five sequentially nested models were estimated in Stata 12.1 using the built-in *clogit* command for MNL estimation, the *mixlogit* command written by Hole (2007) for MXL estimation, and the *gmnl* command written by (Gu et al., 2013) for generalized multinomial logit (GMNL) estimation:

1. *MNL* – this basic multinomial logit specification assumes preference homogeneity for all attributes and hence treats all preference parameters as fixed;
2. *MXL* – this mixed logit model relaxes the preference homogeneity assumption for all attributes except price and treats them as normally and independently distributed across individuals. Treating price as fixed ensures that the marginal utility of income is negative in keeping with the expectations of economic theory;
3. *MXL-C* – *MXL* + correlated preference parameters;
4. *GMNL-C* – *MXL-C* + unobserved scale heterogeneity for all attributes; and
5. *GMNL-CH* – *GMNL-C* + observed scale heterogeneity. In addition to unobserved scale heterogeneity, the scale term's mean is conditioned on the car category which the consumer was targeting. This allows the accommodation of scale effects at play across categories, most notably with the category-specific attributes price which ranges varied widely between categories, and to a lesser extent, fuel consumption. Indeed this also allows for more flexibility to differentiate WTP distributions by car category while preserving parsimony.

Given that the models are sequentially nested, we were able to conduct likelihood ratio (LR) tests in order to select the best model specification. The results of the LR tests are presented in Table 4. In addition, we present the Akaike and Bayesian information criteria (AIC and BIC, respectively) for each model to assist in model selection. LR tests are confined to comparing nested model specifications. A significant LR statistic generally supports the unrestricted model specification, while an insignificant statistic would support the restricted model specification nested within the latter. As for AIC and BIC, these can be used to compare both nested and non-nested models, whereby models with lower values are preferred. It is worth noting that the BIC penalizes the addition of parameters more heavily than AIC, and therefore is more conservative.

The LR test, AIC and BIC seem to prefer MXL-C to both MXL and MNL, supporting the presence of significant correlated heterogeneity in preferences. Similarly, the GMNL-C model is preferred by all three indicators to the MXL-C model, supporting the presence of unobserved scale heterogeneity as well. Finally, the GMNL-CH model is preferred to the GMNL-C model, supporting the introduction of observed scale heterogeneity in response to car category. We will therefore restrict all discussions hereafter to the GMNL-CH model outputs.

Model and WTP Estimates

The GMNL-CH model estimates are presented in Table 5. First, as expected, the price parameter or marginal utility of income is significantly negative. As for the random parameters' means, both gasoline and HEV types have significantly positive parameters. Moreover, a z-test indicates that all else being equal, an HEV is significantly preferred to gasoline ($p<0.01$). The fuel consumption's parameter mean is also significantly negative in line with the expectation that utility increases with fuel efficiency. Finally, the financial incentive's (car registration fee exemption) parameter was significantly positive, as expected. Moving to the standard deviation estimates (square roots of the diagonal terms in the variance-covariance matrix, $\Sigma\Sigma'$), all were significant, suggesting considerable heterogeneity in preferences governing all car aspects. Indeed all except two of the elements of the Cholesky matrix (Σ) were significant, indicating that tastes are not only heterogeneous but also correlated.

Moving to the scale term's parameters, the significant scale variance estimate suggests that considerable scale heterogeneity is taking place alongside preference heterogeneity, or to adopt the more conservative interpretation of Hess and Rose (2012), significant flexibility is gained from accounting for unobserved heterogeneity in the scale term. Moreover, the scale's mean shifters are all highly significant, with generally more negative parameters the higher the luxury level and size. This suggests that on average, scale decreases (i.e. idiosyncratic error increases) with higher luxury and size, which in turn may be signaling lower 'ability to choose' or 'choice certainty'. On a more practical note, we argue that these parameters allow for a more variegated accommodation of heterogeneity, in particular of price sensitivity relative to other attribute preferences, hence allowing for a more flexible characterization of WTP distribution (more on this later). Finally, the estimate for the weighting parameter, γ, is negative, suggesting that, in general, "the standard deviation of βn increases more than proportionately as β is scaled up by σn" (Keane & Wasi, 2013).

WTP estimates were derived from individual-level parameters, whereby for any given attribute att, where price is in -$10,000s. For car types, the premium for HEVs relative to gasoline was reported with WTPHYBvsGAS=WTPHyb–WTPGas. Results suggest that estimates of this latter are only significant for small, small luxury, and medium car categories, but not for medium luxury, SUV and SUV luxury categories; this is probably a reflection of the larger scale terms for these three categories with the attendant increase in response noise. For fuel consumption, all WTP estimates are significant and generally increase with level luxury and size, suggesting that in return for the higher premium paid for the increased provision of these features, buyers, in compensation, would reserve higher value for additional fuel consumption savings, at least in part to compensate for the generally higher premium paid for such cars. Finally, respondents valued the car registration fee exemption significantly for the small, small luxury, medium and SUV categories, with WTPs in the region of $2,000, suggesting that this incentive would be effective in promoting the sales of HEVs. In comparison, the registration fee (around 7%) for a typical brand new $30,000 car would be $2,100, which is very close to the respondents' valuation. Therefore it is clear that respondents to this CE are well-informed about the procedures and fees involved in buying a car and willing to enact this knowledge in processing the information content of choice tasks and making valid trade-offs.

Policy Simulations

The results of the policy simulations are presented in Table 7. Starting with Scenario 1, results suggest that without policy incentives in the form of tax exemptions or reductions, and in the absence of awareness about the fuel efficiency advantage of HEVs, the potential market share of HEVs, their fuel consumption and CO_2 emissions reduction are the lowest among all scenarios. The potential market share would be sizable (45.5%), yet still below 50%, which is unfortunate for a viable alternative to conventional gasoline cars that does not require major infrastructural investments to become operational. Moreover, the additional cost of buying an HEV, which amounts to $3,270, would be prohibitively high, and would be considered a major deterrent by car buyers. This is despite the substantial fuel consumption reductions (17.3%) and gains from fuel savings ($320/car sale/year), as an average of 10.2 years would be needed to recoup the additional cost of HEVs; indeed very often cars are replaced before that. Finally, the gains in terms of reduced CO_2 emissions ($6.6/car sale/year) are lowest among all scenarios, and the total net benefit from every brand new car sale is in the negative (-$2,943/car sale/year), suggesting that an HEV market under this do-nothing scenario is not worthwhile in terms of societal well-being.

As for Scenario 2, the picture is not much different. Though awareness about fuel efficiency gains from driving HEVs raises their potential market share considerably (66.4%) as well as fuel consumption reduction (25.5%), the added cost of purchasing HEVs increases further, reducing the number of years to break-even due to fuel savings only slightly (9.8 years). Under this scenario net benefits would dip further into the negative, suggesting, along with Scenario 1, that an HEV market without policy incentives is not rewarding in terms of societal well-being. We will therefore move to discuss the next two scenarios in which such incentives are offered.

Scenario 3 is clearly the most rewarding to motorists as is revealed in the highest potential market share (80%), fuel consumption reduction (30.9%) and savings ($572/car sale/year), emissions reduction (19.2%) achieved across all scenarios, and the fact that car buyers would actually be saving $5,100 by buying a hybrid instead of a conventional gasoline vehicle, putting the yearly net benefit at a high of $5,684 per brand new car sale. This scenario would however be unsustainable and undesired by the government on the long-run as it stipulates the total exemption of taxes, both custom and excise, for HEV imports which would reduce public revenues considerably. Nevertheless, and following the suggested tax revenue amendments, article 83 which states that HEVs would be exempt at import from custom duties and excises for a period of three years, Scenario 3 could serve as a transitional phase during which the government would give up its revenues temporarily to encourage the growth and anchoring of a viable HEV market in the country.

Finally, under Scenario 4, in which excise and custom taxes are restored but only at a 50% discount, a win-win situation seems to be emerging for both buyers and the government. Under this scenario, market share drops slightly but is maintained at the high level of 75.6%. Likewise for fuel cost reductions (29.1%) and savings ($533/car sale/year) and CO_2 emission reductions (19.2%). Buyers would be subject to a minimal average additional cost per brand new car sale for HEVs amounting to a mere $282 and would require only six months to break even on their investment by means of fuel savings. A key incentive in this scenario is the exemption from car registration fees which are relatively expensive in Lebanon compared to other countries and are potentially more so for HEVs. In this scenario the government would only be foregoing 50% of its custom and excise tax revenues, rendering the former a sustainable and long-term policy that would effectively abate air quality degradation without crippling public revenues.

Given a yearly average of 35,000 brand new car sales in Lebanon (BankMed S.A.L., 2013), and to the extent that our results could be generalized to the whole of Lebanon, national aggregate figures can be derived. We have decided to use the results from Scenario 4 to motivate this exercise, as it seems to be the most promising long-run policy setting for promoting the HEV market. Under this scenario, aggregate fuel cost savings would amount to $18.66 million, which more than compensate the added cost of purchasing HEVs ($9.87 million), resulting in net private gains of $8.79 million. In terms of its environmental impact represented by its CO_2 emissions reductions, these amount to 23,100 tons of avoided CO_2 emissions. With total emissions in the region of 20 million tons, of which the transportation sector contributes about 4 million, Scenario 4 would contribute a 0.12% reduction of total emissions, and 0.58% from transportation emissions proper.

As for the social benefit from reduced CO_2 emissions, it is estimated to reach $392,000/year under Scenario 4, raising aggregate net benefits further to around $9.18 million/year.

4. Conclusion

The paper investigates the willingness of motorists to purchase HEVs in Beirut, Lebanon. Out of the total range of available clean-fuel vehicles, HEVs were selected as they are the closest to conventional gasoline cars and accordingly motorists' decision to purchase them would be smooth and straight-forward. A choice experiment is used to elicit motorists' propensity to purchase HEVs, and hence indirectly the value they place on reduced CO_2 emissions and air quality in general. Results are analyzed by means of a generalized multinomial logit model which accounts for both taste and scale heterogeneity. Model outputs are then used to simulate aggregate switching behavior under four alternative scenarios of financial incentives that range from a do-nothing scenario to full custom and excise exemptions to discounted taxes and registration fee waivers. The simulated outputs included the average fuel consumption reduction, CO_2 emissions reduction, monetized fuel consumption savings, additional cost of purchasing an HEV, societal benefits from reduced CO_2 emissions, and the resulting total net benefits, all expressed per year and per brand new car sale.

Clearly, Scenario 3 which assumed that HEVs were exempt from customs and excise taxes was the most rewarding to motorists as was revealed in the elevated market share standing to be captured. The scenario predicted an actual gain from investing in purchasing an HEV, with an average yearly gain of $5,100 per brand new car sale. They would also be enjoying a 30.5% reduction in fuel consumption which would lead to $572 in fuel cost savings per year. This scenario also has the highest environmental impact as CO_2 emissions are reduced by 20.5% per brand new car sale. Indeed, we argue that the endorsement of Article 83 proposed by the Ministry of Finance in 2010 and simulated under Scenario 3, is crucial for the development of an HEV market in Lebanon. Although the mentioned custom and excise tax exemptions are only valid for three years, they seem to be necessary to stimulate initial interest both from the consumer and supply sides. We argue that this transitory phase can be followed by a more sustainable one, depicted in Scenario 4, which would include partial tax discounts, following the example of Jordan (Obeidat, 2014). This would provide a win-win situation for both government and car buyers, and would almost maintain fuel cost and CO_2 emission reductions triggered by Scenario 3. Buyers would be subject to a minimal price premium on HEVs that would require a few months to recoup by means of fuel cost savings. They would also enjoy a 29.1% reduction in fuel consumption, translating into $533 fuel cost savings per brand new car sale. A key incentive in this scenario is the exemption of car registration fees which are relatively expensive in Lebanon compared to other countries and are more so for HEVs. In this scenario the government would only be foregoing 50% of its custom and excise tax revenues, rendering it a sustainable long-term policy that would effectively abate air quality degradation without emptying public coffers.

Additional financial and non-financial measures are required for the creation of a thriving HEV market in Lebanon. MoE et al. (2012) propose an extensive range of such measures that we reproduce in brief herein. These would include extending tax (e.g. VAT) exemptions on HEV spare parts (e.g. battery and electric motor) which are known to be expensive and potential deterrents both to suppliers and buyers. Another policy avenue would be to exempt buyers from the relatively high registration fees in addition to providing them with preferential loan conditions (e.g. extension of loan repayment periods, reduced loan interest or full subsidy on loan interests for heavy mileage motorists such as taxi drivers). Also, reconsidering road-usage fees according to fuel efficiency and emissions instead of engine displacement would be considered as a key incentive as well. Finally, one cannot overstate the importance of raising citizens' awareness about critical issues such as climate change, air quality degradation and potential mitigation measures and strategies dealing with these problems (of which HEVs are but one instance). Indeed this may help shift preferences in favor of HEVs, with the welcome side-effect of relieving part of the need for fiscal and financial incentives to promote the demand for hybrid and other types of clean-fuel vehicles.

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References

Achtnicht, M. (2012). German car buyers' willingness to pay to reduce CO_2 emissions. ***Climatic Change, 113***(3-4), 679-697. doi: 10.1007/s10584-011-0362-8

Baalbaki, R., Al-Assaad, K., Mehanna, C.-J., Saliba, N. A., Katurji, M., & Roumie, M. (2013). Road versus roadside particle size distribution in a hot Mediterranean summer-Estimation of fleet emission factors. ***Journal of the Air and Waste Management Association, 63***(3), 327-335. doi: 10.1080/10962247.2012.761660

BankMed S.A.L. (2013). ***Analysis of car sales and car imports in Lebanon***. September 2013. http://www.bankmed.com.lb/LinkClick.aspx?fileticket=e3YItnDsQL0%3D&portalid=0

Bedel, E. E. (2014). Purchasing a Hybrid Car. ***Inside Indiana Business with Gerry Dick.*** Retrieved April 8, 2014, from https://www.insideindianabusiness.com/contributors.asp?id=1569

Chaaban, F. B. (2008). Air Quality. In M. K. Tolba & N. W. Saab (Eds.), ***Arab Environment: Future Challenges. 2008 Report of the Arab Forum for Environment and Development*** (pp. 45-62).

Chaaban, F. B., Nuwayhid, I., & Djoundourian, S. (2001). A study of social and economic implications of mobile sources on air quality in Lebanon. ***Transportation Research Part D: Transport and Environment, 6***(5), 347-355. doi: 10.1016/s1361-9209(01)00004-9

Christie, M., & Gibbons, J. (2011). The effect of individual 'ability to choose' (scale heterogeneity) on the valuation of environmental goods. ***Ecological Economics, 70***(12), 2250-2257. doi: 10.1016/j.ecolecon.2011.07.011

Edmunds. (2013). What You Should Know Before Buying a Hybrid. Retrieved April 8, 2014, from http://www.edmunds.com/hybrid/before-buy.html

El-Fadel, M., Rachid, G., El-Samra, R., Bou Boutros, G., & Hashisho, J. (2013). Emissions reduction and economic implications of renewable energy market penetration of power generation for residential consumption in the MENA region. ***Energy Policy, 52***, 618-627. doi: 10.1016/j.enpol.2012.10.015

Ewing, G., & Sarigollu, E. (2000). Assessing consumer preferences for clean-fuel vehicles: A discrete choice experiment. ***Journal of public policy & marketing, 19***(1), 106-118. doi: 10.1509/jppm.19.1.106.16946

Ferrini, S., & Scarpa, R. (2007). Designs with a priori information for nonmarket valuation with choice experiments: A Monte Carlo study. ***Journal of Environmental Economics and Management, 53***(3), 342-363.

Fiebig, D. G., Keane, M. P., Louviere, J. J., & Wasi, N. (2010). The generalized multinomial logit model: Accounting for scale and coefficient heterogeneity. ***Marketing Science, 29***(3), 393-421.

Frisman, P. (2004). ***Effect of replacing conventional vehicles with hybrid vehicles*** OLR Research Report no. 2004-R-0523, Office of Legislative Research, Connecticut General Assembly, July 8, 2004. http://www.cga.ct.gov/2004/rpt/2004-R-0523.htm

Greene, W. H., & Hensher, D. A. (2010). Does scale heterogeneity across individuals matter? An empirical assessment of alternative logit models. ***Transportation, 37***(3), 413-428.

Gu, Y., Hole, A. R., & Knox, S. (2013). Fitting the generalized multinomial logit model in Stata. ***Stata Journal, 13***(2), 382-397.

Hensher, D. A. (2010). Hypothetical bias, choice experiments and willingness to pay. ***Transportation Research Part B: Methodological, 44***(6), 735-752.

Hensher, D. A., & Greene, W. H. (2003). The mixed logit model: the state of practice. ***Transportation, 30***(2), 133-176. doi: 10.1023/a:1022558715350

Hess, S., & Rose, J. M. (2012). Can scale and coefficient heterogeneity be separated in random coefficients models? ***Transportation, 39***(6), 1225-1239. doi: 10.1007/s11116-012-9394-9

Högberg, M. (2007). ***Eco-driving? A discrete choice experiment on valuation of car attributes.*** (M.Sc. Thesis), School of Econmics and Management, Lund University. Retrieved from http://www.diva-portal.org/smash/get/diva2:674001/FULLTEXT01.pdf

Hole, A. R. (2007). Fitting mixed logit models by using maximum simulated likelihood. ***Stata Journal, 7***(3), 388-401.

IEA. (2012). ***CO_2 Emissions from Fuel Combustion (Ed. 2012)***. Mimas, University of Manchester. http://dx.doi.org/10.5257/iea/co2/2012

IPCC. (2007). ***Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]***. Geneva, Switzerland.

Keane, M., & Wasi, N. (2013). Comparing alternative models of heterogeneity in consumer choice behavior. ***Journal of Applied Econometrics, 28***(6), 1018-1045. doi: 10.1002/jae.2304

Kragt, M. E. (2013). The effects of changing cost vectors on choices and scale heterogeneity. ***Environmental and Resource Economics, 54***(2), 201-221. doi: 10.1007/s10640-012-9587-x

Li, X., Clark, C. D., Jensen, K. L., & Yen, S. T. (2014). Will consumers follow climate leaders? The effect of manufacturer participation in a voluntary environmental program on consumer preferences. ***Environmental Economics and Policy Studies, 16***(1), 69-87. doi: 10.1007/s10018-013-0071-9

Louviere, J., & Eagle, T. (2006). Confound it! That pesky little scale constant messes up our convenient assumptions. ***Proceedings of the Sawtooth Software Conference.*** (pp. 211-228).

Louviere, J., Street, D., Carson, R., Ainslie, A., Deshazo, J. R., Cameron, T., . . . Marley, T. (2002). Dissecting the random component of utility. ***Marketing Letters, 13***(3), 177-193. doi: 10.1023/A:1020258402210

Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). ***Stated Choice Methods: Analysis and Applications***. Cambridge: Cambridge University Press.

Louviere, J. J., Meyer, R. J., Bunch, D. S., Carson, R., Dellaert, B., Hanemann, W. M., . . . Irwin, J. (1999). Combining sources of preference data for modeling complex decision processes. ***Marketing Letters, 10***(3), 205-217.

Louviere, J. J., Street, D., Burgess, L., Wasi, N., Islam, T., & Marley, A. A. J. (2008). Modeling the choices of individual decision-makers by combining efficient choice experiment designs with extra preference information. ***Journal of Choice Modelling, 1***(1), 128-164. doi: 10.1016/S1755-5345(13)70025-3

MoE, GEF, & UNDP. (2011). ***Lebanon's Second National Communication to the United Nations Framework Convention on Climate Change***. Republic of Lebanon Ministry of Environment, Global Environmental Facility and United Nations Development Programme, February 2011. http://unfccc.int/resource/docs/natc/lebanon_snc.pdf

MoE, URC, GEF, & UNDP. (2012). ***Lebanon: Technology Needs Assessment***. Republic of Lebanon Ministry of Environment (MoE), UNEP Risø Centre on Energy, Climate and Sustainable Development (URC), Global Environment Facility (GEF) and United Nations Development Programme (UNDP), December 2012. http://unfccc.int/ttclear/sunsetcms/storage/contents/stored-file-20130327162628519/TechnologyNeedsAssessment-ClimateChange_Lebanon.pdf

MoF. (2010). ***2010 Budget Proposal***. Republic of Lebanon Ministry of Finance

Obeidat, O. (2014, February 9). Imports of hybrid cars increased by almost sixfold in 2013, Newspaper article, ***The Jordan Times***. Retrieved from http://jordantimes.com/imports-of-hybrid-cars-increased-by-almost-sixfold-in-2013

Potoglou, D., & Kanaroglou, P. S. (2007). Household demand and willingness to pay for clean vehicles. ***Transportation Research Part D: Transport and Environment, 12***(4), 264-274. doi: 10.1016/j.trd.2007.03.001

Stern, N. (2007). ***The economics of climate change: the Stern review***: Cambridge University Press.

Train, K. E. (2009). ***Discrete Choice Methods with Simulation*** (2nd ed.). New York: Cambridge University Press.

UNEP. (2009). ***Hybrid Electric Vehicles: An overview of current technology and its application in developing and transitional countries***. United Nations Environment Programme, Nairobi, Kenya, September 2009. http://www.unep.org/transport/pcfv/pdf/hev_report.pdf

Table 1: Attributes and attribute levels used in the choice experiment

		Levels				
Attribute	Vehicle category	1	2	3	4	5
Car type (type)		Gasoline	Hybrid			
Fuel consumption (km/tank) (fuel)	Small	160	190	220	250	280
	Small luxury	160	190	220	250	280
	Medium	100	130	170	200	240
	Medium luxury	100	130	170	200	240
	SUV	90	110	130	150	170
	Luxury SUV	90	110	130	150	170
Purchase price (price)*	Small	$10,000	$12,000	$13,000	$15,000	$17,000
	Small luxury	$25,000	$30,000	$35,000	$40,000	$45,000
	Medium	$15,000	$20,000	$25,000	$30,000	$35,000
	Medium luxury	$35,000	$45,000	$60,000	$75,000	$100,000
	SUV	$25,000	$35,000	$40,000	$50,000	$60,000
	Luxury SUV	$55,000	$70,000	$85,000	$100,000	$120,000
Financial incentive (fi)	Gasoline	None				
	Hybrid	None	Registration fee exemption			

* In the econometric model, price was divided by -10000 in order to ensure tractable estimation and obtain easy to read parameter estimates (which are now expected to be positive).

Table 2: Sample characteristics

Characteristic	Percentage
Gender	
Male	69.1
Female	30.9
Age	
18-39	60.9
40-59	32.4
60-79	6.7
Education	
Elementary/Intermediate	9.3
Secondary/High school (12 years of schooling)	31.8
Technical or vocational school	8.9
University undergraduate/bachelor degree or equivalent	43.1
Postgraduate degree (e.g. MSc, PhD)	6.9
Monthly Household Income	
$500-$1,499	7.1
$1,500-$2,499	28.7
$2,500-$3,499	16.2
$3,500-$4,499	9.8
$4,500 or more	12.9
Refuse to answer/Don't know	25.3
Car ownership	
Owns the car currently driven	76.4
Shares the car with family members	14.7
Drives a company car	0.2
Doesn't currently drive	8.7
Average monthly fuel cost	
Less than or equal to $100	21.56
Between $101 and $200	42
Greater than $200	22.44
Don't know/refuse to answer	14
Car type targeted for purchase in the near future	
Small	26.9
Small Luxury	12.0
Medium	21.7
Medium Luxury	18.6
SUV	12.6
Luxury SUV	8.0

Table 3: Fuel consumption and price assumptions for policy simulations

	Fuel consumption (km/tank)		Price ($)				
	Gasoline	Hybrid	Gasoline	Hybrid			
			-	S1	S2	S3	S4
Small	241.8	371.2	$13,000	$15,600	$15,600	$13,000	$14,300
Small luxury	241.8	371.2	$35,000	$42,000	$42,000	$28,000	$35,000
Medium	177.6	310.6	$25,000	$30,000	$30,000	$20,000	$25,000
Medium luxury	177.6	310.6	$60,000	$72,000	$72,000	$48,000	$60,000
SUV	127.4	215.0	$40,000	$48,000	$48,000	$32,000	$40,000
Luxury SUV	127.4	215.0	$85,000	$102,000	$102,000	$68,000	$85,000

Table 4: Information on the various models estimated

	Nr. of respon-dents	Nr. of choice occasions	Nr. of param-eters	Log-likelihood at zero - LL(0)	Log-likelihood at con-vergence - LL(β)	Pseudo-R2	LR χ2	P-value	AIC	BIC
MNL	450	4500	5	-6238.32	-5205.26	0.166	-	-	10420.52	5209.46
MXL	450	4500	9	-6238.32	-3746.77	0.399	2916.97	0.000	7511.54	3750.98
MXL-C	450	4500	15	-6238.32	-3646.67	0.415	200.21	0.000	7323.34	3650.87
GMNL-C	450	4500	17	-6238.32	-3453.37	0.446	386.60	0.000	6940.74	3457.57
GMNL-CH	450	4500	22	-6238.32	-3422.85	0.451	61.04	0.000	6889.69	3427.05

Table 5: GMNL-CH model estimates

Attribute	Coeff.	t-value
Non-random parameters		
Purchase price ($1000's)	-7.0608***	-11.84
Random parameters: means		
Car type – Gasoline	3.3865***	3.51
Car type – Hybrid	4.8356***	5.02
Fuel consumption (km/tank)	0.0601***	10.90
Financial incentive	1.3075***	5.74
Random parameters: standard deviations		
Car type – Gasoline	16.4622***	9.54
Car type – Hybrid	13.5499***	9.79
Fuel consumption (km/tank)	0.0729***	9.60
Financial incentive	1.4622***	5.53
Cholesky matrix: diagonal values		
Car type – Gasoline	-16.4622***	-9.54
Car type – Hybrid	8.4258***	10.55
Fuel consumption (km/tank)	0.0490***	9.74
Financial incentive	1.1790***	4.73
Cholesky matrix: below diagonal values		
Hybrid: Gasoline	-10.6116***	-8.55
Fuel consumption: Gasoline	0.0473***	8.15
Financial incentive: Gasoline	0.7861***	3.18
Fuel consumption: Hybrid	0.0258***	9.39
Financial incentive: Hybrid	0.1007	0.43
Financial incentive: Fuel consumption	-0.3463	-1.47
Scale: heterogeneity in mean parameters		
Small luxury	-0.2462***	-3.03
Medium	-0.5595***	-9.56
Medium luxury	-1.2654***	-19.31
SUV	-0.5905***	-6.79
Luxury SUV	-1.5701***	-20.56
Scale: variance parameter (τ)	1.0077***	19.84
Weighting parameter (γ)	-0.6249***	-9.35

Legend: * p<.1; ** p<.05; *** p<.01.

Table 6: WTP estimates (t-values in brackets; estimates significant at the 5% confidence level are in bold)

	Small	Small luxury	Medium	Medium luxury	SUV	Luxury SUV
Car type - Hybrid vs. Gasoline	$1,808 (2.06)	$7,467 (2.84)	$8,631 (3.46)	$9,927 (1.32)	$3,657 (1.02)	$15,191 (1.41)
Fuel consumption (km/tank)	$79 (16.78)	$115 (7.74)	$132 (8.22)	$252 (5.34)	$134 (5.54)	$256 (4.01)
Financial incentive	$1,934 (15.76)	$2,127 (8.40)	$2,291 (14.29)	$316 (0.48)	$1,415 (2.98)	$1,698 (1.25)

Table 7: Policy simulation results

	HEV purchasing probability	% Fuel consumption reduction	Fuel consumption reduction (L/car/year)	% CO_2 emissions reduction	CO_2 emissions reduction (t/car/year)	Additional cost of buying an HEV ($/car/year)	Fuel cost savings ($/car/year)	Years to break-even	Social benefit from reduced CO_2 emissions ($/car/year)	Net benefit from buying an HEV ($/car/year)
Scenario 1	45.5%	17.3%	291.3	11.5%	0.39	$3,270	$320	10.2	$6.6	-$2,943
Scenario 2	66.4%	25.5%	422.0	16.8%	0.57	$4,546	$464	9.8	$9.7	-$4,072
Scenario 3	80.0%	30.9%	520.2	20.5%	0.70	-$5,100	$572	-	$11.9	$5,684
Scenario 4	75.6%	29.1%	484.9	19.2%	0.66	$282	$533	0.5	$11.2	$263

Figure 1. Example of a choice set

	Option 1	Option 2	Option 3	
Car Type	Gasoline Car	Hybrid Car	Hybrid Car	**None of these**
Fuel Consumption *(Km/tank)*	190 Km/tank	220 Km/tank	280 Km/tank	
Purchase Price *(including VAT and registration fees)*	$15,000	$13,000	$15,000	
Financial Incentive	-	Car registration fee exemption	-	
Please choose the ONE option you prefer most	☐	☐	☐	☐

The Issam Fares Institute for Public Policy and International Affairs (IFI)

American University of Beirut | PO Box 11-0236, Riad El Solh 1107 2020, Beirut, Lebanon
Tel: +961-1-374374, Ext: 4150 | Fax: +961-1-737627 | Email: ifi@aub.edu.lb | Website: www.aub.edu.lb/ifi