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Analysis

Social Benefits From Controlling Invasive Asian Tiger and Native Mosquitoes: A Stated Preference Study in Athens, Greece

Kostas Bithas[a], Dionysis Latinopoulos[b,*], Antonis Kolimenakis[a], Clive Richardson[a]

[a] Institute of Urban Environment & Human Resources, Department of Economic and Regional Development, Panteion University, 14 Aristotelous St., GR-17671 Kallithea, Athens, Greece

[b] School of Spatial Planning and Development, Aristotle University of Thessaloniki, GR-54124, Thessaloniki, Greece

1. Introduction

The problems associated with mosquitoes in Athens, Greece - a representative Mediterranean urban system - have intensified recently due to invasion by the Asian tiger mosquito (*Aedes albopictus*). Its arrival was favored by both the geographical position of Greece and climatic conditions, both representative of the vulnerable Mediterranean region. The Asian tiger mosquito was first detected in Greece in 2003 (Samanidou-Voyadjoglou et al., 2005) and was confirmed for the first time in the Athens metropolitan area in 2008 (Koliopoulos et al., 2008). Its establishment is expected to be accompanied by increasing risks of mosquito-borne diseases, higher nuisance levels and increased expenses for the confrontation of invasive species (ECDC, 2012).

A recent study (Kioulos et al., 2014) revealed that the eight most common native mosquito species recorded in the Athens Metropolitan area, all of the *Culex* and *Anopheles* genera, are: *Culex pipiens*, *C. longiareolata*, *C. hortensis*, *C. theileri*, *C. territans*, *C. impudicus*, *Anopheles maculipennis complex* and *A. claviger*. Mosquito species of medical importance, such as *C. pipiens* and *A. maculipennis*, proliferate in the natural breeding sites provided by permanent water bodies. These species, which are active for several months of the year, transmit vector-borne diseases such as West Nile virus and malaria (*Plasmodium vivax*), threatening a large proportion of the population in many areas of Athens.

The newcomer, the Asian tiger mosquito, has already developed considerable populations with increasing trends in the urban environment of the Athens Metropolitan area (Giatropoulos et al., 2012). The larvae of this container-breeding mosquito develop in tree-holes, phytotelmata and artificial containers such as tires, barrels, cans, etc. (Tsiodras et al., 2016; Giatropoulos et al., 2012; Reiter and Sprenger, 1987; Grist, 1993; Simard et al., 2005). Its presence in the Greek capital was accompanied by the characterization of "an aggressive day-time biting mosquito". The Asian tiger mosquito is implicated in the transmission of a wide range of human pathogens. Along with other representatives of the *Aedes* genus such as *A. aegypti*, it is a laboratory competent vector of at least 22 arboviruses including chikungunya virus, dengue and the Zika virus. Recent cases of autochthonous transmission of dengue in both France and Croatia in 2010 and chikungunya virus in Italy (2007) and France (2010) underline the need for awareness of the risk of the introduction and spread of serious diseases in continental Europe by the Asian tiger mosquito (Giatropoulos et al., 2012; Grandadam et al., 2011; Rezza et al., 2007).

Only a limited number of studies have been designed to assess the non-market benefits of mosquito control programs (e.g. John et al., 1992; von Hirsch and Becker, 2009; Dickinson and Paskewitz, 2012; Halasa et al., 2014; Brown et al., 2015; Bellini et al., 2014). The present study aims to enrich the literature by evaluating the non-market benefits that are potentially induced by prevention programs, focusing on two general categories of benefits (Dickinson and Paskewitz, 2012): (1) reductions in the risk of disease transmission (health impacts) and (2) reductions in the (biting) nuisance caused by mosquitoes. The present work also aims to extend the existing literature on using choice experiments to study public preferences and social benefits regarding the control of invasive species (Adams et al., 2011; Beville et al., 2012; Fleischer et al., 2013; Rolfe and Windle, 2014) by identifying attributes that vary considerably between invasive and native species.

We employ the choice experiment method - a stated preference approach - to investigate the potential social benefits of improving the public mosquito control program in the Metropolitan area of Athens, Region of Attica, which is the most populated region of Greece (about 35% of the country's population, approximately 3.8 million citizens). Apart from its importance in terms of demographics and economic activity, this region was selected primarily because of the scientific recording of the presence and spread of the Asian tiger mosquito across Athens's municipalities and neighborhoods. Eight municipalities were selected representing the variety and diversity of socio-economic conditions. The selected study area offered the possibility of analyzing citizens' preferences across different degrees of exposure to the problems associated with either the Asian tiger mosquito or native mosquito species and within a different socio-economic context. Our economic valuation can serve as a decision aid for the ex-ante evaluation of alternative mosquito control programs. The results will be of wider interest as Athens is representative of urban areas with high vulnerability because of climate change, intensive trade and population movements

* Corresponding author.
E-mail addresses: kbithas@eesd.gr (K. Bithas), dlatinop@plandevel.auth.gr (D. Latinopoulos), crichard@panteion.gr (C. Richardson).

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(tourism, migration), while at the same time severe public budget constraints, induced by the ongoing economic crisis, demand clear justification of the cost of control programs.

2. Methodology

2.1. The Choice Experiment Method

The choice experiment method has its roots in Lancaster's characteristics theory of value, in random utility theory and in experimental design (Hanley et al., 1998). Lancaster's (1966) theory implies that consumer decisions are determined by the utility (satisfaction) derived from the attributes of a good or service and by the levels that these attributes take. Within this framework, individuals are presented with a set of alternatives and are asked to choose the most attractive (preferred) alternative under the assumption that these are the only options available (Arana and Leon, 2009).

According to random utility theory, the utility function U_{ij} of individual i for choice j is comprised of a deterministic component V_{ij} and a random error term e_{ij} that captures the effect of unobserved and omitted variables. Under the premise that individuals act rationally by selecting from a choice set the option that yields the highest utility, the probability of selecting a given option is the probability that the utility provided by this alternative is the highest among the different choices.

Under the assumptions that (a) the relationship between utility and attributes is linear in the parameters and variables, and (b) the random error terms are distributed independently and identically with a type I extreme value distribution, the probability of choosing the specific public mosquito control program j from among the set C of all the available alternative programs can be expressed by a conditional logit model:

$$P(U_{ij} > U_{in}, \forall\ n \neq j) = \frac{\exp(V_{ij})}{\sum_{n \in C} \exp(V_{in})} \tag{1}$$

As the systematic component is a linear function of attributes, the conditional indirect utility function for the jth alternative can be specified as follows:

$$V_{ij} = \beta_{ASC} ASC + \sum_{k} \beta_k Z_{j,k} \tag{2}$$

where β_k is the coefficient (to be estimated) of the k-th choice attribute Z_k and β_{ASC} is the coefficient of the alternative specific constant (ASC), which is a dummy that takes the value 1 if the status quo alternative is chosen or the value 0 if one of the hypothetical alternative programs is chosen. Eq. (2) is the main effects model, which can be extended in order to incorporate a set of individual socio-economic or attitudinal variables (i.e. characteristics of respondent i) in the utility function. Since these characteristics are constant across choices for any given individual, they can be entered as interaction terms with specific attributes (Hanley et al., 2001) or as interaction terms with the alternative specific constant (Morrison et al., 1999).

The choice experiment is consistent with utility maximization and demand theory (Hanemann, 1984). Therefore if a monetary/cost attribute (representing the marginal utility of income) is included in the choice set, welfare estimates can be derived. Specifically, for the conditional logit model, compensating surplus (CS) welfare estimates can be obtained from the formula:

$$CS = \frac{\ln \sum_i \exp(V_i^1) - \sum_i \exp(V_i^0)}{\beta_I} \tag{3}$$

where β_I is the marginal utility of income (usually represented by the coefficient of the monetary attribute) and V_i^0, V_i^1 represent the indirect utility before and after the change under consideration, respectively. Furthermore, given the linear utility function, the willingness to pay (WTP) for a marginal change in each attribute level is estimated by dividing the coefficient of this attribute by the coefficient of the cost attribute (Hoyos, 2010). Finally, when interaction terms are included in the model, the WTP function is modified as necessary in order to include the effect of the respondent-specific characteristics.

It should be noted that the conditional logit model is often criticized for imposing the independence of irrelevant alternatives (IIA) property, which requires that the relative probabilities of two alternatives being chosen should be unaffected by the presence of other alternatives. If this property is violated then the conditional logit results will be biased and other discrete choice models, such as mixed (random parameter) logit models or latent class models should be used. These models are also thought to be better suited to account for the unconditional unobserved heterogeneity among the respondents (random parameter logit models) or for demographic and psychographic differences among groups of respondents (latent class models). However, this can be also done through a conditional logit model that incorporates several individual characteristics of the respondents, under the limitation that these characteristics should be selected a priori.

2.2. Survey Design and Administration

2.2.1. Selection of Attributes and Attribute Levels

The first step in designing our choice experiment is to select the appropriate set of attributes in order to assess the benefits of improved mosquito control programs. Alternative levels of those attributes must be also determined. The aim of this step is to enable participants to choose their preferred mosquito control program by comparing hypothetical programs which differ with regard to the levels of the selected attributes. This is not a trivial task as it involves, among other things, a realistic representation of the good under valuation (Hensher et al., 2005; Rodrigues et al., 2016). A realistic representation of policy options is to provide a status quo alternative for people who are not willing to pay for the proposed improvements (Louviere et al., 2000). All other policy options can be considered as improvements over the current programs and the status quo option can be regarded as a baseline, zero-cost scenario.

The initial choice of attributes in this study was based on feedback provided by experts. Next, an extensive web-based pilot study (180 questionnaires) was conducted in November 2014 in the study area aiming to identify the main factors that may influence the acceptance of future mosquito control programs. Finally, a small scale pilot study (30 questionnaires with face-to-face interviews) was conducted in May 2015 in order to refine the selected attributes and their levels. As a result, we reduced the complexity of the choice task by limiting the number of attributes and their levels to only those that have a clear relationship with mosquito control programs while this relationship is articulated in operational terms easily perceived by citizens.

There are two main categories of benefits from improved mosquito control programs: less nuisance and reduced risks to health. Another distinction in the present study, which is quite novel, is between benefits from controlling native mosquitoes and benefits from controlling invasive mosquitoes (such as the Asian tiger mosquito). Two health risk attributes were used: (a) one related to the health risks that are mainly associated with native mosquitoes (such as the West Nile Virus - WNV) and (b) one related to the health risks that are due only to the Asian tiger mosquito (such as chikungunya fever). Similarly, the nuisance attributes were also separated into: (a) nuisance during the day-time, which is a problem that is caused mainly by the Asian tiger mosquito, an “aggressive day-time biting mosquito” (Giatropoulos et al., 2012), and (b) nuisance at night mainly associated with the native mosquito species. Next, a cost attribute was included in order to elicit welfare effects, as determined by individuals' preferences between alternative mosquito control programs.

The control of the native species is mainly carried out through annual activities which include monitoring and surveillance of the mosquito larvae population, implementation of larvicidal, adulticidal and