

Measuring heterogeneous preferences for adaptation strategies in response to sea-level rise:

Evidence from Miami-Dade County

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Abstract

Despite mounting threats from rising sea levels, adaptation to sea-level rise (SLR) is often challenged by limited funding and understanding of residents' preferences. Using an online choice experiment, we investigate residents' preference for three SLR adaptation strategies: building seawalls, replenishing the beach, and installing stormwater pumps in Miami-Dade County. We control the preference, scale, and alternative heterogeneity using generalized multinomial logit models with error components. Results show that residents prefer additional adaptation strategies to the status quo, and valuations of adaptation attributes are correlated with residents' sociodemographics. Accounting for alternative heterogeneity also significantly improves model performance.

Key words: Adaptation strategies, choice experiment, generalized multinomial logit (GMNL) models, preference heterogeneity, sea level rise, climate change.

JEL codes: Q51, Q54

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1. Introduction

The mean global sea level is estimated to rise by 65 ± 12 cm (26 ± 5 inches) above the 2005 mean sea level by 2100 (Nerem et al. 2018). This process is caused by the expansion of seawater due to global warming and water mass input from land ice melt as well as land water reservoirs (Nicholls and Cazenave 2010). The consequence of sea-level rise (SLR) includes inundation and flooding, loss of coastal land, erosion of beaches, salt-water intrusion to surface water, and loss of coastal wetlands and saltmarshes, which will inflict considerable economic loss and ecological damage (Caldwell and Segall 2007; Nicholls and Cazenave 2010; Nicholls et al. 2011; Reidmiller et al. 2018).

The projected economic losses due to SLR could be massive without mitigation or adaptation efforts. Using Florida as an example, inaction to climate change could result in a total loss of \$92 billion by 2050 (in 2006 U.S. dollars) and \$345 billion by 2100 (5% of the state's GDP) in tourism revenue, commercial and residential property values, and cost of living in the state (Stanton and Ackerman 2007). Adaptation strategies to reduce the vulnerability of economic, social, and biological systems may be cost-effective in the long run to prevent more significant damage from SLR.

Adaptation strategies to SLR can be categorized into protection, accommodation, retreat, and avoidance (FDEP 2018). Protection involves providing hard artificial (e.g., seawalls and bulkheads) or natural barriers (e.g., sand dunes and mangrove wetlands) between water and land. Accommodations allow economic activities to continue with the rising sea by elevating roads and infrastructures or improving planning and warning systems. Retreat includes relocation to upper land while abandoning or demolishing damaged properties (Fankhauser 1995; Hallegatte 2009). Avoidance involves barring development in hazard zones. The costs of adaptations vary

widely, with some being quite expensive. For example, the U.S. Geological Survey estimates that protecting the vulnerable 1710 miles along the 4000 miles of Florida's shoreline with seawalls would cost \$9 billion (Lu et al. 2012). Without beach replenishment, the rising sea level in South Florida could accelerate the rate of beach erosion as high as 30-50% (Finkl 1996). The costs of elevating roads and structures, and replenishing beaches could be as high as \$21.6 billion along the Gulf Coast and \$7.8 billion along the Atlantic Coast, without considering the rising cost of sand to replenish beaches (Titus et al. 2009). The feasibility of various adaptations to SLR is site-specific because coastal flooding hazards are influenced by location-specific factors such as local elevation, change of elevation, regional variations in the rate of SLR, and exposure to storm surges induced by local extreme weather events (Wdowinski et al. 2016). Because there is little literature focusing on the empirical estimate of the economic benefits of local SLR adaptation and the perceived importance of different attributes of the adaptation strategies demanded by local residents, this study will provide essential information for adaptation planning and cost-benefit analysis.

Previous studies have used preference elicitation methods such as discrete choice experiments to examine the economic benefits and welfare changes for non-market goods such as climate change adaptation strategies (Shoyama et al., 2013; Andreopoulos et al., 2015; Remoundou et al., 2015; Ščasný et al., 2017). However, few have examined the public preferences for tradeoffs of adaptation strategies and to what extent that specific attributes of adaptations influence preferences. Obtaining such information is essential for developing effective SLR adaptation strategies because adaptation strategies differ significantly in costs, effectiveness, and expected planning horizons. For instance, beach nourishment needs to be replenished periodically as they erode over time, and the nourishment costs are expected to

increase due to erosion and a limited supply of natural sand. Armoring shorelines with hard structures, such as seawalls, helps protect beaches along the artificial barrier but increases beach erosion in nearby areas and endangers wildlife habitats. Furthermore, it reduces beach access and induces further economic development in at-risk areas, which may exacerbate future damages. Installing stormwater pumps to mitigate flooding damages has failed to prevent flooding from occurring in low-lying, populous coastal areas such as Miami (FDEP 2018).

This study contributes to the literature on the valuation of SLR adaptations by using the adaptation strategies adopted in Miami-Dade County, Florida, as an example. Specifically, we focus on three protective adaptation strategies implemented in the county to elicit homeowners' preferences for these adaptations via a choice experiment in an online survey of representative homeowners in the county. The three adaptation strategies are building seawalls, replenishing the beach, and installing stormwater pumps.

We focus on Miami-Dade County because this area is a highly economically vulnerable area to SLR (Melillo 2014). The rate of SLR has accelerated in southeast Florida, from $3 \pm 2 \text{ mm}$ (0.12 ± 0.08 inches) per year pre-2006 to $9 \pm 4 \text{ mm}$ (0.35 ± 0.16 inches) post-2006 (Wdowinski et al. 2016). After 2006, the frequency of rain-induced and tide-induced flooding has grown by 33% and 400%, respectively (Wdowinski et al. 2016). Miami-Dade County is also the seventh most populous county in the United States (United States Census Bureau 2018a). Projections show that the number of people affected by a 1.8-meter SLR in Broward and Miami-Dade Counties in Florida accounts for more than a quarter of the impacted population by SLR in the United States (Hauer et al. 2016). Furthermore, Florida's economy is heavily reliant on tourism and real estate, especially in southeast Florida. In 2018, Florida beaches had about 810 million beach day visits (Florida Trend, 2019). The loss of property values due to SLR

inundation between 2005 and 2016 is estimated to be \$465 million (McAlpine and Porter 2018). Rising sea level is also expected to reduce the values of the properties prone to flooding even further.

In response to the mounting risks from SLR, Miami voters supported the \$400 million Miami Forever general obligation bond in November 2017 (MiamiForever.org). The bond will fund public projects to reduce flooding risks, improve stormwater infrastructure, increase affordable housing, and upgrade cultural services to the most vulnerable population. In 2018, Miami Beach, one of the cities in Miami-Dade County, promoted a \$500 million plan to elevate roads and install pumps to adapt to SLR (Harris 2018). This is noteworthy, as Florida lacks state-coordinated adaptation planning despite the scientific agreement on the projections of accelerated SLR (Ariza et al. 2014). Understanding residents' perceived benefits of SLR adaptations can provide essential insights for the local government to identify key attributes of adaptation strategies valued by local residents and communicate the tradeoffs of different SLR adaptations.

Our study differs from existing studies in the following ways. First, we focus on specific attributes that can describe the benefits of adaptation strategies and are easier to use to communicate with residents. The attributes include the expected duration of protection and the expected change in flood insurance premiums. Estimates on residents' valuation of these attributes can inform future reform on incentive programs to encourage and support adaptation strategies. Second, while previous studies focus only on preference heterogeneity, we address preference heterogeneity, scale heterogeneity, and alternative heterogeneity by using a Generalized Multinomial Logit Model (G-MNL) with an Error Component (E.C.) that allows the alternatives to have specific individual or group impacts for different adaptation strategies

(Scarpa et al. 2005; Caputo et al. 2017). This model helps decompose the heterogeneity that may come from preference, scale, and alternatives. As a result, it provides better estimates of the preferences for SLR adaptation strategies. Third, we estimate the marginal willingness to pay (MWTP) for each attribute with respect to each respondent's sociodemographics and home property characteristics to identify factors affecting the perceived benefits from adaptation strategies. At last, we estimated the total MWTP that homeowners are willing to pay by increasing the stormwater utility fee, providing a reference point for the local government to design appropriate programs for sea-level rise adaptation using public funds.

2. SLR Adaptation Strategies

Rising sea levels accelerate beach erosion. Beach, as a natural resource, is a valuable asset providing both use and non-use economic values to residents. Numerous studies have documented that residents are willing to support the replenishment of beaches (beach nourishment) to obtain greater recreational benefits, support wildlife, or improve property values (see review in Landry 2011; Penn et al. 2016; Pascoe 2019). For example, the MWTP for beach nourishment is estimated to be between \$100 and \$8000 per square foot in Georgia, North Carolina, and South Carolina (Pompe 1999; Landry et al. 2003; Gopalakrishnan et al. 2011). Several studies have examined the recreational benefits and non-use economic values of beaches in Florida using contingent valuation methods and travel costs. The study by Bell and Leeworthy (1990) estimates that the value of a beach day in Florida is \$34 (1984 U.S. dollars) for those households traveling great distances. Shrivani et al. (2003) characterize three South Florida beaches and elicit visitors' MWTP for beach nourishment using the contingent valuation method (CVM). They find that the MWTP for using beach nourishment to maintain turtle nesting habitat is \$2.12 per visit, while the MWTP for beach recreational activities alone is \$1.69 per visit.

Previous studies have examined residents' preference for adaptation strategies to combat the adverse effects of climate change, such as SLR and coastal flooding (Holladay et al. 2016; Johnston and Abdulrahman 2017; Johnston et al. 2018; Landry et al. 2018; Makriyannis et al. 2018; Hindsley and Yoskowitz 2020). Using CVM, Holladay et al. (2016) find that respondents in New York with homes damaged by Hurricane Sandy are willing to pay \$7 per month more to fund a comprehensive flood control system in New York than those with undamaged homes. While residents in New Orleans prefer hard physical (artificial) structures to coastal wetland restoration (Landry et al. 2011), residents in North Carolina strongly oppose shoreline armoring and are willing to support beach nourishment and retreat (Landry et al. 2018). Earlier studies have found that respondents' income, residence, familiarity with beaches, and presence of sand dunes are positively correlated with respondents' MWTP for beach erosion control in the northeastern region of the United States (Lindsay et al. 1992). Other studies have used the discrete choice experiment (DCE) to assess the value of climate change risk reduction methods and adaptation strategies (Johnston and Abdulrahman 2017; Johnston et al. 2018; Makriyannis et al. 2018; Hindsley and Yoskowitz 2020). Using the DCE method, those studies evaluated the tradeoffs of different attributes related to coastal hazard adaptations and provided implications for future studies on climate change.

However, none of the studies have focused on one of the most populous, economically prospective, yet vulnerable counties, such as Miami-Dade, and investigated the residents' perceived values for SLR adaptations in Florida. In contrast to the existing studies, this study examines the perceived benefits of adaptation strategies concerning two key attributes: increasing the duration of protection and offsetting growth in flood insurance premiums by reducing flooding risks. We further explore Florida residents' MWTP for these attributes and

their distribution based on sociodemographics. The information on these two attributes can be used to provide valuations on new adaptation strategies yet to be implemented to reduce flooding risks.

3. Choice Experiment Design and Survey

We designed a choice experiment with three adaptation strategy options (beach nourishment, seawalls, and stormwater pumps) and one status quo option. In each choice set, respondents were asked to select their most preferred one among the alternatives. If the respondents were unsure which adaptation strategy to choose or simply disliked all the alternatives, they could choose the status quo option, which is the default. The adaptation strategies vary in three attributes: additional *years of protection*, the *percent change of flood insurance premium*, and additional *monthly stormwater utility fees*. We selected the attribute levels of the status quo, beach nourishment, seawalls, and stormwater pumps based on the literature and discussions with the experts of SLR adaptation and local stakeholders in Miami-Dade County.

All the attributes and corresponding levels of the three adaptation strategies are summarized in Appendix Table A1. The status quo is set to have an additional eight years of protection, with an average of 15% increase in flood insurance premium and a zero additional monthly stormwater utility fee. The status quo and its attribute levels are estimated based on the adaptation strategies currently being implemented in Miami-Dade County. For the three adaptation strategies (beach nourishment, seawalls, and stormwater pumps), the attribute *additional years of protection* includes duration levels of 16, 24, 32, and 38 years, which are 8, 16, 24, and 30 years longer, respectively, than that of the status quo (8 years). The levels are selected based on the information that the lifespan of seawalls, stormwater pumps, and beach

nourishment ranges from 6 to 50 years (Frenning 2001; Phillips and Jones 2006; Caracas et al. 2014; McInerney et al. 2017). That is, the longer the years of protection, the longer the lifespan of the project. The *percent change of flood insurance premium* associated with the three adaptations includes an increase of 2%, 5%, and 8%, which are estimated based on the reported average increase rate due to the increased flooding risks associated with SLR (Hurtibise 2016). It is expected that flood insurance premiums for residential and commercial properties will increase in the future, affecting both homeowners who have flood insurance and those who do not have flood insurance. If additional adaptations are implemented, the increase in flood insurance premiums will be slower than the increase under the status quo (15%). *Additional monthly stormwater utility fees* to fund the adaptation strategies include an additional \$4, \$8, \$12, and \$16 per month compared with the status quo (\$0). Established in 1991, stormwater utility fees are the primary funding collected by the local government to provide adequate flood protection (Regulatory Economic Resources 2019). These fees are mandated for both developed residential and non-residential properties and are calculated as a function of equivalent residential units (ERU). As of 2019, each property is charged \$4 per month for one unit of ERU (set at 1548 square feet). We choose to use utility fees as the payment vehicle because Florida has no state income tax, and the Department of Water and Sewer in Miami-Dade County serves approximately 85% of the local population.

Since each type of adaptation has unique characteristics, we use a labeled choice experiment design in this study to help respondents better understand the attribute information (Louviere et al. 2000; Lusk and Schroeder 2004; de Bekker-Grob et al. 2010). The design also allows us to estimate consumer preference for each of the adaptation strategies by estimating the alternative specific constants. The D-efficient design is used to generate the choice experiment

by minimizing the D-error of the determinant of the asymptotic variance-covariance matrix of the parameters from a conditional logit model using Ngene1.1.2 (ChoiceMetrics 2014). We generate the choice experiment assuming there is no prior information (using “zero” as the prior parameter values). This is because little information is known about preferences for SLR adaptation strategies (Huber and Zwerina, 1996; Kessels et al. 2006). Designing the choice experiment without prior information is an appropriate choice since using low-quality prior information might result in an even less optimal design than the one without any prior information (Ferrini and Scarpa 2017). Ngene generates 20 choice questions, and the design ends with an MNL D-Error of 0.3145¹. To reduce the cognitive burden on respondents, we randomize the 20 choice questions into two blocks, with each having ten choice tasks (Carson et al. 1994; Swait and Adamowicz 2001). Therefore, respondents are randomly assigned to one block and answer the ten choice questions in that block.

Appendix Table A2 illustrates an example of a choice question presented to the respondents: The premium of flood insurance is likely to increase by 15% in eight years if no additional adaptation actions are taken (Status Quo in row 1, column 5). In this case, without additional adaptations, the increase in monthly stormwater utility fees is zero, and the years of protection offered by the current level of adaption are eight years. Beach nourishment, seawalls, and pumps have different levels for the three attributes correspondingly.

An online survey with the choice experiment was administered by a market research firm (Qualtrics) to their panel members with residency in Miami-Dade County in May 2017, following a one-week pre-test in April and before the highly publicized “Miami-Forever” Ballot

¹ After collecting about 10% samples from the soft launch of the survey, we estimated the conditional logit model and used the parameter estimate as the prior to generate a new choice experiment. However, the new choice experiment was very close to our original choice experiment, with similar D-Errors. Therefore, we decided to use the original choice experiment.

in November 2017. Conducting a pre-test during the survey development period using focus groups was recommended in the study by Johnston et al. (2017). We developed and tested the survey design with extension specialists and researchers working on climate resilience and SLR issues in the state, graduate students, and faculty members working in the field to ensure respondents' understanding and comprehension of the survey questions. After the survey instruments were finalized, we first soft-launched the study by collecting 10% of the sample in the online panel. The soft launch ensured the online survey flow was executed correctly, and there were no major problems with our survey instruments. The soft launch results did not indicate any major issues with our survey.

The survey was designed in both English and Spanish since around 64% of the Miami residents speak Spanish, and 28% of them speak English as of 2010.² Survey invitations were sent to panel members until the quota was completed, and qualified responses were recorded. Participants of the survey were required to be (1) year-round residents of Miami-Dade County, (2) at least 18 years old, and (3) homeowners. The sample was stratified to ensure that the survey participants represent the adult population in Miami-Dade County in terms of gender and racial composition.

After the screening questions, participants answered questions on their perception and knowledge about SLR and their experience with storm-induced and sunny-day flooding. Next, participants were presented with information about the benefits and limitations of the three adaptation strategies (beach nourishment, seawalls, and stormwater pumps). To ensure respondents' comprehension of the benefits and limitations, we asked them to answer a set of true-or-false questions after information about the three adaptation strategies was presented. We

² ["Modern Language Association Data Center Results of Miami-Dade County, Florida"](#). Modern Language Association. Retrieved July 27, 2013.

also used the cheap talk script to reduce potential hypothetical bias while introducing the three adaptation strategies before conducting the choice experiment (Champ et al., 2009; Penn and Hu, 2019; Wuepper et al., 2019). The cheap talk script is presented in Figure A1, and an example of the choice experiment question is presented in Figure A2. At the end of the survey, participants provided information about their sociodemographics, such as household income, home property values, and whether they had purchased flood insurance in the past 12 months.

4. Methodology

Econometric Models

Following the random utility theory (McFadden 2001), we assume that individuals will choose a product with the attribute bundle that maximizes their utility. The individual n 's utility of choosing the alternative i from a choice set of J alternatives in a situation t can be specified as

$$U_{nit} = X_{nit} * \beta + \varepsilon_{nit} \quad [1]$$

where X_{nit} is the variable attributes in the study. β is a vector of unknown preference coefficients that weight the exogenous attributes. ε_{nit} is the stochastic component of utility, which captures the unobserved factors that affect the utility. A variety of models can be used based on the assumption of the distribution of both the preference coefficients and error terms (Bazzani et al. 2017). Equation [1] can be estimated using a Conditional Logit (CL) model when ε_{nit} is independent and identically distributed (IID) with Gumbel distribution (Meas et al. 2014). However, CL assumes homogeneous preference and independence of irrelevant alternatives (IIA). Previous research studying consumer preference has concluded that heterogeneity needs to be considered from both the methodological and empirical standpoints (Lusk et al., 2003; Greene et al., 2006; Ortega et al., 2011; Greene and Hensher, 2013; Wongprawmas and Canavari, 2017). When heterogeneity exists, the CL model could bring biased results, and it needs a more flexible

model. Revelt and Train (1998) propose the mixed logit model (MIXL) that relaxes the IIA assumption and captures the heterogeneity in preference by allowing preference coefficients to vary across individuals. In MIXL, coefficient vector β is assumed to follow a density function $f(\beta|\theta)$ where θ is the parameter of the distribution. Typically, β can be specified as $\beta_i = \bar{\beta} + L * u_i$, where $\bar{\beta}$ is the population mean, and u_i is the individual-specific heterogeneity, with a mean of zero and standard deviation of one (Greene 2012). Under the assumption of intra-respondent homogeneity of the MIXL model, the choice probability can be specified as a weighted average of a product of logit formulas evaluated at a different level of β , given the weight by the density function $f(\beta|\theta)$.

In most applications, the coefficient vector is assumed to follow a multivariate normal distribution (Liu et al., 2019). However, research has also found that the multivariate normal distribution may not correctly reflect the real choice behavior (Louviere and Meyer, 2008; Louviere et al., 2008). In addition to preference heterogeneity, a scale effect can also contribute to the heterogeneity in attribute coefficients. For some respondents, the scale of the error term for some respondents is more substantial than for other respondents. This is also referred to as scale heterogeneity, which may occur when choice behavior has greater dispersion for some respondents than for others. A scaled multinomial logit model (S-MNL) can be implemented to capture scale heterogeneity (Fiebig et al. 2010). Fiebig et al. (2010) further developed a generalized multinomial logit model (G-MNL) that nests MIXL and S-MNL. The models accounting for both scale and preference heterogeneity (namely, G-MNL) perform better than MIXL in all ten datasets examined in Fiebig et al. (2010). Greene and Hensher (2010) also conclude the improvement of using the generalized mixed logit model (same as G-MNL) over the standard mixed logit model. Following Fiebig et al. (2010), Greene and Hensher (2010), and

Greene (2012), we also apply the G-MNL model in this study to take into account both the preference heterogeneity and scale heterogeneity. The utility function in G-MNL is specified as

$$U_{nit} = X_{nit} * \beta_i + \varepsilon_{nit} \quad [2]$$

where ε_{nit} is IID with the Gumbel distribution, and β_i is specified as

$$\beta_i = \theta_i * \beta + [\gamma + \theta_i(1 - \gamma)] * L * u_i \quad [3]$$

and u_i follows a certain distribution, $0 \leq \gamma \leq 1$

$$\theta_i = \exp\left(-\frac{\tau^2}{2} + \tau * w_i\right), w_i \sim N(0,1) \quad [4]$$

The G-MNL model is nested with all the major models used for the choice experiment data. To be specific, when $\tau = 0$ & $L \neq 0$, the G-MNL results in a MIXL model; when $\gamma = 0$ & $L = 0$, the G-MNL results in S-MNL. The model can be estimated using a simulated maximum likelihood method (Ouma et al. 2007).

To further improve the robustness of the model and its accuracy in reflecting respondents' choice behavior in this specific study, we take additional steps to refine the model. In this study, respondents are asked to make a decision (choose) among three adaptation strategies along with the status quo option. Although the three adaptation strategies vary by attribute levels, the status quo option remains the same in all ten choice sets. Research has concluded a higher utility variance exists for the designed alternatives than the utility of the status quo (Scarpa et al. 2005; Caputo et al. 2017, 2018). This implies that the unobserved utility of the three adaptation strategies might have a more considerable discrepancy than the status quo (Caputo et al. 2013; Bazzani et al. 2017). Therefore, three adaptation strategies may share similar alternative specific random effects that are unobservable, which indicates a higher correlation in the error terms of the three adaptation strategies than the status quo (Caputo et al. 2018). In our study, we further improve the G-MNL model by adding the alternative specific error components

(E.C.) with zero mean to capture the potential correlated error terms across different adaptation strategies (Scarpa et al. 2005; Gao et al. 2019). The utility function U_{nit} for the four alternatives in this study is specified as

$$U_{n,seawall,t} = \alpha_{n,seawall} + \beta_{n,year} * Year_{n,seawall,t} + \beta_{n,insurance} * Insurance_{n,seawall,t} + \beta_{n,fee} * Fee_{n,seawall,t} + \theta_1 EC_{n,1} + \varepsilon_{n,seawall,t} \quad [5]$$

$$U_{n,beach,t} = \alpha_{n,beach} + \beta_{n,year} * Year_{n,beach,t} + \beta_{n,insurance} * Insurance_{n,beach,t} + \beta_{n,fee} * Fee_{n,beach,t} + \theta_2 EC_{n,2} + \varepsilon_{n,beach,t} \quad [6]$$

$$U_{n,pump,t} = \alpha_{n,pump} + \beta_{n,year} * Year_{n,pump,t} + \beta_{n,insurance} * Insurance_{n,pump,t} + \beta_{n,fee} * Fee_{n,pump,t} + \theta_3 EC_{n,3} + \varepsilon_{n,pump,t} \quad [7]$$

$$U_{n,status_quo,t} = \beta_{n,year} * Year_{n,status_quo,t} + \beta_{n,insurance} * Insurance_{n,status_quo,t} + \beta_{n,fee} * Fee_{n,status_quo,t} + \theta_4 EC_{n,4} + \varepsilon_{n,status_quo,t} \quad [8]$$

where $EC_{n,i}$ ($i=1,2,3,4$) is the error component associated with individual n and alternative i . $\varepsilon_{n,i,t}$ is assumed to be IID with Gumbel distribution (i =seawall, beach, pump, status quo). $\alpha_{n,i}$ is the individual n 's alternative specific constant of choosing alternative i , and $\beta_{n,i}$ is the preference coefficient weighting the attributes in the choice experiment. $U_{n,status_quo,t}$ does not include a constant because the status quo is used as the base category in the study to avoid multicollinearity. The definition of the variables in the utility functions is provided in Appendix Table A1 as well.

Different error component structures can be specified based on theoretical justification and empirical estimation. We hypothesized three error component structures given the study context:

- (1) two independent error components ($EC_{n,123}, EC_{n,4}$), where $EC_{n,1} = EC_{n,2} = EC_{n,3} = EC_{n,123}, EC_{n,123} \neq EC_{n,4}$.

(2) three independent error components ($EC_{n,13}, EC_{n,2}, EC_{n,4}$), where $EC_{n,1} = EC_{n,3} =$

$EC_{n,13}, EC_{n,13} \neq EC_{n,2} \neq EC_{n,4}$.

(3) one independent error component for status quo and three random alternative

specific constants (ASCs) for three adaptation strategies, where $EC_{n,1} = EC_{n,2} =$

$EC_{n,3} = 0$ and $EC_{n,4} \neq 0$

The error components capture the “alternative specific random individual effects that account for choice situation invariant variation” (Greene 2012). Therefore, the three cases imply different relationships between the adaptation strategy-specific random effects. Case (1) assumes that the three adaptation strategies share the alternative specific random effects. Therefore, the utilities of the three adaptation strategies are correlated but independent from that of the status quo. Case (2) assumes that the hard structure adaptation strategies (i.e., seawalls and stormwater pumps) share the same alternative specific random effect. In contrast, the soft structure adaptation strategy (i.e., beach nourishment) and status quo have their own unique alternative specific random effects. Case (3) assumes each alternative and status quo have their own independent alternative specific random effects. Thus the utilities of all three adaptation strategies and the status quo are independent. Since prior information on the structure of error components is unknown, model performance measures such as the log-likelihood, Akaike information criterion (AIC), and Pseudo- R^2 are compared to select the model with the most appropriate structure.

Estimation of MWTP

We estimate a G-MNL with an error component in the MWTP space in this study.

Although in the preference space, MWTP can be obtained by taking the negative ratio of the coefficients of the non-price attribute and the cost attribute ($-\frac{\beta_{n,k}}{\beta_{n,fee}}$). MWTP can be estimated

directly in the MWTP space model (Louviere et al. 2000; Train and Weeks 2005; Hynes et al.

2008). MWTP space estimation may reduce the goodness-of-fit of the models more than preference space estimation in some cases. However, this inferiority is minimized significantly when both scale and preference heterogeneity are identified using the G-MNL model (Hensher and Greene 2011). In addition, models in MWTP space result in a more behaviorally plausible MWTP range and a better statistical fit (Scarpa et al. 2005, 2008; Balcombe et al. 2009; Shi et al. 2018).

When estimating the models, the coefficient of stormwater utility fees ($\beta_{n,fee}$) are fixed as one and $Fee_{n,i,t}$ is specified as the negative value of the *additional monthly stormwater utility fees* of the choice experiment. As a result, the coefficients (e.g., $\beta_{n,year}$ and $\beta_{n,insurance}$) in the utility function can be directly interpreted as the MWTPs for corresponding attributes (e.g., year and insurance). For comparison, the mixed logit models with/without error components in preference space are also presented along with the G-MNL models with/without error components in MWTP space.

5. Results

Summary of Survey Response

A total of 267 residents completed the survey.³ Table 1 presents the sociodemographic profiles of the sample in the current study and compares it with the 2011–2015 American Community Survey (ACS) 5-Year Estimates and ACS 2016 1-Year in Miami-Dade County. The sample in this study represents the local population in Miami-Dade County compared to the U.S.

³ The sample size is large enough for efficiently estimating the population preference parameters, with a 95% confidence interval and a 0.05 margin of error (Dillman et al. 2008), assuming respondent's choice of an option is an 80/20 split. The 80/20 split assumption is reasonable considering that each of the four alternatives in the choice experiment has a 25% (20/80) chance to be selected. Besides, the sample size is much larger than the minimum sample size requirement if we focus on generating statistically significant parameter estimates for the choice experiments. Based on Rose and Bliemer (2013) and de Bekker-Grob et al. (2015), we only need 100 respondents to generate statistically significant parameter estimates for our choice experiment.

census data in terms of gender (52.4% versus 51.5% females). Since the respondents are homeowners, the sample over-represents the middle-aged and elder groups (35 to 74 years old) compared with the U.S. census data. In general, respondents have higher educational attainment than the average Miami-Dade County resident (33.3% and 35.6% of the respondents have a bachelor's degree or graduate degree compared with 18% and 10%, respectively). Using \$50,000 as a cutoff value, 21.4% of the respondents have an annual household income below \$49,999, which is lower than the average of households in Miami-Dade County (55.8%). The middle-income households (\$50,000 to 99,999) account for 35.5% of the sample compared to 25.9% of the households in Miami-Dade County. The high-income range (\$100,000 and above) represents 55.8% of the sample, compared to 23% of the households in Miami-Dade County. The divergence in income between the sample and the general population in Miami-Dade County could come from the fact that we required the participants of the survey to be homeowners.

[Insert Table 1]

Perception and Preference

We first measured respondents' awareness, perception, and attitude toward SLR using a five-point Likert scale based on their level of agreement with a set of statements, as presented in Figure 1. It shows that around 76.5% (37.5%+39.0%) of the respondents in the sample strongly agree or agree that the sea level is rising, and 67.8% (31.1%+36.7%) agree that the rate of SLR is increasing. Only 25.9% (9.4%+16.5%) of the respondents never thought about SLR before taking the survey. About two-thirds of the respondents (63.7%) agree or strongly agree that more frequent flooding is due to SLR, and most respondents (71.2%) agree that Florida should minimize future development on the oceanfront. More than one-third (43.8%) of the respondents agree that the intensity of hurricanes has increased due to SLR. These results indicate that

homeowners in Miami-Dade County have a relatively strong awareness of SLR and its potential consequences.

[Insert Figure 1]

Using pictures as illustrations, we presented respondents with the major functionality, implementation methods, advantages, and limitations of each adaptation strategy. Following this presentation, respondents were asked about their familiarity with each adaptation strategy. Figure 2 shows that many respondents (55.8% and 45.3%, respectively) have seen seawalls and beach nourishment prior to the survey. Respondents are relatively less familiar with stormwater pumps, with most respondents (44.2%) hearing about them and only 27.0% having seen them before the survey. About 8.6%, 4.5%, and 6.4% of the respondents agree that stormwater pumps, seawalls, and beach nourishment projects, respectively, are implemented in their neighborhoods. At the end of this section of the survey, participants were asked to rank the three adaptation strategies based on their preference, irrespective of the costs. Beach nourishment is chosen as the most preferred strategy, followed by seawalls and stormwater pumps (Figure 3).

[Insert Figure 2]

[Insert Figure 3]

Regression Results

The final choice experiment data include a total of 2670 observations based on each of the 267 respondents answering ten choice questions. In total, eight models or four sets of mixed logit models in the preference space and generalized multinomial logit models in the MWTP space, respectively, are estimated using Nlogit 6.0 (Greene 2012). The first set of models includes standard models (MIXL and G-MNL), the second set includes models with two error components (MIXL+2ECs and G-MNL+2ECs, case [1]), the third set includes models with three

error components (MIXL+3ECs and G-MNL+3ECs, case [2]), and the fourth set includes models with one error components and three random alternative specific constants (ASCs) for three adaptation strategies (MIXL+1EC and G-MNL+1EC, case [3]).

All the models are estimated using Halton draws with 500 simulations in Nlogit 6.0 (Revelt and Train 1998; Meas et al. 2014). In the MIXL, all the non-price attributes are assumed to follow normal distributions, and the coefficient of *Fees* is specified as a fixed coefficient so that the MWTP for the non-price attributes is normally distributed as well (Hensher and Greene 2003; Gao and Schroeder 2009). Assuming fixed price parameters are a strong behavioral assumption, the results of these models in this study are only used as the benchmark for comparison with the models in MWTP spaces. As discussed in previous sections, the price coefficient is fixed at one in the G-MNL model in the MWTP space.

Table 2 reports the log-likelihood, AIC, and Pseudo- R^2 of various models. We find that G-MNL models perform better than MIXL models when they have the same error structure (e.g., G-MNL vs. MIXL, G-MNL+2ECs vs. MIXL+2ECs, etc.). G-MNL models have larger log-likelihood and Pseudo- R^2 and smaller AIC than the corresponding MIXL models. This is consistent with previous studies that showed the G-MNL model in the MWTP space results in a better model fit than the MIXL model in the preference space (Scarpa et al. 2005, 2008; Balcombe et al. 2009). Additionally, G-MNL models with error components perform better than the corresponding MIXL and G-MNL models without error components (e.g., G-MNL+2ECs/3ECs/1EC vs. G-MNL). These results show that the inclusion of the error component improves the model fit and demonstrate the importance of accounting for the alternative specific random individual effects of different options in choice experiments.

[Insert Table 2]

All the G-MNL models with error components are very similar regarding model performance. The Pseudo- R^2 of G-MNL+2ECs/3ECs/1EC models are 0.310, 0.311, and 0.310, respectively. Furthermore, the AICs of these models are 5136.2, 5133.9, and 5132.0, respectively. After considering the model performance measures and the significance of the error components of the three models (G-MNL+2ECs/3ECs/1EC), we decided to use the results of the G-MNL+2ECs model. This is because the error component ($E.C_{n,2}$) associated with the soft-structure (beach nourishment) in the G-MNL+3ECs model is not statistically significant (Table A3, row 9, column 9), indicating a model with two error components is more appropriate. We select G-MNL+2ECs with a significant error component shared by the three SLR adaptation strategies (Table 3) because G-MNL+1EC (Table A4) assumes that the utilities of the three adaptation strategies are independent. The significant error component shared by the three adaptation strategies in G-MNL+2ECs implies that the utilities or preferences of the three adaptation strategies are correlated. Our results confirm that the three SLR adaptation strategies share the same unobservable error components that are different from the status quo. The much larger standard deviation of the error component of the status quo indicates that respondents have a more heterogeneous preference for the status quo than for the three SLR adaptation strategies in the current study (Table 3, row 9, column 9). The more divided opinions on the status quo imply that some residents may consider the current adaptation strategies good enough while others think quite differently.

[Insert Table 3]

Because the G-MNL+2ECs model performs equivalently to the other two G-MNL models with error components but gives more behaviorally reasonable results, the discussions below will focus on the G-MNL+2ECs model (Table 3, columns 8 and 9). Table 3 also includes

the MIXL, MIXL+2ECs, and G-MNL models for comparison purposes. Results in Table 3 show that the coefficients of all the attributes of the SLR adaptation strategies are statistically significant. The coefficients of *Fees* are significantly negative in both MIXL and MIXL+2ECs, implying a negative marginal utility of cost. *Seawall*, *Beach*, and *Pump* are all positive, indicating that respondents in Miami-Dade County are willing to pay more for additional SLR adaptations than maintaining the status quo. The coefficients of *Protection (Years)* are also positive, which means that respondents are willing to pay for additional *Years of protection* associated with the adaptation strategies. The coefficients of *insurance* are all negative, implying that respondents are willing to pay more to reduce flood insurance premiums brought by additional SLR adaptations. The significance of the standard deviation of the random parameters in all four models in Table 3 reveals the existence of preference heterogeneity regarding the SLR adaptations and their different attributes (Hensher et al. 2005; Meas et al. 2014).

MWTP for SLR Adaptation Strategies

Since the G-MNL+2ECs model is estimated in the MWTP space, the mean estimates of SLR adaption attributes in Table 3 can be directly interpreted as MWTP. Table 3 illustrate that respondents are willing to pay the highest for additional seawalls (\$21.32/month), followed by beach nourishment (\$18.99/month) and stormwater pumps (\$16.09/month). Respondents are also willing to pay \$0.51/month for each extra year of protection bought by these adaptation strategies. The WTP for an additional 1% decrease in the flood insurance premium is about \$1.34/month.

The relative dispersion in MWTP can be measured by the coefficient of variation (CV), the ratio of the standard deviation to the mean.⁴ The CV can be interpreted as the measurement of preference heterogeneity. A higher CV indicates a more heterogeneous preference for certain adaptation strategies or attributes, and a lower CV indicates a more homogeneous preference. Results in Table 3 illustrate that the MWTP for seawalls is more heterogeneous (CV=0.54) than those for beach nourishment (CV=0.46) and stormwater pumps (CV=0.42). Moreover, *years of protection* has a higher CV (1.00) than *percent change of flood insurance premium* (0.88), indicating that the preference for the years of protection provided by SLR adaptation strategies is more heterogeneous than the preference for the changes in flood insurance premium associated with the adaptation strategies.

In Miami-Dade County, 858,289 households are homeowners, at a homeownership rate of 52.2% (United States Census Bureau, 2018b). The total MWTP for seawalls would roughly be \$18.3 million per month and \$219.6 million per year.⁵ Total MWTP for beach nourishment and stormwater pumps would be approximately \$195.6 million and \$165.7 million per year, respectively. Stormwater utility fees are currently collected and used to support the planning, operation, and maintenance of the existing stormwater management systems in Miami-Dade County (Regulatory Economic Resources 2019). In the fiscal year 2018, a \$33 million utility fee was collected in Miami-Dade County to support the maintenance of the existing systems (Miami-Dade County Bond Administration 2018). In the same year, Miami-Dade County promoted a \$500 million plan for SLR adaptation (Harris 2018). The \$500 million budget is

⁴ The standard deviation can demonstrate the deviation and dispersion in MWTP estimates. However, since the scale of the MWTP can be quite different, a relative dispersion needs to be calculated to better compare the dispersion across different scales of MWTP. Therefore, relative dispersion in MWTP is important.

⁵ 18.3M is obtained by multiplying the total number of households (858,289) by the average MWTP for seawalls (\$21.32).

slightly smaller but close to the total annual MWTP (\$219.6M+\$195.6M+\$165.7M=\$581M) for all three adaptation strategies examined in the current study. The results indicate that public support for SLR adaptation is strong, and there is a potential to generate continuous funding support through stormwater utility fees for additional SLR adaptations.

Factors Influencing Individual MWTP

To further explore the potential distribution effect of implementing adaptations, we examine the extent to which individual-level MWTPs are influenced by demographic variables, property characteristics, and familiarity with the adaptation strategies. The individual-level MWTPs for each attribute are computed based upon the individual-specific posterior distribution derived from the sequence of observed choices in the experiments (Train 2009). Following Lindsey et al. (1992), we focus on factors related to respondents and properties. Seemingly unrelated regressions are used where the dependent variables are the individual-level MWTP for building a seawall, installing pumps, and replenishing beaches, the additional years of protection for the adaptation strategies, and additional decreases in the flood insurance premium. The use of seemingly unrelated regressions is a convenient approach to compare the means of MWTPs among different types of respondents while accounting for multiple correlated hypotheses since the individual-level MWTP are generated from the same model estimates. The independent variables of the model are respondents' ethnicity, sociodemographics (age, gender, income), home property characteristics (location and value), and familiarity with the SLR adaptation strategies⁶. The results are presented in Table 4.

[Insert Table 4]

⁶ Based on the familiarity and experiences with the adaptation strategies, two dummy variables were created. They equal to 1 if a respondent has heard or seen a particular strategy; or the strategy is implemented in their neighborhood.

For the MWTP for each of the three SLR adaptation strategies (columns 1 through 3), we find that ethnicity does not significantly affect MWTP for the three specific SLR adaptation strategies, except that Hispanic respondents prefer the pumping system more than other ethnic groups (column 3, row 3). Older respondents have a significantly higher MWTP for an additional decrease in flood insurance premium (column 6, row 4). Male respondents have a significantly lower MWTP for additional years of protection than do females (column 5, row 5). Household income significantly positively correlated with respondents' MWTP for seawall and additional decreases in flood insurance premiums (columns 1 and 6, row 6). Our results indicate that lower-income and young households are less willing to pay extra fees to control the increase in their flood insurance premiums compared to higher-income and older households. The coefficients statistically significant at the 10% significance level are age for additional years of protection (+), male for beach nourishment (+) and additional decrease in flood insurance (-), home values for seawalls (-), flood insurance holder for seawalls (-) and pumping (+). These results indicate that the preferences for different SLR adaptation strategies and the attribute of adaptation strategies depend largely on socio-demographics, such as ethnicity, age, gender, and household income.

The degree of residents' familiarity with adaptation strategies also influences their MWTP for the strategies differently. For instance, whether heard or seen the three types of adaptation strategies does not affect residents' MWTP for all the strategies. However, respondents who experienced seawalls being implemented in the neighborhood strongly dislike seawalls. Those who have beach nourishment implemented in the neighborhood, however, strongly prefer seawalls instead. Respondents whose neighborhoods have pumping implemented strongly dislike beach nourishment. In summary, the distributional effects of SLR adaptations

will potentially depend on the extent to which they will affect flood insurance premiums, the neighborhoods with greater concentrations of older and female populations, and higher-income households.

6. Discussions and Conclusion

Discussions

Miami-Dade County is actively developing plans for SLR adaptation. In 2018, Miami Beach, one of the cities in Miami-Dade County, promoted a \$500 million plan to elevate roads and install stormwater pumps to adapt to SLR (Harris 2018). Understanding residents' preference for SLR adaptation is vital to sustaining these projects because the local governments primarily undertake the SLR adaptation projects. Local governments engaging in strategies to protect the at-risk areas need to consider residents' preferences of different SLR adaptations to identify effective outreach and communication efforts and gather public funding support.

Using survey data from 267 homeowners in Miami-Dade County, this study finds that residents are generally willing to support additional SLR adaptation strategies rather than maintaining the status quo. Specifically, our results show that residents prefer seawalls over beach nourishment, which both are preferred over reactionary stormwater pumping systems. Stormwater pumping, as a protective measure, is described as reactionary because it only plays a significant role during flooding and severe SLR (Crider et al., 2014; London, 2017). We estimated that the MWTP for seawalls, beach nourishment, and stormwater pumps are \$21.32/month, \$18.99/month, and \$16.09/month, respectively. We also found that respondents value the longevity of the adaptation strategies by offering \$0.51/month for each extra year of protection. Meanwhile, homeowners care about their flood insurance premium and are willing to pay \$1.34/month to avoid 1% increase in the insurance premium. The results are consistent with previous findings that people generally prefer seawalls to beach nourishment (Fankhauser 1995;

Betzold and Mohamed 2017; Rulleau and Rey-Valette 2017). However, it is hard to directly compare the MWTP in our studies with what has been found previously since most of these studies have been conducted in quite different settings, using different attributes, across different countries, and for different types of participants. Previous studies in New Zealand, Japan, and Germany have found the MWTP for seawalls ranging from \$34.51 (for 0.3 km) to \$101.05 (for additional 5 meters higher of seawalls) annually, and beach nourishment ranging from \$11.26 to \$48 (Phillips and Council 2010; Matthews et al. 2017; Omori 2021; Meyerhoff et al. 2021). Our study is the few conducted in the U.S., and the MWTP estimates are relatively higher than the previous results. This is because we focus on the homeowners and conduct the survey in Miami-Dade County, a place prone to flooding and has a higher level of awareness of SLR due to local campaigns to adapt to SLR. In contrast, most previous studies focus on tourists or residents (Imamura et al. 2016; Matthews et al. 2017; De Salvo et al. 2018; Omori. 2021).

For preference among different strategies, we find that homeowners prefer hard barrier structures (seawalls), especially among higher-income communities, even though the survey provided a description of the benefits and limitations of seawalls. Previous research shows that safety is an essential priority in considering an adaptation strategy (de Bruin et al. 2009). It is likely that homeowners still perceive seawalls as providing the best protection for their properties against flooding. This highlights the need for better communication on the tradeoffs of adaptation strategies. For example, hard structure protection may not be the optimal solution from the environmental, social, and engineering aspects. Beach access and habitat provide vital market and non-market values for the local economy and support residents' livelihood in Miami-Dade County (Shivlani et al. 2003; Klein et al. 2004). If not well planned, building seawalls may potentially bring increased erosion, visual blight, and loss of public beaches, negatively

impacting ecosystems and more impoverished communities in the long run (Caldwell and Segall
 2007). Seawalls on some sections of the shoreline may disrupt the natural landscape and cause
 the degradation of natural shorelines and nearby wetlands (Gittman et al. 2016). In addition,
 given the porous limestone bedrock under Miami-Dade County, even with seawalls, seawater
 can still seep through the soil, bypassing the seawalls and disrupting their effectiveness (Goodell
 2013; Crider et al. 2014). Conversely, soft shoreline management approaches, such as beach
 replenishment and restoration of mangroves, offer ecological and recreational benefits (Spurgeon
 1999; Vo et al. 2012). However, the availability of sand for replenishment within the range of the
 nourishment site could be a problem, and it could become costly for large projects (Dobkowski,
 1998; Parsons and Powell, 2001). Therefore, both hard barrier structures and soft shoreline
 management approaches have their own advantages and limitations. The tradeoff of different
 types of adaptation strategies should be examined with consideration of the local residents'
 preferences when planning for SLR adaptation. The distributional effects from adaptation should
 also be considered in the planning process. Moreover, a more holistic evaluation of the
 adaptation strategies is needed when there is a mismatch between public choice and optimal
 strategies that are more scientifically sound.

We also found heterogeneous preferences among different groups of residents. Hispanic
 residents generally prefer the stormwater pumping system, and other groups of communities
 seem to be indifferent to the three adaptation strategies in the study. Unlike those respondents
 with higher household incomes who strongly prefer seawalls to other adaptation strategies,
 respondents who have more expensive home properties and have flood insurance tend not to like
 seawalls. It is possible that homeowners perceive seawalls as reducing the aesthetic value of
 highly-valued properties and being a substitute for flood insurance. Meanwhile, we found that

flood insurance holders prefer stormwater pumping, indicating a complementary effect between flood insurance and stormwater pumping rather than the substitutional effect between flood insurance and seawalls. The reasons may be that in Miami-Dade County, stormwater pumps were used as a reactionary strategy. That is, stormwater pumps have limited ability to prevent flooding. However, they can help businesses and communities return to normal faster after hazards in a large area by pumping away large volumes of water during and after heavy rain or flooding (Crider et al., 2014; London, 2017). As such, stormwater pumps are more likely to benefit residents who are in the flood zones. Therefore, flood insurance holders who are more likely to be in the flood zones are willing to pay more for stormwater pumps as an adaptation strategy against sea-level rise.

The familiarity with SLR adaptation strategies generally has little impact on their preference for those strategies. These results indicate that residents' familiarity and experience with a particular adaptation strategy do not necessarily lead to its support. Residents may have been making tradeoffs based on the actual and perceived effectiveness of the adaptation strategy. Thus, their perception and experience need to be examined for adaptation planning. Regarding the preference of adaptation attributes, older and female respondents prefer to have long years of protection and more reduction in flood insurance premiums (in %). Households with higher incomes are the most sensitive to changes in flood insurance premiums (in %). Potential explanations are that older and female respondents are more risk-averse and price-sensitive than are younger and male respondents (Kousky 2011).

Contribution to the Literature

A comparison with previous studies further demonstrates the significance and contribution of this study, mainly from three different aspects. First of all, a handful of previous

research has put a substantial emphasis on the comparison of residents' preference and MWTP for hard structure (seawall) versus soft infrastructure (beach nourishment) or other alternatives such as managed retreat (Rulleau and Rey-Valette 2017; De Salvo et al. 2018; Johnston et al. 2018; Makriyannis et al. 2018; Oliveira and Pinto 2021; Omori 2021). Few research studies preferences and MWTP for stormwater pumping and compares the three adaptation strategies in one study. Besides, some previous studies only focus on the adaptation strategies without including the attributes of these strategies (Rulleau and Rey-Valette 2017; De Salvo et al. 2018; Makriyannis et al. 2018). For those studies that differentiate adaptation strategies by attribute, the most common attributes are construction characteristics such as height and length of seawalls and area of beach nourishment (Imamura et al. 2016; Johnston et al. 2018; Meyerhoff et al. 2021; Omori. 2021), or attributes related to the common good such as the environment (Makriyannis et al. 2018; Oliveira and Pinto 2021). Given we have three different adaptation strategies with various physical characteristics (for example, it is difficult to compare a one-foot increase in seawall height with a one-foot increase in beach length), we focus on easy-to-communicate attributes related to residents' livelihood, such as years of protection, change in insurance premium, and stormwater utility fees. Therefore, we contribute to the literature by including both hard and soft strategies and stormwater pumping, which has been rarely studied in the previous research.

The second contribution that distinguishes our study from previous research is that we generated insightful policy implications for the local government. Previous studies usually estimate the individual level MWTP, while our research calculates the total MWTP to provide more information for the local government's decision-making. In particular, by recruiting homeowners in Miami-Dade County as participants of our study, we show that residents are

willing to support sea level rise adaptations because the stormwater utility fee paid by them is one of the primary sources of funds for the cost of SLR adaptations. In the monetary aspect, our results estimate an annual fund of \$581 million for the three adaptation strategies, which is substantial compared to the \$500 million budget for SLR adaptation in Miami-Dade County (Harris 2018). The total MWTP estimates demonstrate a feasible continuous funding resource for SLR adaptation in the area.

Lastly, in addition to the empirical results and policy implications, the significance of the error component models provides insights into an issue that many studies have overlooked when valuing heterogeneous preferences for SLR adaptations. Previous studies have shown the importance of scale and preference heterogeneity in choice experiment settings through various experiments (Fiebig et al. 2010; Greene and Hensher 2010; Hensher and Greene 2011). SLR adaptation strategies may have unique features and characteristics that might not be fully captured by elicited attributes in the choice experiment. We use a labeled design of different strategies as alternatives to address this problem, considering that adaptation strategy alternatives might not have identical error terms across different options. The results in the current study demonstrate the importance of incorporating alternative-specific random error components in modeling people's choices of different options to adapt to SLR or climate change. First, consistent with previous studies, our results show that consumers' preference for the three SLR adaptation strategies is more homogenous than for the status quo (Scarpa et al. 2005; Caputo et al. 2017). We also find a strong correlation in respondents' preference for the three SLR adaptation strategies, and the preference is significantly different from that for the status quo. Second, we find respondents have more divided opinions about the status quo than for the adaptation strategies. Although it is safe to include only two alternative specific error

components (one for the status quo and the other for all other options) in our study, future studies could explore more complex structures and use information-based criteria to select appropriate structures of the error components.

Conclusion and Future Research

We demonstrate that homeowners in Miami-Dade County are willing to pay the most stormwater utility fees to support additional protection provided by seawalls, followed by beach nourishment and stormwater pumps. The total MWTP is slightly higher than the \$500 million budget for SLR adaptation in Miami-Dade County (Harris 2018), indicating strong financial support by the residents for SLR adaptations in the area. Besides, there are heterogeneous preferences for adaptation strategies primarily influenced by respondents' sociodemographics and their exposure to potential flooding hazards. This result implies that adopting any single or combination SLR adaptation strategies would result in heterogeneous welfare change for different groups of residents. Therefore, a comprehensive evaluation of the cost and benefit of different SLR adaptation strategies should be conducted before their implementation.

Notwithstanding the results of this study, there are implications for future studies. First, the proximity to coastlines might play a critical role in people's choices of strategies to adapt to SLR (Schmidt et al. 2013). Our random sample is not geographically distributed, limiting this study to explore the impacts of proximity to coastline and storm surge areas. Future studies may examine these geographical factors and explore how spatial heterogeneity affects the preference for adaptation strategies. Second, our study focuses on homeowners in Miami-Dade County. Future studies may extend the geographic scope to include other coastal communities for comparison with this study. Third, we use stormwater utility fees as a financing mechanism for coastal communities as the damages from floods and storm surges related to SLR are more severe in

728 coastal areas than in inland areas. However, damages from SLR and climate change would affect
729 the inland areas regardless of interconnected labor, assets, and financial markets (Sukop et al.
730 2018). There is a need to identify effective communication and financing strategies to encourage
731 adaptation to SLR and climate change across heterogeneous social groups and regions, including
732 both inland and coastal areas (United Nations Development Programme 2007).

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Tables

Table 1
Comparison of Sample and Population’s Sociodemographics

Variable	Sample (2017)	Population (2016) ⁷
Number	267	2,712,945
Sex (%)		
Female	52.4	51.5
Age (%)		
18 to 24 years	1.9	8.7
25 to 34 years	4.5	14.3
35 to 44 years	21.4	13.8
45 to 54 years	17.2	14.8
55 to 64 years	28.5	12.0
65 to 74 years	21.7	8.5
75 to 84 years	4.5	5.1
85 years and over	0.4	2.3
Educational attainment (%)		
Primary school (through 9 th grade)	0.8	19
High school diploma or GED	7.5	28
Some college, no degree	12.7	25
Associate degree	10.1	
Bachelor’s degree	33.3	18

⁷ U.S. Census data: ACS 2016 1-year

Variable	Sample (2017)	Population (2016) ⁷
Graduate/professional degree	35.6	10
Number of kids (%)		
# of kids in the household=0	71.5	
# of kids in the household=1	14.6	
# of kids in the household=2	12.0	
# of kids in the household>=3	1.9	
Annual household income (%)		
Less than \$19,999	5.2	
\$20,000 to 29,999	3.8	55.8
\$30,000 to 39,999	7.5	
\$40,000 to 49,999	4.9	
\$50,000 to 59,999	4.5	
\$60,000 to 69,999	6.7	25.9
\$70,000 to 79,999	12.7	
\$80,000 to 99,999	11.6	
\$100,000 to 129,999	13.9	9.9
\$130,000 to 149,999	9.0	
\$150,000 to 199,999	7.5	3.7
More than \$200,000	12.7	4.7
Flood insurance holders (%)		
Yes	54.3	

Table 2

Model Fitness Comparisons

	Models without E.C.s		Models with 2 ECs (Table 3)		Models with 3 ECs (Table A3)		Models with 1 EC (Table A4)	
	MIXL	G-MNL	MIXL+2EC s	G- MNL+2ECs	MIX+3ECs	G- MNL+3ECs	MIX+1EC	G- MNL+1EC
Log-likelihood	-2642.18	-2578.17	-2617.77	-2554.09	-2614.54	-2551.96	-2621.87	-2553.00
Information criterion AIC	5306.4	5180.3	5261.5	5136.2	5257.1	5133.9	5267.7	5132.0
Pseudo- R^2	0.286	0.303	0.293	0.310	0.294	0.311	0.292	0.310

Table 3

Regression Results with Two Error Component

Variable	MIXL		MIXL+2ECs		G-MNL		G-MNL+2ECs	
	Mean Estimate	St. Dev Estimate	Mean Estimate	St. Dev Estimate	Mean Estimate	St. Dev Estimate	Mean Estimate	St. Dev Estimate
Seawall	1.205*** (0.260)	1.657*** (0.138)	1.586*** (0.432)	1.628*** (0.152)	18.372*** (2.212)	12.864*** (1.074)	21.322*** (2.765)	11.408*** (0.996)
Beach	1.145*** (0.248)	1.050*** (0.151)	1.461*** (0.437)	0.894*** (0.158)	16.046*** (1.909)	2.053 (2.165)	18.990*** (2.764)	8.685*** (0.923)
Pump	0.817*** (0.251)	1.085*** (0.155)	1.146** (0.450)	1.037*** (0.132)	10.928*** (2.178)	10.948*** (1.089)	16.088*** (2.660)	6.688*** (0.892)
Protection (Years)	0.054*** (0.007)	0.086*** (0.007)	0.056*** (0.007)	0.086*** (0.009)	0.554*** (0.060)	0.519*** (0.058)	0.511*** (0.053)	0.513*** (0.060)
Insurance	-0.132*** (0.019)	0.215*** (0.019)	-0.136*** (0.018)	0.171*** (0.022)	-1.450*** (0.187)	1.217*** (0.146)	-1.337*** (0.145)	1.171*** (0.178)
Fees	-0.108*** (0.008)		-0.107*** (0.009)		1.0 Fixed	0.0 Fixed	1.0 Fixed	0.0 Fixed
EC (Strategies)			0.0 Fixed	1.640** (0.664)			0.0 Fixed	3.131** (1.542)
E.C. (Status quo)			0.0 Fixed	2.137*** (0.647)			0.0 Fixed	14.607*** (2.261)
Sigma								
Sample mean (Sample standard deviation)					2.053** (0.904)		8.685*** (0.049)	
Log-likelihood	-2642.18		-2617.77		-2578.17		-2554.09	

Information criterion		5261.5		
AIC	5306.4		5180.3	5136.2
Pseudo- R^2	0.286	0.293	0.303	0.310
Sample size	267	267	267	267

Standard errors in parentheses except for Sigma
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4
Seemingly Unrelated Regression on Individual-level MWTP

Variables	Individual-level MWTP				
	(1) Seawall	(2) Beach Nourishment	(3) Pump	(4) Additional Years of Protection	(5) Additional Decrease in Flood Insurance Premium
Constant	15.890*** (2.975)	21.569*** (1.962)	15.133*** (1.289)	0.254* (0.135)	0.858*** (0.248)
White (Caucasian)	1.498 (1.599)	-1.625 (1.054)	0.571 (0.693)	0.021 (0.072)	-0.007 (0.133)
Hispanic	-0.873 (1.730)	-1.902* (1.141)	1.919** (0.750)	0.012 (0.078)	-0.012 (0.144)
Age	0.492 (0.363)	0.018 (0.239)	-0.053 (0.157)	0.029* (0.016)	0.059* (0.030)
Male	0.161 (1.002)	1.264* (0.661)	-0.285 (0.434)	-0.116** (0.045)	-0.164* (0.084)
Household income	0.461** (0.185)	0.047 (0.122)	-0.108 (0.080)	0.001 (0.008)	0.041*** (0.015)
Have waterfront residence ^a	2.024* (1.172)	0.031 (0.773)	-0.572 (0.508)	0.076 (0.053)	-0.019 (0.098)
Home values ^b	-2.917* (1.610)	0.034 (1.062)	0.531 (0.698)	0.011 (0.073)	0.018 (0.134)
Flood insurance holder ^c	-1.741* (0.982)	-0.802 (0.648)	0.776* (0.426)	0.007 (0.044)	-0.073 (0.082)
Heard/Seen seawall ^d	-2.301 (1.921)	-0.308 (1.267)	0.821 (0.832)	0.056 (0.087)	0.091 (0.160)
Heard/Seen beach nourishment	2.152 (1.488)	-0.732 (0.981)	-0.418 (0.645)	0.088 (0.067)	-0.111 (0.124)

Heard/Seen pumping	1.253 (1.303)	-1.137 (0.859)	0.199 (0.565)	-0.028 (0.059)	-0.011 (0.109)
Implemented seawall ^e	-5.620* (3.179)	-0.351 (2.096)	1.003 (1.378)	0.131 (0.144)	-0.239 (0.265)
Implemented beach nourishment	5.888** (2.582)	-1.132 (1.703)	0.041 (1.119)	-0.016 (0.117)	-0.249 (0.216)
Implemented pumping	-3.148 (2.130)	-2.588* (1.405)	1.233 (0.923)	0.042 (0.096)	0.035 (0.178)
Sample size	251	251	251	251	251

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Notes: ^a Dummy variable for having waterfront residence. ^b Home values were asked and recorded in unit of million. ^c Dummy variable was created to indicate whether those homeowners hold flood insurance for now. ^d Dummy variables were created to indicate whether the respondents have heard or seen each of the three adaptation strategies. ^e Dummy variables were created to indicate whether the respondents have each of the three adaptation strategies implemented in their neighborhood.

Figures

Figure 1

Respondents' Perceptions about SLR

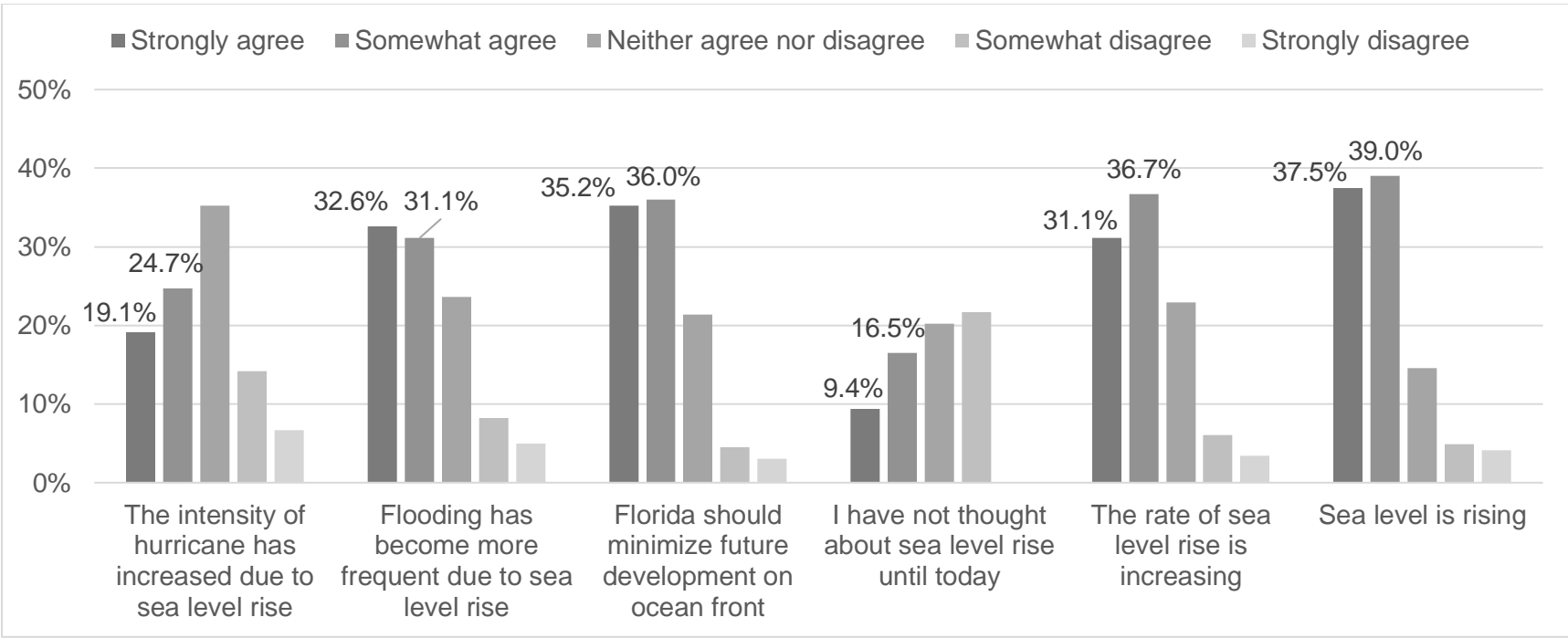


Figure 2

Familiarity of the Three Adaptation Strategies

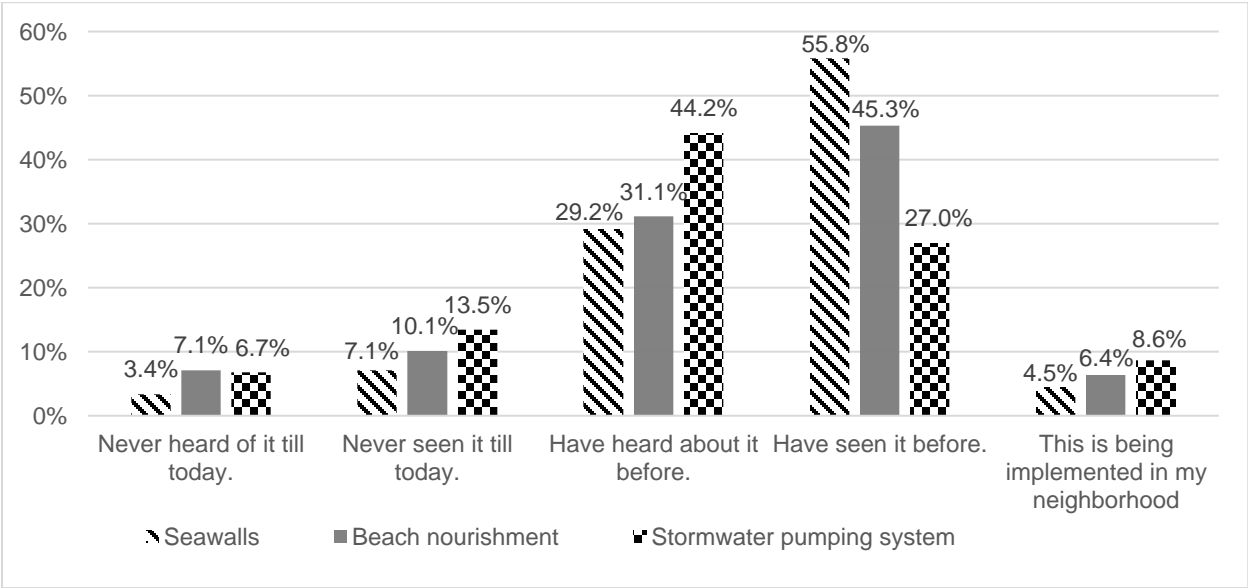


Figure 3

Ranking Preference of the Three Adaptation Strategies

