

Governing climate change adaptation at the Baltic Sea Coast

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List of Abbreviations

| | |
|-------------|--|
| ASC | Alternative Specific Constant |
| BIC | Bayesian Information Criterion |
| CE..... | Choice Experiment |
| CL..... | Conditional Logit |
| CS | Compensating Surplus |
| CV | Contingent Valuation, Compensating Variation |
| DCE..... | Discrete Choice Experiment |
| GAK | Improvement of Agricultural Structure and Coastal Protection |
| GDR | German Democratic Republic |
| IPCC..... | Intergovernmental Panel on Climate Change |
| LC..... | Latent Class |
| MNL..... | Multinomial Logit |
| MWP | Mecklenburg-Western Pomerania |
| mWTP | marginal Willingness-To-Pay |
| SLR..... | Sea Level Rise |
| SSP | Shared Socioeconomic Pathway |
| StALU | Staatliche Ämter für Landwirtschaft und Umwelt Mittleres Mecklenburg |
| WTP | Willingness-To-Pay |

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Introduction

Climate change requires the implementation of both mitigation and adaptation strategies. Adaptation, defined as the process of adjusting to the effects of climate change, has increasingly been recognized and framed not as a rival, but as a complement to climate change mitigation, which focuses on limiting climate change through reductions in greenhouse gas emissions (IPCC, 2022; Orlove, 2022).

Adapting coastal regions to climate change is particularly important because of the significant impacts climate-induced sea-level rise and extreme sea-level events will have such as storm surges, flooding and erosion. Coastal regions host a substantial share of the global population, with over a third of the world's population living within 100 kilometers of the coastline (Reimann et al., 2023), contain around 40% of the world's-built capital, including infrastructure, and contribute over 70% to the overall value of global ecosystem services (Martínez et al., 2007).

Relative to the period from 1995 to 2014, the projected global mean sea level rise is estimated to be between 0.15 and 0.29 meters by 2050 and between 0.28 and 1.01 meters by 2100, depending on the socioeconomic scenario (i.e., Shared Socioeconomic Pathway (SSP)). Over the longer time horizon of the next 2000 years, it is anticipated that the global mean sea level will rise by approximately 2-3 meters, if global warming is restricted to 1.5°C, and by 2-6 meters, if it is limited to 2°C, although the confidence in these projections is low. Furthermore, extreme sea level events that currently occur once every 100 years are projected to occur at least once a year by 2100 at more than half of the sites considered by the Intergovernmental Panel on Climate Change (IPCC) with high confidence and independent of the SSP (IPCC, 2023).

Given these projections, a comprehensive approach to adapting coastal regions to climate change is needed (IPCC, 2023). Coastal adaptation is often broadly categorized into “accommodation”, “protection” and “retreat” (Dronkers et al., 1990; Bijlmsa et al., 1996). It involves the modification of human activities and infrastructure to adapt to changing conditions. Accommodation can mean raising the height of buildings and improving drainage systems. Protection can include traditional hard structures like dykes, seawalls, and flood barriers as well as soft, sediment-based approaches such as dunes, beach nourishments, and increasingly ecosystem conservation and restoration (Schoonees et al., 2019; Temmerman et al., 2013). In

contrast, retreat entails relocating infrastructure and communities away from high-risk areas (e.g., Oppenheimer et al., 2019).

Implementing coastal adaptation can be complex beyond engineering, as societies are affected by both coastal climate change and the adaptation measures taken to address it, both today and in the future (Gopalakrishnan et al., 2018; van den Hurk et al., 2022). Financial resources are limited and competing goals exist. Consequently, there will be winners and losers and not all objectives can be achieved simultaneously. For instance, promoting coastal tourism might conflict with efforts to restore natural habitats, leading to difficult choices about priority actions from a societal point of view (Meyerhoff et al., 2021). Therefore, trade-offs must be made, carefully weighing which measures should be implemented and to what extent (Johnston et al., 2018).

Choice Experiments (CEs) emerge as a powerful tool for measuring and analyzing public preferences and making trade-offs visible. CEs allow us to simulate decision-making scenarios in which respondents are presented with a set of hypothetical alternatives, each characterized by different attributes and levels. Through their choices, respondents reveal their preferences and the trade-offs they are willing to make (Champ et al., 2017). The inclusion of a monetary attribute along with the foundational random utility framework of CEs (Manski, 1977; McFadden, 1974) further enables the estimation of welfare estimates, such as the willingness to pay (WTP) compensation for changes in the levels of environmental attributes (Bennett & Blamey, 2001; Hanemann, 1984).

This method offers several notable advantages. Firstly, CEs are flexible and can measure preferences for non-use values (Hanley et al., 1998) and future changes (Adamowicz et al., 1994). This makes them particularly well-suited for coastal adaptation strategies, which are non-marketed and involve future implementation. Secondly, consistent with Lancaster's (1966) theory of value, which posits that the value of a good is derived from its individual characteristics, i.e., attributes, CEs can be tailored to investigate a wide range of attributes. This includes specific aspects relevant to coastal adaptation, such as the extent of beach nourishment, dyke heightening or access to dunes. Building on these points, thirdly, CEs provide quantifiable data on preferences, which is essential for evidence-based policy-making. By translating CE data on preferences into monetary terms to measure changes in individual utility resulting from variations in the provision of environmental goods and services, these insights can be incorporated into cost-benefit analysis. This approach is ideally the foundation for making

informed decisions, including those on adaptation options (Revell et al., 2021). Finally, advances in statistical modeling techniques have significantly enhanced the ability of CEs to account for the heterogeneity of preferences within a population (Train, 2009). This provides nuanced insights into how different groups perceive and value various adaptation options, which is essential for developing effective and targeted adaptation policies and, once again, making well-informed decisions.

A comprehensive overview of choice experiments on coastal adaptation can be found in Meyerhoff et al. (2021). Since then, several studies have expanded on this area, broadly categorized into socio-demographic and spatial variations, valuation of infrastructure and ecosystems as well as methodological advancements. Regarding socio-demographic and spatial variations, Chen et al. (2023) examine adaptation strategies in Miami-Dade County, revealing significant differences in preferences based on socio-demographic factors and respondents' exposure to potential flooding hazards. For example, higher-income respondents strongly prefer seawalls to other strategies, while respondents who have more expensive home properties and flood insurance tend to dislike seawalls. Similarly, Meng and Mozumder (2023) find that Florida's seasonal residents are more willing to pay for adaptation plans than yearlong residents due to higher risk perceptions and income levels. Additionally, those living closer to the coastline and at lower elevations are more likely to support sea-level rise adaptation plans with preferences varying significantly between short-term and long-term strategies. In the area of valuation of infrastructure and ecosystems, Nguyen et al. (2023) study the nonmarket values of restoring coastal dunes in the US Pacific Northwest, emphasizing that locals highly value closeness to the natural ecosystem and recreational opportunities. Rolfe et al. (2021) estimate economic values for beach and foreshore assets in Victoria, Australia, highlighting public preferences for preserving these areas to protect against climate change impacts. Omori (2021) analyze preferences for engineered, nature-based and hybrid solutions, that combine both, finding that hybrid solutions are preferred in Japan. Bax et al. (2024) explore beach user perspectives on scaling up sand nourishments in response to sea level rise in the Netherlands, demonstrating a preference for maintaining the recreational quality of the beach. In terms of methodological advancements, Bujosa Bestard and Riera Font (2021) investigate the effects of varying attribute ranges on preferences for climate change adaptation policies in Mallorca, finding that wider attribute ranges increase random choices and can potentially lead to biased policy recommendations. Makriyannis et al. (2024) assess the role of numerical probabilities in promoting informed stated preference responses under outcome uncertainty within the context

of coastal adaptation policies in the US. They conclude that explicit probabilities do not significantly enhance response reliability, indicating a need for alternative approaches to communicate risks within coastal adaptation policies.

This dissertation uses CEs to explore public preferences for coastal adaptation on the German Baltic Sea in the federal state of Mecklenburg-Western Pomerania (MWP). Climate change and its consequences, including the need for adaptation, are highly relevant also for this region. The “NASA Sea Level Projection Tool”, which is based on data from the 6th IPCC Assessment Report, provides sea level rise projections for several locations at the Baltic Sea Coast in MWP.¹ One example is the coastal district of Warnemünde, part of the city of Rostock. There, a median sea level rise is projected until 2100 from 0.40 m (under the SSP scenario 1-2.6, which stays below 2.0°C warming relative to 1850-1900) to 0.8 m (under the SSP5-8.5, a high reference scenario with no additional climate policy) relative to a 1995-2014 baseline (Fox-Kemper et al., 2021). The Baltic surge of 12 and 13 November 1872 remains the highest recorded storm surge on the German Baltic coastline that has been recorded. If a similar storm surge were to occur today, the State Office for Agriculture and Environment of Central Mecklenburg expects that it would directly affect 182,000 people living in the vulnerable coastal areas of MWP, about 11% of the state’s population. In addition, around 80,000 jobs would be affected and the potential damage could amount to around €1.96 billion (StALU, 2009).

The core of this dissertation is composed of three papers, each utilizing choice data derived from the same survey instrument. Paper I, offering a broad nationwide perspective, uses Germany-wide data from a first survey wave that ran in spring 2020. Paper II, exploring the stability of preferences over time, combines data from the first wave and a second wave with minor adjustments to the attributes, conducted in September 2020. Lastly, Paper III provides a localized view specific to MWP residents, using data from an additional sample drawn during the first survey wave. The CE investigates the trade-offs between different adaptation measures using six attributes: the extent of beach nourishment, the heightening of dykes, protection of cliffs, access to dunes, the realignment of dykes and dunes, and the cost expressed as a coastal protection levy. Respondents choose from four alternatives: two adaptation alternatives (Adaptation A and B), an alternative keeping today’s measures (Present measures), and an alternative continuing with today’s budget (Present budget).

¹ The „NASA Sea Level Projection Tool“ can be assessed at <https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool>.

In the following, I briefly summarize each chapter of this dissertation and highlight its relevance and main findings.

Chapter 1: “Preferences for coastal adaptation to climate change: evidence from a choice experiment”

The first chapter presents joint work with Katrin Rehdanz (Kiel University) and Jürgen Meyerhoff (HWR Berlin). In this chapter we analyze the choice decisions among participants of the nationwide survey (N=1878), which is justified by the organization of coastal protection as a national task in Germany (BMEL, 2023). Accounting for preference heterogeneity, we identify three latent groups. Based on the characteristics of the preferences in each group, we name these groups accordingly. The first group, labelled *dykes*, (39% of the sample) consists of respondents who prefer the heightening of dykes but are not willing to financially support any measures beyond the current ones. Respondents likely to be in group two, labelled *improve* (38% of the sample), prefer extensive changes, namely: broader beaches, higher dykes, access to dunes, more extensive cliff protection, and more locations where dykes and dunes are realigned. Group three, labelled *no payments* (23% of the sample), is comprised of respondents who are not willing to spend more money than they currently do.

Respondents assigned to the *improve* group tend to be younger than those in the other classes and have the highest income and education levels. The *no payments* group has the lowest levels of education and income. Residency in a coastal state or MWP is not associated with class membership. However, those in the *no payments* group were less likely to have visited both German coasts before and more likely to have only visited the Baltic Sea. Additionally, fewer respondents in the *no payments* class believe that the impacts of climate change are already noticeable compared to the other two classes.

To further assess the implications of these preferences, we calculate aggregated welfare measures for different adaptation scenarios. The scenarios combine certain levels of the attributes. The aggregated welfare measures indicate that the adaptation scenario “*recreation*”, associated with the recreational use of the Baltic Sea, ranks highest followed by “*safety*” and “*nature*”, which focus on protection of the hinterland and nature, respectively.

Chapter 2: “A test–retest analysis of stated preferences in uncertain times”

The second chapter, which is again joint work with Katrin Rehdanz (Kiel University) and Jürgen Meyerhoff (HWR Berlin), investigates the stability of the preferences captured in

Chapter 1 during uncertain times. The stability of preferences is particularly important when information derived from choice experiments is used to inform policy decisions (Schaafsma et al., 2014). Here, we test preference stability during Covid-19. To do so, we conducted a retest survey five months after the initial survey using mostly the same survey instrument and compare individual preferences and resulting welfare estimates over the course of the pandemic. The test and retest survey were conducted at the beginning of the first and second Covid-19 waves in Germany, respectively. By applying a matching procedure, we identify 266 respondents who participated in both survey waves.

The descriptive analysis reveals that participants increasingly opt for the *present measures* alternative, resulting in fewer selections of the two hypothetical and generally more expensive options. Furthermore, we observe the same underlying preference heterogeneity pattern in the retest survey as in the test survey with the three classes *dykes*, *improve* and *no payment* as outlined in detail in Chapter 1 of this dissertation. However, there are differences in the valuation of single attributes. For example, respondents likely to be in the *dykes* group are no longer influenced by a decrease in beach width in the retest survey, while those in the *improve* group no longer rated changes in the cliff protection attribute positively. Additionally, respondents in the *no payments* group no longer exhibit a negative valuation for an extension of existing dyke heights in the retest survey.

Most interestingly, we observe a change in the size of the latent classes, indicating that preferences have changed. Fewer respondents are assigned to the class favoring overall improvements, while more are allocated to the class that prefers the heightening of dykes. On average, this indicates a shift in preferences towards the most basic and essential adaptation measure, which is dyke heightening.

These results carry over to the welfare measures. While the welfare measure for the adaptation scenario “*safety*” increases across the survey waves, the scenarios that focus on “*recreation*” or “*nature*” show decreasing welfare effects. This suggests that individuals prioritize safety over recreational and nature-focused adaptations in uncertain times.

Chapter 3: “Evidence from a choice experiment on coastal adaptation: Does distance matter for local preferences?”

The last chapter of my dissertation focuses on the preferences among MWP residents who are first to be affected by climate change at the Baltic Sea coast and adaptation to it. I use a sample

of 281 MWP residents to study whether there is heterogeneity in preferences and whether preferences vary with distance to the coast concerning the two attributes “dyke heightening” and “access to dunes”. I hypothesize that residents living closer to the coast are likely to prioritize measures that provide greater flood protection, such as higher dykes and well-maintained dune systems. In contrast, those residing further inland may place higher importance on landscape aesthetics, preferring lower dykes and value recreational access to the dunes. As outlined in Chapter 1, residency in MWP is interestingly not associated with class memberships in these models.

In line with the analysis in Chapters 1 and 2 of this dissertation, I test different latent class models. However, these models either fail to provide meaningful interpretations or do not converge. Specifically, I cannot replicate the preference structures identified in the previous chapters. Therefore, I employ conditional logit (CL) models to examine the role of distance and random parameter logit (RPL) models to analyze both the role of distance and preference heterogeneity. I integrate distance by including interaction terms between distance to the coastline (measured both continuously and as a dummy variable, following a coastal region definition by the European Commission) and the two attributes of interest.

Firstly, my analysis detects significant heterogeneity in preferences among MWP residents for most of the adaptation measures. Secondly, preferences for dyke heightening and dune access do not show significant variation with continuous distance from the coastline in the CL model. The interaction with the dummy variable for coastal residents indicates that those living closer to the coast generally oppose higher dykes more than those living further inland and tend to be less supportive of dune access, although this latter trend is typically not statistically significant. In the RPL model, which includes interactions with distance, proximity to the coast does not significantly account for differences in preferences for dyke heightening, suggesting the influence of other unobserved factors. Overall, the interaction with the coastal residency dummy variable shows a less favorable view of dune access among coastal residents compared to non-coastal residents, which aligns with the findings from the CL model.

In sum, the chapters of this thesis significantly advance the limited literature on individual preferences for coastal adaptation to climate change, particularly in Germany. Collectively, they underscore the importance of understanding preference heterogeneity for effective and publicly acceptable adaptation strategies. Beyond that, Chapter 1 offers a novel national perspective, reflecting the organization of coastal protection as a national task in Germany.

Chapter 2 contributes to the scarce literature on preference stability, a critical factor for policymakers aiming to implement long-term adaptation strategies. Chapter 3 adds a spatial dimension by showing how proximity to the coast influences preferences among MWP residents, highlighting the specific needs and priorities of those first impacted by climate change at the coast. Together, these chapters provide a comprehensive understanding of public preferences for coastal adaptation, informing on national trends, the impact of temporal stability and localized needs. Importantly, the recent severe coastal storm surge in late 2023 calls for informed policy decisions along the German coast (Wasserstraßen- und Schifffahrtsverwaltung des Bundes, 2023) to which this dissertation can contribute by demonstrating how adaptations can be economically evaluated. This economic evaluation helps to prioritize different measures and their urgency from a societal perspective.

References

- Adamowicz, W., Louviere, J., & Williams, M., 1994. Combining revealed and stated preference methods for valuing environmental amenities. *Journal of Environmental Economics and Management*, 26(3), 271–292./ doi:10.1006/jeem.1994.1017.
- Adamowicz, W. L., 2004. What's it worth? An examination of historical trends and future directions in environmental valuation. *Australian Journal of Agricultural and Resource Economics*, 48(3), 419–443, doi:10.1111/j.1467-8489.2004.00258.x.
- Akerlof, K. L., Timm, K., Ebbin, S. A., Gambill, J. M., Grifman, P. M., Miller, T., & Moser, S., 2022. Asking questions for adaptation. In J.-E. Yusuf & B. St. John (Eds.), *Routledge Studies in Environmental Communication and Media. Communicating climate change: Making environmental messaging accessible*. Routledge.
- Bax, V., van de Lageweg, W. I., Groot, S. de, & Moerbeek, W., 2024. Beach user perspectives on the upscaling of sand nourishments in response to sea level rise – A discrete choice experiment. *Ocean & Coastal Management*, 253, 107139, doi:10.1016/j.ocecoaman.2024.107139.
- Bennett, J., & Blamey, R. (Eds.), 2001. *New horizons in environmental economics. The choice modelling approach to environmental valuation*. Edward Elgar Publishing, doi:10.4337/9781781956601.
- Bijlsma, L., Ehler, C.N., Klein, R.J.T., Kulshrestha, S.M., McLean, R.F., Mimura, N., Nicholls, R.J., Nurse, L.A., Perez Nieto, H., Stakhiv, E.Z., Turner, R.K., & Warrick, R.A., 1996. Coastal zones and small islands. In: Watson, R.T., Zinyowera, M.C., Moss, R.H. (Eds.), *Climate Change 1995: Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge and New York, pp. 289-324.
- BMEL, 2023. *Erläuterungen zu den Rechtsgrundlagen der GAK*.
- Bujosa Bestard, A., & Riera Font, A., 2021. Attribute range effects: Preference anomaly or unexplained variance? *Journal of Choice Modelling*, 41, 100321, doi:10.1016/j.jocm.2021.100321.
- Cabana, D., Rölfer, L., Evadzi, P., & Celliers, L., 2023. Enabling climate change adaptation in coastal systems: A systematic literature review. *Earth's Future*, 11(8), Article e2023EF003713, doi:10.1029/2023EF003713.

- Champ, P. A., Boyle, K. J., & Brown, T. C., 2017. *A primer on nonmarket valuation* (Second edition). *The economics of non-market goods and resources: volume 13*. Springer, doi:10.1007/978-94-007-7104-8.
- Chen, X., Gao, Z., & Bi, X., 2023. Measuring heterogeneous preferences for adaptation strategies in response to sea level Rise: Evidence from Miami-Dade County. *Land Economics*, 99(1), 38–62, doi:10.3368/le.062620-0093R1.
- Dronkers, J., Gilbert, J. T. E., Butler, L.W., Carey, J.J., Campbell, J., James, E., McKenzie, C., Misdorp, R., Quin, N., Ries, K.L., Schroder, P.C., Spradley, J.R., Titus, J.G., Vallianos, L., & von Dadelszen, J., 1990. Strategies for adaptation to sea level rise. Report of the IPCC Coastal Zone Management Subgroup: Intergovernmental Panel on Climate Change. Geneva: Intergovernmental Panel on Climate Change.
- Esteban, M., Jamero, M. L., Nurse, L., Yamamoto, L., Takagi, H., Thao, N. D., Mikami, T., Kench, P., Onuki, M., Nellas, A., Crichton, R., Valenzuela, V. P., Chadwick, C., Avelino, J. E., Tan, N., & Shibayama, T., 2019. Adaptation to sea level rise on low coral islands: Lessons from recent events. *Ocean & Coastal Management*, 168, 35–40, doi:10.1016/j.ocecoaman.2018.10.031.
- Fox-Kemper, B., Hewitt, H. T., Xiao, C., Aðalgeirsdóttir, G., Drijfhout, S. S., Edwards, T. L., Golledge, N. R., Hemer, M., Kopp, R. E., Krinner, G., Mix, A., Notz, D., Nowicki, S., Nurhati, I. S., Ruiz, L., Sallée, J.-B., Slangen, A. B. A., & Yu, Y., 2021. Ocean, cryosphere and sea level change. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou (Eds.), *Climate change 2021: The physical science basis: Working Group I contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1211–1362). Cambridge University Press, doi:10.1017/9781009157896.011.
- Hanemann, W. M., 1984. Discrete/continuous models of consumer demand. *Econometrica*, 52(3), 541, doi:10.2307/1913464.
- Hanley, N., Wright, R. E., & Adamowicz, V., 1998. Using choice experiments to value the environment. *Environmental and Resource Economics*, 11(3/4), 413–428, doi:10.1023/A:1008287310583.
- IPCC, 2022. Summary for Policymakers. In H.-O. Pörtner, D. C. Roberts, E. S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, & A. Okem (Eds.), *Climate Change 2022 – Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental*

- Panel on Climate Change* (pp. 3–33). Cambridge University Press, doi:10.1017/9781009325844.001.
- IPCC, 2023. Summary for Policymakers. In: *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1–34, doi: 10.59327/IPCC/AR6-9789291691647.001.
- Johnston, R. J., Makriyannis, C., & Whelchel, A. W., 2018. Using ecosystem service values to evaluate tradeoffs in coastal hazard adaptation. *Coastal Management*, 46(4), 259–277, doi:10.1080/08920753.2018.1474067.
- Lancaster, K. J., 1966. A new approach to consumer theory. *Journal of Political Economy*, 74(2), 132–157, doi:10.1086/259131.
- Makriyannis, C., Johnston, R. J., & Zawojnska, E., 2024. Do numerical probabilities promote informed stated preference responses under inherent outcome uncertainty? Insight from a coastal adaptation choice experiment. *International Journal of Disaster Risk Reduction*, 107, 104481, doi:10.1016/j.ijdr.2024.104481.
- Manski, C. F., 1977. The structure of random utility models. *Theory and Decision*, 8(3), 229–254, doi:10.1007/BF00133443.
- Martínez, M.L., Intralawan, A., Vázquez, G., Pérez-Maqueo, O., Sutton, P., & Landgrave, R., 2007. The coasts of our world: Ecological, economic and social importance. *Ecological Economics* 63 (2), 254–272, doi:10.1016/j.ecolecon.2006.10.022.
- McFadden, D., 1974. Conditional logit analysis of qualitative choice behavior. In P. Zarembka (Ed.), *Economic theory and mathematical economics. Frontiers in econometrics* (pp. 105–142). Academic Press.
- Meng, S., & Mozumder, P., 2023. Spatial heterogeneity of preferences for sea-level rise adaptation: Empirical evidence from yearlong and seasonal residents in Florida. *Climate Risk Management*, 40, 100515, doi:10.1016/j.crm.2023.100515.
- Meyerhoff, J., Rehdanz, K., & Wunsch, A., 2021. Preferences for coastal adaptation to climate change: Evidence from a choice experiment. *Journal of Environmental Economics and Policy*, 10(4), 374–390, doi:10.1080/21606544.2021.1894990.
- Nguyen, T., Kling, D. M., Dundas, S. J., Hacker, S. D., Lew, D. K., Ruggiero, P., & Roy, K., 2023. Quality over quantity: Nonmarket values of restoring coastal dunes in the U.S. Pacific Northwest. *Land Economics*, 99(1), 63–79, doi:10.3368/le.040721-0036R.

- Omori, Y., 2021. Preference heterogeneity of coastal gray, green, and hybrid infrastructure against sea-level rise: A choice experiment application in Japan. *Sustainability*, 13(16), 8927, doi:10.3390/su13168927.
- Oppenheimer, M., Glavovic, B. C., Hinkel, J., van de Wal, R., Magnan, A. K., Abd-Elgawad, A., Cai, R., Cifuentes-Jara, M., DeConto, R. M., Ghosh, T., Hay, J., Isla, F., Marzeion, B., Meyssignac, B., & Sebesvari, Z., 2019. Sea level rise and implications for low-lying islands, coasts and communities. In H.-O. Pörtner, D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, V. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, & N. M. Weyer (Eds.), *IPCC special report on the ocean and cryosphere in a changing climate* (pp. 321–445). Cambridge University Press, doi:10.1017/9781009157964.006.
- Orlove, B., 2022. The concept of adaptation. *Annual Review of Environment and Resources*, 47(1), 535–581, doi:10.1146/annurev-environ-112320-095719.
- Reimann, L., Vafeidis, A.T., Honsel, L.E., 2023. Population development as a driver of coastal risk: Current trends and future pathways. *Cambridge Prisms: Coastal Futures*, 1:e14, doi:10.1017/cft.2023.3.
- Revell, D., King, P., Giliam, J., Calil, J., Jenkins, S., Helmer, C., Nakagawa, J., Snyder, A., Ellis, J., & Jamieson, M., 2021. A holistic framework for evaluating adaptation approaches to coastal hazards and sea level rise: A case study from Imperial Beach, California. *Water*, 13(9), 1324, doi:10.3390/w13091324.
- Rolfe, J., Scarborough, H., Blackwell, B., Blackley, S., & Walker, C., 2021. Estimating economic values for beach and foreshore assets and preservation against future climate change impacts in Victoria, Australia. *Australasian Journal of Environmental Management*, 28(2), 169–187, doi:10.1080/14486563.2021.1919232.
- Schaafsma, M., Brouwer, R., Liekens, I., & de Nocker, L., 2014. Temporal stability of preferences and willingness to pay for natural areas in choice experiments: A test–retest. *Resource and Energy Economics*, 38, 243–260, doi:10.1016/j.reseneeco.2014.09.001.
- Schoonees, T., Gijón Mancheño, A., Scheres, B., Bouma, T. J., Silva, R., Schlurmann, T., & Schüttrumpf, H., 2019. Hard structures for coastal protection, towards greener designs. *Estuaries and Coasts*, 42(7), 1709–1729, doi:10.1007/s12237-019-00551-z.
- StALU, 2009. Regelwerk Küstenschutz Mecklenburg–Vorpommern – Übersichtsheft - Grundlage, Grundsätze, Standortbestimmung und Ausblick. Rostock, Germany: Staatliches Amt für Umwelt und Natur - Abteilung Küste - Ministerium für Landwirtschaft, Umwelt und Verbraucherschutz Mecklenburg -Vorpommern.

- Temmerman, S., Meire, P., Bouma, T.J., Herman, P.M.J., Ysebaert, T., & de Vriend, H.J., 2013. Ecosystem-based coastal defence in the face of global change. *Nature*, 504(7478), 79–83, doi:10.1038/nature12859.
- Train, K., 2009. *Discrete choice methods with simulation* (2. ed.). Cambridge University Press, doi:10.1017/CBO9780511805271.
- van den Hurk, B., Bisaro, A., Haasnoot, M., Nicholls, R. J., Rehdanz, K., & Stuparu, D., 2022. Living with sea-level rise in North-West Europe: Science-policy challenges across scales. *Climate Risk Management*, 35, 100403, doi:10.1016/j.crm.2022.100403.
- Wasserstraßen- und Schifffahrtsverwaltung des Bundes., 2023, November 28. *Sturmflut Oktober 2023 im Bereich der Deutschen Ostseeküste*.

First Paper: Preferences for coastal adaptation to climate change: evidence from a choice experiment

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Abstract

Climate change adaptation is essential for coastal areas. This paper adds to the limited evidence on the trade-offs people are willing to make concerning coastal adaptation strategies along an entire coast of a state (Baltic Sea coast of Mecklenburg-Western Pomerania). The trade-offs are conceptualised in a choice experiment in terms of six attributes: the extent of beach nourishment, dyke heightening, cliff protection, access to dunes, realignment of dykes and dunes, and cost in terms of a coastal protection levy. The attributes were selected and designed in close cooperation, among others, with governmental decision-makers. Accounting for preference heterogeneity, we identified three latent groups among the participants of a nationwide online survey in Germany. Respondents who prefer extensive changes, respondents who are willing to pay only for an increase in dyke height, and respondents who are unwilling to cover additional expenses for adaptation. The aggregated welfare measures indicate that an adaptation scenario *Recreation* ranks highest followed by *Safety* and *Nature*. However, the scenarios do not represent unequivocal alternatives and provide essential insights into peoples' preferences not only to policymakers and the administration in the case study region.

Keywords: Adaptation strategies, choice experiment, climate change, coastal protection

1.1 Introduction

For coastal areas adaptation to climate change is essential. Coastal areas are highly populated, accommodate significant amounts of economic assets and provide essential ecosystem services. In Europe, for example, one third of the population lives within 50 km of the coast generating over 30% of the total EU GDP.² Climate change poses a significant threat to these areas. Even if greenhouse gas emissions would be limited to well below 2°C, the IPCC (2019) projects a rise in sea level over the 21st century in the range of 0.29-0.59 m compared to the period 1971-2015.³ In future, more and stronger storm surges than before are to be expected.

Coastal adaptation, however, is not only an engineering challenge (Gopalakrishnan et al., 2018). At its core, it is also an economic question about a societies' willingness to use scarce resources for adjusting and improving coastal protection. Decisions on which adaptation measures to implement and to what extent require costly trade-offs (Johnston et al., 2018). Not all objectives may be achieved simultaneously due to financial constraints but also because of competing goals. One may argue, for example, against the protection of cliffs as their erosion is a natural process. Seen from a recreational perspective though, protecting cliffs allows preserving hiking and cycling trails running along with them. Further, a managed realignment of dykes and dunes, which is the deliberate removal of coastal protection measures further inland, would restrict land use options but could benefit nature by providing new habitats for flora and fauna. It is therefore essential to reflect the potential welfare changes of adaptation options societies would face.

How people evaluate trade-offs in coastal management options has been investigated in a couple of studies employing stated preference techniques. To a large extent, these relate to measures taken at local study sites. Several of them focus on coastal erosion providing useful findings for decision makers, not necessarily considering adaptation to climate change (e.g., Matthews et al., 2017a, 2017, Marzetti et al., 2016). Studies that address adaptation to climate change, the focus of our analysis, also mostly refer to local study sites and focus on either single (e.g., Remoundou et al., 2015; Dachary-Bernard et al., 2019; Liski et al., 2019) or sets of adaptation measures (e.g., Rulleau & Rey-Valette, 2013, 2017; Johnston et al., 2018; Chen et al., 2020; Landry et al., 2020; Oliveira & Costa Pinto, 2020). Remoundou et al. (2015), for

² See https://ec.europa.eu/environment/iczm/state_coast.htm; last retrieved August 18, 2020.

³ According to the European Environmental Agency, the rise in relative sea level change along most of the European coastline is projected to be reasonably similar to the global average (<https://www.eea.europa.eu/data-and-maps/indicators/sea-level-rise-6/assessment>; last retrieved August 18, 2020).

example, study preferences for maintaining beaches in the Santander Bay area, Northern Spain, in their current state through nourishments. Marzetti and Disegna (2009) include beach nourishment as an artificial defence measure at Lido di Dante, a coastal tourist resort in Italy. Liski et al. (2019) investigate the impact of deliberative interventions on preferences for realignment as an adaptation strategy for the Inner Forth Estuary in Scotland. Dachary-Bernard et al. (2019) study preferences depending on risk perception for modalities of realignment schemes (timing, size and consultation process of the population) of both coastal and hinterland residents around Béziers, France.

Turning to studies that analyse sets of measures, Rulleau and Rey-Valette (2013, 2017) focus on long-term adaptation measures for local study sites in France. Residents face the choice between moving seafront property further inland and seawalls (Rulleau & Rey-Valette, 2017), tourists are surveyed regarding their perceptions of different adaptation measures (i.e., nourishment, breakwaters, dykes, and seawalls). Rulleau and Rey-Valette (2013) and Johnston et al. (2018) investigate trade-offs people in Waterford and Old Saybrook, Connecticut, United States, are willing to make between conservation of coastal assets and effects on other ecosystem services. Chen et al. (2020) compare preferences for conventionally engineered seawalls and nature-based protections identified as living shoreline for residents of the Eastern Shore of Virginia, United States. Landry et al. (2020) analyse preferences for coastal erosion management of North Carolina's beaches, United States, including nourishment, armouring of the coastline and realignment. Olivera and Costa Pinto (2020) investigate users' preferences over alternative options of coastal erosion management at Praia da Amorosa, North of Portugal, including lighter interventions (palisades, gangways) and heavy infrastructures (rockfills, seawalls, groynes).

Against this background, this paper contributes to the literature in at least four different ways. First, we add to the limited evidence on the trade-offs people are willing to make when it comes to climate change adaptation along coasts. For Germany, to the best of our knowledge, this is the first study eliciting individual preferences. Second, we aim at assessing the benefits of different adaptation measures along an entire coast and not only for certain sections or single locations. The Baltic Sea coast of Mecklenburg-Western Pomerania (MWP) serves as an example. If the sea level on this coast continues to rise at about the same rate as the global average in the future, Baltic storm surges could reach 30 to 90 cm higher by the end of the century simply because of the higher starting level. Storm surges, which are classified as very severe events today and currently occur about every 50 years, would then return at much shorter

intervals (Meinke et al., 2014). As climate continues to change and impacts to increase, rising investments are required to keep up with the changes. Adaptation along the coast in MWP requires different measures at different sections of the coast, including, e.g., dykes, beach nourishments and groynes, which are embedded in our study. Third, unlike in other countries, coastal protection is a national task in Germany, delegated to the coastal states, and limited to the protection of settlements. At present, 70% of the expenses for coastal protection are financed by the national government, while 30% are covered by the coastal states' government (StALU, 2009). This regulation is part of the joint task "Improvement of Agricultural Structure and Coastal Protection" (GAK), an agreement between the federation and the states in Germany. The GAK is the most important national funding instrument in Germany for agriculture, forestry, and coastal protection, among others (BMEL, 2020). Its budget, which was about € 17 Mio. for the year 2019 (BMEL, 2020), is the result of a political negotiation process that does not take into account the individual preferences of citizens.

The fact that coastal protection under the GAK is financed not only by the coastal states in Germany, but all federal states, implies that also people who live far away from the coast or do not visit it contribute through their taxes to its protection. Their preferences should, therefore, be taken into account when deciding about adaptation to climate change. We do so by surveying the whole of Germany. Fourth, investigating preferences and their heterogeneity across a society will provide valuable insights for policy makers on future funding in Germany. We employ a choice experiment (CE) to investigate people's preferences for coastal adaptation options (Holmes et al., 2017) as CEs enable to assess a range of adaptation strategies and provide richer information for decision making than other valuation approaches. This proves to be particularly suitable for our study as results are intended to support decision maker in politics and administration in the state of MWP. Adaptation measures were developed in cooperation with coastal engineers and in consultation with the responsible authority for coastal protection in MWP (Staatliches Amt für Landwirtschaft und Umwelt Mittleres Mecklenburg) to ensure that results would in fact be meaningful for decision making.

1.2 The study area

The German Baltic Sea coast of Mecklenburg-Western Pomerania (MWP) is characterised by its distinctive bodden-type bays which are brackish water bodies forming lagoons. These bays are separated from the open sea by the islands Rügen, Usedom and the peninsula Fischland-Darss-Zingst. The coastline stretches over 1945 km in total, of which the outer coast amounts

to 377 km and the considerably longer inner coast to 1568 km (Figure 1.1). The majority of coastal protection structures are implemented at the outer coast because of its direct exposure to coastal hazards (StALU, 2009). About one half of the outer coast is subject to flooding, while about one third is protected by coastal structures. In the event of a storm surge comparable to that of 1872, an area of 1080 km² at the inner and outer coast would be flooded and about 200,000 residents directly affected if no defensive measures were taken.

On the outer coast, protection focuses on protecting flat coasts, which are prone to both flooding and erosion, and account for about 80% of the length of the coast. There, primarily dykes and dunes are employed which operate as a system together with groynes and sand nourishments. Cliffs are only exceptionally protected. This is because long stretches of the coastline in MWP are so-called graded shorelines (*Ausgleichsküste*) (StALU, 2009). Sediments of the cliffs are carried away and transported along the shoreline disembarking at flat coasts. Any disruption of this natural process by the prevention of abrasion will raise the need for intervention at flat coastal stretches. A lack of sediment will emerge and will necessitate further sand nourishments. As priority is given to the protection of settlements by the Water Act, the statutory basis for coastal protection in MWP, the federal state of MWP is legally not obliged to protect cliffs as settlements are uncommon in these areas (LWaG, 1992).

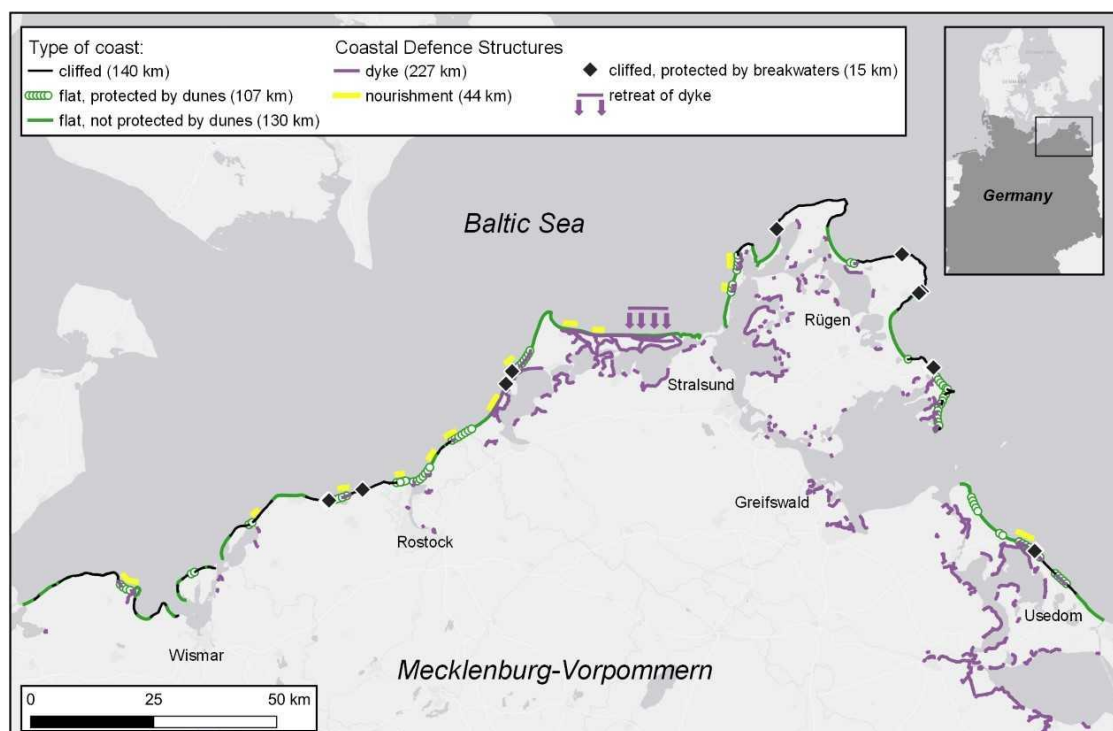


Figure 1.1: Map showing the coast of MWP and coastal defence structures

Note: Type of coast refers to outer coast. Image courtesy of J. Tiede (LUH), based on data provided by StALU.

1.3 Method

A central element of designing a CE is to decide on the number and types of alternatives, and to select the attributes and associated levels that describe these. The choice tasks in the present survey (Figure 1.2) provided individuals with three distinct types of alternatives. They could choose among two hypothetical alternatives (*Adaptation A and B*), the alternative to go ahead with the present set of protection measures (*Present measures*) or the alternative to go ahead with the present budget (*Present budget*). These types of alternatives are meant to reflect the basic options people in Germany have with respect to coastal adaptation.

Describing them in reversed order, the alternative *Present budget* reflects that individuals might not be willing to pay additionally for future adaptation. This implies that it would not be possible to maintain the current level of measures as costs will increase in the future. The alternative *Present measures* reflects that individuals might prefer to maintain today's measures and are willing to pay more for this compared to what people in Germany pay on average today for coastal protection. Finally, the two generic alternatives *Adaptation A* and *Adaptation B* reflect that individuals prefer to not only maintain the current conditions but to carry out further measures to adapt the coast to potential future changes. Each alternative implies a change in an attribute level of at least one of the non-monetary attributes and incurs also payments that are generally higher than those for the alternative *Present measures*.

The attributes aim at representing dimensions of adaptation that are crucial for future coastal protection in MWP. Adaptation measures considered here are confined to the outer coast because climate change is expected to impact here first. They and the associated attribute levels were selected based on literature reviews and expert interviews, especially with representatives from the responsible authority for coastal protection in MWP (Staatliches Amt für Landwirtschaft und Umwelt Mittleres Mecklenburg). The attributes and pictograms, developed to make them more recognisable for respondents, were tested in a series of focus groups in four cities of MWP (Schwerin, Rostock, Stralsund, Greifswald) in October 2019. Participants were randomly drawn from the populations living in and around those cities. The invitation as well as the moderation of the focus groups was conducted by the survey company that was also responsible for the main survey. On average, between eight to ten people participated in each focus group. After the series of focus groups, the attributes and pictograms were revised.

The final set of attributes is presented in Table 1.1. The first two, *beach nourishment* and *dyke heightening*, directly relate to coastal protection. Both are coastal protection measures regularly

applied in MWP. Beach nourishment is used at flat coasts and sections protected by dunes. Due to erosion, it must be repeated every few years. The responsible office generally aims at an average beach width of 40 m after a nourishment. The attribute's levels reflect that in future, the average width could be maintained or either increased to 60 m or decreased to 20 m. In order to account for future sea level rise in the Baltic Sea, dykes are currently adjusted in height by an extra 50 cm upon renewal (StALU, 2012). The levels of this attribute include to maintain this practice, to increase the extension to 75 cm or decrease it to 25 cm.

The next attributes (access to dunes and protection of cliffs) concern recreational opportunities. First, dunes are crucial for coastal protection at the coast of MWP. To stabilise them and maintain their safety capacity, they are generally planted with beach grass. To protect the vegetation, people are usually not allowed to trespass, including walking and sunbathing. These activities are, however, popular among beach users. The attribute access to dunes offers the opportunity to use limited parts of the dunes for recreational purposes if people are willing to pay for the higher effort needed to restore the vegetation. Second, cliffs that characterise features of the coast in MWP are subject to constant erosion. This may threaten public infrastructure such as cycling and hiking trails along the cliffs. While this natural process cannot be stopped, measures such as breakwaters and bank walls can slow down this process. Currently, efforts to limit cliff erosion are implemented at various sections summing up to 15 km of the coastline. Technically, it would be possible to extend these measures to a total of 30 km or 45 km of the coastline.

The fifth attribute considers the *realignment of dykes and dunes* at selected parts. This measure involves actively moving dykes and dunes into the hinterland creating new 'inter-tidal zones' between the sea and land which could be flooded. Doing so, new habitats for typical animal and plant species may arise. Realigning dykes and dunes may also be beneficial for coastal protection as it reduces the technical effort required to maintain the coastline. The realignment, however, does not include withdrawal of houses or settlements, as it is an explicit objective to protect inhabited areas (StALU, 2009). So far, one realignment has been carried out on the Zingst peninsula creating a new inter-tidal zone of around 1500 ha. Dykes and dunes could be realigned, as reflected by the attribute levels, at one or two further locations. Finally, the monetary attribute was set up as a new coastal protection levy to be charged annually per household nationwide from 2021 on for the next 10 years. After this period, the measures would be reassessed and a decision would be made on further financing.

The attribute levels were constant for the alternatives *Present measures* and *Present budget* (Figure 1.2) on all choice tasks except for payment in the alternative *Present measures*. In this case, payment had three levels that were assigned to this alternative via the experimental design. For the two remaining alternatives (*Adaptation A* and *Adaptation B*) all attribute levels were allocated through the experimental design. It is based upon a Bayesian efficient design with uniform priors. Small prior values were employed to indicate the expected sign of the coefficients. For example, a negative sign for the cost coefficient was used. D-efficiency as design criterion was optimised for an MNL model under both random utility maximisation and random regret minimisation with equal weights (van Cranenburgh & Collins, 2019). To allow for uncertainty in the prior values, 1000 Sobol draws were taken for each parameter prior. Overall, 48 choice tasks were created and blocked into four sequences of 12 choice tasks each.

The CE was embedded in a nationwide online survey. We informed participants that the funding is for coastal adaptation in the state of MWP. In the introduction to the CE, we also noted that further surveys would be carried out for the remaining coastal areas of Germany. This way, we wanted to point out that this survey is not meant to state preferences for coastal adaptation in other states as MWP. After requesting socio-demographics, which were used for the quota sampling, respondents were asked whether they visited the coast in Germany before the interview and how familiar they are with coastal protection measures. Afterwards, a map of MWP's coast (Figure 1.1) locating, among others, the current coastal protection measures were shown to all respondents. Measures comprise 227 km of dykes, 43.5 km of nourished beaches, 15 km of fortified cliffs, and the newly created inter-tidal area on the Zingst peninsula.

Next, we introduced the choice scenario by describing past sea-level-rise at the Baltic Sea coast in MWP and referring to the latest projections of the IPCC by 2050. We informed respondents that an increase in extreme weather events, especially storm surges, is expected. Therefore, coastal protection likely has to be increased. To make adjustments, authorities have to decide upon measures already today. It was also highlighted that climate change impacts are associated with a level of uncertainty even for experts.⁴ Measures discussed in our application would be

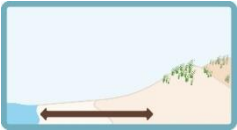
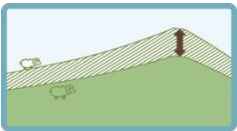




⁴ Please note, that in Germany coastal protection planning by the state government is not based on avoided damage costs. To calculate the dimension of the required protection measures (e.g., dykes), the state government takes the design flood as a basis and adds a climate change extension (e.g., 50 cm for dykes). Although this should be sufficient to account for the uncertainty associated with climate change, we hypothesize that respondents may have preferences for either higher or lower extensions, which may depend on their risk aversion, among other factors.

implemented gradually by 2050.⁵ Respondents could then familiarize themselves with the dimensions of coastal adaptation we examine in this study (Table 1.1) before they faced the choice tasks. On each task an opt-out reminder was employed (Ladenburg & Olsen, 2014) instructing respondents to choose the zero-price alternative if they find the other alternatives too expensive. The device helps to mitigate the hypothetical bias inherent in stated preference surveys. The questionnaire ended with follow-up questions on attitudes and further requests for socio-demographics.

The finalized version of the survey instrument was implemented in spring 2020 after we administered a pilot study to about 50 individuals. As for the pilot, also the sample for the online survey was drawn from the panel provided by norstat, a company that relies exclusively on active participant recruitment. To get closer to a representation of the target population, we used quotas for age, gender, state of residence, and education. The latter, however, was defined by three broad categories to maintain some flexibility. The invitation to the survey was kept as neutral as possible to reduce the effects of respondent self-selection, i.e., it did not include information about the content.

⁵ Note that implemented structures may well provide protection after the time considered here. Due to the uncertainty of climate change, it may nevertheless be necessary to consider other adaptation pathways in the future.

Table 1.1: Attributes and attribute levels

| Attribute | Pictogram | Description | Attribute levels |
|---|---|--|---|
| Beach nourishment (44 km total) |  | Wider beaches and higher dunes offer better protection for the land behind. Despite the use of groynes, sand is currently being washed up along the coast on 13 sections with a total length of 44 km. To maintain this condition, this process must be repeated every few years. In the future, beach nourishments may also be necessary on further sections. Usually, the beach is about 40 m wide after a nourishment. However, less or more sand could also be used for nourishment. | Beach width of: 20 m 40 m 60 m |
| Dyke heightening (227 km total) |  | Dykes protect the land behind them from flooding. In order to meet future requirements for coastal protection, dykes are currently being heightened by 50 cm during scheduled maintenance. However, this increase could also be lower or higher. | Height of: 25 cm 50 cm 75 cm |
| Access to dunes |  | The stability of dunes is increased by planting, especially with beach grass. It also acts as a natural sand catcher. Walking on dunes can impair these functions and is therefore not allowed. In selected sections where dunes are of less importance for coastal protection and where this is compatible with nature conservation, access could be allowed in the future. There, dunes would then have to be maintained more comprehensively. This would involve additional costs. | Length of: 0 km 6 km 15 km 28 km |
| Protection of cliffs |  | The sea continuously erodes parts of the cliffs and shifts the coastline. Breakwaters and seawalls can slow down this process. They are currently used in 10 sections where settlements are endangered by the demolition of cliffs. As a result, 15 km of the cliffs are currently fortified. Further sections could be fortified, for example to preserve coastal cycle or hiking paths for a longer period. | Length of: 15 km 30 km 45 km |
| Realignment of dykes and dunes |  | At selected spots along the coast, the protection line (dykes and dunes) could be moved to the hinterland. There, natural bays and wetlands are created which provide habitats for typical coastal animal and plant species. Access to the areas would be restricted and existing cycle and hiking paths would have to be relocated. The safety of settlements would not be endangered at any time. So far, one major realignment has been implemented on the Zingst peninsula (about 15 km ² or 1500 ha). Similar projects would be conceivable in other parts of the coast. | 1 spot (15 km²) 2 spots (30 km ²) 3 spots (45 km ²) |
| Payment |  | The existing coastal protection in Germany is financed jointly by the federal government and the coastal states from taxes. For further measures in Mecklenburg-Western Pomerania, a new coastal protection levy would have to be charged per household nationwide from 2021 on. It would have to be paid annually for the next 10 years. After this period, the measures would be reassessed, and a decision would be made on further financing. | 0 € , 5 / 10 / 15 € (PM) 8 / 20 / 35 / 70 / 110 / 190 € (A_B) |

Note: Attribute levels in bold indicate current values.

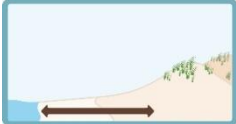
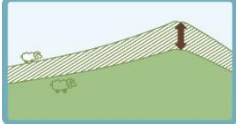


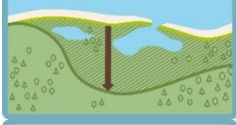

| If only the following alternatives would be available: Which alternative would you prefer? Please choose one of the alternatives. If the payment associated with an alternative is above that amount of money you are actually willing to pay, please reconsider your choice. | | | | | |
|--|---|-------------------------------|-------------------------------|------------------------------|------------------------------|
| | | Adaptation A | Adaptation B | Present measures | Present budget |
| Beach nourishment (44 km total) |  | 40 m width | 60 m width | 40 m width | 20 m width |
| Dyke heightening (227 km total) |  | 75 cm height | 75 cm height | 50 cm height | 25 cm height |
| Access to dunes |  | Yes. Over a distance of 20 km | Yes. Over a distance of 10 km | No | No |
| Protection of cliffs |  | 30 km distance | 45 km distance | 15 km distance | 15 km distance |
| Realignment of dykes and dunes |  | 3 spots (45 km ²) | 1 spot (15 km ²) | 1 spot (15 km ²) | 1 spot (15 km ²) |
| My payment |  | 110 € | 300 € | 15 € | no payment |
| I choose | | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Figure 1.2: Example choice task with opt-out reminder

1.4 Econometric modelling

Assuming that the researcher does not possess complete information regarding the preferences of individual n , random utility theory (McFadden's, 1974) serves as the starting point for the econometric modelling. Accordingly, individual preferences are considered as the sum of a systematic (V) and a random (ε) component:

$$U_{ni} = V_{ni}(x_{ni}\beta) + \varepsilon_{ni} \quad (1)$$

with U_{ni} the true but unobservable utility associated with alternative i out of a set of available alternatives j , V_{ni} is the deterministic part that is a function of the attributes (x_{ni}) and ε_{ni} a unknown random part. The vector of coefficients (β) reflects the desirability of the attributes. Assuming that the error components are distributed independently and identically (IID)

following a type 1 extreme value distribution, one gets the conditional logit (CL) model where the probability of individual n choosing alternative i is:

$$P_{ni} = \frac{\exp(\mu V_{ni})}{\sum_{j \in C} \exp(\mu' V_{nj})} \quad (2)$$

The scale parameter μ is commonly normalised to 1. As the CL assumes same preferences across individuals, we additionally apply a latent class (LC) model (Hess, 2014). It allows to capture unobserved heterogeneity in taste sensitivities by assuming that a finite number of a priori unknown segments exist in a population, each with different values for taste coefficients β . Using a probabilistic class allocation model, every individual is assumed to belong to each of the classes in the model with a certain probability π_s . This probability lies between 0 and 1 and sums to 1 across all classes. Applying the LC model requires the external specification of the number of classes. The common procedure is to sequentially estimate models with an increasing number of classes s ($s = 1, 2, 3, 4, \dots, S$) and to select the number of classes using information criteria such as the Bayesian Information Criteria (BIC) but also accounted for the significance of parameter estimates and the meaningfulness of the parameter signs (Scarpa et al., 2007). To test for potential non-linearities in the attribute levels we applied likelihood-ratio tests.

Changes in welfare due to a marginal change in a given attribute can be expressed through the marginal willingness to pay ($mWTP$) measure. It is defined as the maximum amount of income an individual is willing to pay in exchange for an improvement in the level of a given attribute provided. In a LC model, the $mWTP$ is calculated separately for each segment s with the class specific coefficient of the attribute of interest and the class specific coefficient of the cost attribute representing the marginal utility of income as follows: $mWTP = \beta_{s_attribute} / \beta_{s_money}$. Note that we estimate two different cost parameters to capture potentially different cost sensitivities associated with the different alternatives. As non-marginal welfare measure, we calculate the compensating variation for coastal adaptation strategies, i.e., combinations of attribute levels, using weighted WTP measures. It is calculated following Hanemann (1984) as:

$$CS_n = -\frac{1}{\beta_{cost_n}} \left[\ln \sum_n \exp V_n^1 - \ln \sum_n \exp V_n^0 \right] \quad (3)$$

where CS is the compensating surplus welfare measure, β_{cost} is the marginal utility of income and V_n^0 and V_n^l represent the n th individuals' indirect utility functions before and after the change under consideration.

1.5 Results

1.5.1 Sample characteristics

Overall, responses from 1878 individuals aged 18 or above were useable for data analysis. The descriptive statistics for the sample and the target population (Table 1.2) indicate that respondents are on average slightly younger and the household size slightly bigger compared to the target population of Germany. Net household income per month is on average EUR 438 higher in the sample population, a finding that is not uncommon for online surveys (e.g., Lindhjem & Navrud, 2011). For gender and residence in a coastal state (Bremen, Hamburg, Lower Saxony, MWP or Schleswig-Holstein), the sample population resembles the target population. The majority of people (82%) had visited the German Sea coast prior to the survey (Table 1.2). More than half of the sample had even visited both, the North and the Baltic Sea coast (52%). The figures point out that visiting the German Sea coast is popular among people living in Germany.

Table 1.2: Descriptive statistics

| <i>Characteristics</i> | Sample population n=1878 | | Target population (Germany) ^a 83 Mio. in 2019 |
|---|-----------------------------|----------|--|
| | mean | std. dev | Mean |
| Age (years) | 48.86 | 16.46 | 52.70 |
| Female (%) | 50.85 | | 50.70 |
| Higher education (%) ^b | 36.94 | | 33.50 |
| Household income ^c (€ per month) | 2533.78 | 1454.10 | 2155.90 |
| People per household (number) | 2.23 | 1.28 | 2.00 |
| Resident in a coastal state (%) | 17.25 | | 18.10 |
| Residents in MWP (%) | 2.10 | | 2.00 |
| Recreational visits to the German Sea coast | | | |
| only to the North Sea (% yes) | 15.10 | | |
| only to the Baltic Sea (% yes) | 15.02 | | |
| to the North and Baltic Sea (% yes) | 51.60 | | |

^a Data is taken from <https://www.destatis.de> and <https://ec.europa.eu/eurostat> (last retrieved September 15, 2020). Average age includes people aged 15 and above. Income refers to the year 2018; Age, education and household size refers to 2019.

^b Defined as education level that is required to study at a university.

^c Due to missing disclosures and some implausible responses to this question the statistics for household income are based on 1552 responses within the range of € 450 to € 10,000.

1.5.2 Preferences for coastal adaptation measures

From the conditional logit (CL) model results, we can infer that two attributes, dyke heightening and costs, are mainly driving the choices (Table 1.3). Assuming all respondents have the same preferences, as the CL model does, raising dyke heights is highly positively significant. Respondents are in favour of higher dykes as a measure to adapt to the consequences of climate change. The other non-monetary attributes are not statistically significant at the 5%-level; access to dunes is close, however. Thus, these attributes do not seem to address important aspects to all respondents and hence do not systematically influence the stated choices. Both cost attributes (Payment_PB and Payment_A_B) are highly significant and have the expected negative sign. On average, respondents prefer alternatives with lower payments. However, the cost sensitivity is lower for the adaptation alternatives, indicating that respondents who are in favour of these alternatives are willing to pay more. The alternative specific constants (ASC) shown in the lower part of Table 1.3 separate the alternatives' effects. As a reference, the ASC for the alternative *Present measures* is fixed. The parameter for the alternative *Present budget* (ASC_PB) is negative and highly significant, indicating that on average respondents do not prefer this alternative over the alternative *Present measures* for reasons that are not captured by the attributes. This result suggests that respondents want to keep today's actions even if this is associated with a higher payment.

Table 1.3: Estimates from conditional (CL) and latent class (LC) logit model

| Label | CL | | | | LC | | | |
|--|-------------------|--------|--------------|-----------|----------------|--------|--------------------|--------|
| | | | Class1 | | Class2 | | Class3 | |
| | Sample size (in%) | | <i>Dykes</i> | | <i>Improve</i> | | <i>No payments</i> | |
| | 100 | | 39 | | 38 | | 23 | |
| | Coeff. | z-val. | Coeff. | z-val. | Coeff. | z-val. | Coeff. | z-val. |
| Beach nourishment (per meter) | | | | | | | | |
| 40 => 20 meters | -0.081 | 2.14 | -0.389 | 3.71 | -0.001 | 0.01 | 0.615 | 2.08 |
| 40 => 60 meters | -0.035 | 0.94 | -0.350 | 3.77 | 0.172 | 3.24 | -0.159 | 0.56 |
| Dyke heightening (per centimetre) | 0.004 | 6.76 | 0.006 | 4.39 | 0.006 | 7.97 | -0.017 | 3.93 |
| Access to dunes (yes) | -0.002 | 1.88 | -0.022 | 6.81 | 0.017 | 10.96 | -0.032 | 3.76 |
| Cliff protection (per kilometre) | -0.001 | 0.75 | -0.012 | 5.01 | 0.008 | 6.29 | -0.022 | 3.04 |
| Realignment of dikes and dunes (per spot) | | | | | | | | |
| 1 spot => 2 spots | -0.050 | 1.51 | -0.174 | 2.01 | 0.267 | 6.02 | -0.720 | 2.79 |
| 1 spot => 3 spots | 0.032 | 1.11 | -0.328 | 3.92 | 0.445 | 11.38 | -1.197 | 5.18 |
| Payment_PM (in €) | -0.022 | 6.05 | -0.044 | 6.04 | 0.043 | 5.58 | -0.203 | 11.91 |
| Payment_A_B (in €) | -0.009 | 29.30 | -0.040 | 20.54 | -0.005 | 13.40 | -0.020 | 5.97 |
| ASC_A | -0.064 | 1.11 | 0.352 | 2.75 | 1.102 | 11.11 | -1.169 | 3.09 |
| ASC_B | -0.019 | 0.32 | 0.493 | 3.83 | 1.117 | 11.22 | -1.250 | 3.29 |
| ASC_PM | | | | Reference | | | | |
| ASC_PB | -0.385 | 6.89 | -2.174 | 16.11 | -1.597 | 11.74 | -0.325 | 0.90 |

N = 1878

The latent class (LC) model, which we use to capture unobserved taste heterogeneity among respondents, provides a more nuanced picture. Testing models with an increasing number of classes, the information criteria indicated that a 3-class segmentation best represents the underlying unobserved taste heterogeneity. In class 1 (named *dykes* group), all parameters are statistically significant but the parameter for *dyke heightening* is the only one with a positive sign.⁶¹ Individuals who are likely to be in class 1 prefer to increase the height of dykes but are unwilling to give up money for a change in any other attribute compared to *Present measures*, the reference alternative. Even extended beaches are not valued positively as a measure to protect the land. An explanation for this might be that those respondents perceive beaches to be more crucial for recreation than for coastal protection. The same reasoning may apply to the attributes *access to dunes* and *cliff protection*.

⁶ We tested whether respondents had lexicographic preferences for this attribute. Across the whole sample, no respondent always selected an alternative with always the highest dyke extension level available on the choice task. A few respondents revealed this choice behaviour on 10 out of the 12 choices tasks, but all were willing to make trade-offs on some tasks.

In the second class, named *improve*, the results are different. All attribute parameters are positive and significant, indicating that respondents, who are likely to be in this class, prefer extensive changes compared to the reference situation *Present measures*. Broader beaches, higher dykes, access to dunes, cliff protection on longer sections and more locations where dykes are realigned are preferred. Another distinct group of respondents is specified by class 3 (named *no payments* group). Respondents more likely to belong to this class do not prefer any changes in relation to the reference situation, except for smaller beaches. They even do not choose higher dyke levels if that would entail to give up money.

To gain further insights into the taste heterogeneity, we characterise each class by reporting descriptive statistics and testing for significant differences. We use common characteristics such as age, gender, income and place of residence in a coastal state, residence in MWP, visits to the North and/or Baltic Sea, and respondent's perceptions of whether the impacts of climate change are already present (Table 1.4). Starting with the first set of characteristics, respondents assigned to the *improve* class are on average close to four years younger than those in the other two classes. Gender shares do not differ, but higher education (level required to enter university) and household income. Those in the class *no payments* are less likely to have a higher education degree and the lowest average income. In contrast, those in the class *improve* have on average the highest income. Household size slightly varies, but differences are not statistically significant. Place of residence in a coastal state in Germany is not associated with class membership. The same is true for residency in MWP. The fact that a respondent has visited the German coast, however, is significant, albeit weakly. The fact that more individuals in the third class had seen only the Baltic Sea might indicate that these people tend to come from the states that belonged to the former German Democratic Republic. For them, the Baltic Sea was an important holiday destination, but travel distances were of course shorter. Respondents not willing to pay for adaptation have on average visited the coast less frequently. Another considerable difference can be observed regarding whether climate change impacts are already present in Germany. Among respondents in class 3 (*no payments* group), a share of 28% perceive impacts of climate change to be noticeable while the percentage is higher in class 1 and class 2 with 35% and 33%, respectively.

Table 1.4: Descriptive statistics across classes

| Label | Class 1 <i>Dykes</i> | Class 2 <i>Improve</i> | Class 3 <i>No payments</i> | Test of sign. differences ¹ |
|---|-------------------------|---------------------------|-------------------------------|--|
| Sample size (in %) | 39 | 38 | 23 | |
| <i>Individual characteristics</i> | | | | |
| Age (years) ^a | 50.14 | 46.28 | 51.07 | 5% |
| Female (%) ^b | 53.50 | 48.05 | 51.40 | no |
| Higher education (%) ^b | 39.18 | 39.64 | 28.43 | 5% |
| Household income (€ per month) ^a | 2513.47 | 2679.86 | 2306.56 | 5% |
| Household size ¹ | 2.18 | 2.32 | 2.16 | no |
| Resident in a coastal state (%) ^b | 18.33 | 17.15 | 15.56 | no |
| Resident in MWP (%) ^c | 30.00 | 37.50 | 32.50 | no |
| Recreational visits to the German Sea coast | | | | |
| only to the North Sea (% yes) ^b | 14.50 | 17.15 | 12.50 | 10% |
| only to the Baltic Sea (% yes) ^b | 14.91 | 13.69 | 17.45 | no |
| to the North and Baltic Sea (% yes) ^b | 54.04 | 53.94 | 43.39 | 5% |
| <i>Perception of climate change</i> | | | | |
| Climate change already present (% yes) ^b | 35.16 | 33.47 | 28.30 | 10% |

Note: ^aKruskal-Wallis test, ^bChi-square test; ^cNote that overall, only 40 respondents are from MWP

1.5.3 Willingness to pay for coastal adaptation

The marginal WTP estimates, reported by class and as a weighted average across classes, reflect the preference patterns (Table 1.5). Increases in dyke height result in positive WTPs in Class 1 and Class 2 with those in the former being substantially lower; confidence intervals do not overlap. Class 3 members would experience clear dis-utilities for attribute levels other than those of the alternative *Present budget*. The weighted average across classes (Table 1.5, last column) is based only on the statistically significant marginal WTP estimates. It is positive overall due to the marginal estimates of Class 2. As the units of measurement differ, we cannot compare the WTP estimates for marginal changes directly. For example, the weighted average marginal WTP for an additional metre of beach nourished is €0.18 per household while it is €13.37 per household for one more spot where dikes and dunes are realigned. Comparing our WTP estimates to actual spending would be misleading, as actual expenditure does not take into account the preferences of citizens; rather, the budget is the result of negotiations at the government level. Further, our DCE captures changes in coastal adaptation beyond current measures (status quo). For example, a beach is currently about 40 m wide after nourishment. In the future, beach nourishments may be necessary on additional sections, and more sand may also be needed.

Table 1.5: Marginal WTP estimates (in €/ year/ household) by class and weighted average

| | Class 1 | Class 2 | Class 3 | Weighted average |
|--------------------------------------|---------------------------|---------------------------|-----------------------------|--------------------------|
| Label | Dykes | Improve | No payments | |
| Sample size (in%) | 39 | 38 | 23 | |
| Beach nourishment | | | | |
| 40 meter => 20 meter | -9.75 (-14.60 / -4.90) | -0.04 (-19.20 / 19.11) | 31.10 (-1.97 / 64.17) | -3.80 (-5.59 / -1.91) |
| 40 meter => 60 meter | -8.77 (-13.20 / -4.34) | 33.70 (10.56 / 56.84) | -8.03 (-35.38 / 19.31) | 9.72 (0.59 / 18.85) |
| Dyke heightening (per centimetre) | 0.15 (0.8 / 0.21) | 1.17 (0.82 / 1.51) | -0.84 (-1.31 / -0.37) | 0.33 (0.16 / 0.50) |
| Access to dunes (per kilometre) | -0.55 (-0.74 / -0.37) | 3.39 (2.59 / 4.18) | -1.62 (-2.60 / -0.63) | 0.74 (0.37 / 1.13) |
| Cliff protection (per kilometre) | -0.30 (-0.43 / -0.17) | 1.58 (1.01 / 2.14) | -1.10 (-1.86 / -0.33) | 0.25 (-0.02 / 0.54) |
| Realignment of dikes and dunes | | | | |
| 1 spot => 2 spots | -4.36 (-0.77 / -0.05) | 52.43 (35.14 / 69.72) | -36.36 (-67.52 / -5.20) | 10.75 (1.05 / 20.44) |
| 1 spot => 3 spots | -8.23 (-12.69 / -3.77) | 87.25 (66.67 / 107.83) | -60.55 (-90.33 / -30.77) | 17.50 (7.04 / 27.96) |

We now turn to non-marginal welfare measures for overall changes. The scenarios *Safety*, *Recreation*, and *Nature* (Table 1.6) differ at least in one attribute from the current situation (*Present measures*). In Scenario 1 (*Safety*), which focuses on better protection of the land behind, we increase beach widths by 20 m and dyke height by 25 cm compared to today. Scenario 2 (*Recreation*) addresses changes that are associated with the recreational use of the Baltic Sea in MWP. Changes relate to beach width, which is increased to 60 m as in Scenario 1, to access to dunes on stretches of overall 28 km length, and cliff protection on another 30 km of coastline. Finally, Scenario 3 (*Nature*) captures nature protection. Two additional spots where dykes and dunes are realigned would establish new inter-tidal areas that would serve the conservation of species typical for these habitats. In Scenario 4 (*Maximum*), all attribute levels are at their maximum values.

Note, however, that the assignment of attribute level changes to adaptation scenarios is not unambiguous. Having a more expansive beach, for example, could serve both safety and recreation. Thus, the streamlining is used to demonstrate the implications for welfare measures. On another note, welfare measures are calculated without including the ASCs. The literature is not clear on whether they reflect an inherent part of welfare and including them would have increased welfare measures substantially. Thus, a CS of about €44 per household/year for *Recreation* is the highest among the three scenarios, followed by *Safety* (about €21) and *Nature*

(about €15). In case all attribute levels are set to their highest levels, the overall welfare gain would on average equal €66.

Table 1.6: Welfare measure for different adaptation strategies (in €/ year/ household)

| | As today | Scenario 1 <i>Safety</i> | Scenario 2 <i>Recreation</i> | Scenario 3 <i>Nature</i> | Scenario 4 <i>Maximum</i> |
|---|----------|-----------------------------|---------------------------------|-----------------------------|------------------------------|
| Beach nourishment (per meter) | 40 m | 60 m | 60 m | 40 m | 60 m |
| Dyke heightening (per centimetre) | 50 cm | 75 cm | 50 cm | 50 cm | 75 cm |
| Access to dunes (for access) | no | no | yes (28 km) | no | yes (28 km) |
| Cliff protection (per kilometre) | 15 km | 15 km | 45 km | 15 km | 45 km |
| Realignment of dikes and dunes (spots) | 1 spot | 1 spot | 1 spot | 3 spots | 3 spots |
| CS in € per year per household ^a | | 21.05 (11.21 / 30.88) | 43.95 (18.79 / 69.11) | 15.09 (6.57 / 27.61) | 66.12 (41.27 / 90.97) |
| CS in mio € across households | | 874 | 1,824 | 626 | 2,744 |

Note: Welfare measures were calculated without incorporating marginal WTP estimates for the ASCs. In bold are the highest attribute levels.

^a In brackets are the 95% confidence intervals.

Aggregating the welfare measures across Germany, we multiply the CS values with the number of households in Germany. At the end of 2019, the total number of households in Germany was about 41.5 million.⁷ The 95% confidence intervals calculated for each of the welfare measures partially overlap, indicating that they are statistically not significantly different from each other. When we use the mean estimates for aggregation, however, the absolute differences become meaningful. The welfare effect is most considerable for Scenario 2 *Recreation* that amounts to €1.8 billion. Next, *Safety* follows with €874 million, while *Nature* results in €626 million. Interpreting these measures requires, however, to keep in mind that households with higher incomes are overrepresented. Using as a simple weight the ratio between the mean income in the target population and the mean value for the sample, which results in a value of 0.85, we get a CS per year and household of €17.9, €37.4, €13.7, and €56.3 for the four scenarios in Table 1.6.

⁷ Taken from <https://www.destatis.de> (last retrieved September 15, 2020).

1.6 Discussion and conclusion

Adaptation to climate change is becoming increasingly crucial for coastal areas. They are often particularly vulnerable to the consequences of climate change, as sea levels continue to rise with more and stronger storm surges. As Gopalakrishan et al. (2018) point out, there is a long list of unvalued or undervalued coastal amenities and ecosystem services affected by climate change adaptation. Having information on how people assess trade-offs between alternative coastal protection modes thus supports decision-making on adaptation strategies. This paper adds to the limited evidence about such trade-offs. We use a CE and focus on adaptation to climate change along the entire coast of MWP, Germany. The trade-offs are conceptualized in the CE in terms of six attributes: the extent of beach nourishment, dyke heightening, cliff protection, access to dunes, realignment of dykes and dunes and cost in terms of a coastal protection levy.

Accounting for taste heterogeneity among respondents identified three preference classes. Respondents in the first class (39% of the sample) are willing to pay for an increase in dyke height but are not ready to give up money for a change in any other attribute. This preference might reflect peoples' understanding of the consequences of climate change-induced sea-level rise, i.e., higher dykes are needed to protect the hinterland. While we vary the height of existing dykes, other studies consider length. Johnston et al. (2018) include the attributes dyke length (they name it seawalls) and whether an emphasis is put on large-scale hardening of the shoreline in their CE. Varying height or length are of course two different ways of looking at adjustments of protection measures and preferences may differ accordingly.

Nevertheless, as Matthews et al. (2017a, 2017b) find invariance to scale regarding dyke length, this suggests that some way of comparison may be allowed. In contrast to our and the results by Matthews et al. (2017a, 2017b), Johnston et al. (2018) do not find any statistically significant direct WTP for dykes. While Johnston et al. (2018) looked at the planning of new dykes, we looked at changes of existing ones which might explain the difference. Of course, apart from differences in survey design, comparability is further limited by varying, among others, site characteristics or sampling design.

Respondents in the second class (38% of the sample) prefer extensive changes including broader beaches, higher dykes, more cliff protection, more realignments of dykes and dunes, and access to dunes. As there are no studies that investigated a similar set of measures, the comparability is limited. Studies focussing on beach size mostly focus on the maintenance of

current beaches. Remoundou et al. (2015), for example, frame beach nourishment as an opportunity for recreation while we described wider beaches as an explicit coastal protection measure. Recreational opportunities would result from this as positive side effects. Marzetti and Disegna (2009) include beach nourishment as an artificial defence measure while Landry et al. (2020) compare different measures for coastal erosion management (nourishment, armouring, retreat). Due to their results, realignment ranks highest, followed by nourishment and armouring. Considering agricultural and industrial wasteland, Liski et al. (2019) find that respondents value realignment of these areas as an adaptation strategy positively. Both Dachary-Bernard et al. (2019) and Matthews et al. (2017a, 2017b) go a step further and include the realignment of buildings in their studies. So far, the responsible state office of MWP does not consider realignment including the withdrawal of houses or settlements. If climate change progresses at high enough speed, this option might be considered, and it would be interesting to elicit preferences for realignment of inhabited land at the Baltic Sea Coast. In this context, one may argue from a more general perspective that the adaptation options evaluated in our study could be perceived as a short-term response to climate change, especially as it covers rather traditional measures (e.g., dykes and nourishments). These measures work only at the pace of delaying climate change induced impacts. Against this backdrop, it is worth mentioning that we considered other soft adaptation options to be included in the CE, but, because we got to know that soft and hard measures cannot be applied interchangeably at the coast of MWP at a spot, dismissed the idea.

Respondents in the third class (23% of the sample) are not willing to cover any additional expenses preferring today's budget. Our results are in line with Chen et al. (2020) who apply a latent class model and identify a class of size 28% they label non-participant. Financing coastal protection is a national task in Germany, with 70% of the costs covered by the federal government. Therefore, decision-makers have to provide tax payers across Germany with a reasonable justification for the additional expenditure to be incurred. Interestingly, being an inhabitant of a coastal state does not differ across classes. An explanation for this might be that the Baltic Sea is a famous holiday destination for people across the whole of Germany, and thus people all over Germany feel attached to this coast. The figures show that more than 65% of the people interviewed have been visiting the Baltic Sea at least once.

Aggregating the mean WTP estimates to welfare measures for the whole population, the scenario *Recreation* ranks highest followed by *Safety* and *Nature*. The scenarios, however, do not represent unequivocal alternatives and are used here mainly for demonstration purposes.

The CE approach allows combining all attribute levels providing a high degree of flexibility. Decision-makers can therefore compose their scenarios which can then be evaluated. At first glance, especially the aggregated figures seem large. However, the survey design aimed at being conservative by applying an opt-out reminder and explicitly offering the alternatives *Present budget* and *Present measures*, the former requiring no additional payments and the latter lower payments. Thus, we argue that the mean welfare estimates are of a reasonable order of magnitude. That the aggregated numbers are high is due to the large number of households that enter the calculation as we include all households in Germany. This is justified by a) the current organisation of coastal protection funding and b) by the high popularity of the Baltic Sea among people in Germany. Still, it needs to be considered that although we aimed at a representative sample of the German population and selected a panel provider that relies exclusively on active participant recruitment, our sample is biased towards more educated respondents and higher levels of income. To our knowledge, this is a problem not only for this study but many surveys relying on online panels. In order to account for this bias, we used a simple weight to adjust the welfare measures.

A further limitation is that the study leaves out sections of the German Sea coast, the Baltic Sea coast in Schleswig-Holstein and the North Sea coast. Not offering comparable adaptation options for the latter may have caused some people to state all their willingness to pay for the Baltic Sea because of the lack of alternatives. This may lead to an overestimation of the true WTP. Anticipating this potential embedding, we informed participants that other surveys would be conducted to record preferences for adaptation at coastal section in other states. Whether this mitigated or even eliminated embedding can only be assessed in future studies. Another source for overestimating the true WTP could be the sole focus on coastal adaptation. If people would be offered a broad portfolio of adaptation options across Germany, some may state a different WTP for coastal adaptation measures. For example, people living further away from the coast might care more about adapting forests to climate change than coastal protection measures. Whether, and to what extent, we overestimate the actual WTP for coastal adaptation is again a topic for future studies.

Finally, the results suggest that citizens value certain adaptation strategies over other. The present results might therefore be also informative for decision-makers at different coasts at least in Europe. Only benefit transfer tests, however, would clarify to what extent preferences are similar across countries. Investigating this would require surveys about coastal climate adaptation along the coasts of other countries.

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References

- BMEL, 2020. Rahmenplan der Gemeinschaftsaufgabe „Verbesserung der Agrarstruktur und des Küstenschutzes“ 2020-2023.
- Chen, Z., Swallow, S.K., Yue, I.T., 2020. Non-participation and heterogeneity in stated preferences: A double hurdle latent class approach for climate change adaptation plans and ecosystem services. *Environmental and Resource Economics* 77, 35–67, doi: 10.1007/s10640-020-00434-z.
- Dachary-Bernard, J., Rey-Valette, H., Rulleau, E.B., 2019. Preferences among coastal and inland residents relating to managed retreat: Influence of risk perception in acceptability of relocation strategies. *Journal of Environmental Management* 232, 772-780, doi:10.1016/j.jenvman.2018.11.104.
- Hanemann, W.M., 1984. Welfare evaluations in contingent valuation experiment with discrete responses. *Am. J. Agric. Econ.* 66, 332–341, doi:10.2307/1240800.
- Hess, S., 2014. Latent class structures: Taste heterogeneity and beyond. In: Hess, S., Daly, A., (Eds.), *Handbook of Choice Modelling*. Cheltenham, 311-329.
- Holmes, T.P., Adamowicz, W.L., Carlsson, F., 2017. Choice experiments, In: Champ, P.A. (Ed.), *A primer on non-market valuation*. Springer, 133-186.
- Johnston, R.J., Makriyannis, C., Whelchel, A.W., 2018. Using ecosystem service values to evaluate tradeoffs in coastal hazard adaptation. *Coastal Management* 46, 259-277, doi:10.1080/08920753.2018.1474067.
- Ladenburg, J., Olsen, S.B., 2014. Augmenting short cheap talk scripts with a repeated opt-out reminder in choice experiment surveys. *Resource and Energy Economics* 37, 39-63, doi:10.1016/j.reseneeco.2014.05.002.
- Landry, C.E., Shonkwiler, J.S., Whitehead, J.C., 2020. Economic values of coastal erosion management: Joint estimation of use and existence values with recreation demand and contingent valuation data. *Journal of Environmental Economics and Management* 103, doi:10.1016/j.jeem.2020.102364.
- Gopalakrishnan, S., Landry, C.E., Smith, M.D., 2018. Climate change adaptation in coastal environments: Modeling challenges for resource and environmental economists. *Review of Environmental Economics and Policy* 12, 48-68, doi:10.1093/reep/rex020.
- Lindhjem, H., Navrud, S., 2011. Are internet surveys an alternative to face-to-face interviews in contingent valuation? *Ecological Economics* 70(9), 1628-1637, doi:10.1016/j.ecolecon.2011.04.002.

- Liski, A.H., Koetse, M.J., Metzger, M.J., 2019. Addressing awareness gaps in environmental valuation: Choice experiments with citizens in the Inner Forth, Scotland. *Regional Environmental Change* 19, 2217-2229, doi:10.1007/s10113-018-01458-4.
- LWaG, 1992. Wassergesetz des Landes Mecklenburg-Vorpommern (LWaG) from 30.11.1992, last changed 05.07.2018.
- Marzetti, S., Disegna, M., 2009. Recreational demand functions on different categories of beach visitors. *Tourism Economics* 15(2), 339–365, doi:10.5367/000000009788254331.
- Marzetti, S., Disegna, M., Koutrakis, E., Sapounidis, A., Marin, V., Martino, S., 2016. Visitors' awareness of ICZM and WTP for beach preservation in four European Mediterranean regions. *Marine Policy* 63, 100-108, doi:10.1016/j.marpol.2015.10.005.
- Matthews, Y., Scarpa, R., Marsh, D., 2017a. Using virtual environments to improve the realism of choice experiments: A case study about coastal erosion management. *Journal of Environmental Economics and Management* 81, 193-208, doi:10.1016/j.jeem.2016.08.001.
- Matthews, Y., Scarpa, R., Marsh, D., 2017b. Stability of willingness-to-pay for coastal management: A choice experiment across three time periods. *Ecological Economics* 138, 64-73, doi:10.1016/j.ecolecon.2017.03.031.
- McFadden, D., 1974. Conditional logit analysis of qualitative choice behaviour. In: Zarembka, P. (Ed.), *Frontiers in Econometrics*. New York: Academic Press, 105-142.
- Meinke, I., Maneke, M., Riecke, W., Tinz, B., 2014. Norddeutscher Klimamonitor – Klimazustand und Klimaentwicklung in Norddeutschland innerhalb der letzten 60 Jahre (1951-2010). *Mitteilungen DMG* 01/2014.
- Oliveira, S., Pinto, L.M.C., 2021. Choice experiments to elicit the users' preferences for coastal erosion management: The case of Praia da Amorosa. *Environ Dev Sustain* 23, 9749-9765, 10.1007/s10668-020-00768-0.
- Remoundou, K., Diaz-Simal, P., Koundouri, P., Rulleau, B., 2015. Valuing climate change mitigation: A choice experiment on a coastal and marine ecosystem. *Ecosystem Services* 11, 87–94, doi:10.1016/j.ecoser.2014.11.003.
- Rulleau, B., Rey-Valette, H., 2013. Valuing the benefits of beach protection measures in the face of climate change: A French case-study. *Journal of Environmental Economics and Policy* 2(2), 133-147, 10.1080/21606544.2013.776213.
- Rulleau, B., Rey-Valette, H., 2017. Forward planning to maintain the attractiveness of coastal areas: Choosing between seawalls and managed retreat. *Environmental Science and Policy* 72, 12-19, 10.1016/j.envsci.2017.01.009.

- Scarpa, R., Thiene, M., Tempesta, T., 2007. Latent class count models of total visitation demand: Days out hiking in the eastern Alps. *Environmental and Resource Economics* 38, 447-460, doi:10.1007/s10640-007-9087-6.
- StALU, 2009. Regelwerk Küstenschutz Mecklenburg–Vorpommern – Übersichtsheft - Grundlage, Grundsätze, Standortbestimmung und Ausblick. Rostock, Germany: Staatliches Amt für Umwelt und Natur - Abteilung Küste - Ministerium für Landwirtschaft, Umwelt und Verbraucherschutz Mecklenburg -Vorpommern.
- StALU, 2012. Hydrodynamische Eingangsparameter für den Entwurf, die Bemessung und die Sicherheitsüberprüfung von Küstenschutzanlagen in M-V. In: Regelwerk Küstenschutz Mecklenburg-Vorpommern, Küstenraum und Bemessungsgrößen von Küstenschutzanlagen in MV 2 -4/2012. Rostock, Germany: Staatliches Amt für Umwelt und Natur - Abteilung Küste - Ministerium für Landwirtschaft, Umwelt und Verbraucherschutz Mecklenburg -Vorpommern.
- van Cranenburgh, S., Collins, A.T., 2019. New software tools for creating stated choice experimental designs efficient for regret minimisation and utility maximisation decision rules. *Journal of Choice Modelling* 31, 104-123, doi:10.1016/j.jocm.2019.04.002.

Second Paper: A test-retest analysis of stated preferences in uncertain times

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Abstract

In environmental valuation, the issue of the temporal stability of stated preferences to changes in environmental (dis)amenities is important because their results can be employed to inform decision-making. This includes cost-benefit analysis for large infrastructure projects such as coastal protection. A couple of studies have investigated stability of stated preferences over varying time periods. However, less evidence is available for temporal stability of stated preferences for (dis)amenities in uncertain times, i.e., times that are characterised by larger degrees of uncertainty regarding the (near) future. Using a choice experiment on coastal adaptation to climate change, this paper examines the test-retest reliability of individual preferences and resulting welfare estimates over the course of the Covid-19 pandemic. We do so by surveying the same respondents at two points in time five months apart during the ongoing pandemic. Using a latent class model, we find similar preference heterogeneity patterns but different class sizes at the two points in time. While the welfare measure of an adaptation scenario that focuses on safety increases across survey waves, scenarios that centre on recreation or nature have decreasing welfare effects. This suggests that individuals set other priorities in uncertain times.

Keywords: adaptation, choice experiment, climate change, coastal protection, Covid-19 pandemic, test re-test

JEL classification: Q51, Q54, Q57

2.1 Introduction

In environmental valuation, the temporal stability of preferences for changes in environmental (dis)amenities is vital as results are used for decision making, i.e., directly incorporated in cost-benefit analyses, or employed for benefit transfer. When the decisions affect large infrastructure projects such as motorways, railway networks or coastal protection, they can have far-reaching consequences. Therefore, the preferences recorded should reflect what people prefer at the time when the preferences are measured. They should also be stable over time, because once projects are implemented they will remain for long periods of time. The issue of temporal stability is particularly relevant for stated preferences recorded on hypothetical markets, which may depend on the context in which they were captured.

First studies on the stability of preferences over time focused on the contingent valuation (CV) approach (see, e.g., the review by McConell et al., 1998). For the use of the other stated preference approaches, in particular choice experiments (CE), empirical evidence is much scarcer.⁸ However, we also find here test-retest studies that analyze temporal stability either using subsamples of the original samples (Liebe et al., 2012; Matthews et al., 2017) or different samples from the same population (e.g., Bliem et al., 2012; Lee & Wallmo, 2017). The distinct periods investigated vary between six months (Rigby et al., 2016) and 17 months (Lew & Wallmo, 2017), and cover a variety of environmental goods and services. To our knowledge, none of the CE studies has investigated temporal preference stability in uncertain times, characterized by insecure employment opportunities and income prospects. Against the backdrop of the current Covid-19 pandemic, associated with these insecurities, the focus of our paper is to do so.

Reviewing this literature, Bliem et al. (2012) and Liebe et al. (2012) were the first to conduct a test-retest CE study. The former found remarkable temporal stability for two surveys within a time-interval of one year regarding river restoration programs in Austria. In contrast to them, Liebe et al. (2012) invited respondents of the first survey to the retest survey. A time interval of eleven months between the test and the retest is used on the valuation of landscape externalities from onshore wind power in Germany. They find a test-retest reliability of about 60% and insignificant differences between all WTP estimates except for one of the choice attributes. A couple of further studies used this framework of intrapersonal choices with varying

⁸ Studies related to health economics are not included in our review. For further information, see e.g., Ryan et al. (2006), Brouwer (2006) or Gamper et al. (2018).

test-retest periods. Based on a test-retest period of one year for land use change scenarios in Flanders, Schaafsma et al. (2014) confirm temporal stability of choices in 57% of the choice occasions but significantly different WTP values. Using a six month delay, Czajkowski et al. (2016) report significantly different WTP parameters for public forest management of the Bialowieza Forest in Poland. Similarly, Matthews et al. (2017) found significant differences in WTP values for beach erosion management of beach visitors to the Coromandel peninsula, New Zealand, using two retests over a six-month period. The existing literature finds mixed evidence regarding temporal stability of preferences, yet indicates a high degree of stability overall, during more secure times.

In contrast to the above test-retest studies, we investigate stability in uncertain times. We are not the first to do this. There are a few studies, that were conducted in times of great economic uncertainty.⁹ Lew and Wallmo (2017) and Loureiro and Loomis (2017) both are related to the global financial crisis. Based on a framework of different samples from the same population and a test-retest period of 17 months during the financial crisis (spring 2009 and autumn 2010). Lew and Wallmo (2017) find temporal stability in preferences and WTP values associated with threatened and endangered marine species protection in the United States. Loureiro and Loomis (2017) compare temporal stability of WTP estimates of a CV-study linked to the environmental damages caused by the Prestige oil spill before (2006) and after (2009) the recession. They note a significant decline in median WTP estimates for Spanish society as a whole, attributing this to changing priorities during the recession.

To our knowledge, the only other study conducting a test-retest study related to the Covid-19 pandemic is Hynes et al. (2021). They compare WTP values associated with alternative environmental management plans on the high seas before (late 2019) and during the pandemic (May 2020). Using different samples from Canada, Scotland, and Norway their results suggest that both preferences and WTP values remain relatively stable. Our DCE test-retest study uses a sample of respondents from Germany who participated in two survey waves during the Covid-19 pandemic. During the first survey wave in April 2020 Covid-19 case numbers rose and began to fall in May/June of the same year. When the second survey wave was conducted five months later, in early September, incidences were low but the arrival of a second wave was anticipated. Instead of comparing choices on the individual level, as done for example by Liebe et al. (2012),

⁹ More generally on the effect of significant changes in information, Morrison and Hatfield-Dodds (2011) used longitudinal surveys to examine the effects of increased media coverage of climate change on public willingness to support greenhouse policies in Australia. The results suggest that support for policies decreases at low and medium costs, while it increases slightly at higher costs.

we compare them on the level of samples, as was done, for example, by Bliem et al. (2012). Focusing on preference stability in uncertain times, we expect mean WTP estimates to generally decline in the second wave, as respondents are likely to feel a higher degree of insecurity about their own future during this period.

2.2 Method

In a choice experiment (CE), respondents are requested to choose their most preferred alternative from a set of mutual exclusive alternatives. Each alternative is described by a number of attributes, whose associated levels are systematically varied due to an underlying experimental design (Mariel et al., 2021). Our CE focuses on coastal adaptation options to climate change on the German Baltic Sea coast of Mecklenburg-Western Pomerania (MWP). As climate continues to change and impacts increase, increasing investment is needed to keep up with the changes. This also applies to coastal protection. In Germany, unlike in other countries, coastal protection is a national task, delegated to the coastal states and limited to the protection of settlements. The expenses are mainly borne by the federal government and to a much lesser extent by the coastal state (StALU, 2009; BMEL, 2020). Therefore, preferences of people who contribute to coastal protection but live far away from it or do not use it need to be considered as well.

In the following, we briefly describe the CE. For a comprehensive overview of the study area, the survey design, and implementation see Meyerhoff et al. (2021) focusing on the first wave. Our CE included the following choice situations: two adaptation alternatives (*Adaptation A and B*), an alternative offering a continuation of present measures (*Present measures*), and an alternative which requires no additional payments compared to today (*Present budget*). The latter alternative *Present budget* reflects that individuals may not be willing to pay extra for future adaptation. This implies that it would not be possible to maintain the current level of measures as costs will increase in the future. The third alternative, *Present measures*, reflects that individuals may prefer to maintain current measures and are willing to pay more for them than people in Germany pay on average for coastal protection today. The payment attribute could only take values from the lower half of the cost vector to reflect that the cost of maintaining the present measures would be lower than the cost of the changes described by the two adaptation alternatives.

In turn, the final set of attributes comprised adaptation measures which directly related to coastal protection (*beach nourishment* and *dyke heightening*), present recreational opportunities

(*access to dunes* and *protection of cliffs*) and the measure *realignment of dykes and dunes*. A coastal protection levy was used as the cost attribute. The set of attributes including a detailed description, associated pictograms presented to respondents and attribute levels is presented in Table A1 in the Appendix. A Bayesian efficient design with uniform priors was used as experimental design to assign attribute levels to the different alternatives. D-efficiency as design criterion was optimised for an MNL model to allow for uncertainty in the prior values, 1000 Sobol draws were taken for each parameter prior. As detailed in Table A1, certain cost attribute levels are only assigned to certain alternatives. In the experimental design, the levels 5 / 10 / 15 Euro are assigned only to the alternative *Present measure* via the experimental design; this is indicated in Table A1 by the addition “(PM)” after these three levels; the other cost levels are assigned to the hypothetical alternatives A or B by the design, indicated by the addition “(A_B)”. Overall, 48 choice tasks were created and allocated to four blocks. Respondents were randomly assigned to a block, and within a block the order of presentation was randomised showing respondents different sequences of choice tasks. An example choice task of the test survey is presented in Figure 2.1.

The finalized version of the survey instrument was implemented for the first nationwide wave (N = 1878) in spring 2020 after we administered a pilot study to about 50 individuals. Five months later, the retest survey was implemented with a smaller sample size due to budget constraints (N = 880). In addition, half of the sample of the second wave consists of persons who had already participated in the first wave and half of newly invited respondents. A test-retest study can thus only be conducted on with a maximum of 440 respondents from the second wave. For both waves, the same survey instrument was used, except that the levels of the attribute *realignment of dykes and dunes* were changed to find out whether the WTP for this attribute was sensitive to the number of sites. Unfortunately, the survey company was not able to provide the same block of choice sets to respondents in the first wave. This has two implications: First, we had to apply a matching procedure to identify the respondents who had participated in both waves with a high level of certainty.¹⁰ Secondly, we can only compare mean estimates across waves as single choices are not comparable due to the different choice sets for each respondent.

The matching approach used the information provided by the survey company about a respondent’s participation in Wave 1 and Wave 2. In addition, we used socio-demographics

¹⁰ We used the two Stata commands *nnmatch* (nearest neighbour) and *psmatch* (propensity score) for matching. Only those respondents that were identified by both approaches were selected for our analysis.

(gender, age, and education), the residence (Federal State and postcode), and information about whether the German Sea coast had been visited by the respondent before the pandemic for matching. This resulted in 266 matches out of the 440 possible matches. This matching procedure is rather restrictive, as postcode information is not provided for all respondents and those who moved to another state or had a birthday between the first and second wave were excluded.

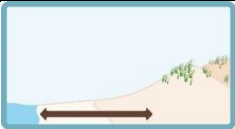
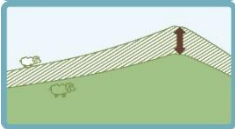




| | | Adaptation A | Adaptation B | Present measures | Present budget |
|--|---|-------------------------------------|-------------------------------------|---------------------------------|---------------------------------|
| Beach nourishment (44 km total) |  | 20 m width | 60 m width | 40 m width | 20 m width |
| Dyke heightening (227 km total) |  | 50 cm height | 25 cm height | 50 cm height | 25 cm height |
| Access to dunes |  | Yes. Over a distance of 28 km | Yes. Over a distance of 15 km | No | No |
| Protection of cliffs |  | 45 km distance | 15 km distance | 15 km distance | 15 km distance |
| Realignment of dykes and dunes |  | 1 spot (15 km ²) | 3 spots (45 km ²) | 1 spot (15 km ²) | 1 spot (15 km ²) |
| My payment |  | 20 € | 35 € | 15 € | No payment |
| I choose | | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Figure 2.1: Example choice task (Wave 1)

Note: The attribute *realignment of dykes and dunes* always has three levels, but the number of spots differs between the waves. In Wave 1 1, 2 and 3 spots were chosen and in Wave 2 1, 4 and 6 spots.

2.3 Econometric modelling

Our analysis of choice data is based on the random utility model by McFadden (1974). Its assumption that complete information regarding an individual n 's preferences is not available to the researcher is captured by modelling an individual n 's utility as the sum of a systematic and a random part:

$$U_{ni} = V_{ni}(x_{ni}\beta) + \varepsilon_{ni} \quad (1)$$

U_{ni} is the true but unobservable utility which an individual derives from choosing an alternative i out of a set of several available alternatives j . The deterministic part V_{ni} is a function of the attributes (x_{ni}) and a vector (β) of unknown coefficients representing the desirability of the attributes. ε_{ni} denotes the unknown random part.

Different assumptions regarding the distribution of the error term lead to different models. A conditional logit model is obtained when assuming that the error terms are distributed independently and identically (IID) and follow a type 1 extreme value distribution. In this case the choice probability of individual n choosing alternative i is:

$$P_{ni} = \frac{\exp(\mu V_{ni})}{\sum_{j \in C} \exp(V_{nj})} \quad (2)$$

To be able to capture unobserved heterogeneity different models are needed. We therefore apply a latent class (LC) model (Hess, 2014). It assumes that an unknown number of classes exist that each possess their own taste coefficient β . So, instead of estimating one single β for the whole population, as done in the conditional logit model, a taste coefficient is calculated separately for each class. Each individual in the population is assumed to belong to each of the classes with a certain probability. The number of classes is a priori unknown and is selected by comparing information criteria (such as the Bayesian Information Criteria (BIC)) while increasing the number of classes sequentially. Moreover, we use likelihood ratio tests to determine whether non-linear specifications of the attributes outperform linear specifications (Mariel et al., 2021).

Including the monetary attribute “*My payment*” allows to calculate the marginal willingness to pay ($mWTP$) for each of the non-monetary attributes by calculating the ratio: $mWTP = \beta_{s_attribute} / \beta_{s_money}$. Based on the LC model results, this is done for each class separately. Using those marginal estimates, we also provide an overall marginal WTP estimate weighted by class size. This weighted estimate is employed for the compensating variation for three coastal adaptation scenarios that we have additionally calculated. Each scenario has a certain focus: safety, recreation, and nature. Following Hanemann (1984) we calculate the welfare measure by applying the following formula:

$$CS_n = -\frac{1}{\beta_{cost_n}} [\ln \sum_n \exp V_n^1 - \ln \sum_n \exp V_n^0], \quad (3)$$

where CS is the compensating surplus welfare measure, β_{cost} refers to the marginal utility of income while V_n^0 and V_n^1 are the n th individuals' indirect utility functions before and after the change respectively. To calculate the welfare measures we used only the cost parameter that reflects the cost sensitivity associated with the two hypothetical adaptation alternatives.

2.4 Results

2.4.1 Sample characteristics

The characteristics of the full sample of respondents in Wave 1 and those in the matched sample are reported in Table 2.1. To test for differences in socio-demographic characteristics and familiarity of the German coast between the full sample and our smaller sample of 266 individuals, we used a logistic regression (Table A2, see Appendix). We find no significant differences between participants in Wave 2 and our matched sample with respect to higher education, household income, household size, state of residence and previous visit to at least one of the German coasts. Significant differences were only found for the variables age and gender. Overall, this points to the fact that the smaller sample of 266 matched respondents appropriately represents the full sample.

Table 2.1: Descriptive statistics

| <i>Characteristics</i> | Wave1 (N = 1878) ^a | | Matched respondents (N = 266) ^b | |
|---|----------------------------------|----------|---|----------|
| | mean | std. dev | mean | std. dev |
| Age (years) | 48.86 | 16.46 | 52.36 | 15.57 |
| Female (%) | 50.85 | | 55.64 | |
| Higher education ^c (%) | 36.94 | | 30.07 | |
| Household income ^d (€ per month) | 2533.78 | 1454.10 | 2489.64 | 1241.43 |
| People per household (number) | 2.23 | 1.28 | 2.15 | 1.13 |
| Resident in a coastal state (%) | 17.25 | | 19.55 | |
| Recreational visits to coast in Germany | | | | |
| only to the North Sea (% yes) | 15.10 | | 12.78 | |
| only to the Baltic Sea (% yes) | 15.02 | | 13.16 | |
| to the North and Baltic Sea (% yes) | 51.60 | | 58.65 | |

^a Note that of the 1878 individuals, 440 participated in Wave 2. For further details see section 2.

^b As expected, there are no significant differences between the characteristics of the two waves, such that only values from Wave 1 are reported here.

^c Higher education here is defined as education level that is required to study at a college/ university.

^d Due to missing disclosures and some implausible responses to this question the statistics for household income are based on a smaller sample, within the range of € 450 to € 10,000.

2.4.2 Descriptive choice analysis

Proceeding with a descriptive analysis of the recorded choices of the matched sample (Table 2.2), we find the alternative *Present measures* accounted for most of the choices in both waves (32.1% and 35.5%, respectively). While the share of choices for this alternative increased from the test to the retest survey, the share for the two hypothetical alternatives decreased. In uncertain times, like the Covid-19 crisis, more respondents chose to maintain the current level of protection and express this by choosing *Present measures* at the expense of the two hypothetical and more costly alternatives. The share of choices for the alternative *Present budget* instead remained quite stable across the two survey waves. Thus, we cannot observe a shift of choices towards the no-cost alternative *Present budget*. A Pearson chi-squared test allows to reject the null hypothesis that the observed frequencies in Wave 1 and Wave 2 are from the same distribution (Pearson $\chi^2(3) = 9.591$, $pr = 0.022$).

Table 2.2: Observed and expected choices across survey waves

| | Wave 1 | | Wave 2 | |
|------------------|---------------|---------|---------------|---------|
| | Frequencies | Percent | Frequencies | Percent |
| Alternative A | 673 / 647.5 | 21.1% | 622 / 647.5 | 19.5% |
| Alternative B | 676 / 651.0 | 21.2% | 626 / 651.0 | 19.6% |
| Present measures | 1023 / 1078.0 | 32.1% | 1133 / 1078.0 | 35.5% |
| Present budget | 820 / 815.5 | 25.7% | 811 / 815.5 | 25.4% |
| Total | 3192 | 100.0% | 3192 | 100.0% |

Note: N = 266; expected frequencies are in italics.

2.4.3 Modelling preferences for coastal adaptation

Table 2.3 presents the results of the LC models. For both waves, the comparison of information criteria statistics suggested that a 3-class segmentation best represents the underlying unobserved taste heterogeneity. The 3-class segmentation is in line with results of a previous study that analysed the entire first wave of the survey, including respondents who were not surveyed a second time (Meyerhoff et al., 2021). The labels assigned to the three classes are still meaningful for the present analysis as well, which also indicates a great stability of the previous results.

In class 1 (named *dykes* group), for both samples the parameter for *dyke heightening* is positive and significant. Respondents likely to be in this class prefer higher dykes compared to the reference alternative *Present measures*. The parameter estimate of ASC_PB, representing the

alternative *Present budget*, is also significant in both surveys and has a negative sign. Respondents prefer the reference alternative *Present measures* against the alternative *Present budget*. In the test survey the attribute parameter for a decrease of beach width from 40 to 20 meters is also significantly negative. So, while a decrease in beach width systematically influences respondents' choices in the test survey, this is not the case in the retest survey. The parameter estimates for all other non-monetary attributes are not significant in both survey waves and thus do not influence choices of respondents in this class.

Respondents who are likely to belong to the second class, named *improvement* group, do not only prefer higher dykes. Compared to the reference alternative *Present measure*, they prefer more extensive changes. For both waves, this applies to the attributes *access to dunes* and the *realignment of dykes and dunes* at further spots.¹¹ In the test survey (Wave 1), respondents also rate changes in the attribute *cliff protection* positively, whereas the protection of cliffs does not influence respondent's choices in the retest survey. Another difference between the two survey waves is that the attribute parameter for a decrease in beach width from 40 to 20 meters is significantly negative for the test survey while it is insignificant for the retest survey. For both survey waves highly positive significant parameters for ASC_A and ASC_B can be observed, and a highly negative significant parameter estimate for ASC_PB. This underlines the high appreciation of respondents in the second class for far-reaching changes of coastal adaptation to climate change.

Turning to respondents likely to be in the third class (named *no payment* group), the only parameter being significant is the *dyke heightening* in the test survey, but not in the retest survey. Respondents in the test survey exhibit a negative valuation for an extension of existing dykes in height. Choices of respondents are not influenced by any other of the non-monetary attributes in both waves.

Investigating class sizes across the two survey waves, the *no payment* group exhibits the smallest class size with a quite stable share of respondents across the two survey waves (24% and 27%, respectively). This does not hold for the two other groups. While the *dyke* group shows a class size of 30% in the test survey, its size increases to 41% in the retest survey. This is reverted for the *improvement* group. Class size decreases from 46% in the test survey to 32% in the retest survey. With regard to class size, the group *improvement* and the group *dykes* switched places.

¹¹ As noted above, the attribute levels for realignment were changed from the test to the retest survey.

Table 2.3: Estimates from latent class (LC) logit models

| | LC-Wave 1 (N=266) | | | | | | LC-Wave 2 (N=266) | | | | | |
|---|----------------------|--------|----------------------------|--------|---------------------------|--------|----------------------|--------|----------------------------|--------|---------------------------|--------|
| Label | Class1 | | Class2 | | Class3 | | Class1 | | Class2 | | Class3 | |
| Sample size (in%) | <i>Dykes</i> 30.0 | | <i>Improvement</i> 45.6 | | <i>No payment</i> 24.4 | | <i>Dykes</i> 40.6 | | <i>Improvement</i> 32.1 | | <i>No payment</i> 27.3 | |
| | Coeff. | z-val. | Coeff. | z-val. | Coeff. | z-val. | Coeff. | z-val. | Coeff. | z-val. | Coeff. | z-val. |
| Beach nourishment | | | | | | | | | | | | |
| 40 => 20 meters | -0.978** | 2.42 | -0.260** | 1.99 | 0.558 | 0.55 | -0.034 | 0.12 | 0.005 | 0.03 | -1.097 | 1.52 |
| 40 => 60 meters | -0.735* | 1.95 | 0.027 | 0.20 | -0.565 | 0.64 | -0.011 | 0.04 | 0.169 | 1.04 | -1.081* | 1.78 |
| Dyke heightening (per centimetre) | 0.014** | 2.57 | 0.007*** | 3.95 | -0.035** | 2.34 | 0.012*** | 3.53 | 0.007*** | 3.26 | -0.009 | 0.79 |
| Access to dunes (yes, per kilometre) | -0.000 | 0.02 | 0.014*** | 3.44 | -0.040 | 1.26 | -0.015* | 1.73 | 0.015*** | 3.04 | -0.004 | 0.17 |
| Cliff protection (per kilometre) | 0.001 | 0.05 | 0.012*** | 3.58 | -0.036 | 1.47 | -0.005 | 0.79 | 0.002 | 0.45 | 0.010 | 0.51 |
| Realignment of dikes and dunes (per spot) ^a | | | | | | | | | | | | |
| 1 spot => 2/4 spots | 0.095 | 0.28 | 0.310*** | 2.61 | 1.320* | 1.78 | 0.096 | 0.41 | 0.412*** | 2.91 | 0.083 | 0.13 |
| 1 spot => 3/6 spots | 0.277 | 0.84 | 0.536*** | 5.30 | -0.086 | 0.10 | -0.082 | 0.37 | 0.494*** | 4.14 | -0.068 | 0.10 |
| Payment_PM (in €) | -0.122*** | 4.59 | 0.049*** | 2.91 | -0.183*** | 3.97 | -0.018 | 0.81 | 0.066*** | 2.93 | -0.209*** | 6.25 |
| Payment_A_B (in €) | -0.117*** | 5.74 | -0.011*** | 9.66 | -0.073*** | 3.42 | -0.045*** | 8.01 | -0.009*** | 6.42 | -0.042*** | 3.54 |
| ASC_A | 0.190 | 0.40 | 1.212*** | 5.32 | -1.164 | 0.14 | 0.144 | 0.38 | 1.718*** | 5.90 | -1.427* | 1.70 |
| ASC_B | 0.567 | 1.17 | 1.169*** | 5.15 | -0.506 | 0.45 | 0.238 | 0.62 | 1.633*** | 5.64 | -1.407* | 1.65 |
| ASC_PM | | | Reference | | | | | | Reference | | | |
| ASC_PB | -1.856*** | 3.76 | -2.555*** | 6.35 | -0.026 | 0.21 | -2.652*** | 7.05 | -2.274*** | 4.71 | 1.147 | 1.30 |

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

^a The attribute *realignment of dykes and dunes* always has three levels, but the number of spots differs between the waves. In Wave 1 1, 2 and 3 spots were chosen and in Wave 2 1, 4 and 6 spots.

2.4.4 Willingness to pay for coastal adaptation

The marginal WTP estimates, which are reported by class and as a weighted average across classes (Table 2.4), mirror the underlying preference patterns of both waves. For comparison, we focus on the weighted means, each of which considers only the statistically significant marginal WTP estimates. In Figure 2.2 we present the weighted mean WTP estimates and their 95% confidence intervals for different changes in the attributes compared across both waves. As the underlying units differ (cm, km etc.) we used non-marginal changes for some of the attributes to better visualize the results. In particular for dykes we estimated an extension of 20 cm, for access to dunes and protection of cliffs we used a length of 10 km for each. As Figure 2.2 reveals, the mean values for most attributes differ across waves while they are very close for the attribute *access to dunes*. Among the most obvious differences, the WTP estimates for reduced *beach nourishments* and *cliff protection* are no longer significant in the second wave. Thus, we cannot compute marginal WTP estimates and assume that the WTP is zero in those cases. In contrast, the marginal WTP estimate for the attribute dyke extension has increased in Wave 2. This applies also for the marginal WTP estimate for the lower level of *the realignment of dykes and dunes* (i.e., four spots instead of one). For the upper level of this attribute, we instead observe a decline from Wave 1 to Wave 2. It is important to note here that the levels of this attribute have changed. In the second wave, *realignment of dykes and dunes* has the same number of levels, but the level values are higher (Table A1). Thus, a direct comparison of the WTP estimates is not possible. Still, we can conclude that more spots are valued more although the increase from one level to the next is rather non-linear. The marginal value for additional sites is significantly lower in Wave 2 compared to Wave 1.

Table 2.4: Marginal WTP estimates (in €/ year/ household) by class and as a weighted average

| | Wave 1 (March 2020) | | | | Wave 2 (September 2020) | | | |
|---|---------------------------|----------------------------|---------------------------|-------------------------------|---------------------------|---------------------------|---------------------------|-------------------------------|
| | Class 1 | Class 2 | Class 3 | Weighted average ^a | Class 1 | Class 2 | Class 3 | Weighted average ^a |
| Label | Dykes | Improvement | No payment | | Dykes | Improvement | No payment | |
| Sample size (in%) | 30.0 | 45.6 | 24.4 | | 40.6 | 32.1 | 27.3 | |
| Beach nourishment | | | | | | | | |
| 40 meter => 20 meter | -8.34 (-15.27 / -1.41) | -24.54 (-47.34 / -1.75) | 7.61 (-20.53 / 35.76) | -13.79 (-24.51 / -3.08) | -0.76 (-12.92 / 11.41) | 0.54 (-34.32 / 35.39) | -26.21 (-57.86 / 5.43) | n.s. |
| 40 meter => 60 meter | -6.27 (-12.95 / 0.40) | 2.56 (-22.64 / 27.77) | -7.71 (-31.75 / 16.33) | n.s. | -0.25 (-11.35 / 10.85) | 19.78 (-20.66 / 60.22) | -25.84 (-54.34 / 2.65) | n.s. |
| Dyke heightening (per centimetre) | 0.11 (0.03 / 0.20) | 0.69 (0.32 / 1.06) | -0.48 (-1.01 / 0.44) | 0.24 (0.02 / 0.45) | 0.27 (0.13 / 0.42) | 0.84 (0.26 / 1.42) | -0.21 (-0.77 / 0.35) | 0.38 (0.19 / 0.57) |
| Access to dunes (per kilometre) | -0.00 (-0.21 / 0.21) | 1.29 (0.52 / 2.07) | -0.55 (-1.55 / 0.45) | 0.59 (0.24 / 0.95) | -0.32 (-0.72 / 0.08) | 1.71 (0.45 / 2.96) | -0.10 (-1.30 / 1.07) | 0.55 (0.14 / 0.95) |
| Cliff protection (per kilometre) | -0.00 (-0.15 / 0.16) | 1.11 (0.45 / 1.78) | -0.50 (-1.26 / 0.27) | 0.51 (0.21 / 0.82) | -0.11 (-0.40 / 0.18) | 0.21 (-0.70 / 1.10) | 0.23 (-0.63 / 1.09) | n.s. |
| Realignment of dikes and dunes ^b | | | | | | | | |
| 1 => 2 spots (W1) | 0.81 | 29.23 | 18.00 | 13.44 | 2.15 | 48.13 | 1.98 | 15.40 |
| 1 => 4 spots (W2) | (-4.78 / 6.40) | (7.56 / 50.89) | (-1.61 / 37.62) | (3.48 / 23.41) | (-7.97 / 12.26) | (13.96 / 82.30) | (-27.81 / 31.78) | (4.46 / 26.34) |
| 1 => 3 spots (W1) | 2.36 | 50.53 | -1.17 | 23.24 | -1.82 | 57.69 | -1.61 | 18.46 |
| 1 => 6 spots (W2) | (-2.97 / 7.70) | (28.94 / 72.10) | (-23.35 / 21.01) | (13.31 / 33.17) | (-11.61 / 7.97) | (23.70 / 91.72) | (-32.18 / 28.94) | (7.57 / 29.35) |

Note: Confidence intervals are reported in parenthesis.

^a We use n.s. to indicate that the weighted averages are not significantly different from zero.

^b The attribute realignment of dykes and dunes always has three levels, but the number of spots differs between the waves. In Wave 1 1, 2 and 3 spots were chosen and in Wave 2 1, 4 and 6 spots

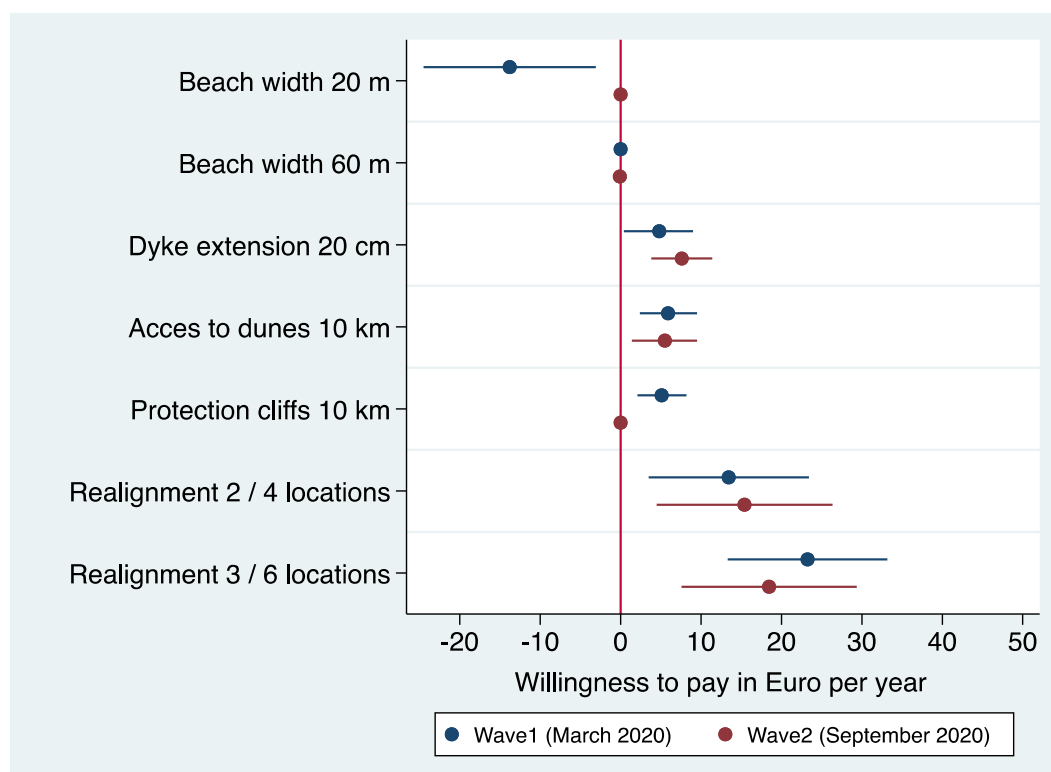


Figure 2.2: Weighted mean WTP estimates by wave

For both waves also non-marginal welfare measures (compensating surplus; CS) for various policy scenarios are calculated. The scenarios combine certain levels of the attributes, thereby emphasizing different aspects of coastal adaptation to climate change (Table 2.5) and differ from the current situation (*Present measures*) in at least the level of one attribute. In terms of a possible aggregation of the non-marginal welfare measures, it should be recalled that only a relatively small sample of the 266 matched respondents serves as basis here. Scenario 1 (*Safety*) focuses on better protection of the hinterland. Beach width is increased by 20 metres and dyke height by 25 to overall 75 cm. Scenario 2 (*Recreation*) stresses aspects related to the recreational use of the Baltic Sea in MWP. Beach width is increased to 60 metres as in Scenario 1, access to dunes is allowed on stretches of overall 28 kilometres length, and cliffs are protected on another 30 kilometres of coastline. Finally, Scenario 3 (*Nature*) addresses nature protection. New inter-tidal areas that would serve the conservation of species typical for these habitats would be created through realigning additional spots with dykes and dunes. Recalling the marginal WTP estimates for both waves, one difference is related to the attribute *dyke heightening*. The increase in the CS value for the policy scenario *Safety* is due to the increase in the valuation for this attribute. The decrease in the CS value for the policy scenario *Recreation* can be explained by the insignificance of the attribute cliff protection in Wave 2.

The CS for the policy scenario *Nature* decreases because the WTP for realignment sites has gone down.

Table 2.5: Welfare measure for policy scenarios (in €/ year/ household)

| | As today | Scenario 1 <i>Safety</i> | Scenario 2 <i>Recreation</i> | Scenario 3 <i>Nature</i> |
|---|-----------------|------------------------------------|--|------------------------------------|
| Beach nourishment (per meter) | 40 m | 60 m | 60 m | 40 m |
| Dyke heightening (per centimetre) | 50 cm | 75 cm | 50 cm | 50 cm |
| Access to dunes (for access) | no | no | yes (28 km) | no |
| Cliff protection (per kilometre) | 15 km | 15 km | 45 km | 15 km |
| Realignment of dikes and dunes (spots) | 1 spot | 1 spot | 1 spot | 3 (6) spots |
| Wave 1 | | | | |
| CS in € per year per household ^a | | 5.90 (0.56/ 11.26) | 32.01 (16.09/ 47.93) | 23.24 (13.31 / 33.17) |
| CS aggregated in mio € ^b | | 244.9 | 1328.4 | 964.5 |
| Wave 2 | | | | |
| CS in € per year per household ^a | | 9.52 (4.70/ 14.34) | 15.29 (4.04/ 26.54) | 18.46 (7.57 / 29.35) |
| CS aggregated in mio € ^b | | 395.1 | 634.5 | 766.1 |

Note: Welfare measures were calculated without incorporating marginal WTP estimates for the ASCs. In bold are attribute levels that have changed compared to “As today”. CS refers to compensation surplus.

^a The 95% confidence intervals are shown in brackets.

^b The number of households at the time of the survey was 41.5 million (<https://www.destatis.de>; retrieved September 15, 2020)

The mean values of the CS measures clearly differ between waves and would result in different policy conclusions if the aggregated values were incorporated in cost-benefit analysis. Testing whether these measures or the marginal WTP estimates are significantly different is ultimately less informative, in our view, as decision makers generally cannot test for those differences. Looking at the aggregate values in Table 2.5 for each wave, this is very likely the case. In all three scenarios the values aggregated across the target population differ by more than € 150 million between the waves. In the case of the scenario *Recreation*, the aggregate measure even halved in Wave 2.

2.5 Discussion and conclusion

Knowledge about the stability of preferences over time is essential when they are used to inform decision-making. This is especially critical for preferences for public goods such as

(dis)amenities that are stated on hypothetical markets. These preferences might be more susceptible to the valuation context, which might change over time, especially in uncertain times like a pandemic. While test-retest studies of stated preferences exist, this study is one of only a small number of studies to assess preference stability in face of uncertain times such as the current pandemic.

We use a CE focusing on adaptation to climate change along the coast of MWP, Germany. While climate change is more and more advancing, adaptation is becoming increasingly crucial for coastal areas. Literature on people's preferences for coastal adaptation options is limited, so is literature that looks at preference stability. This paper adds to both, but the latter forms the focal point. Along with the Covid-19 pandemic developing significantly in Germany in March and April 2019, the first wave of our survey had to go online. A few months later, the possibility arose to test for preference stability. Applying a matching procedure, we identified 266 respondents who participated in both survey waves. Firstly, the descriptive choice analysis revealed that the share of choices for the alternative *Present measures* increased at the expense of less choices devoted to the two hypothetical, generally more costly alternatives *Alternative A* and *Alternative B*. Secondly, a latent class model with three classes had proven to perform best to model existing preference heterogeneity in both waves. One group of respondents, labelled *dykes*, is willing to pay for an increase in dyke height but is not ready to give up money for a positive change in any other attribute. Respondents in the class *improvement* prefer extensive changes also for attributes such as *access to dunes* and *realignment* in addition to the heightening of dykes. To the contrary, respondents in the class *no payment* are generally not willing to cover any additional expenses required for adapting the German Baltic Sea coast to climate change.

When comparing the results of the two waves in more detail, we find mixed evidence. For two attributes - *beach nourishment* and *cliff protection* - the weighted average WTP values became insignificant in the second wave. For the attribute *dyke extension*, the weighted average WTP value increased while for the attribute *access to dunes* the value rather slightly decreased. A direct comparison of the marginal WTP for the attribute *realignment* is aggravated because the number of potential realignment sites was increased for the second wave. However, we found a lower mean WTP estimate in the second wave for this attribute although the number of realignment sites had increased. This indicates that the mean marginal WTP per relocation site has become smaller. Turning to non-marginal welfare effects, we found a significantly higher effect for the adaptation scenario *Safety* which is due to the attribute dyke. That the value of the

policy scenario *Recreation* decreased is instead driven by the attributes *beach nourishment* and *cliff protection* which became insignificant in Wave 2. The decrease in the value for the scenario *Nature* again is caused by the attribute *realignment*.

Despite the differences between the two waves, a similar preference heterogeneity pattern was revealed by the latent class models. Both times we identify a class of people who focused on dyke heightening, on overall improvements, and who are not willing to pay for adaptation measures. The important difference relates to the change in class sizes. This change indicates that preferences have changed and respondents did choose differently in the second wave. While we observe an increase in the size of the *dykes* labelled class from about 30% to 41%, the size of the *improvement* labelled class decreased from 46% to 32%. For the third class, gathering people who are not willing to pay for adaptation measures, class size increased slightly by 3%. Thus, although the underlying preference heterogeneity pattern remain stable, we observe changes in the size of the latent classes: Fewer respondents are allocated to the class with preferences for overall improvements at the expense of more respondents being assigned to the class only exhibiting preferences for the heightening of dykes. This points, on average, to preference changes towards the most basic and fundamental adaptation measure, dyke heightening. Doing so seems comprehensible, as dykes as hard-engineered constructions may be perceived as safest and thus most important option and stronghold against rising sea-level and flooding events by respondents. Additionally, focusing solely on a single adaptation measure incurs a smaller payment compared with the expenses associated with more extensive adaptation options respondents in the *improvement* labelled class are willing to cover. In this regard, these findings are in line with the results of the descriptive choice analysis that detected a shift of choices from the generally more expensive *Alternative A and B* towards the generally cheaper *Present measures* alternative.

The welfare measures aggregated across the target population result in clearly different values for both waves. For the scenario *Safety*, this estimate has increased by around € 150 million in the second wave. In contrast, for the scenarios *Recreation* and *Nature* there are huge decreases on the order of several million euros. Thus, a cost-benefit analysis using these estimates might reach different conclusions, and decision makers with only the results of the first or the second survey wave available might have concluded differently with respect to investments in adaptation measures. One conclusion from this finding is that in uncertain times it might be necessary to monitor the preferences of the public more closely over time when large-scale investments are involved.

As analysing preference stability in uncertain times, to the best of our knowledge, is novel, a comparison with results from existing literature is rather difficult. However, it can be summarized, that already in secure times, which most existing test-retest studies are embedded in, temporal preference stability is not unambiguous, though a tendency towards stability can be observed. We broadly characterized uncertain times as providing insecure employment opportunities and income perspectives to people. The only other test-retest study that considers the Covid-19 pandemic as setting is by Hynes et al. (2021). However, it is not comparable to our study because it differs regarding the timing of the survey and content wise. Hynes et al. (2021) contrast preferences elicited prior to the pandemic with preferences during the pandemic for environmental management plans on the high seas. Instead, our analysis provides insights on preference stability concerning coastal adaptation at two points in time during the pandemic, i.e. at the advent of the 1 and 2 Covid-19 wave in Germany.

The rather vague term of *uncertain times* as used by us calls for future work on a classification of uncertain times. It is conceivable that, for example, uncertainty during a financial crisis is perceived differently in particular in terms of severity than uncertainty during a pandemic. While the current pandemic is causing financial impairments, its level of uncertainty may nevertheless be perceived lower than, for instance, during a financial crisis. With respect to future research, it would also be interesting to direct investigations towards preference stability in light of an extreme event (e.g., storm flood) representing an external shock which is directly related to the environmental good at consideration as pointed out earlier by Bliem et al. (2012). Applied to coastal adaptation options, it would be interesting to check how preferences especially of local people differ subsequent to a larger storm flood.

A limitation of our study is that we could not test preference stability at the individual level and in particular not test choice stability. This is due to the fact that, because of restrictions of the survey company, it was not possible to assign respondents in the retest survey the choice cards they faced in the test survey. Consequently, we can only report results on the aggregated level of the sample, but not on an individual level.

Overall, our analysis provides insights on preference stability during uncertain times, i.e., preferences captured at the advent of the first and second Covid-19 wave in Germany. That more respondents focus on the heightening of dykes in uncertain times seems plausible. Along with the similar preference heterogeneity pattern found in both survey waves, with differing

class sizes, however, this constitutes a valuable piece of information for policy makers in directing future adaptation efforts at coastal areas at the German Baltic Sea coast.

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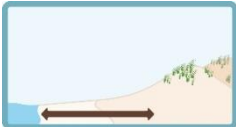
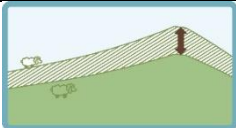


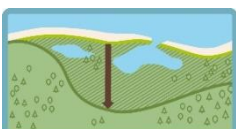

References

- Bliem, M., Getzner, M., Rodiga-Laßnig, P., 2012. Temporal stability of individual preferences for river restoration in Austria using a choice experiment. *Journal of Environmental Management* 103, 65–73, doi:10.1016/j.jenvman.2012.02.029.
- BMEL, 2020. Rahmenplan der Gemeinschaftsaufgabe “Verbesserung der Agrarstruktur und des Küstenschutzes” 2020–2023.
- Brouwer, R., 2006. Do stated preference methods stand the test of time? A test of the stability of contingent values and models for health risks when facing an extreme event. *Ecological Economics* 60(2), 399–406, doi:10.1016/j.ecolecon.2006.04.001.
- Czajkowski, N., Bartczak, A., Budziński, W., Giergiczny, M., Hanley, N., 2016. Preference and WTP stability for public forest management. *Forest Policy and Economics* 71, 11–22, doi:10.1016/j.forpol.2016.06.027.
- Gamper, E., Holzner, B., King, M.T., Norman, R., Viney, R., Nerich, V., Kemmler, G., 2018. Test-retest reliability of discrete choice experiment for valuations of QLU-C10D health states. *Value Health* 21(8), 958–966, doi:10.1016/j.jval.2017.11.012.
- Hanemann, W.M., 1984. Welfare evaluations in contingent valuation experiment with discrete responses. *American Journal of Agricultural Economics* 66, 332–341, doi:10.2307/1240800.
- Hess, S., 2014. Latent class structures: Taste heterogeneity and beyond. In: Hess, S., Daly, A., eds., *Handbook of Choice Modelling*. Cheltenham, 311–329, doi: 10.4337/9781781003152.00021.
- Hynes, S., Armstrong, C.W., Xuan, B.B., Ankamah-Yeboah, I., Simpson, K., Tinch, R., Ressurreiçao, A., 2021. Have environmental preferences and willingness to pay remained stable before and during the global Covid-19 shock? *Ecological Economics* 189, doi:10.1016/j.ecolecon.2021.107142.
- Lew, D.K., Wallmo, K., 2017. Temporal stability of stated preferences for endangered species protection from choice experiments. *Ecological Economics* 131, 87–97, doi:10.1016/j.ecolecon.2016.08.009.
- Liebe, U., Meyerhoff, J., Hartje, V., 2012. Test–retest reliability of choice experiments in environmental valuation. *Environmental and Resource Economics* 53, 389–407, doi: 10.1007/s10640-012-9567-1.
- Loureiro, M., Loomis, J., 2017. How sensitive are environmental valuations to economic downturns? *Ecological Economics* 140, 235–240, doi: 10.1016/j.ecolecon.2017.05.008.

- Mariel, P., Hoyle, H., Meyerhoff, J., Czajkowski, M., Dekker, T., Glenk, K., Jacobsen, J.B., Liebe, U., Olsen, S.B., Sagebiel, J., Thiene, M., 2021. Environmental valuation with discrete choice experiments. In: *Guidance on Design, Implementation and Data Analysis*. Springer.
- Matthews, Y., Scarpa, R., Marsh, D., 2017. Stability of willingness-to-pay for coastal management: A choice experiment across three time periods. *Ecological Economics* 138, 64–73, doi: 10.1016/j.ecolecon.2017.03.031.
- McConnell, K.E., Strand, I.E., Valdés, S., 1998. Testing temporal reliability and carry-over effect: The role of correlated responses in test-retest reliability studies. *Environmental and Resource Economics* 12, 357–374, doi:10.1023/a:1008264922331.
- McFadden, D., 1974. Conditional logit analysis of qualitative choice behaviour. In: P. Zarembka, P., *Frontiers in Econometrics*. New York: Academic Press, 105–142.
- Meyerhoff, J., Rehdanz, K., Wunsch, A., 2021. Preferences for coastal adaptation to climate change: Evidence from a choice experiment. *Journal of Environmental Economics and Policy*, doi: 10.1080/21606544.2021.1894990.
- Morrison, M., Hatfield-Dodds, S., 2011. The success and failure of an inconvenient trust and the stern report in influencing Australian public support for greenhouse policy. *Econ. Rec.* 87(277), 269–281, doi: 10.1111/j.1475-4932.2010.00706.x.
- Rigby, D., Burton, M., PluskeJ., 2016. Preference stability and choice consistency in discrete choice experiments. *Environmental and Resource Economics* 65, 441–461, doi: 10.1007/s10640-015-9913-1.
- Ryan, M., Netten, A., Skåtun, D., Smith, P., 2006. Using discrete choice experiments to estimate a preference-based measure of outcome – an application to social care for older people. *Journal of Health Economics* 25(5), 927–944, doi:10.1016/j.jhealeco.2006.01.001.
- Schaafsma, M., Brouwer, R., Liekens, I., Nocker, L., 2014. Temporal stability of preferences and willingness to pay for natural areas in choice experiments: A test–retest. *Resource and Energy Economics* 38, 243–260, doi:10.1016/j.reseneeco.2014.09.001.
- StALU, 2009. Regelwerk Küstenschutz Mecklenburg–Vorpommern – Übersichtsheft - Grundlage, Grundsätze, Standortbestimmung und Ausblick. Rostock, Germany: Staatliches Amt für Umwelt und Natur - Abteilung Küste - Ministerium für Landwirtschaft, Umwelt und Verbraucherschutz Mecklenburg –Vorpommern.

Appendix

Table A1: Attributes and attribute levels

| Attribute | Pictogram | Description | Attribute levels |
|--|---|--|---|
| Beach nourishment (44 km total) |  | Wider beaches and higher dunes offer better protection for the land behind. Despite the use of groynes, sand is currently being washed up along the coast on 13 sections with a total length of 44 km. To maintain this condition, this process must be repeated every few years. In the future, beach nourishments may also be necessary on further sections. Usually the beach is about 40 m wide after a nourishment. However, less or more sand could also be used for nourishment. | Beach width of: 20 m 40 m 60 m |
| Dyke heightening (227 km total) |  | Dykes protect the land behind them from flooding. In order to meet future requirements for coastal protection, dykes are currently being heightened by 50 cm during scheduled maintenance. However, this increase could also be lower or higher. | Height of: 25 cm 50 cm 75 cm |
| Access to dunes |  | The stability of dunes is increased by planting, especially with beach grass. It also acts as a natural sand catcher. Walking on dunes can impair these functions and is therefore not allowed. In selected sections where dunes are of less importance for coastal protection and where this is compatible with nature conservation, access could be allowed in the future. There, dunes would then have to be maintained more comprehensively. This would involve additional costs. | Length of: 0 km 6 km 15 km 28 km |
| Protection of cliffs |  | The sea continuously erodes parts of the cliffs and shifts the coastline. Breakwaters and seawalls can slow down this process. They are currently used in 10 sections where settlements are endangered by the demolition of cliffs. As a result, 15 km of the cliffs are currently fortified. Further sections could be fortified, for example to preserve coastal cycle or hiking paths for a longer period. | Length of: 15 km 30 km 45 km |
| Realignment of dykes and dunes ^a |  | At selected spots along the coast, the protection line (dykes and dunes) could be moved to the hinterland. There, natural bays and wetlands are created which provide habitats for typical coastal animal and plant species. Access to the areas would be restricted and existing cycle and hiking paths would have to be relocated. The safety of settlements would not be endangered at any time. So far, one major realignment has been implemented on the Zingst peninsula (about 15 km ² or 1500 ha). Similar projects would be conceivable in other parts of the coast. | 1 spot (15 km²) 2 spots (30 km ²) 3 spots (45 km ²) |
| Payment |  | The existing coastal protection in Germany is financed jointly by the federal government and the coastal states from taxes. For further measures in Mecklenburg-Western Pomerania, a new coastal protection levy would have to be charged per household nationwide from 2021 on. It would have to be paid annually for the next 10 years. After this period, the measures would be reassessed, and a decision would be made on further financing. | 0 € , 5 / 10 / 15 € (PM) 8 / 20 / 35 / 70 / 110 / 190 € (A_B) |

Note: Attribute levels in bold indicate current levels; ^a In Wave 2 the attribute levels for realignment of dykes and dunes were increased from 2 and 3 spots to 4 and 6 spots.

Table A2: Logit model participation second wave

| | Coeff. | z-val. |
|---|-----------|--------|
| Female (=1) | 0.314** | 2.23 |
| Age | 0.014 | 3.07 |
| State (categorical) | | |
| Baden-Wuerttemberg | Reference | |
| Bavaria | -0.138 | -0.51 |
| Berlin | -0.184 | -0.46 |
| Brandenburg | 0.298 | 0.76 |
| Bremen | 0.931 | 1.48 |
| Hamburg | 0.068 | 0.14 |
| Hesse | -0.122 | -0.38 |
| Mecklenburg Western Pomerania | -0.318 | -0.56 |
| Lower Saxony | 0.136 | 0.48 |
| North Rhine-Westphalia | 0.024 | 0.10 |
| Rhineland Palatinate | -0.658 | -0.18 |
| Saarland | -0.390 | -0.60 |
| Saxony | 0.122 | 0.35 |
| Saxony-Anhalt | -0.234 | -0.49 |
| Schleswig Holstein | 0.010 | 0.02 |
| Thuringia | 0.333 | 0.79 |
| Higher education (= 1) | -0.210 | -1.26 |
| Household size (number) | -0.022 | -0.31 |
| Income (categories) | | |
| >900€ | 0.240 | 0.68 |
| 900€ - 1.300€ | -0.197 | -0.55 |
| 1.300€ - 1.500€ | Reference | |
| 1.500€ - 2.000€ | 0.065 | 0.19 |
| 2.000€ - 2.600€ | 0.145 | 0.43 |
| 2.600€ - 3.200€ | 0.329 | 0.97 |
| 3.200€ - 4.500€ | 0.243 | 0.73 |
| 4.500€ - 6.000€ | -0.248 | -0.54 |
| > 9000€ | 0.516 | 1.05 |
| not given | -0.020 | -0.06 |
| Visitor at North or Baltic Sea coast (=1) | 0.148 | 0.75 |
| Constant | -2.829*** | -5.96 |
| Number of observations | 1,810 | |

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Third Paper: Evidence from a choice experiment on coastal adaptation: Does distance matter for local preferences?

Abstract

People living in close proximity to the coastline will be the first to be affected by sea level rise and higher storm tides. This applies to people living at the German Baltic Sea coast in Mecklenburg-Western Pomerania (MWP) as well. Using a choice experiment on coastal adaptation to climate change, this paper examines preferences for various protection measures among MWP residents (N=281) including: the extent of beach nourishment, dyke heightening, cliff protection, access to dunes, realignment of dykes and dunes. Cost is expressed as a coastal protection levy. I use standard Conditional Logit (CL) and RPL (Random Parameter Logit) models to analyse whether preference heterogeneity is present in the sample, and whether preferences among residents vary with distance to coast with respect to the two adaptation measures dyke heightening and access to dunes. Results reveal substantial preference heterogeneity for some of the attributes, but this cannot be explained by distance to the coastline. Further, results on the role of distance for respondents' preferences are mixed, only indicating trends for coastal residents. They tend to oppose higher dykes compared to non-coastal residents, and also exhibit a tendency to be more opposed to allow access to dunes. The results shed light on locals' preferences and interests regarding a topic that is to the financial extent largely decided upon at a broader national level, though associated with direct consequences where implemented.

Keywords: adaptation, choice experiment, climate change, coastal protection, preference heterogeneity, distance decay

3.1 Introduction

Climate change poses a considerable threat to coastal areas, with those living near coastlines, including the German Baltic Sea coast in Mecklenburg-Western Pomerania (MWP), among the first to be affected by sea level rise and higher storm tides. Sea level rise here is expected to broadly align with global projections (Meinke, 2020; Bingham & Hughes, 2012; Grindsted, 2015; Pellikka et al., 2020), necessitating enhanced adaptation efforts along this coastline. Recent political momentum in Germany, following the IPCC special report SROCC (IPCC, 2019), has led to agreement among coastal states to adjust dyke precautionary measures and significantly increase government funding for coastal protection from 2023 (LAWA, 2020; FMFA, 2023).

To understand local preferences for adaptation measures, this study employs a choice experiment (CE), a survey method where respondents select their preferred options from sets of hypothetical adaptation scenarios and provides insights into the values and priorities of the public regarding coastal adaptation. Earlier research has highlighted heterogeneous preferences for adaptation measures among the German population (Meyerhoff et al., 2021). Building on that, the current study focuses on whether heterogeneity exists specifically among MWP residents, who are potentially more affected by these changes. The analysis includes a sample of 281 MWP residents, examining whether and how proximity to the coastline influences preferences for adaptation measures, particularly “dyke heightening” and “access to dunes”. These two measures were chosen due to their significance in coastal defence. Dykes, serving as primary barriers against sea level rise and flooding, are a traditional and widely acknowledged method for protecting coastal areas. Their visible presence and direct role in protecting homes and livelihoods make them an essential aspect of coastal management especially from a local point of view. Unlike dykes, intact dunes systems are a nature-based solution to coastal flooding. Walking in dunes is not allowed in MWP. Their relevance for coastal protection was stressed in focus group discussions with coastal residents of MWP (Meyerhoff et al., 2021).

The study hypothesizes that proximity to the coast might affect preferences for dyke heightening and dune access in the following way: Residents closer to the coast may prioritize measures offering higher flood protection, such as higher dykes and intact dune systems, while those further away might consider landscape aesthetics, favouring lower dykes, and value recreational access to dunes. Explicitly, I aim to answer two questions: (1) Is there

heterogeneity in preferences among MWP residents? (2) Do these preferences vary with distance to the coast concerning “dyke heightening” and “access to dunes”?

To answer these questions, I analyse preferences using the Conditional Logit (CL) and the Random Parameter Logit (RPL) model. The CL model, commonly used in CEs, allows for the assessment of main effects and interactions among variables. It operates under the assumption that individual preferences are homogeneous across the sample. The RPL model adds further depth by accounting for both observed and unobserved heterogeneity among respondents. This model is particularly valuable for understanding variations in how different individuals might value the same attribute, such as “dyke heightening” or “access to dunes”. The spatial factor “distance to the coastline” is integrated into both the CL and RPL models by interacting distance to the coast, based on respondents’ postal codes, with the key attributes of “dyke heightening” and “access to dunes”.

This paper expands upon a range of studies that have explored preferences for coastal adaptation strategies. Meyerhoff et al. (2021) provide a recent overview. The studies reviewed generally survey populations expected to be first affected by changes along the coastline, including local residents in coastal or hinterland areas (e.g., Chen et al., 2020; Johnston et al., 2018; Liski et al., 2019) and direct users (Oliveira and Pinto, 2020; Marzetti et al., 2016). To capture preference heterogeneity, studies mostly implement RPL models (e.g., Remoundou et al., 2015; Liski et al., 2019; Johnston et al., 2018) and to a lesser extent latent class models (e.g. Dachary-Bernard et al., 2019; Chen et al., 2020; Meyerhoff et al., 2021). This body of work has uncovered heterogeneous preferences for increased beach sizes through nourishments (Remoundou et al., 2015), realignment strategies (Liski et al., 2019; Dachary-Bernard et al., 2019) and protection against flooding, as well as the loss of beaches and dunes (Johnston et al., 2018). Recent findings, including those from Omori (2021) and Nguyen et al. (2023), indicate preference heterogeneity in aspects such as seawall heightening and dune access. Interestingly, using a latent class model, Meyerhoff et al. (2021) residency in MWP did not differ between the three classes detected there. In the following, the aim is to delve deeper into these findings, particularly focusing on the impact of distance to the coast on local preferences.

Turning to the role of distance, the literature acknowledges that both use and non-use values for environmental goods may vary with space, with potential distance decay effects – meaning that demand for a good decreases with distance to it (e.g., Khan et al., 2019; Liekens et al., 2013; Schaafsma et al., 2012). However, findings from the scarce literature directly related to

coastal adaptation show mixed results. Studies like Chen et al. (2020) and Oliveira and Pinto (2020) report no significant effect of distance on preferences for alternative coastal adaptation and coastal erosion management, respectively. In contrast, Ardeshiri et al. (2019) and Luisetti et al. (2011) observe distance decay effects in the case of beach erosion control and new wetland sites as flood defence, respectively. Further, Christie (2009) identifies differing preferences for increasing seawall heights based on residents' home elevation levels. Furthermore, De Salvo et al. (2018) discover that distance is a significant factor in preferences for emerged barriers and sand nourishments, while Dachary-Bernard et al. (2019) find that it is cognitive, rather than physical distance from the coast that drives public preferences for relocation strategies. These studies integrate the factor of distance in different ways: as one of the attributes of the CE (Ardeshiri et al., 2019; Luisetti et al., 2011), as a variable that might affect the membership function in latent class models (De Salvo et al., 2018; Chen et al., 2020; Dachary-Bernard et al., 2019) and as an explanatory variable included in the utility functions (Oliveira and Pinto, 2020; Christie, 2009).

This paper contributes to the existing literature in several ways. First, it adds to the limited literature on individual preferences for coastal adaptation in response to climate change, especially considering potential preference heterogeneity. Second, it provides valuable insights for policymakers on the preferences of residents who are most immediately and significantly affected by climate change impacts along the Baltic Sea coast. For example, in the absence of adequate coastal protection, a major storm surge could directly impact about 200,000 of the 1.6 million residents of MWP, as indicated by StALU (2009). Third, this research also responds to calls for greater consideration of spatial dimensions in welfare analysis, as highlighted by Glenk et al. (2020). Lastly, by focusing on local preferences, the study acknowledges the high recreational value of the coast for residents and explores how adaptation measures might impact these values. The relevance of this focus is underscored by the fact that nearly everyone in the sample has visited the Baltic Sea coast, with a substantial majority having visited the MWP coast within the year prior to the survey. To sum up, the results contribute to a more informed approach to addressing the challenges posed by climate change along the Baltic Sea coast.

3.2 Choice Experiment on Coastal Adaptation

In a CE, respondents receive several choice sets, which they evaluate one by one. Each choice set contains a number of alternatives to choose from, which are described by so-called attributes. These attributes, in turn, take one of several levels which describe ranges over which

the attributes vary. The CE here elicits preferences on coastal adaptation options to climate change at the German Baltic Sea coast of MWP among residents of MWP.

Meyerhoff et al. (2021) provide detailed information on study area, survey design and implementation focusing on a nationwide sample. Therefore, I will only briefly describe the CE here. Figure 3.1 shows one example choice set. Each choice set comprised four alternatives: two adaptation alternatives (*Adaptation A and B*), an alternative maintaining today's measures (*Present measures*), and an alternative instead maintaining today's budget (*Present budget*). Because costs are likely to increase, maintaining today's measures in the future implies an additional payment compared to today. For the same reason, maintaining today's budget, will not allow to keep the current level of measures in the future. In order that the cost of choosing the alternative *Present measures* is lower than the cost of choosing one of the adaptation alternatives, the payment attribute, a coastal protection levy implemented for the next 10 years, was restricted to lower values for this alternative. The set of non-monetary attributes used to describe coastal adaptation included "classic" coastal protection measures as *beach nourishment* and *dyke heightening*, addressed both recreational and coastal protection aspects related to *access to dunes* and the *protection of cliffs*, as well as the *realignment of dykes and dunes*. *Beach nourishments* add sand to beaches to compensate for erosion. In practice, the aim is to achieve an average width of 40 metres, although this may be adjusted to 20 or 60 metres width in the future. Dykes were raised by 50 cm, at the time of the survey, to accommodate future sea-level rise, with potential adjustments to 25 or 75 cm considered in the CE. While *access to dunes* may offer some recreational opportunities, vegetated dunes primarily serve a coastal protection function. Their stability is maintained by the planting of vegetation, such as beach grass, which can be disturbed by human activity. Controlled access would require the restoration of the vegetation. The implementation of measures designed to slow down cliff erosion, such as the construction of breakwaters and bank walls, protects infrastructure, including cycling and hiking trails. An extension of these protective measures may be possible. Lastly, moving dykes and dunes inland creates new inter-tidal zones for animals and plants. This does not involve relocating houses and has been done successfully on the Zingst peninsula. Dykes and dunes could be realigned at further spots. Appendix B1 includes detailed attribute descriptions.

The CE was part of an online survey that included questions on previous visits to the coast, familiarity with coastal protection measures and general attitudes towards climate change as

well as on coastal protection issues.¹² The finalized online survey was carried out in spring 2020 drawing one sample of MWP residents in addition to the nationwide sample analysed in Meyerhoff et al. (2021).

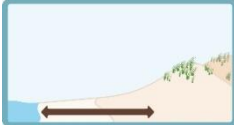
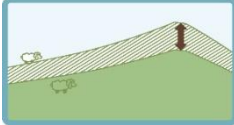


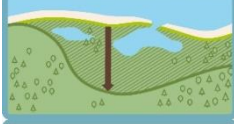

| | | Adaptation A | Adaptation B | Present measures | Present budget |
|---|---|------------------------------------|------------------------------------|---------------------------------|---------------------------------|
| Beach nourishment (44 km total) |  | 60 m width | 20 m width | 40 m width | 20 m width |
| Dyke heightening (227 km total) |  | 25 cm height | 50 cm height | 50 cm height | 25 cm height |
| Access to dunes |  | Yes. Over a distance of 6 km | Yes. Over a distance of 6 km | No | No |
| Protection of cliffs |  | 45 km distance | 15 km distance | 15 km distance | 15 km distance |
| Realignment of dykes and dunes |  | 2 spots (30 km ²) | 1 spot (15 km ²) | 1 spot (15 km ²) | 1 spot (15 km ²) |
| My payment |  | 20 € | 190 € | 5 € | 0 € |
| I choose | | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Figure 3.1: Example choice task

I use the information respondents provide on their postal code or city of their home to calculate the shortest distance (*geodesic*) from a resident's home to the coastline in MWP in R using the function 'dist2Line' of the 'geosphere' package (R. Core Team, 2023; Hijmans, 2022). Distance to the coastline varies with people living directly by the coast (min: 1,5m) and people living about 90km away from it (Figure 3.2). The sample is not spatially balanced, with more observations in cities like Rostock, Schwerin, Wismar and Stralsund (see Figure 3.3). Further, a large share of respondents (72%) can be classified as living in a coastal region following the

¹² The choice scenario was introduced by providing information on past sea-level rise at the German Baltic coast and pointing to projections made by the IPCC for 2050 rendering an increase of coastal protection likely necessary. Respondents were informed that for a gradual implementation of measures up to 2050, choices about adaptation already had to be made today. However, choices would at first affect the next 10 years as the measures would be reassessed after 10 years. Next, respondents were familiarized with the adaptation options and proceeded with the CE.

definition by the European Commission (Eurostat, 2018). The European Commission defines a coastal region as a statistical region of the European Union at NUTS level 3 if it has a coastline or if more than half of its population is living less than 50 km from the sea (Eurostat, 2018)¹³.

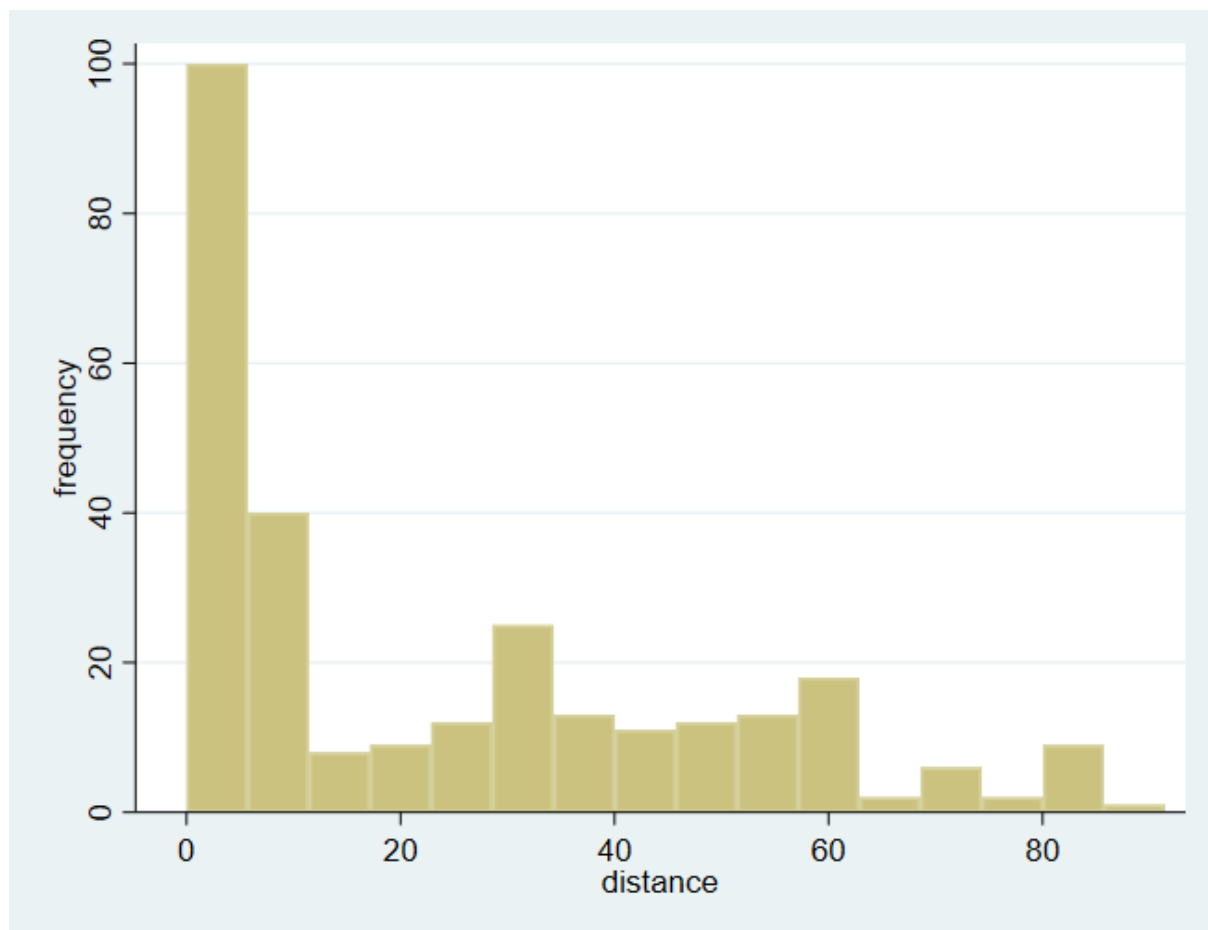


Figure 3.2: Histogram of distance to coast (in km)

¹³ Generally, NUTS-3 regions have a population of 150,000 to 800,000 inhabitants. Germany's NUTS-3 regions typically consist of districts, referred to as "Kreise" or are designated as "kreisfreie Städte" (Statistisches Bundesamt (Destatis), 2023; Eurostat, 2018)

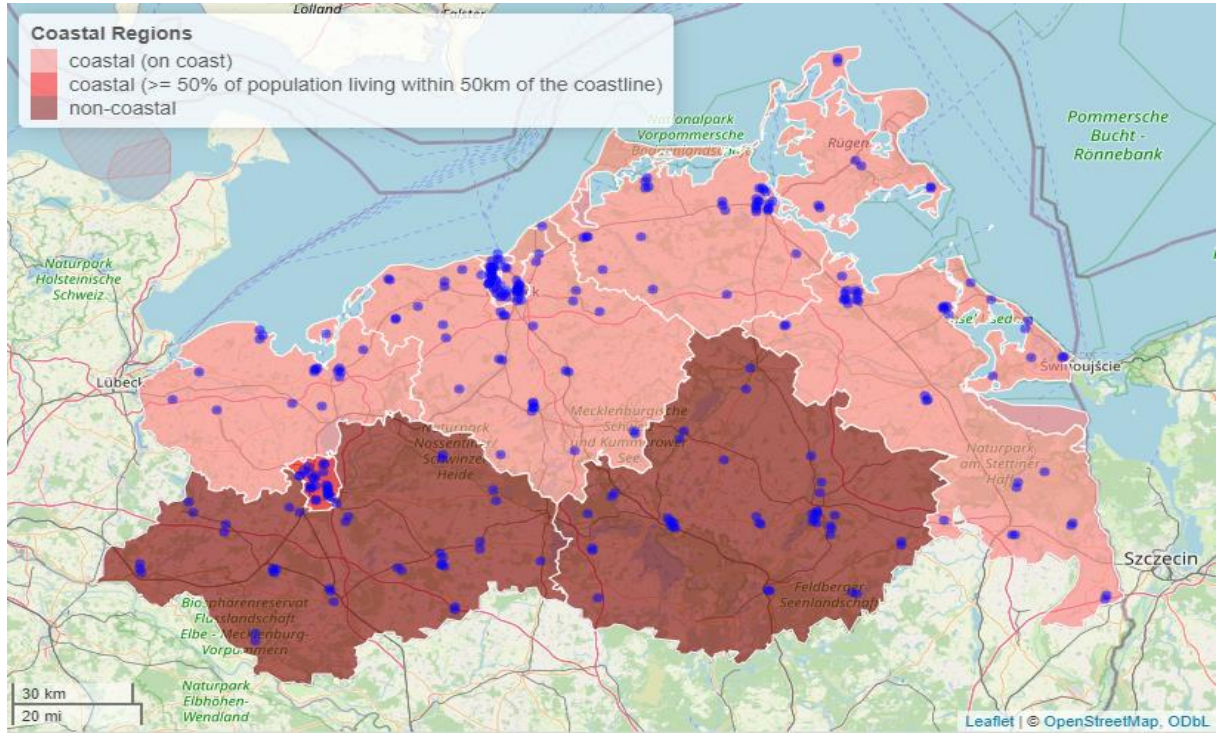


Figure 3.3: Residents' location

^a Own illustration created with the “leaflet” package in R (Cheng et al., 2023). Data is taken from European Environment Agency and Bundesamt für Kartographie und Geodäsie. Jittering of the data points was applied to better account for more data points in larger cities.

^b The map distinguishes between coastal regions with a sea border and coastal regions with 50% of the population living within 50 km distance to the coastline and non-coastal regions. The analysis, however, does not differ between the two definitions for “coastal”.

3.3 Econometric modelling

I apply CL and RPL models (McFadden, 1974; Hensher & Greene, 2003; Revelt & Train, 1998) to analyse the responses from the CE above. These models are based on McFadden’s (1974) random utility theory assuming that researchers cannot observe all factors that influence an individual n ’s preferences. Hence, the latent utility U_{ni} an individual derives from choosing an alternative i out of a set of available alternatives j , is considered to be decomposable into an observable term, V_{ni} , and an unobservable term ε_{ni} . It can be represented as:

$$U_{ni} = V_{ni}(x_{ni}\beta) + \varepsilon_{ni}, \quad (1)$$

with x_{ni} being a vector that contains the attributes (here: *beach nourishment, dyke heightening, access to dunes, protection of cliffs, realignment of dykes and dunes and my payment*) as well as other explanatory variables, and β the vector of corresponding parameters reflecting the desirability of the attributes.

Assuming the unobservable part ε_{ni} to be extreme value type 1 distributed with scale parameter 1, one arrives at the CL model. The choice probability of individual n choosing alternative i then is:

$$P_{ni} = \frac{\exp(V_{ni})}{\sum_{j \in C} \exp(V_{nj})}. \quad (2)$$

The CL builds on the restrictive assumption of homogenous preferences across individuals. To account for unobserved taste heterogeneity, I additionally apply a RPL model (Johnston et al., 2017). The latent utility U_{nit} an individual now derives from choosing an alternative i out of a set of available alternatives j , in choice situation t is:

$$U_{nit} = V_{nit}(x_{nit}\beta_n) + \varepsilon_{nit}, \quad (3)$$

with x_{nit} being a vector of the attribute levels, now in choice situation t and ε_{nit} the unobservable term following a type 1 extreme value distribution again. However, β_n now is no longer fixed as in the CL model, but is a vector of individual-specific parameters. It varies over individuals according to a distribution that has to be specified by the researcher. According to (2), the probability of individual n choosing alternative i in choice situation t conditional on knowing β_n is given by the following expression:

$$L_{nit}(\beta_n) = \frac{\exp(\beta_n' x_{nit})}{\sum_{j \in C} \exp(\beta_n' x_{njt})}. \quad (4)$$

The true log-likelihood function has no analytical form. The parameters that characterize the distribution (e.g., the mean and standard deviation) can be calculated approximately by simulation. Often, the assumption is made that the coefficients are normally distributed, while the cost coefficient is assumed to be fixed or log-normally distributed (Train, 2003). I follow this practice here and assume that the cost coefficient is log-normally distributed, while the coefficients of the non-monetary attributes are normally distributed.

Observable, individual characteristics, as distance to the coast, may influence choices. But, in contrast to attributes, individual-specific characteristics are constant over alternatives. To incorporate this (observable) heterogeneity into the model, one can create interactions between attributes and individual characteristics. Doing so creates differences in utility over the alternatives which ultimately determine the probability of choosing one alternative over the other (Train, 2003). Distance then is directly included into the utility function, both in the CL models and RPL models interacted with the two attributes *dyke heightening* and *access to*

dunes.¹⁴ I test for specifying the distance variable as continuous as well as categorical according to the European Commission definition.¹⁵ In order to do so, I create a dummy variable that indicates whether a respondent lives in a coastal or non-coastal region in MWP (1/0).¹⁶

To gain a better understanding of the results, one can calculate the marginal willingness to pay (MWTP), that relates the coefficients of non-monetary attributes to those of the monetary attribute. Generally, these values are derived as follows: $mWTP = \frac{\beta_{attribute}}{\beta_{money}}$ (Hanemann, 1984; Train, 1998)¹⁷. This reveals how much money individuals are willing to forgo in order to obtain their desired attribute level. However, when using RPL models, there are two important considerations. First, the estimated price parameters in the RPL model are the mean and standard deviation of the natural logarithm of the price coefficient. To obtain the actual values of the coefficient itself, a transformation reverting the estimates to the original scale is necessary (Train, 2003).¹⁸ Second, due to the inherent asymmetry of the log-normal distribution and its susceptibility to outliers, the mean can give a distorted picture of WTP as it can be heavily influenced by extreme values. This limitation makes the mean a less reliable measure in practical applications, leading to potentially implausible estimates. In contrast, the median is not affected by extreme values and is therefore considered a more robust measure of central tendency in such cases. Recognising this, Daly et al. (2012), followed by Sagebiel et al. (2017) and Rommel and Sagebiel (2017), have recommended the use of the median for MWTP calculations. Consequently, I adopt the median as the basis for the analysis presented here. Unless otherwise specified, the analysis was conducted using Stata. The mixed logit model is estimated using the module “mixlogit” for Stata provided by Hole (2007).

¹⁴ In accordance with the previous analysis of the sample in Meyerhoff et al. (2021), I also tested Latent class specifications, with 2, 3 and 4 classes. However, the models could not be interpreted meaningfully or did not converge. In particular, the preference structure that was detected in Meyerhoff et al. (2021) and Wunsch et al. (2022) could not be observed.

¹⁵ Inverse and squared specifications were also tested.

¹⁶ Data from NUTS-postal codes and NUTS-coastal region matching tables were used (*European Union – GISCO, 2021; Eurostat, n.d.*).

¹⁷ Two different cost parameters were estimated to account for different cost sensitivities corresponding to the different alternatives. For welfare calculations I only used the cost parameter that reflects the cost sensitivity corresponding to the two hypothetical adaptation alternatives.

¹⁸ The median, mean and standard deviation are calculated with the following formulae: *Median*: $-\exp(\mu)$; *Mean*: $-\exp\left(\mu + \frac{\sigma^2}{2}\right)$; *St. Dev.*: $\exp\left(\mu + \frac{\sigma^2}{2}\right) * \sqrt{\exp(\sigma^2) - 1}$.

3.4 Results

3.4.1 Sample characteristics

Overall, responses from 281 individuals aged 18 or above were useable for data analysis.¹⁹ The descriptive statistics for the sample and the target population (Table 3.1) indicate that respondents are on average slightly older compared to the target population of MWP. Further, there is a slightly larger share of females in the sample. Net household income per month is higher in the sample population, a finding that is however not uncommon for online surveys (e.g., Lindhjem and Navrud, 2011). The share of people with higher education is larger. Household size is only slightly larger in the sample. By and large, the sample population resembles the target population. A large share of the sample population visited the Baltic Sea

Table 3.1: Descriptive statistics

| <i>Characteristics</i> | Sample population n=281 | | Target population (MWP) ^a 1.61 Mio. in 2020 |
|---|----------------------------|----------|---|
| | mean | std. dev | mean |
| Age ^b (years) | 50.70 | 14.92 | 50.36 |
| Female (%) | 52.67 | | 50.73 |
| Household income ^c (€ per month) | 2386.61 | 1278.73 | 1789.87 |
| Higher education ^d (%) | 47.33 | | 24.84 |
| People per household (number) | 2.16 | 1.12 | 1.92 |
| Recreational visits to the Baltic Sea coast | | | |
| last visit within last 12 months (% yes) | 72.60 | | |
| visit frequency within last 12 months (median) ^e | 5.00 | | |
| Distance to coastline (km) | 24.32 | 24.51 | |
| Living in coastal region (%) | 72.24 | | |

^a Data is taken from www.destatis.de (last retrieved 16.11.2023) and Statistisches Amt Mecklenburg-Vorpommern (2021; 2022; 2022a; 2022b; 2023). Average age includes people aged 17 and above. Higher education refers to the year 2019.

^b Due to some implausible responses to this question the statistics for age are based on 279 responses.

^c Due to missing disclosures and some implausible responses to this question the statistics for household income are based on 225 responses within the range of € 420 to € 10,000.

^d Higher education is defined as education level that qualifies for studying at a university/college.

^e Based on 204 responses of those who actually visited the Baltic Sea coast within the last 12 months before the survey.

¹⁹ Of the 307 individuals residing in MWP, 283 provided information on residence. Further, two individuals were identified as potential protest voters, always choosing the first option “Adaptation A”. Omitting these individuals, the final sample size covers responses from 281 individuals.

Further, I excluded respondents who can likely be considered to be protest voters always choosing the first option “Adaptation A” (2).

coast at least once within 12 months before the survey (73%). The median visit frequency over the last 12 months was 5 times. The figures point out that visiting “their” coast is popular among people living in MWP.

3.4.2 Preferences for coastal adaptation measures

The distribution of decisions among the four alternatives was as follows: Adaptation A accounted for 19.5%, Adaptation B for 22.6%, Present measures for 32.1%, and Present budget for 25.8% (Table 3.2). This shows that, overall, the continuation of today’s measures is a popular alternative.

Table 3.2: Observed choices

| | Frequencies | Percent |
|------------------|-------------|---------|
| Adaptation A | 2,632 | 19.5% |
| Adaptation B | 3,048 | 22.6% |
| Present measures | 4,328 | 32.1% |
| Present budget | 3,480 | 25.8% |
| Total | 13,488 | 100.0% |

Note: N = 281

Table 3.3 shows the estimates from the CL models. Initially treating each attribute as categorical variable revealed that only the *dyke heightening* attribute demonstrated linear effects. Thus, it was treated as a continuous variable in subsequent analyses while the remaining attributes, exhibiting non-linear relationships, were incorporated into the models as dummy-coded variables. The alternative specific constants (ASC) shown in the upper part of Table 3.3 separate the effects of the alternatives. As a reference, the ASC for the alternative *Present measures* (ASC_{PM}) is fixed. In the basic CL model without any interactions, the parameter of the ASC for the alternative *Alternative B* (ASC_B) is positive and significant at the 5%-level, indicating that on average respondents prefer this alternative over the alternative *Present measures* for reasons that are not captured by the attributes.

Turning to the parameters of the attributes: the parameters of the attribute *beach nourishment* (*beach20* and *beach60*) are significant, and both have a negative sign. This means that respondents, on average, prefer the reference situation of 40 m wide beaches after a nourishment. The parameters of the attributes *dyke heightening* (*dyke*) and *cliff protection* (*cliff30* and *cliff45*) are not statistically significant. The CL model assumes that all respondents have the same preferences, so these attributes do not seem to address aspects that are important to all respondents and hence do not systematically influence the stated choices. Further, higher

levels of *access to dunes* were, on average, chosen significantly less often. The parameters of the attribute that capture access over 15km (*access15*) and 28km (*access28*) of length are negative and statistically significant at the 5%-level in comparison to the reference level (0km). Respondents negatively value more locations where dykes and dunes are realigned on average, however this is only statistically significant at the 10% level for one further location (*realign2*). The cost attribute (*Payment_AB*) is highly significant and has the expected negative sign. On average, respondents prefer alternatives with lower payments.

Next, the two attributes of interest *dyke heightening* and *access to dunes* were interacted with distance (measured continuously). The parameters of the interaction effects are not statistically significant for any of the attributes. So, respondents' preferences with respect to these two coastal adaptation measures do not vary with proximity to the coastline. In addition, the dummy variable *coastal region*, that captures whether a respondent lives in a coastal region or not was interacted with the two attributes. For the dyke attribute, the main effect represents the preference parameter of non-coastal residents (coast = 0). The *dyke heightening* attribute interacted with the coastal resident dummy variable reveals that there is a difference between coastal region residents and non-coastal region residents. Non-coastal residents have a positive coefficient for dyke heightening, which is statistically significant at the 5%-level. The positive sign indicates that higher dykes increase indirect utility for this group of respondents. The interaction term between dyke and the coastal resident dummy is negative and significant at the 1%-level. The coefficient estimate of the dyke attribute for coastal residents is the sum of the two terms (i.e., $0.005 + (-0.006) = -0.001$), indicating that coastal residents in contrast to non-coastal residents oppose higher dykes. Turning to *access to dunes*, the main effects are not statistically significant. However, the negative, mostly not significant, interaction effects with the coastal region dummy variable indicate a tendency towards coastal residents being more opposed to allow access to dunes.

Table 3.3: Estimates from conditional logit model (CL)

| | Basic CL | | Interacted with distance | | Interacted with coastal region | |
|-----------------------|-----------|----------|--------------------------|----------|--------------------------------|----------|
| ASC_A | 0.241 | (1.53) | 0.245 | (1.55) | 0.241 | (1.53) |
| ASC_B | 0.388** | (2.47) | 0.392** | (2.50) | 0.390** | (2.48) |
| ASC_PM | | | <i>Reference</i> | | | |
| ASC_PB | -0.061 | (-0.42) | -0.064 | (-0.44) | -0.064 | (-0.44) |
| Beach20 | -0.301*** | (-2.99) | -0.299*** | (-2.96) | -0.302*** | (-2.99) |
| Beach40 | | | <i>Reference</i> | | | |
| Beach60 | -0.178* | (-1.79) | -0.177* | (-1.78) | -0.178* | (-1.79) |
| Dyke | 0.001 | (0.65) | -0.000 | (-0.01) | 0.005** | (2.41) |
| Access0 | | | <i>Reference</i> | | | |
| Access6 | -0.082 | (-0.80) | -0.119 | (-0.95) | 0.026 | (0.17) |
| Access15 | -0.216** | (-2.31) | -0.295** | (-2.56) | 0.118 | (0.85) |
| Access28 | -0.181** | (-2.11) | -0.089 | (-0.86) | -0.066 | (-0.52) |
| Cliff15 | | | <i>Reference</i> | | | |
| Cliff30 | -0.097 | (-1.09) | -0.099 | (-1.12) | -0.099 | (-1.11) |
| Cliff45 | -0.009 | (-0.11) | -0.010 | (-0.13) | -0.006 | (-0.08) |
| Realign1 | | | <i>Reference</i> | | | |
| Realign2 | -0.152* | (-1.75) | -0.153* | (-1.77) | -0.154* | (-1.78) |
| Realign3 | -0.016 | (-0.21) | -0.020 | (-0.26) | -0.016 | (-0.21) |
| Payment_AB | -0.009*** | (-10.50) | -0.009*** | (-10.52) | -0.009*** | (-10.52) |
| Payment_PM | -0.017* | (-1.87) | -0.017* | (-1.86) | -0.017* | (-1.85) |
| Dist*dyke | | | 0.000 | (0.91) | | |
| Dist*access6 | | | 0.002 | (0.53) | | |
| Dist*access15 | | | 0.003 | (1.19) | | |
| Dist*access28 | | | -0.004 | (-1.52) | | |
| Coast*dyke | | | | | -0.006*** | (-2.66) |
| Coast*access6 | | | | | -0.149 | (-0.94) |
| Coast*access15 | | | | | -0.462*** | (-3.15) |
| Coast*access28 | | | | | -0.157 | (-1.16) |
| N | 13488 | | 13488 | | 13488 | |
| Log likelihood (Null) | -4674.6 | | -4674.6 | | -4674.6 | |
| Log likelihood | -4469.9 | | -4467.3 | | -4459.9 | |
| Chi2 | 409.3 | | 414.5 | | 429.4 | |

t statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The RPL model, which I use to capture unobserved heterogeneity among respondents, provides a more nuanced picture (Table 3.4). The coefficients of all attributes were specified as random. The coefficient of the cost attribute (*Payment_AB*) was specified to follow a log-normal

distribution.²⁰ The remaining attributes were specified with a normal distribution. The interaction terms were specified as non-random. Further, 1000 Halton draws were used.²¹

In the basic RPL model without interactions, the parameters of the ASCs for the alternative *Adaptation A/ B* (*ASC_A* and *ASC_B*) are positive and highly significant, indicating that, on average, respondents do prefer these alternatives over the alternative *Present measures* for reasons that are not captured by the attributes. The parameter of the ASC for the alternative *Present budget*, in turn, is negative and highly significant here. This result suggests that respondents at least want to keep today's measures even if this is associated with a higher payment. Turning to the attributes, the mean coefficients of *dyke heightening*, *cliff protection* of 30 km compared to 15 km (*cliff30*) and *realignment* of three spots (*realign3*) are positively significant. On average, respondents are in favour of higher dykes, increased cliff protection and two further spots where dykes and dunes are realigned as a measure to adapt to the consequences of climate change. The mean coefficients of *beach nourishment* (*beach20* and *beach60*) are negatively significant as in the CL model. Respondents oppose a deviation from the reference of 40 meters beach width after a nourishment.

There is preference heterogeneity present for all of the non-monetary attributes except *access6* and *access15* and *cliff30*, as well as for the alternative specific constants. This is indicated by the statistically significant standard deviations of the parameters displayed in the first column in the lower part of Table 3.4. Following the considerations in Omori (2021), calculating the specific percentage of the distribution of the attributes lying above or below zero provides insight into the average response of respondents to that attribute. For example, the distribution of the dyke heightening attribute had an estimated mean of 0.005 and an estimated standard deviation of 0.010 (Table 3.4, first column), such that 69.4% of the distribution was above zero and 30.6% was below.²² Thus, slightly more than two-third of the respondents favour dyke heightening, while one-third opposes it.

As the estimated price parameters in the RPL model are the mean and standard deviation of the natural logarithm of the price coefficient *Payment_AB*, the median, mean, and standard deviation of the price coefficient itself are calculated using the formulae outlined in the econometrics modeling chapter 3.3. Exemplary values for the model without interactions are as follows: median = -0.124; mean = -0.035; standard deviation = 0.432. I calculated the standard

²⁰ The coefficient of the second cost attribute (*Payment_PM*) is assumed to be fixed.

²¹ The number of draws was increased gradually up to 1000 and different starting values were tested.

²² This is for a calculated z-score of -0.508.

errors using nlcom. All values are highly significant at the 1%-level. The mean and the median value of the cost attribute parameter are negative. A negative sign means that with increasing costs utility decreases. In line with intuition lower costs are preferred also here. Further, the standard deviation of 0.423 implies unobserved preference heterogeneity in the cost attribute. That the RPL demonstrates a superior fit to the CL model, is revealed by its higher chi-square value of 3376.8 and a greater improvement in the log likelihood, from -4469.9 (Null) to -2781.5. Especially, with respect to the *dyke* attribute and the *access28* attribute, it is of interest to see whether the preference heterogeneity in these attributes can be attributed to the proximity to the coastline. This would become evident if significant interaction effects as well as decreased standard deviations are found. Moving to the right in table 3.4, it can be observed that the parameter of the interaction term of the attribute *dyke* heightening with distance is not statistically significant. Thus, the preference heterogeneity with respect to the *dyke* attribute cannot be explained by proximity to the coastline. The significant standard deviation of *dyke* indicates that there are other unobserved sources of preference heterogeneity. The main effects of the *access to dunes* attribute are not statistically significant. The interaction terms with *access6* and *access15* are positive, albeit only weakly significant at the 10%-level.

Turning to the model specification with the two attributes of interest interacted with the coastal region dummy, neither the coefficient of the *dyke* attribute nor its interaction is significant. The parameters of *access6* and *access15* become positive significant at the 5% and the 10%-level, respectively. Further, their interactions with the dummy variable are negative significant. This indicates that coastal region residents generally value *access to dunes* less positive than non-coastal residents which is in line with the tendency observed in the CL model.

Table 3.4: Estimates from random parameters logit model (RPL)

| | Basic RPL | | Interacted with distance | | Interacted with coastal region | |
|-----------------------|-----------|----------|--------------------------|----------|--------------------------------|----------|
| Mean | | | | | | |
| ASC_A | 1.107*** | (4.86) | 1.104*** | (4.85) | 1.113*** | (4.88) |
| ASC_B | 1.278*** | (5.74) | 1.272*** | (5.71) | 1.280*** | (5.75) |
| ASC_PM | | | Reference | | | |
| ASC_PB | -4.558*** | (-5.42) | -4.566*** | (-5.68) | -4.528*** | (-5.70) |
| Beach20 | -0.593*** | (-4.16) | -0.590*** | (-4.13) | -0.591*** | (-4.14) |
| Beach40 | | | Reference | | | |
| Beach60 | -0.329** | (-2.32) | -0.326** | (-2.30) | -0.328** | (-2.31) |
| Dyke | 0.005** | (2.32) | 0.006** | (1.99) | 0.004 | (1.13) |
| Access0 | | | Reference | | | |
| Access6 | 0.225 | (1.58) | -0.020 | (-0.11) | 0.595** | (2.37) |
| Access15 | 0.197 | (1.46) | 0.005 | (0.03) | 0.672*** | (2.89) |
| Access28 | 0.129 | (0.95) | 0.185 | (1.09) | 0.284 | (1.32) |
| Cliff15 | | | Reference | | | |
| Cliff30 | 0.235* | (1.92) | 0.229* | (1.79) | 0.226* | (1.78) |
| Cliff45 | 0.150 | (1.28) | 0.151 | (1.29) | 0.145 | (1.24) |
| Realign1 | | | Reference | | | |
| Realign2 | 0.178 | (1.36) | 0.176 | (1.33) | 0.170 | (1.28) |
| Realign3 | 0.274** | (2.29) | 0.271** | (2.25) | 0.277** | (2.31) |
| Payment_AB | -3.354*** | (-22.35) | -3.392*** | (-22.44) | -3.385*** | (-22.39) |
| Payment_PM | 0.027* | (1.92) | 0.027* | (1.95) | 0.0271* | (1.93) |
| Dist*dyke | | | -0.000 | (-0.39) | | |
| Dist*access6 | | | 0.010* | (1.95) | | |
| Dist*access15 | | | 0.008* | (1.71) | | |
| Dist*access28 | | | -0.003 | (-0.60) | | |
| Coast*dyke | | | | | 0.001 | (0.28) |
| Coast*access6 | | | | | -0.529* | (-1.83) |
| Coast*access15 | | | | | -0.666** | (-2.54) |
| Coast*access28 | | | | | -0.229 | (-0.96) |
| SD | | | | | | |
| ASC_A | 0.518*** | (4.15) | 0.525*** | (4.19) | 0.514*** | (4.06) |
| ASC_B | 0.283* | (1.88) | 0.264* | (1.73) | 0.263* | (1.73) |
| ASC_no | 7.820*** | (8.68) | 7.815*** | (8.91) | 7.837*** | (8.77) |
| Beach20 | 0.358* | (1.95) | 0.335* | (1.69) | 0.337* | (1.74) |
| Beach60 | 0.504*** | (3.56) | 0.498*** | (3.54) | 0.496*** | (3.54) |
| Dyke | 0.010** | (2.57) | 0.010*** | (2.62) | 0.010** | (2.50) |
| Access6 | 0.312 | (1.11) | 0.325 | (1.16) | 0.344 | (1.28) |
| Access15 | 0.291 | (1.35) | -0.239 | (1.07) | 0.266 | (1.24) |
| Access28 | 0.617*** | (3.46) | 0.610*** | (3.33) | 0.632*** | (3.55) |
| Cliff130 | 0.017 | (0.04) | 0.258 | (0.69) | 0.218 | (0.56) |
| Cliff145 | 0.749*** | (5.75) | 0.752*** | (5.77) | 0.750*** | (5.77) |
| Realign2 | 0.558** | (2.33) | 0.629*** | (2.66) | 0.640*** | (2.75) |
| Realign3 | 0.710*** | (5.37) | 0.717*** | (5.41) | 0.720*** | (5.45) |
| Payment_AB | 1.592*** | (14.35) | 1.601*** | (14.18) | 1.604*** | (14.26) |
| N | 13488 | | 13488 | | 13488 | |
| Log likelihood (Null) | -4469.9 | | -4467.3 | | -4459.9 | |
| Log likelihood | -2781.5 | | -2777.6 | | -2777.4 | |
| Chi2 | 3376.8 | | 3379.5 | | 3365.0 | |

t statistics in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; SD – standard deviation

3.4.3 Willingness to pay for coastal adaptation

Table 3.5 presents the median MWTP estimates in € per year per household, exemplary for the basic RPL.²³ With respect to the attribute beach nourishment, respondents would on average experience clear disutilities for levels other than those of today's extent. For a reduction of beach width from 40 m to 20 m they would need to be compensated by €16.99, while needing to be compensated by €9.43 for an increase of 40 m to 60 m as well. Both median MWTP estimates are significant at the 1% and the 5%-level, respectively. For an additional centimetre of dyke heightened, respondents would be willing to pay €0.14 on average. Further, the median MWTP for 30 meters of cliff protected instead of 15 metre and for realigning dykes and dunes at 3 instead of 1 spot are €6.73 and €7.85 per household per year.

Table 3.5: Median MWTP estimates (in €/ year/ household) based on basic RPL

| | WTP | Confidence interval |
|--------------------------------|------------|----------------------------|
| Beach nourishment | | |
| 40 m => 20 m | -16.99*** | (-25.69 / -8.28) |
| 40 m => 60 m | -9.43** | (-17.47 / -1.39) |
| Dyke heightening (per cm) | 0.14** | (0.02 / 0.27) |
| Access to dunes | | |
| 0 km => 6 km | 6.45 | (-1.39 / 14.29) |
| 0 km => 15 km | 5.65 | (-1.91 / 13.21) |
| 0 km => 28 km | 3.70 | (-3.88 / 11.27) |
| Cliff protection | | |
| 15 m => 30 m | 6.73* | (-0.13 / 13.59) |
| 15 m => 45 m | 4.29 | (-2.15 / 12.33) |
| Realignment of dikes and dunes | | |
| 1 spot => 2 spots | 5.09 | (-2.15 / 12.33) |
| 1 spot => 3 spots | 7.85** | (0.92 / 14.79) |

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

To return to the CL model, that exhibited a significant main and interaction effect for the dyke attribute and the coastal region dummy, the MWTP estimate for non-coastal residents would be €0.60 ($p < 0.05$; CI: 0.1/ 1.11) per centimetre of dyke heightening, while €-0.09 for coastal residents. However, the latter is not significant ($p > 0.1$; CI -0.46 / 0.28).

3.5 Discussion and conclusion

This study focused on understanding local preferences for coastal adaptation strategies in Mecklenburg-Western Pomerania (MWP), Germany. Using a CE specific emphasis was on

²³ Doing so is especially justified as the model fit when including interaction effects does not significantly increase.

examining two key aspects: preference heterogeneity and the influence of proximity to the coastline on preferences for dyke heightening and access to dunes.

First, the CE revealed significant heterogeneity in preferences among the respondents. This aligns with previous findings in the literature (e.g., Omori, 2021; Nguyen et al., 2023; Remoundou et al., 2015; Liski et al., 2019; Dachary-Bernard et al., 2019), suggesting a diverse range of views on coastal adaptation strategies. With respect to the heightening of dykes, two other studies even detected similar preference patterns. For the case of a moderate SLR scenario between 0.5 and 1.0 m, Omori (2021) observes that roughly two-third of the respondents favour heightening, while one-third oppose it. Similarly, Meyerhoff et al. (2021) using a Germany-wide sample to analyse preferences for coastal adaptation at the coast of MWP, detect about 77% of their sample to derive positive utility of heightened dykes, while the remaining 23% deriving a clear disutility. Further, in terms of magnitude, the marginal WTP of €0.15 per centimetre they estimated at least for those likely to be in the dykes class is comparable to the median MWTP estimates of €0.14 per centimetre dyke heightening I find among MWP residents.

Second, the study found mixed results with respect to the role of physical distance from the coastline for preference formation. Again, the scarce literature on distance directly related to coastal adaptation provides mixed results itself. In the CL model preferences for the two measures, dyke heightening and access to dunes, do not vary with proximity to the coastline, when considering distance as continuous. However, coastal residents tend to oppose higher dykes compared to non-coastal residents, and there is an indication that coastal residents may also exhibit a tendency to be more opposed to allowing access to dunes, although the latter effect was generally not statistically significant. In the RPL model with distance interactions, proximity to the coastline does not significantly explain preference heterogeneity for dyke heightening, suggesting other unobserved factors at play. Coastal region residents generally value access to dunes less positively than non-coastal residents, a trend consistent with the CL results.

The results deviate from my initial expectations on two aspects. Firstly, I had anticipated that the distance of one's residence from the coastline would play a clear and significant role in constructing preferences. Secondly, I held a clearer expectation regarding the direction of effects. Initially, I expected that individuals living closer to the coast would exhibit stronger preferences for hard coastal protection measures such as dyke heightening. I also hypothesized

that they would place greater importance on dune vegetation for coastal protection, implying a focus on the aspect of coastal defence. Conversely, I had anticipated that individuals residing farther from the coast might prioritize recreational aspects i.e. lower dykes and more accessible dunes.

In line with my intuition, Christie (2009) did find preferences with respect to dykes (calling it seawalls) to significantly differ between respondents living in lower and upper Borth, a coastal village in the UK, with Lower Borth residents being at higher risk of flooding with no raised dyke, and upper Borth residents' sea view being affected by higher dykes. Lower Borth residents, so those closer to the shoreline, indeed derive positive utility from heightened dykes, while upper Borth residents incur a disutility. However, Christies (2009) differentiation between the two groups of residents differs from mine in the way that the definition of coastal region resident that I use, says nothing about whether someone is at risk of flooding or not. A coastal region resident in MWP, being and/or feeling not at risk of flooding, may well perceive higher dykes as intrusive to the landscape. This is further supported by the findings of Johnston et al. (2018), who argue that it is perhaps not surprising that the protection of built assets in their study has a lower value to residents than is typically assumed, as a large proportion of respondents are not at risk of flooding and place limited value on the protection of other people's assets. In the same vein, non-coastal residents may perceive dykes as coastal defence structure per se and attribute dykes the largest effects in terms of protection while not feeling impaired because of the distance to it.

Turning to dune access, so far, no study looked at the role of distance and access to dunes. The study by Nguyen (2023) considers access to dunes explicitly and finds that respondents prefer limited access. However, they do not assess whether these preferences differ with distance. Access to dunes in MWP is currently prohibited because of keeping their coastal protection function. I could not reject my hypothesis that respondents in closer proximity to the coastline value the importance of dunes for coastal protection higher. However, I could only observe a tendency in the data that is in line with my intuition.

A limitation of this study is the spatial imbalance in the sample distribution, which compromised the ability to categorize distance groups effectively. The construction of groups here was solely theory driven and based on the coastal region definition by the European Commission. Further, it may indeed not be the physical distance from the coast that drives public preferences, but rather a cognitive or psychological distance. For example, Dachary-

Bernard et al. (2019) could detect that cognitive distance matters for preferences for relocation strategies. However, no questions which can detect psychological distance, nor individual risk perception, were included in the survey here. Future research could especially benefit from integrating flooding maps into the analysis, offering a more detailed assessment of risk exposure and potentially addressing the cognitive aspects of distance in preference formation, as suggested by Dachary-Bernard et al. (2019).

The study's results suggest that uniform coastal adaptation measures may not effectively address the needs of diverse groups within MWP. Policymakers should consider tailored approaches and differentiated communication strategies to accommodate the varied interests and preferences of residents. This approach is crucial for ensuring effective and inclusive policy implementation along the Baltic Sea coast. In summary, while revealing preference heterogeneities among MWP residents for coastal adaptation, the study highlights the complex nature of preference formation and the need for nuanced policy approaches that go beyond simple assumptions about the influence of physical proximity.

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References

- Ardeshiri, A., Swait, J., Heagney, E. C., & Kovac, M., 2019. Willingness-to-pay for coastline protection in New South Wales: Beach preservation management and decision making. *Ocean and Coastal Management* 178, doi:10.1016/j.ocecoaman.2019.05.007.
- Bingham, R. J., & Hughes, C. W., 2012. Local diagnostics to estimate density-induced sea level variations over topography and along coastlines. *J. Geophys. Res-Oceans* 117, doi:10.1029/2011jc007276.
- Bliemer, M. C. J., & Rose, J. M., 2013. Confidence intervals of willingness-to-pay for random coefficient logit models. *Transp. Res. B Methodol.* 58, 199–214, doi:10.1016/j.trb.2013.09.010.
- Chen, Z., Swallow, S. K., & Yue, I. T., 2020. Non-participation and heterogeneity in stated: A double hurdle latent class approach for climate change adaptation plans and ecosystem services. *Environmental and Resource Economics* 77, 35–67, doi:10.1007/s10640-020-00434-z.
- Cheng, J., Karambelkar, B. & Xie, Y., 2022. leaflet: Create Interactive Web Maps with the JavaScript 'Leaflet' Library. R package version 2.1.1.
- Christie, M., 2009. An economic assessment of the amenity benefits associated with alternative coastal defence options. *Reef Journal* 1(1), 247-266.
- Dachary-Bernard, J., Rey-Valette, H., & Rulleau, E. B., 2019. Preferences among coastal and inland residents relating to managed retreat: Influence of risk perception in acceptability of relocation strategies. *Journal of Environmental Management* 232, 772-780, doi:10.1016/j.jenvman.2018.11.104.
- Daly, A., Hess, S., & Train, K., 2012. Assuring finite moments for willingness to pay in random coefficient models. *Transportation* 39, 19–31, doi:10.1007/s11116-011-9331-3.
- De Salvo, M., Signorello, G., Cucuzza, G., Begalli, D., & Agnoli, L., 2018. Estimating preferences for controlling beach erosion in Sicily. *AESTIMUM* 72, 27-38, doi:10.13128/AESTIMUM-23739.
- European Union – GISCO, 2021. Postal code point dataset, Licence CC-BY-SA 4.0.
- Eurostat, 2018. Methodological manual on territorial typologies.
- Eurostat, n.d.. Methodology - Coastal, island and outermost regions.
- Federal Ministry of Food and Agriculture (FMFA), 2021. Rahmenplan der Gemeinschaftsaufgabe “Verbesserung der Agrarstruktur und des Küstenschutzes” 2021-2024. Bonn.

- Federal Ministry of Food and Agriculture (FMFA), 2023. Planungsausschuss für Agrarstruktur und Küstenschutz fasst Beschluss über Änderungen für den GAK-Rahmenplan 2023-2026. Pressemitteilung 02. Feb 2023 Nr. 14/2023.
- Glenk, K., Johnston, R. J., Meyerhoff, J., & Sagebiel, J., 2020. Spatial dimensions of stated preference valuation in environmental and resource economics: Methods, trends and challenges. *Environmental and Resource Economics* 75(2), 215–242, doi:10.1007/s10640-018-00311-w.
- Grinsted, A., 2015. Projected change – Sea level rise. In BACC II Author Team (Eds.), Second assessment of climate change for the Baltic Sea basin regional climate studies (pp. 253-263). Springer Cham, doi:10.1007/978-3-319-16006-1.
- Hagedoorn, L. C., Addo, K. A., Koetse, M. J., Kinney, K., & van Beukering, P. J., 2021. Angry waves that eat the coast: An economic analysis of nature-based and engineering solutions to coastal erosion. *Ocean & Coastal Management* 214, 105945, doi:10.1016/j.ocecoaman.2021.105945.
- Hanemann, W. M., 1984. Welfare evaluations in contingent valuation information with discrete responses. *Am. J. Agric. Econ.* 66(3), 332–341, doi:10.2307/1240800.
- Hensher, D. A., & Greene, W. H., 2003. The mixed logit model: The state of practice. *Transportation* 30, 133–176, doi:10.1023/A: 1022558715350.
- Hijmans, R., 2022. *_geosphere: Spherical Trigonometry_*. R package version 1.5-18.
- Hole, A. R., 2007. Fitting mixed logit models by using maximum simulated likelihood. *Stata Journal*, 7(3), 388–401, doi:10.1177/1536867X0700700306.
- IPCC, 2019. Special report on the ocean and cryosphere in a changing climate. Edited by H.-O. Pörtner, D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, et al. Translated by U1606. Cambridge: Cambridge University Press.
- Johnston, R. J., Boyle, K. J., Adamowicz, W., Bennett, J., Brouwer, R., Cameron, T. A., & Hanemann, W. M., 2017. Contemporary guidance for stated preference studies. *Journal of the Association of Environmental and Resource Economists* 4(2), 319– 405, doi:10.1086/691697.
- Johnston, R. J., Makriyannis, C., & Whelchel, A. W., 2018. Using ecosystem service values to evaluate tradeoffs in coastal hazard adaptation. *Coastal Management* 46, 259-277, doi:10.1080/08920753.2018.1474067.
- Khan, S. U., Khan, I., Zhao, M., Chien, H., Lu, Q., Sufyan Ali, M. A., Khan, A. A., & Fahad, S., 2019. Spatial heterogeneity of ecosystem services: A distance decay approach to quantify willingness to pay for improvements in Heihe River Basin ecosystems.

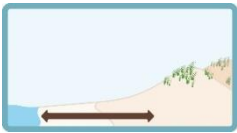
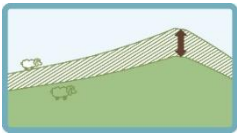




- Environmental Science and Pollution Research* 26, 25247–25261, doi:10.1007/s11356-019-05691-0.
- LAWA, 2020. Auswirkungen des Klimawandels auf die Wasserwirtschaft – Bestandsaufnahme, Handlungsoptionen und strategische Handlungsfelder 2020 (Kurtzitel: LAWA Klimawandel-Bericht 2020). Bund/Länder-Arbeitsgemeinschaft Wasser (LAWA) (in German)
- Liekens, I., Schaafsma, M., De Nocker, L., Broekx, S., Staes, J., Aertsens, J., & Brouwer, R., 2013. Developing a value function for nature development and land use policy in Flanders, Belgium. *Land Use Policy* 30(1), 549–559, doi:10.1016/j.landusepol.2012.04.008.
- Lindhjem, H., & Navrud, S., 2011. Are internet surveys an alternative to face-to-face interviews in contingent valuation? *Ecological Economics* 70(9), 1628-1637, doi:10.1016/j.ecolecon.2011.04.002.
- Liski, A. H., Koetse, M. J., & Metzger, M. J., 2019. Addressing awareness gaps in environmental valuation: Choice experiments with citizens in the Inner Forth, Scotland. *Regional Environmental Change* 19, 2217-2229, doi:10.1007/s10113-018-01458-4.
- Luisetti, T., Turner, R. K., Bateman, I. J., Morse-Jones, S., Adams, C., & Fonseca, L., 2011. Coastal and marine ecosystem services valuation for policy and management: Managed realignment case studies in England. *Ocean and Coastal Management* 54(3), 212–224, doi:10.1016/j.ocecoaman.2010.11.003.
- Marzetti, S., Disegna, M., Koutrakis, E., Sapounidis, A., Marin, V., & Martino, S., 2016. Visitors’ awareness of ICZM and WTP for beach preservation in four European Mediterranean regions. *Marine Policy* 63, 100-108, doi:10.1016/j.marpol.2015.10.005.
- McFadden, D., 1974. Conditional logit analysis of qualitative choice behaviour. In P. Zarembka (Ed.), *Frontiers in Econometrics* (pp. 105–142). New York: Academic Press.
- Meinke, I., 2020. Küste im Wandel. In EUCC – Die Küsten Union Deutschland e.V. (Hrsg.), *Meer & Küste – Deutsche Ostsee*, 8, 6-7. Warnemünde.
- Meyerhoff, J., Rehdanz, K., & Wunsch, A., 2021. Preferences for coastal adaptation to climate change: Evidence from a choice experiment. *Journal of Environmental Economics and Policy* 10(4), 374–390, doi:10.1080/21606544.2021.1894990.
- Nguyen, T., Kling, D. M., Dundas, S. J., Hacker, S. D., Lew, D. K., Ruggiero, P., & Roy, K., 2023. Quality over quantity: Nonmarket values of restoring coastal dunes in the US Pacific Northwest. *Land Economics* 99(1), 63-79, doi:10.3368/le.040721-0036R.

- Oliveira, S., & Pinto, L. M. C., 2020. Choice experiments to elicit the users' preferences for coastal erosion management: The case of Praia da Amorosa. *Environment, Development and Sustainability* 644, doi:10.1007/s10668-020-00768-0.
- Omori, Y., 2021. Preference heterogeneity of coastal gray, green, and hybrid infrastructure against sea-level rise: A choice experiment application in Japan. *Sustainability* 13(16), 8927, doi:10.3390/su13168927.
- Pellikka, H., Särkkä, J., Johansson, M., & Pettersson, H., 2020. Probability distributions for mean sea level and storm contribution up to 2100 AD at Forsmark (p. 49). Swedish Nuclear Fuel and Waste Management Company (SKB).
- R Core Team, 2023. *_R: A language and environment for statistical computing_*. R Foundation for Statistical Computing, Vienna, Austria.
- Remoundou, K., Diaz-Simal, P., Koundouri, P., & Rulleau, B., 2015. Valuing climate change mitigation: A choice experiment on a coastal and marine ecosystem. *Ecosystem Services* 11, 87–94, doi:10.1016/j.ecoser.2014.11.003.
- Revelt, D., & Train, K., 1998. Mixed logit with repeated choices: Households' choices of appliance efficiency level. *Review of Economics and Statistics* 80(4), 647–57, doi:10.1162/003465398557735.
- Rommel, K., & Sagebiel, J., 2017. Preferences for micro-cogeneration in Germany: Policy implications for grid expansion from a discrete choice experiment. *Appl Energy* 206, 612–622, doi:10.1016/j.apenergy.2017.08.216.
- Sagebiel, J., Glenk, K., & Meyerhoff, J., 2017. Spatially explicit demand for afforestation. *Forest Policy Econ* 78, 190–199, doi:10.1016/j.forpol.2017.01.021.
- Schaafsma, M., Brouwer, R., & Rose, J., 2012. Directional heterogeneity in WTP models for environmental valuation. *Ecological Economics* 79, 21–31, doi:10.1016/j.ecolecon.2012.04.013.
- StALU, 2009. Regelwerk Küstenschutz Mecklenburg–Vorpommern – Übersichtsheft - Grundlage, Grundsätze, Standortbestimmung und Ausblick. Rostock, Germany: Staatliches Amt für Umwelt und Natur - Abteilung Küste - Ministerium für Landwirtschaft, Umwelt und Verbraucherschutz Mecklenburg -Vorpommern.
- Statistisches Amt Mecklenburg-Vorpommern, 2021. Bevölkerung nach Alter und Geschlecht in Mecklenburg-Vorpommern Teil 1: Kreisergebnisse – 2020. Statistische Berichte. A133K 2020 00 (in German)
- Statistisches Amt Mecklenburg-Vorpommern, 2022. Statistisches Jahrbuch Mecklenburg-Vorpommern 2022. Z011 2022 00 (in German)

- Statistisches Amt Mecklenburg-Vorpommern, 2022a. Mecklenburg-Vorpommern – Ein Porträt in Zahlen. Schwerin (in German)
- Statistisches Amt Mecklenburg-Vorpommern 2022b. Bevölkerung nach Alter und Geschlecht in Mecklenburg-Vorpommern. Statistische Berichte. A133K 2021 00 (in German)
- Statistisches Amt Mecklenburg-Vorpommern, 2023. Einkommen 2021 in M-V. Pressemitteilung 09.05.2023 Nr. 35/2023 (in German)
- Statistisches Bundesamt (Destatis), 2023. NUTS classification.
- Train, K., 2003. Discrete choice methods with simulation. Cambridge: Cambridge University Press, doi:10.1017/CBO9780511805271.
- Train, K. E., 1998. Recreation demand models with taste differences over people. *Land Econ.* 74(2), 230–239, doi:10.2307/3147053.
- Wunsch, A., Meyerhoff, J.& Rehdanz, K., 2022. A test–retest analysis of stated preferences in uncertain times. *Economic Analysis and Policy* 73, 725-736, doi:10.1016/j.eap.2021.12.021.

Appendix

Table B1: Attributes and attribute levels

| Attribute | Pictogram | Description | Attribute levels |
|---|---|--|---|
| Beach nourishment (44 km total) |  | Wider beaches and higher dunes offer better protection for the land behind. Despite the use of groynes, sand is currently being washed up along the coast on 13 sections with a total length of 44 km. To maintain this condition, this process must be repeated every few years. In the future, beach nourishments may also be necessary on further sections. Usually the beach is about 40 m wide after a nourishment. However, less or more sand could also be used for nourishment. | Beach width of: 20 m 40 m 60 m |
| Dyke heightening (227 km total) |  | Dykes protect the land behind them from flooding. In order to meet future requirements for coastal protection, dykes are currently being heightened by 50 cm during scheduled maintenance. However, this increase could also be lower or higher. | Height of: 25 cm 50 cm 75 cm |
| Access to dunes |  | The stability of dunes is increased by planting, especially with beach grass. It also acts as a natural sand catcher. Walking on dunes can impair these functions and is therefore not allowed. In selected sections where dunes are of less importance for coastal protection and where this is compatible with nature conservation, access could be allowed in the future. There, dunes would then have to be maintained more comprehensively. This would involve additional costs. | Length of: 0 km 6 km 15 km 28 km |
| Protection of cliffs |  | The sea continuously erodes parts of the cliffs and shifts the coastline. Breakwaters and seawalls can slow down this process. They are currently used in 10 sections where settlements are endangered by the demolition of cliffs. As a result, 15 km of the cliffs are currently fortified. Further sections could be fortified, for example to preserve coastal cycle or hiking paths for a longer period. | Length of: 15 km 30 km 45 km |
| Realignment of dykes and dunes |  | At selected spots along the coast, the protection line (dykes and dunes) could be moved to the hinterland. There, natural bays and wetlands are created which provide habitats for typical coastal animal and plant species. Access to the areas would be restricted and existing cycle and hiking paths would have to be relocated. The safety of settlements would not be endangered at any time. So far, one major realignment has been implemented on the Zingst peninsula (about 15 km ² or 1500 ha). Similar projects would be conceivable in other parts of the coast. | 1 spot (15 km²) 2 spots (30 km ²) 3 spots (45 km ²) |
| Payment |  | The existing coastal protection in Germany is financed jointly by the federal government and the coastal states from taxes. For further measures in Mecklenburg-Western Pomerania, a new coastal protection levy would have to be charged per household nationwide from 2021 on. It would have to be paid annually for the next 10 years. After this period, the measures would be reassessed, and a decision would be made on further financing. | 0 € , 5 / 10 / 15 € (PM) 8 / 20 / 35 / 70 / 110 / 190 € (A_B) |

Note: Attribute levels in bold indicate current level

Erklärungen

Erklärung zum selbständigen Verfassen der Arbeit:

Ich erkläre hiermit, dass ich meine Doktorarbeit „Governing climate change adaptation at the Baltic Sea coast“ selbstständig und ohne fremde Hilfe angefertigt habe und, dass ich als Koautorin maßgeblich zu den weiteren Fachartikeln beigetragen habe. Alle von anderen Autor:innen wörtlich übernommenen Stellen, wie auch die sich an die Gedanken anderer Autor:innen eng anlehnenden Ausführungen der aufgeführten Beiträge wurden besonders gekennzeichnet und die Quellen nach den mir angegebenen Richtlinien zitiert.

Ort, Datum:

Kiel,

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