Chapter 6

Conclusions, policy recommendations, and future research directions

6.1 Summary of the main findings

The nuclear accident of 2011 in Fukushima, Japan, and the subsequent transition of the world's energy supply towards the increasing use of renewable sources spurred the Swiss government to develop a new long-term energy policy (SFOE, 2013). A key pillar of this policy, called "Energy Strategy 2050", is the expansion of hydropower. Taking into account that the hydropower industry in Switzerland faces considerable uncertainty with respect to its long-term economic viability and its public acceptance, an expansion of hydropower production is a challenging task.

Embedded in this policy context, this dissertation has aimed to shed light on the public's preferences for hydropower, building upon international experience by means of a global meta-analysis, and by a discrete choice experiment (DCE) carried out among a representative sample of the Swiss population. The meta-analysis quantitatively analyzed the economic values for hydropower externalities, and explained their determinants based on available secondary data from the existing literature, while the DCE elicited public preferences and willingness-to-pay (WTP) for a hypothetical expansion of hydropower among the Swiss population. The central hypothesis postulated in this PhD thesis is that public preferences for an expansion of hydropower in Switzerland are intrinsically linked

to the phasing-out of nuclear power, as the Swiss Energy Strategy 2050 envisages a partial replacement of nuclear energy with hydropower. An expansion of hydropower is likely to render the phasing-out of nuclear power more probable, because it would compensate for a decline in the country's electricity production. This PhD dissertation has contributed to the existing literature by demonstrating the importance of nuclear risk as an indirect externality of hydropower. The role of nuclear risk perception in public preferences for hydropower expansion was captured by including nuclear risk as an explicit choice attribute in the DCE design. This is the first study in the stated preference (SP) literature that explicitly links public preferences for reducing nuclear risk to public preferences for a renewable source of energy. On the basis of the findings, it is recommended that future SP studies which elicit preferences for a specific source of energy should also take into account public preferences, attitudes, and the WTP for other sources of energy.

The main focus of the chapters of this thesis was to test two standard economic axioms underlying consumer choice (monotonicity and continuity), as well as the conventional assumption that preferences are known and stable in the context of a DCE. Moreover, the significance of prospect theory, and, in particular, the reference dependence of choice behavior, in this specific risk management context was examined.

Chapter 2 aimed at explaining the variation observed in the non-market values for hydropower externalities worldwide. For this purpose, a quantitative meta-analysis of existing studies that estimated the non-market values of hydropower externalities was performed. The contribution presented here is novel, since this is the first quantitative meta-analysis that focuses exclusively on hydropower externalities. Sample and study characteristics were controlled for in the estimated meta-regression models. The obtained results suggest the existence of public aversion towards the deterioration of landscape, vegetation, and wildlife caused by hydropower operations. In contrast, empirical evidence on respondents' WTP for mitigating the hydropower impacts on these environmental resources is limited. The avoidance of greenhouse gas emissions, which is the most important positive external effect of hydropower electricity generation, proved to exert a significant positive influence on welfare estimates, but only in combination with the share of hydropower in a country's national electricity production. In other words, the positive effect of hydropower on greenhouse gas emissions is only valued in countries that already have a high share of hydropower in their national electricity supply. This is possibly related to

a higher level of public awareness in these countries of the beneficial effects of hydropower on greenhouse gas emissions. It was also found that the impacts of hydropower on aesthetic and recreational amenities do not exert a significant influence on welfare measures. The analysis furthermore showed sensitivity to scope across all externalities.

The results from the meta-analysis served as inputs in designing the DCE on a hypothetical expansion of hydropower in Switzerland. The DCE aimed to elicit public preferences for the proposed hydropower extension, accounting for the reduction in nuclear power risk, and at the same time answer the main methodological research questions of this dissertation. Chapter 3 investigated the common and idiosyncratic determinants of choice certainty, choice consistency, and choice monotonicity in DCEs. These factors are linked to the axiom of monotonicity and the standard assumptions of known and stable preferences made in microeconomic theory. Adding to the existing literature, Chapter 3 investigated these concepts simultaneously and was based on the same sample of respondents. This allowed for an assessment of their common and idiosyncratic determinants. The results provided several insights. First, there are significant differences between the choice behavior of certain and uncertain respondents, as well as between consistent and inconsistent respondents. Second, no procedural effect of posing the choice certainty question was found. This holds for both an entire choice-task sequence and individual choice tasks. The latter effect had not been tested before in the literature. Third, the position of a repeated choice task had no effect on choice consistency. Finally, a variety of idiosyncratic determinants of choice certainty, consistency, and monotonicity were identified, and only gender and the utility difference between choice alternatives were identified as common drivers. It was found that female respondents display less certainty but a higher degree of consistency and monotonicity in their choice behavior. Both measures of choice-task complexity were found to be relevant for choice certainty, but only the utility difference was reported to have an effect on consistency and monotonicity, by and large consistent with previous research in this particular area of choice-task complexity.

A common violation of the standard economic axiom of preference continuity in DCEs is attribute non-attendance (ANA). Chapter 4 aimed to answer the research question which concerned how a visual measure of ANA based on mouse-tracking performs in explaining ANA behavior compared with stated and inferred ANA. It represents the first study that investigates ANA in DCEs by

means of mouse-tracking. Contrary to eye-tracking, mouse-tracking records visual activity online, which has a number of distinct advantages over eye-tracking, such as lower survey costs and access to a larger pool of potential respondents. The results of Chapter 4 support the findings reported in the existing studies that analyze ANA using eye-tracking data (Balcombe, Fraser, and McSorley, 2015; Van Loo et al., 2014). The performance of the choice models that incorporate mouse-tracking information on ANA was compared with models that use stated and inferred ANA information. The results suggest that choice models estimated using visual ANA data do not outperform the models estimated using stated ANA information. Nevertheless, choice models based on visual ANA result in a slight improvement over both choice models that do not take ANA into account and choice models that use inferred ANA information.

Finally, Chapter 5 addressed the question whether comparative risks shown on risk ladders serve as reference points, and hence influence the preferences and welfare estimates for changes in risks. Chapter 5 is concerned with a key assumption in prospect theory, i.e. the dependence of preferences on reference points. As opposed to most of the valuation literature, which assumes that reference points coincide with the status quo, this chapter hypothesized that different ranges of probabilities of comparative risks on risk ladders also serve as reference points in the choice process of survey respondents. The obtained results support theoretical expectations: While keeping the location of the valued risk change constant in the two risk ladders, the ladder with a wide range of probabilities associated with comparative risks has a smaller impact on respondents' choices than the risk ladder with a narrow range of probabilities. This finding is supported by the observed differences in marginal WTP for the risk changes between the two samples that were shown the two different risk ladders. More generally, the findings in Chapter 5 suggest that it is improbable that comparative risks serve as a unique reference point, and it is expected that multiple reference points, including the status quo, influence respondents' choices in DCEs.

6.2 Directions for future research

This dissertation suggests a number of new directions for future research concerning the methodological aspects of DCEs. To start, the work presented here emphasizes the potential benefits of using visual tracking technologies to better monitor and understand the visual information acquisition process of DCE

respondents. Although the impact of using mouse-tracking information in the estimated choice models in Chapter 4 proved to be limited, more studies using mouse-tracking are needed to assess the robustness of the results found here, as it provides several crucial advantages over eye-tracking. In general, mouse-tracking can be used to extend the limits to the amount of information that can be inferred from stated choice data, since deeper insights into the axioms and assumptions of consumer choice theory can be gained by establishing a clearer relationship between respondents' visual activity and choice behavior.

Specific research questions of interest here include, among others, "How does the visual activity of certain, consistent, and monotonic respondents in a DCE vary between uncertain, inconsistent, and non-monotonic participants?" and "How does the understandability of a DCE or task complexity relate to their visual representation?" The visual activity of respondents who state a high survey understandability, or who spend much time on informational pages, may be contrasted with the visual activity patterns of survey participants who state a low understandability or who spend only a little time on informational pages. Such research may provide detailed insights into the characteristics of a well-understood DCE. Also, the tracking of the visual information acquisition process may contribute to understanding gender differences related to the choice-making process, which is currently an under-researched aspect. Such research could lead to improvements in the design of DCEs, and produce results that are less prone to choice uncertainty, inconsistency, and non-monotonicity, hence increasing the conformity of choice behavior with the assumptions underlying consumer choice in economics.

Research using visual data could provide more definite insights into precisely how ANA behavior manifests itself visually, and increase the reliability of the results found in this PhD thesis. Further studies could possibly aim to 'dynamically' adjust a choice design based on an individual's visual activity during a choice-task sequence. It could, for example, be investigated whether adjusting the position of an attribute in a choice task alters the visual attendance by respondents who displayed non-attendance to this attribute in prior choice tasks. Similarly to how mouse-tracking can be used to gain information on ANA, there is potential to use mouse-tracking for investigating other heuristics in attribute processing, such as lexicographic or elimination-by-aspects decision strategies. As an example, further research could focus on whether common-metric attributes are evaluated separately or combined. Frequent gaze shifting between two common-metric attributes as revealed by mouse-tracking may indicate a

combined evaluation of attributes. Finally, visual data can also provide more in-depth knowledge about the premises of prospect theory. This thesis argued for the existence of reference points that are associated with the communication of risk information preceding the actual choice tasks. Visual data could help to identify relevant reference points by mapping the visual uptake of information to choice behavior. As an example, the relative importance of textual and graphical information and their potential role as reference points could be further investigated.

However, visual tracking methods also seem to have a limit with respect to how much information on choice behavior can be obtained. Deeper insights may be gained by applying neuroeconomic methods. Neuroeconomics is the logical continuation in the development of economic theory. While behavioral economics attempts to uncover the psychological basis of economic choice in contrast to standard economic theory, neuroeconomics aims to explain economic behavior from a biological point of view. Neuroeconomic studies assess the neural antecedents of economic behavior, and try to find neural representations of value and utility (see, e.g., Bruce, Crespi, and Lusk (2015) and Lusk et al. (2016) for and overview). Up till now, there have been only a few applications of neuroeconomics in the realm of the economic valuation of environmental resources (e.g. Sawe, 2017; Sawe and Knutson, 2015). Most neuroeconomic valuation studies use functional magnetic resonance imaging (fMRI), when respondents answer valuation questions in a DCE or a contingent valuation setting. fMRI tracks blood oxygenation level-dependent signals over time which represent neural activity in a certain brain region (Sawe, 2017). Some studies that investigate the link between the activity in certain parts of the brain and choice behavior have been able to predict individual choice decisions (Lusk et al., 2016). Other studies have managed to: distinguish true zero values from protest bids; measure the degree of abstraction that a scenario has for a survey respondent; visualize the influence of positive or negative affective responses on WTP; and link neural responses associated with specific choice attributes to ANA behavior (Sawe, 2017; Sawe and Knutson, 2015). In conclusion, more research on the neural correlates of environmental choice behavior would likely yield more profound insights into the heuristics and biases that characterize the behavior of respondents in DCEs.

6.3 Policy recommendations

The results obtained from the meta-analysis in Chapter 2 provide several policy-relevant indications. A strong impact of negative hydropower externalities on economic values, combined with a lack of significant public WTP for mitigating such effects, suggests a challenging point of departure for policies which aim to expand hydropower and/or mitigate its negative environmental impacts. This result shows that the prevention of negative environmental externalities of hydropower projects, such as the impacts on landscape, vegetation, and wildlife, is paramount. Projects in environmentally sensitive areas, for example, conservation areas or national parks, are hence likely to meet public resistance. At the same time, mitigating the negative environmental effects of a hydropower project should not lead to additional public spending. The results of the meta-analysis also suggest that an expansion of hydropower is more likely to receive public support in those countries that already have a high share of hydropower in their national electricity production. Finally, and in contrast to the findings of the literature on wind power (e.g. Mattmann, Logar, and Brouwer, 2016b) and photovoltaics (e.g. Faiers and Neame, 2006), the aesthetic and recreational impacts of hydropower projects do not prove to play a significant role and, hence, represent secondary concerns in planning procedures.

In this dissertation, the DCE conducted on a representative sample of Swiss respondents produced various results that are relevant for Swiss energy policy. First of all, an initial survey question on a hypothetical popular vote indicates that an overwhelming majority of the survey participants (92%) stated that they would vote in favor of an expansion of hydropower if they had the opportunity to do so. Moreover, 78% of the survey respondents expressed their approval of phasing-out nuclear power. This finding is corroborated by respondents' answers about preferred energy sources: Only 5.7% of the respondents included nuclear power among their preferred sources of energy, while 63.3% of them claimed that hydropower would represent one of their favorite sources of energy. Only coal and oil are less preferred primary sources of energy than nuclear power, whereas only solar and wind power are preferred to hydropower.

The importance of the choice attribute concerning a reduction in nuclear risk for the preferences for the potential expansion of hydropower supports the need for a holistic view on energy policy. This is relevant not only for the purpose of research design, but also from a policy point of view. Changes in energy policy are more likely to receive public support if the anticipated relationships between

the different sources of energy are clearly explained.

The choice model estimated for the entire sample of survey respondents indicates a high WTP for the extension of existing hydropower plants relative to the construction of new plants (roughly 180 Swiss Francs (CHF) per household and per year). This finding reflects substantial public WTP to avoid the detrimental environmental effects of additional hydropower generation, since respondents were informed that extensions lead to weaker, and new constructions to stronger, environmental consequences. This positive WTP for reducing the negative environmental effects of hydropower contradicts the results from the international literature synthesized in the meta-analysis. The Swiss public seems to be willing to pay a significant amount of money in order to avoid the adverse environmental impacts of hydropower, which is not unambiguously the case in a global setting. In Switzerland, an expansion of hydropower that focuses on the extension of existing plants is hence more likely to be successful than an expansion that requires the construction of new facilities, even if the former involves higher costs.

Finally, the risks associated with hydropower expansion and the phasing-out of nuclear power are important drivers of public preferences. The annual average WTP per household for an increase in the risk of dying from a dam breach by 20% instead of 40% amounts to roughly 70 CHF, while the WTP for a reduction in the risk of dying from a nuclear accident by 60% instead of 30% equals 160 CHF. Although these money values seem high, they only imply an increase of the average annual electricity bill of a Swiss household of between 8% and 19%. Assuming an expansion scenario that resulted in the lowest WTP, i.e. an expansion based on constructing new plants that is associated with an increase in hydropower risk of 40% and a decrease in nuclear risk of 20%, the average annual WTP per household for an expansion of hydropower amounts to an increase of the current average electricity bill of almost 50%. In conclusion, these results suggest a considerable WTP for a future expansion of hydropower in Switzerland.