PATTERN

Providing operational economic appraisal methods and practices for decision-making on climate and environmental policies

Best Practices in economic appraisal methods

Deliverable 1.2

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1. EXECUTIVE SUMMARY

This document is the deliverable D1.2 – Best practices in Economic Appraisal Methods of the European Union's Horizon Europe project PATTERN - Providing operational, economic appraisal methods and practices for decision-making on climate and environmental policies (hereinafter referred to as PATTERN), project reference: 101056734.

Here we analyse a number of economic appraisal methods used in the context of climate and biodiversity policies in order to extract best practices that can be useful in the case studies in PATTERN. Section 1 provides a general description of the main approaches related to the proposed analysis in the case studies. In section 2 we revise several applied case studies to extract common best practices proposed in the different approaches. Section 3 is focusing on the methods proposed for the PATTERN case studies evaluation: Q-method, discrete choice experiment, carbon handprint, life cycle impact assessment, REMES-EU CGE model and Agent based model. Finally, section 4 accounts for the main challenges and needs identified in the analysis.

When analysing economic appraisal methods, it is important to consider the specific goals and objectives of the project or policy, as well as the context in which it will be implemented. Different methods may be suitable depending on the specific circumstances of the project or policy. Some best practices identified for using economic appraisal methods in PATTERN include: (i) clearly defining the scope of the analysis; (ii) using appropriate discount rates; (iii) use reliable data and to consider all relevant costs and benefits, tangible and intangible; (iv) to conduct sensitivity analysis to understand how changes in key assumptions or variables can affect the results of the analysis; (v) to consult with relevant practitioners to ensure that the analysis reflects their concerns and interests. Overall, the best practice for using economic appraisal methods is to use a combination of approaches and to carefully consider the specific context and goals of the project or policy.

Conducting effective appraisal methods requires a thorough understanding of the relevant valuation approaches and techniques, as well as the ability to address challenges and needs that may arise during the appraisal process.

The intended audience of the PATTERN Project Management Plan consists of participant organizations of the PATTERN consortium, the Project Officer, and the Financial Officer.

1.0 State of the art: A description of PATTERN related economic appraisal methods

1.1 Revealed and stated preferences methods

a. Method description

Revealed preference methods and stated preference methods are two different approaches that can be used to study consumer behaviour in economics.

Revealed preference methods are based on the idea that people's preferences can be inferred from their observed choices in the market. For example, if a person consistently buys a certain brand of cereal over other brands, it can be inferred that they prefer that brand of cereal. Revealed preference methods can be useful for studying consumer behaviour because they are based on actual data and do not require people to directly report their preferences. However, these methods can be limited in some cases because they only consider observed choices and do not account for factors that may have influenced those choices, such as the availability of certain products or changes in the consumer's income.

Stated preference methods, on the other hand, are based on the idea that people's preferences can be directly elicited through surveys or other methods. In a stated preference study, people are typically asked to make choices between different hypothetical products or scenarios, and their responses are used to infer their preferences. Stated preference methods can be useful because they allow researchers to directly elicit people's preferences and to study a wider range of choices than what might be possible in the market. However, these methods can be subject to bias because people's stated preferences may not always match their actual behaviour in the market.

Overall, both revealed preference methods and stated preference methods have their advantages and disadvantages, and the appropriate approach to use can depend on the specific research question and context. Revealed preference technique is used to estimate the use value only; on the other hand, stated preference technique is applicable to estimate both use and non-use value. This indicates that stated preference technique has broader scope than revealed preference. Revealed preference methods can provide valuable insights into people's actual behaviour, but they may not capture all the factors that influence people's decisions. On the other hand, stated preference methods can provide more detailed information about people's preferences, but they may not always reflect people's true preferences or the choices they would make in the market.

The stated preferences method is a technique used in economics and other fields to measure the preferences or values of individuals for certain goods or services. This method involves asking individuals directly about their preferences through surveys or other forms of questionnaires. The responses are then used to determine the relative importance or value that individuals place on different options and then used to construct a model or framework that can be used to analyse the preferences of the individuals in the study. This method can be useful for evaluating the potential demand for a product or service, as well as for comparing the preferences of different groups of people.

This method can be useful for evaluating the potential demand for a product or service, as well as for comparing the preferences of different groups of people.

b. Recent method improvements

The stated and revealed preferences method is a way of measuring people's preferences and choices to inform policy decisions. One improvement that has been made to this method is the use of more sophisticated modelling techniques to better understand the underlying preferences of individuals. This has allowed for more accurate predictions of behaviour and better targeting of policy interventions. Additionally, the use of survey data and other forms of direct feedback from individuals has helped to improve the accuracy of stated preferences. This has allowed policy makers to consider the preferences of the public more effectively when making decisions.

c. Methodology challenges

There are several challenges associated with the methodology of revealed and stated preference analysis. Some of the most significant challenges include:

- Incomplete or inaccurate data: Revealed preference data are often based on observed behaviour, which may be incomplete or may not accurately reflect the true preferences of individuals or households. For example, individuals may not have the opportunity to consume all the goods or services that they prefer, or they may not have the information or resources needed to make the best choices. Similarly, stated preference data may be subject to errors or biases, such as survey response bias or self-selection bias.
- Difficulties in disentangling preference from other factors: Revealed and stated preference data often reflect the combined effects of multiple factors, such as individual preferences, income, and prices. This can make it difficult to disentangle the effects of preference from other factors and can lead to errors in the estimates of preference.
- Modelling and estimation challenges: Revealed and stated preference data are often used to estimate the preferences of individuals or households, or to model the behaviour of markets. This requires the use of sophisticated statistical and econometric methods, which can be challenging to apply in practice. The accuracy and reliability of the results obtained from revealed and stated preference data will depend on the quality of the modelling and estimation methods used.

Overall, the methodology of revealed and stated preference analysis is subject to several challenges, which can affect the accuracy and reliability of the results obtained from the data. These challenges can be addressed through careful data collection and analysis, and by using appropriate modelling and estimation methods.

d. Application areas

Revealed and stated preference data can be used in a wide range of fields and areas of study, including economics, sociology, psychology, and environmental science. Some specific examples of the types of applications for revealed and stated preference data include:

- Developing consumer demand models: Revealed preference data can be used to develop models that estimate the demand for different goods or services by consumers, based on their observed behaviour in the market. These models can be used to understand how demand for different goods or services varies over time and can help to inform decision-making by firms and policy makers.
- Evaluating the effectiveness of interventions: Stated preference data can be used to evaluate the effectiveness of interventions or policies by eliciting the preferences of individuals or households before and after the intervention is implemented. This can help to identify the factors that influence the effectiveness of the intervention and can inform the design of future interventions.
- Measuring the value of non-market goods or services: Revealed or stated preference data can be used to measure the value that individuals or households place on non-market goods or services, such as the value of clean air or the value of improved healthcare. This can help to inform the design of policies or interventions that aim to improve the availability or quality of these goods or services.

Overall, revealed, and stated preference data can be applied to a wide range of fields and areas of study and can provide valuable insights into the preferences of individuals and households.

e. Type of results

Revealed and stated preference refers to the preferences of individuals or households that are directly elicited through surveys or other methods of direct questioning. The type of results that can be obtained from revealed and stated preference data will depend on the specific research question and the methods used to analyse the data. In general, however, revealed, and stated preference data can be used to:

- Estimate the value that individuals or households place on different goods or services, such as the value of clean air or the value of improved healthcare.
- Identify the factors that influence the preferences of individuals or households, such as their income, their age, or their education level.
- Understand how preferences change over time, such as how preferences for certain goods or services may change because of changes in the economy or the environment.
- Develop policies or interventions that are based on the preferences of individuals or households, such as policies that aim to improve the efficiency of the market or policies that aim to promote certain behaviours.

Overall, revealed, and stated preference data can provide valuable insights into the preferences of individuals and households and can be used to inform decision-making and policy development.

f. How to deal with uncertainty?

One way to deal with uncertainty in the stated and revealed preferences method is to use modelling techniques that account for this uncertainty. This can involve using probabilistic models that incorporate a range of possible outcomes, rather than just a single expected outcome. This can help to account for the fact that people's preferences and choices may not always be consistent or predictable. Additionally, incorporating feedback from individuals and using survey data can help to improve the accuracy of stated preferences, which can reduce uncertainty in policy decisions. Overall, the key to dealing with uncertainty in this context is to use a combination of sophisticated modelling techniques and direct feedback from individuals to better understand and predict behaviour.

1.2 Environmental and Social Impact Assessments (ESIA)

a. Method description

Environmental and Social Impact Assessment (ESIA) is a method of policy evaluation that offers great potential for integrating scientific policy analysis into a socio-economic perspective. Social impact assessment is defined as “the process of identifying the future consequences of a current or proposed action which are related to individuals, organizations and social macro-systems” (Becker, 2001).

Currently, there are several techniques for assessing the social impacts within a system. The studies performed by Brouwer and Van Ek (2004), Klang et al. (2003) and Kijak and Moy (2004)are examples of these approaches. They aimed to carry out sustainability assessments, applying different procedures for the social analysis. Common methodological aspects of these studies are the data collection procedures and data sources considered for the study: local social reports, the opinions of social experts and interviews with local stakeholders (citizens, companies, local authorities, etc.). These studies proposed the application of scores and the interpretation of results are performed based on the comparison with international or local social regulations (Aparcana & Salhofer, 2013).

Environmental and Social Impact Assessments (ESIAs) are evaluations of the potential environmental and social impacts of a proposed project or activity. ESIAs are typically carried out before the project is implemented, to identify any potential negative impacts and to propose measures to mitigate or avoid those impacts.

ESIAs are often required by governments or other regulatory bodies as a condition of granting approval for a project. They are intended to ensure that the project is carried out in a way that is environmentally and socially responsible, and that any negative impacts are minimized.

ESIAs typically involve several steps, including:

1. Identifying the potential impacts of the project, including both positive and negative impacts.
2. Assessing the likelihood and significance of each potential impact.
3. Developing measures to mitigate or avoid any negative impacts.
4. Developing an implementation plan for the project, including the proposed mitigation measures.
5. Monitoring the project during implementation to ensure that the mitigation measures are effective and that any unanticipated impacts are identified and addressed.

Overall, ESIAs are an important tool for ensuring that projects are carried out in a way that is environmentally and socially responsible, and that any potential negative impacts are identified and addressed.

b. Recent method improvements

Policy oriented social research has changed substantially in the recent times (Becker, 2001). The major developments are that:

(i) Not only computer simulation but also gaming or man-based simulations is available.

(ii) The number of practitioners of social impact assessment is growing progressively all over the world. In many Western countries social impact assessment is obligatory now in the preparation of government actions. Many business corporations and no-profit organizations have adopted social impact assessment as a standard requirement in policy formation.

(iii) Wider applications and broader analysis are being computed, such as environmental impact assessment, technology assessment, economic and fiscal impact assessments, etc. In most cases nowadays in a project of environmental impact assessment a sub-project providing social impact assessment is incorporated. In occasions, technology assessment, economic and fiscal impact assessment are combined with a social impact assessment sub-project too as a rule (Becker, 2001).

c. Methodology challenges

There are several challenges associated with conducting environmental and social impact assessments. One of the main challenges is the need to assess the potential impacts of a given project or policy on a wide range of different environmental and social factors. This can be difficult because it requires a comprehensive understanding of the potential impacts on air and water quality, biodiversity, social and economic factors, and other factors. Additionally, assessing the potential impacts of a project or policy can be difficult because it requires making predictions about the future, which is inherently uncertain. Another challenge is that the methods used to conduct impact assessments can be complex and time-consuming, which can make it difficult to incorporate them into the decision-making process. Additionally, there may be challenges associated with obtaining reliable and accurate data on the potential impacts of a project or policy, which can make it difficult to make informed decisions.

d. Application areas

Three types of social impact assessment can be identified: micro, meso and macro. The types are constructed based on their predominant features: (i) Micro-social impact assessment, focuses on individuals and their behaviour, (ii) Meso-social impact assessment, focuses on organizations and social networks (including communities), while (iii) Macro-social impact assessment, focuses on national and international social systems. The three types can be found in different settings, sometimes exclusively focused on social impacts, while at other times, they can be integrated with other forms of impact assessment. They can be project based, or they can be applied to policies when it is also called strategic impact assessment.

e. Type of results

Environmental and social impact assessments (ESIAs) evaluate the potential impacts of a project or policy on the environment and the surrounding community. The result of an ESIA is typically a detailed report that outlines the potential impacts of the proposed project or policy, as well as any recommended mitigation measures. The report may also include an assessment of the feasibility of the project or policy and may make recommendations for alternative courses of action. The specific contents of an ESIA report will vary depending on the nature of the project or policy being evaluated, and on the requirements of the relevant regulatory authorities. In general, however, the result of an ESIA is intended to provide decision makers with the information they need to make informed decisions about the potential environmental and social impacts of a project or policy.

f. How to deal with uncertainty?

One way to deal with uncertainty in the context of environmental and social impact assessments (ESIAs) is to use a range of different methods and techniques to evaluate the potential impacts of a project or policy. This can include the use of probabilistic models that consider a range of possible outcomes, rather than just a single expected outcome. It can also involve the use of scenario-based analysis, where different scenarios are considered and the potential impacts of each are evaluated. Additionally, using a range of different data sources and incorporating feedback from stakeholders can help to reduce uncertainty and improve the accuracy of ESIA results. Overall, the key to dealing with uncertainty in the context of ESIAs is to use a combination of different methods and techniques, and to incorporate as much information and feedback as possible to improve the accuracy and reliability of the results.

1.3 Computable General Equilibrium Models (CGEMs)

a. Method description

Computable general equilibrium (CGE) models are a type of economic model that is used to study the behaviour of agents in an economy. These models are based on the general equilibrium framework, which assumes that all agents in the economy are rational and have complete information about the state of the economy. CGE models are used to study how changes in economic policy, such as changes in taxes or trade policies, can affect the overall performance of the economy.

CGE models are typically used to study the macroeconomic effects of policy changes, such as changes in GDP, employment, and prices. These models are often used by governments and international organizations to evaluate the potential impacts of proposed policy changes and to inform policy decisions.

One of the key advantages of CGE models is that they are highly flexible and can be adapted to study a wide range of economic phenomena. These models can be used to study both short-term and long-term effects of policy changes, and can incorporate a wide range of factors, such as changes in technology, demographics, and international trade.

The CGE comprise a representation of most economic sectors, where countries are linked through trade volume, prices in international markets and financial flows. A change in relative prices induces general equilibrium effects that are passed through to the economy. Although partial equilibrium models also allow estimating the benefits of certain public policies or programs and can consider substitution processes in production and consumption through market balance conditions, CGEs also allow adjustment to the other sectors and are therefore useful when considering the effects on the growth of the economy as a whole, as they take into account the interactions between intermediate inputs and markets for other goods and the link between factor remuneration and consumer income among others.

CGE models capture both supply and demand in the economy and therefore allow for an adjustment of both quantities and prices following a policy shock. Their main advantage lies in their flexibility, as they can be adapted to simulate a wide range of policies and shocks. CGE models are widely used by governments, international and research organizations, such as World Bank, OECD, FAO, WMO among others.

One of the more widely used CGEs is the model developed by the GTAP project[1] and the GTAP8.5 database coordinated by the Center for International Trade Analysis of the Department of Agricultural Economics at Purdue University. This model has been used in numerous previous studies to analyse the economic consequences of hydro-climatic impacts in many sectors. A full and detailed description of the model and its assumptions can be found on the official project website[2].

The economic impact of the environmental policy being modelled is estimated by comparing the economy before and after the shock. The baseline is generated by fitting the model equations and the behavioural parameters to the base year data. In general, this implies that the base year will reflect the current structure of the economy. The baseline assumes that the economy starts from an equilibrium position--i.e. markets clear, although some models, relax some of these assumptions for example allowing for unemployment in the labour market.

When a policy change or economic shock is introduced, the economy converges to a new equilibrium, following the economic relationships identified by the system of equations. The model finds a new set of prices and allocation of goods and factors that places the economy is in an equilibrium again. Some CGE models, such as the one used by the Scottish Government[3], can trace the path of adjustment to the new steady-state, whereas static ones will show long-run changes only. Modelling the adjustment path provides a much richer understanding of the evolution of the economy in response to a given shock or policy.

CGE models consider the interdependencies between different sectors, agents, and markets in the economy. CGE analysis can therefore shed light on the broader economic impact of policies and sometimes reveal their indirect or unintended effects. Since CGE models are based on economic theory, the results can be explained using economic intuition, with the advantage that the economic impact can

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[1] Global Trade Analysis Project (GTAP) from Center for Global Trade Analysis in Purdue University's Department of Agricultural Economics.

[2] In Internet: https://www.gtap.agecon.purdue.edu

[3] https://www.gov.scot/publications/cge-modelling-introduction

also be quantified using real data. Unlike partial equilibrium models, which focus on a single section of the economy, CGE models cover the entire economy and consider the interactions and chain effects between its various segments. Unlike input-output models, which only consider demand and assume that there are no capacity constraints, CGE models incorporate supply and thus allow for price movements.

Compared to macroeconometric forecasting models, CGE models have a stronger basis in economic theory. Macroeconometric forecasting models tend to be more data-driven, combining time series with economic theory, and often omit the detailed industry data that CGE models provide. Stochastic Dynamic General Equilibrium (DSGE) models aim to capture business cycle fluctuations and therefore focus more on short-term impacts. Unlike many CGE models, these types of models are less disaggregated and allow for random variations to account for uncertainty.

b. Recent method improvements

Computable equilibrium models are a type of economic model that are used to study the behaviour of agents in an economy. These models are based on the general equilibrium framework, which assumes that all agents in the economy are rational and have complete information about the state of the economy. Over the years, there have been many improvements to the methods used in computable equilibrium models, which have made these models more accurate, flexible, and useful for policy analysis.

One of the key improvements to computable equilibrium models has been the development of more sophisticated algorithms and computational methods. These methods have made it possible to solve these models more quickly and accurately, which has allowed researchers to study more complex economic phenomena and to analyse the effects of policy changes more precisely.

Another important improvement has been the development of more flexible modelling frameworks. These frameworks allow researchers to incorporate a wider range of factors into their models, such as changes in technology, demographics, and international trade. This has made it possible to study the effects of policy changes on an economy, rather than just focusing on a limited number of variables. In addition, there have been many advances in the data and statistical methods used in computable equilibrium models. These methods have made it possible to incorporate a wider range of data sources into the models, which has increased their accuracy and realism. Additionally, these methods have allowed researchers to better account for uncertainty and to conduct more robust sensitivity analyses, which can help to identify the key drivers of economic behaviour and to assess the robustness of model results.

Overall, these and other improvements to the methods used in computable equilibrium models have made these models more powerful and useful tools for policy analysis. These models continue to be widely used by economists, governments, and other organizations to study the effects of policy changes and to inform decision-making.

c. Methodology challenges

There are several challenges that are associated with using general equilibrium models. One of the main challenges is that the assumptions underlying these models are often unrealistic. For example, the assumption that agents have complete information about the state of the economy is often not true in practice. Additionally, the assumption that agents are perfectly rational can also be problematic, as people often make decisions based on emotions or other factors that are not purely rational.

Another challenge with general equilibrium models is that they can be difficult to solve mathematically since often involving many equations and variables, which can make it difficult to find solutions that are both mathematically tractable and meaningful. Additionally, the solutions to these models may be sensitive to changes in the assumptions or parameter values, which can make it difficult to draw meaningful conclusions from the results. GEMs have been sometimes criticized for being too far from real-world situations. These models can provide useful insights, but they may not always accurately capture the complexity of real-world economies.

d. Application areas

A general equilibrium model can be applied in several different economic areas. Some possible application areas for a general equilibrium model include:

- Macroeconomic policy analysis: A general equilibrium model can be used to evaluate the potential effects of different macroeconomic policies, such as changes in monetary or fiscal policy, on the overall behaviour of the economy.
- Trade policy analysis: A general equilibrium model can be used to study the effects of different trade policies, such as changes in tariff rates or trade agreements, on the behaviour of households and firms and on the overall economy.
- Environmental economics: A general equilibrium model can be used to study the effects of environmental policies, such as carbon taxes or cap-and-trade programs, on the behaviour of households and firms and on the economy.
- Development economics: A general equilibrium model can be used to study the potential effects of different policies or interventions on economic growth and development in developing countries.

Overall, the use of a general equilibrium model can be helpful for understanding the complex interactions between different agents in the economy and for evaluating the potential impact of different policies on the economy.

e. Type of results

The results of a CGE model can vary depending on the specific assumptions and parameters used in the model, but in general, a CGE model can be used to study the effects of different economic policies or shocks on the overall behaviour of the economy. For example, a CGE model could be used to evaluate the potential effects of a change in tax policy on the behaviour of households and firms, or to study the impact of a new technological innovation on the economy. The results of a CGE model can include measures of economic activity, such as gross domestic product (GDP) and employment, as well as changes in the distribution of income and wealth among different groups in the economy. These results can be useful for policymakers and other decision-makers as they consider different economic policies and decisions.

f. How to deal with uncertainty?

One way that CGE models can deal with uncertainty is by using a range of different assumptions or scenarios in the model. For example, a CGE model could be run using a "base case" scenario that assumes a certain set of economic conditions and policies, and then the model could be run again using alternative assumptions or scenarios that represent different possible outcomes. This can help to illustrate the potential effects of uncertainty on the economy and can provide policymakers with a range of possible outcomes to consider. Additionally, CGE models can incorporate statistical techniques, such as Monte Carlo simulation, which can help to account for uncertainty by generating numerous random samples from a given probability distribution. This can provide a more comprehensive view of the potential effects of uncertainty on the economy.

1.4 Complexity Models

a. Method description

Complexity models are mathematical or computational models that are used to study complex systems. These systems are often composed of many interacting components, such as individuals in a population or agents in a market, and are characterized by emergent behaviour, meaning that the behaviour of the overall system is not simply the sum of the behaviours of its individual components. Complexity models can be used to study a wide range of phenomena, including the spread of diseases, the evolution of species, and the behaviour of financial markets. Some common approaches to complexity modelling include agent-based modelling, network theory, and cellular automata.

There are several different approaches to complexity modelling, each with its own methodology. Some common approaches include:

- Agent-based modelling: This approach involves simulating the behaviour of individual agents in a system and observing how they interact with each other over time. The behaviour of each agent is typically defined using a set of rules that specify how the agent should respond to different stimuli or events.
- Network theory: This approach involves representing the system as a network of nodes and edges, where the nodes represent the individual components of the system, and the edges represent the connections or interactions between them. The behaviour of the system is then studied by analysing the properties of the network, such as its connectivity or its modular structure.
- Cellular automata: This approach involves representing the system as a grid of cells, each of which can be in one of a finite number of states. The behaviour of the system is then defined using a set of rules that specify how the state of each cell should evolve over time based on the states of its neighbouring cells.

Other approaches to complexity modelling include dynamical systems theory, evolutionary computation, and machine learning. The specific methodology used in each approach will depend on the nature of the system being studied and the goals of the modelling exercise.

b. Recent method improvements

There have been many recent developments and improvements in the methods used for complexity modelling. Some of the most significant include:

- The use of machine learning techniques: Machine learning algorithms, such as deep learning and reinforcement learning, can be used to learn the rules governing the behaviour of a complex system from data, rather than having to specify the rules explicitly. This can make it easier to build models of complex systems and can improve the accuracy of the predictions made by the model.
- The development of better simulation tools: There have been many advances in the development of simulation tools for complexity modelling, including the use of high-performance computing, distributed computing, and cloud-based platforms. These tools can make it easier to run complex simulations and can enable the use of larger and more detailed models.
- The use of interactive visualization: Visualization tools, such as web-based platforms and virtual reality environments, can be used to make it easier to understand and analyse the results of

complexity models. These tools can help modelers to explore the behaviour of complex systems and to identify patterns and trends that may not be apparent from numerical data alone.

Overall, there have been many recent developments in the methods used for complexity modelling, which are making it easier to build and analyse models of complex systems. These developments are helping to improve the accuracy and usefulness of complexity models and are enabling new and more sophisticated studies of complex phenomena.

c. Methodology challenges

One of the main challenges in complexity modelling is that complex systems often exhibit emergent behaviour, meaning that the behaviour of the overall system cannot be predicted from the behaviour of its individual components. This makes it difficult to model such systems, as the behaviour of the system may not be easily described by a simple set of rules or equations. Additionally, complex systems are often highly dynamic, meaning that they can change rapidly over time, making it difficult to capture their behaviour accurately in a model.

Another challenge is that complex systems often consist of many interacting components, which can make it difficult to analyse and understand the system. This can make it difficult to identify the key factors that drive the behaviour of the system, or to determine how changes in one part of the system will affect the rest of the system.

Finally, complex systems often operate at multiple scales, with behaviour at one scale influencing behaviour at other scales. This can make it difficult to develop models that accurately capture the behaviour of the system at all scales and can lead to problems such as oversimplification or overfitting.

d. Application areas

Complexity models can be applied to a wide range of fields and areas of study, including biology, sociology, economics, and computer science. Some specific examples of the types of systems that can be studied using complexity models include:

- The spread of diseases in a population: Complexity models can be used to study how diseases spread through a population and how different interventions, such as vaccination or quarantine, can affect the spread of the disease.
- The behaviour of financial markets: Complexity models can be used to study how the actions of individual investors and market forces interact to determine the overall behaviour of financial markets.
- The evolution of species: Complexity models can be used to study how species evolve over time and how different factors, such as competition for resources or changes in the environment, can affect their evolution.
- The emergence of social norms and institutions: Complexity models can be used to study how social norms and institutions arise from the interactions of individual agents, and how they can influence the behaviour of those agents.

Complexity models can be used to study a wide range of phenomena and can provide valuable insights into the behaviour of complex systems. It can be designed for specific problems

e. Type of results

The type of results that can be obtained from complexity models will depend on the specific goals of the modelling exercise and the methods used to build and analyse the model. In general, however, complexity models can be used to generate a wide range of results, including:

- Predictions about the future behaviour of a system: By simulating the behaviour of a complex system over time, a complexity model can be used to make predictions about how the system will evolve in the future. For example, a model of the spread of a disease in a population could be used to predict the number of cases of the disease at a future point in time.
- Insights into the underlying mechanisms that drive the behaviour of a system: By studying the behaviour of a complexity model, it is possible to gain insights into the factors that drive the behaviour of the system and how they interact with each other. For example, a model of the behaviour of a financial market could be used to identify the key factors that determine the price of a stock.
- Identifying the potential effects of interventions: By manipulating the parameters of a complexity model, it is possible to explore the potential effects of different interventions on the behaviour of a system. For example, a model of the spread of a disease in a population could be used to explore the potential effects of different vaccination strategies on the spread of the disease.

Overall, the results of complexity modelling can provide valuable insights into the behaviour of complex systems and can be used to inform decision-making and policy development.

f. How to deal with uncertainty?

Uncertainty is an inherent part of complexity modelling, as it is often difficult to know with certainty the exact rules or parameters that govern the behaviour of a complex system. There are several ways that complexity models can be used to deal with uncertainty, including:

- Sensitivity analysis: This involves varying the parameters of a model and observing how the results of the model change in response. This can help to identify which parameters are most important for determining the behaviour of the system and can provide insights into the robustness of the model.
- Monte Carlo simulations: This involves running a model multiple times with different sets of parameter values, and then analysing the distribution of the results to assess the uncertainty in the model. This can help to identify the range of possible outcomes and the likelihood of different scenarios.
- Probabilistic modelling: This involves representing uncertainty in the model using probability distributions, rather than precise values. This can help to capture the inherent uncertainty in the system and can provide a more realistic representation of the behaviour of the system.

Overall, dealing with uncertainty in complexity modelling requires a combination of careful model design, sensitivity analysis, and probabilistic modelling. By using these techniques, it is possible to develop models that can provide useful insights into the behaviour of complex systems, even in the presence of uncertainty.

2.0 Best practices applied to case studies

Appraisal methods have gradually unfolded into a type of policy oriented social research, that is applied in all sectors of society. Appraisal methods have evolved into a type of policy-oriented social and environmental research that is applied in many different sectors of society, including agriculture, healthcare, energy, government, and business. These methods are used to evaluate the effectiveness of various programs, policies, and initiatives, and to identify areas for improvement.

Appraisal methods, as previously stated, often involve collecting and analysing data, conducting surveys and interviews, and using other research methods to gather information about a particular program or policy. This information is then used to make recommendations for improving the program or policy, and to help decision-makers make informed decisions about how to allocate resources and implement changes. Here we have collected several case studies using the analysed methods in different contexts of environmental policy analysis. This report does not aim to be a systematized meta-analysis of the existing methods, it likely focuses on a set of studies analysing environmental policies related to climate and biodiversity related policies. The studies have been analysed to extract conclusions on the best practices included in those studies rather than generalized to a broader objective.

Table 2.1 shows a summary of the strengths, weaknesses and best practices of the economic appraisal methods analysed in relation with the climate and biodiversity related policies relevant for the PATTERN case studies. A complete detailed table with the studies considered is included in Annex 1.

Table 2.1 Strengths, weaknesses and best practices in the economic appraisal methods related to PATTERN case studies

Method	Strengths	Weaknesses	Best practices
Revealed (RP) and stated preferences (SP)	RP are based on actual behaviour, which is often seen as a more reliable measure. SP provides detailed information about preferences and can be used to study a wide range of topics	Revealed preference methods can be limited by the availability of data and by the assumption that individuals always act in their own best interests. SP can be subject to biases, such as social desirability bias or framing effects. Rely on individuals accurately reporting their preferences.	SP and RP have their limitations, and it is often beneficial to use both methods and sources to triangulate and validate the results. Complement with data from different sources to check for consistency and validity. Considering the context and assumptions. Communicate and interpret the results carefully
Environmental and Social Impact Assessment (ESIA)	Structured and systematic approach for evaluating the potential impacts of a development project. ESIAs can build trust and support from local communities by demonstrating that the potential impacts of a project have been considered and addressed.	Time-consuming and costly to conduct for complex projects. ESIAs rely on data and assumptions that may not always be accurate or complete, which can affect the reliability of the results. Only as effective as the measures that are put in place to mitigate impacts. Discount rate selection is an	Engaging with local stakeholders, including local communities, NGOs, and government agencies, to ensure that their concerns and perspectives are taken into account. Developing plans to mitigate negative impacts and to enhance positive one. Monitoring and evaluating to adjust mitigation plans as necessary.

		important source of uncertainty.	Assessment carried out by qualified professionals with relevant expertise.
Computable General Equilibrium Model (CGEM)	Trade-based linkages between sectors in the economy. Considers transition mechanisms. They are driven by market prices.	Based on equilibrium processes and competitive markets. Not place for non-marketable benefits (ie. environmental impacts, reduction of conflictivity, etc).	Well-define the model assumptions grounded in economic theory. Carefully specifying the equilibrium conditions, variables, and parameters. Considering how results might be affected by changes in the underlying assumptions.
Complexity Models (CM)	Can provide insight into the mechanisms that drive the behaviour of the system and can help researchers identify key factors that influence its behaviour. CM can also be used to make predictions about the behaviour of a complex system over time, which can be useful for forecasting and planning.	CM often rely on simplifying assumptions that may not accurately capture the complexity of real-world systems. Can be computationally intensive which can limit their practicality. Only as reliable as the data and assumptions that they are based on. Calibration difficulties. Sensitive to small changes in inputs.	Model being well-suited to addressing the problem. Choosing the appropriate specification. Using appropriate evaluation metrics. Regularly assessing and updating the model can help ensure that it continues to perform well over time. Consider the ethical implications of the model.

Source: Own elaboration based on Annex 1 information.

Revealed and stated preferences methods have their strengths and weaknesses, some best practices for using these methods effectively include: (i) clearly defining the research question and objectives: Before collecting and analysing data, it is important to clearly define the research question and objectives, and to choose the appropriate method for addressing them. This can help to ensure that the data collected are relevant and useful, and that the results of the analysis are meaningful and actionable; (ii) using multiple methods and sources: Both revealed preference and stated preference methods have their limitations, and it is often beneficial to use multiple methods and sources to triangulate and validate the results. For example, revealed preference data can be complemented with stated preference data, or data from different sources can be compared to check for consistency and validity; (iii) considering the context and assumptions: Both revealed preference and stated preference methods are based on certain assumptions, such as rationality, consistency, and self-reported preferences. It is important to consider these assumptions and their relevance to the specific context and research question, and to adjust the methods and analysis; accordingly, (iv) communicate and interpret the results carefully: The results of revealed preference and stated preference analyses can be complex and difficult to interpret, and it is important to communicate them clearly and accurately to different audiences. This can include providing appropriate summary measures, visualizations, or examples, and explaining the limitations and assumptions of the analysis. Overall, revealed preference and stated preference are powerful tools for measuring and analysing consumer preferences, but they should be used carefully and in combination with other methods to provide the most accurate and useful results.

Environmental and social impact assessments are important tools for evaluating the potential impacts of a project on the environment and local communities. Best practices for conducting such assessments include: (i) identifying the potential impacts of the project on the environment and local communities, including direct and indirect impacts; (ii) engaging with local stakeholders, including local communities, NGOs, and government agencies, to ensure that their concerns and perspectives are taken into account; (iii) developing a plan to mitigate any negative impacts of the project, and to enhance any positive impacts; (iv) regularly monitoring and evaluating the impacts of the project, and adjusting the mitigation plan as necessary; (v) ensuring that the assessment is carried out by qualified professionals with relevant expertise; (vi) providing transparent and accessible information about the assessment process, findings, and mitigation plans to all stakeholders. The main goal of an environmental and social impact assessment is to ensure that a project is developed and implemented in a way that minimizes negative impacts and maximizes benefits for the environment and local communities.

General equilibrium models represent the interrelationships between different markets in an economy. The best practices for using these models include making sure that the assumptions used in the model are well-defined and grounded in economic theory, carefully specifying the equilibrium conditions, and clearly defining the variables and parameters in the model. It is also important to carefully analyse the results of the model and consider how they might be affected by changes in the underlying assumptions. Additionally, it is crucial to consider the limitations of the model and how it may not capture certain real-world phenomena.

Complexity models depend on the specific context and goals of the model. However, here are some general best practices that are often recommended when using complexity models will depend on the specific context and goals of the model. Best practices include: (i) Clearly defining the problem and the goals of the model. This will help ensure that the model is well-suited to addressing the problem at hand and will also provide a basis for evaluating the model's performance; (ii) choosing the appropriate complexity model. Different types of complexity models are better suited to different types of problems. For example, a simple linear model may be sufficient for predicting the value of a single variable, while a more complex non-linear model may be needed for predicting the behaviour of a complex system; (iii) using appropriate evaluation metrics. Different complexity models may be evaluated using different metrics, depending on the specific goals of the model. For example, if the goal is to accurately predict the value of a variable, a model's accuracy may be its most important metric. However, if the goal is to understand the underlying relationships between variables, other metrics such as interpretability or generalizability may be more important; (iv) regularly assess and update the model. Complexity models are not static and will often need to be updated or refined as new data becomes available or the underlying assumptions of the model change. Regularly assessing and updating the model can help ensure that it continues to perform well over time; (v) consider the ethical implications of the model. Complexity models can have significant impacts on individuals and society, and it is important to consider the potential consequences of using these models. This may include considering issues such as bias and fairness and taking steps to mitigate any potential negative impacts.

3.0 Appraisal methods used in PATTERN

3.1 Q-method (Q)

a. Method description

Q method is a research methodology used to study people's subjective experiences and perspectives. It combines elements of both qualitative and quantitative research methods and involves having participants rank a set of statements or items according to how well they reflect the participant's own views or experiences. The resulting data is then analysed using statistical techniques to identify common patterns and trends in participants' perspectives (Živojinović & Wolfslehner, 2015). Q method is often used in psychology and sociology research and can provide valuable insights into how people think and feel about a particular topic. The Q methodology breaks the barriers between the quantitative and qualitative research traditions and combines the strengths of both traditions and is therefore widely used in social science research. Q methodology explore correlations between persons or whole aspects of persons. In doing this the methodology neither tests its participants nor imposes a priori meanings (Alfie-Cohen & Garcia-Becerra, 202). Participants are asked to decide what is meaningful and significant from their perspective. They do this through what is known as a Q-sort.

A Q method experiment follows the next steps for its implementation:

Step 1: Identify the topic.

Step 2: Develop the Q-set.

Step 3: Piloting.

Step 4: Participant selection.

Step 5: Data collection—Q-sorting.

Step 6: Analysis and Interpretation —Quantitative analyses to obtain factors and interpretation of factors.

In step one, the researcher identifies the topic or research question they want to explore. In the second step, the researcher develops the Q-set, which is a collection of statements or items that represent different perspectives or viewpoints on the topic. In the third step, the researcher conducts a pilot study to test the Q-set and ensure that it is appropriate for the research question. In step four, the researcher selects participants for the study and obtains their consent. In the fifth step, the participants engage in the Q-sorting process, where they rank the items in the Q-set according to how well each item represents their own perspective on the topic (Grimsrud, Graesse, & Lindhjem, 2020). The sixth and final step, the researcher analyses the data collected through the Q-sorting process using statistical techniques to identify common factors among the participants' rankings. These factors represent different viewpoints or perspectives on the topic. The researcher then interprets these factors to understand how people think about and perceive the topic under study (Byrne, Byrne, & Ryan, 2017).

b. Recent method improvements

Q method has been used for a long time, and it has undergone many developments and improvements over the years. Some recent developments in Q method include the use of computer-based Q-sorting and the incorporation of new statistical techniques for data analysis.

One improvement in Q method is the use of computer-based Q-sorting, which allows participants to rank the items in the Q-set using a computer or mobile device. This makes the Q-sorting process more convenient and efficient for both the participants and the researcher (Brannstrom, 2011).

Another improvement is the incorporation of new statistical techniques for data analysis. For example, researchers may use factor analysis, multidimensional scaling, or structural equation modeling to identify the factors that represent different perspectives on the topic under study (Vargas, Diaz, & Aldana-Domínguez, 2019). These techniques can provide more detailed and nuanced insights into how people think about and perceive the topic.

Additionally, Q method has been applied in new areas, such as neuroscience. For example, researchers may use Q method to understand how people's brain activity relates to their beliefs, attitudes, and opinions. This broadens the scope and applicability of Q method in the social sciences.

c. Methodology challenges

There are several challenges that researchers may face when implementing a Q method study. One challenge is the development of the Q-set, which is a collection of statements or items that represent different perspectives on the topic. Developing a well-crafted and comprehensive Q-set can be difficult and time-consuming, as it requires the researcher to thoroughly understand the topic and the various perspectives on it (Cuppen, Bosch-Rekveldt, Pikaar, & Mehos, 2016).

Another challenge is participant selection. In Q research, each participant is self-referenced to represent a point of view and is not influenced by the researcher's pre-defined attitudes, effectively reducing the researcher's bias. Q methodology allows for an overall analysis of these points of view and the integration of the main and unique points of view. It is suitable for conducting exploratory research, which is conducive to generating new research ideas and hypotheses (Bumbudsanpharoke, Moran, & Dominic, 2009). However, Q-method samples are small and do not allow for random sampling, so the researcher's selection of participants is particularly important. Also, the researcher is targeting a structured sample of components based on the question of the current study, so the generalizability of the classification of personnel types is often not high.

Additionally, data analysis can be a challenge in Q method studies. The Q-sorting data collected from participants can be complex and multidimensional, and it can be difficult to identify the factors that represent different perspectives on the topic. Researchers may need to use advanced statistical techniques to analyse the data, which can be time-consuming and require specialized knowledge and skills (Bumbudsanpharoke, Moran, & Hall, 2009).

Finally, interpretation of the results can also be a challenge in Q method studies. The factors identified through data analysis may not always be clearly interpretable, and it can be difficult to draw meaningful conclusions and implications from the results. It is important for researchers to carefully consider the factors identified and their relevance to the research question in order to interpret the results accurately and meaningfully (Cools, Moons, Janssens, & Wets, 2009).

d. Application area

Although the Q methodology originated in psychology, it has also been widely used in political science, human geography, health care and other fields (Zabala, Sandbrook, & Mukherjee, 2018), and in teaching to promote student engagement (Judge, Deborah, & Deborah, 2018), and even in agriculture to explore stakeholder perceptions of pesticide use (Lehrer & Sneegas, 2018). Overall, Q method provides a useful tool for researchers to explore and understand people's perspectives, attitudes, and beliefs on a wide range of topics.

3.2 Discrete Choice Experiment (DCE)

a. Method description

Discrete choice experiments (DCE), pioneered by Louviere and Woodworth after the 1970s, are quantitative techniques for eliciting preferences, used in the absence of data showing preferences. The method involves asking individuals to state their preferences for hypothetical alternatives, goods, or services as a way to carve out a statistical model of individual behaviour that can inform decisions. (Mangham, Hanson, & McPake, 2009).

The design and implementation of a DCE requires the following steps to ensure the quality of the experiment: conceptualizing the choice process, selecting attributes and levels, experimental design, questionnaire design, pilot testing, sampling and sample size, data collection, coding of data, econometric analysis, validity, interpretation and welfare and policy analysis (Wang Y. , et al., 2021).

In the first step, the researcher conceptualizes the choice process and defines the decision-making context for the experiment. This involves identifying the choices that participants will be asked to make, the attributes that will be used to describe the choices, and the levels of each attribute that will be presented to the participants. In the second step, the researcher designs the experimental conditions and creates the questionnaire that will be used to collect data from the participants. This involves specifying the attributes and levels and arranging them in a way that will allow the researcher to measure the participants' preferences (Ščasný, Zvěřinová, Czajkowski, Kyselá, & Zagórska, 2017).

- In the third step, the researcher conducts a pilot study to test the questionnaire and ensure that it is appropriate for the research question. This allows the researcher to identify and address any potential issues with the questionnaire before collecting data from the full sample of participants.
- In the fourth step, the researcher selects a sample of participants and obtains their consent to participate in the study. The sample should be representative of the population of interest, and the sample size should be large enough to provide sufficient statistical power for the analysis.
- In the fifth step, the researcher collects data from the participants using the questionnaire. This involves presenting the participants with the attributes and levels and asking them to choose the option that they prefer.
- In the sixth step, the researcher codes the data and prepares it for analysis. This involves organizing the data in a way that allows the researcher to apply econometric techniques to measure the participants' preferences.
- In the seventh step, the researcher conducts an econometric analysis to identify the participants' preferences and estimate the marginal willingness to pay (MWTP) for each attribute and level. This allows the researcher to understand how people value different aspects of the choices presented to them.
- In the eighth step, the researcher evaluates the validity of the results. This involves checking the assumptions of the econometric model and testing the robustness of the results to ensure that they are reliable and valid.
- In the ninth step, the researcher interprets the results and considers their implications for welfare and policy analysis. This involves examining the MWTP estimates and considering their relevance to the research question and the decision-making context (Byun, Shin, & Lee, 2018). The researcher may also consider how the results could be used to inform policy decisions or improve decision-making in the real world.

Overall, these steps are important for ensuring the quality and validity of a DCE experiment. By following these steps, researchers can design and implement a DCE that provides valuable insights into people's preferences and decision-making (Ndunda & Mungatana, 2013).

b. Recent method improvements

DCE has been used for many years in a variety of fields, and it has undergone many developments and improvements over time (Raux, Chevalier, Bougna, & Hilton, 2015). Some recent developments in DCE include the use of advanced econometric techniques, the incorporation of new types of attributes and levels, and the application of DCE in new areas such as health care, environment, and sustainability.

One improvement in DCE is the use of advanced econometric techniques. In recent years, researchers have developed new methods for estimating preferences and MWTP that can provide more detailed and nuanced insights into people's decision-making (Shoyama, Managi, & Yamagata, 2013). For example, researchers may use mixed logit models, latent class models, or random parameter models to estimate preferences more accurately.

Another improvement is the incorporation of new types of attributes and levels. In DCE, attributes are the characteristics of the choices that are presented to participants, and levels are the different values or levels of each attribute (Van Oijstaeijen, Van Passel, Back, & Cools, 2022). In recent years, researchers have used DCE to study a wider range of attributes and levels, such as multiple-choice attributes, non-linear attributes, and attributes that vary over time. This allows DCE to be applied in a wider range of decision-making contexts and to provide more detailed and comprehensive insights into people's preferences.

Finally, DCE has been applied in new areas, such as health care and environment and sustainability (Byun, Shin, & Lee, 2018). For example, researchers may use DCE to study people's preferences for different health care treatments or to explore people's willingness to pay for environmental improvements (Schwirplies, Dütschke, Schleich, & Ziegler, 2019). This broadens the scope and applicability of DCE in the social sciences

c. Methodology challenges

There are several challenges that researchers may face when implementing a DCE. One challenge is the conceptualization of the choice process and the definition of the attributes and levels (Vanstockem, Vranken, Bleys, Somers, & Hermy, 2018). In DCE, it is important to define the decision-making context and the choices that participants will be asked to make clear and comprehensive. However, this can be difficult, as it requires the researcher to thoroughly understand the topic and the various aspects of the choices that are relevant to participants (Gundlach, Ehrlinspiel, Kirsch, Koschker, & Sagebiel, 2018).

Another challenge is questionnaire design. In DCE, the questionnaire is a crucial tool for collecting data from participants. However, designing a well-crafted and effective questionnaire can be difficult, as it requires the researcher to carefully consider the attributes and levels, and to arrange them in a way that will accurately measure participants' preferences. Due to the differences in cognitive levels between researchers and participants, it will be a challenge to effectively pre-set the questionnaire (Mangham, Hanson, & McPake, 2009).

Additionally, data analysis can be a challenge in DCE studies. The data collected through the questionnaire can be complex and multidimensional, and it can be difficult to apply econometric techniques to measure participants' preferences. Researchers may need to use advanced statistical methods and software, which can be time-consuming and require specialized knowledge and skills (Johnston & Abdulrahman, 2017).

Finally, interpretation of the results can also be a challenge in DCE studies. The preferences and MWTP estimates obtained from the data analysis may not always be clearly interpretable, and it can be difficult to draw meaningful conclusions and implications from the results. It is important for researchers to carefully consider the results and their relevance to the research question to interpret them accurately and meaningfully (Nthambi, Markova-Nenova, & Wätzold, 2021).

d. Application area

DCE has been applied in a wide range of fields and disciplines, including economics, marketing, health, transportation, and environmental science. In economics, for example, DCE has been used to study consumer demand and market behaviour (Veronesi, Chawla, Maurer, & Lienert, 2014). In marketing, DCE has been used to study product preference and brand loyalty. In public health, DCE has been used to study people's preferences for health care treatments and interventions. In transportation, DCE has been used to study people's preferences for different modes of transportation and travel options. In environmental science, DCE has been used to study people's willingness to pay for environmental improvements, applications related to environmental policy are still somewhat lacking (Chovan, 2022). Overall, DCE provides a useful tool for researchers to explore and understand people's preferences and decision-making in a wide range of contexts.

3.3 Carbon Handprint

a. Method description

Carbon handprint is the opposite of Carbon footprint. Carbon footprint is a measure of an organization's "carbon consumption" and is a collection of greenhouse gas emissions caused by a business organization, activity, product or individual through transportation, food production and consumption, and various production processes. Carbon handprint, on the other hand, is used to measure the actions we take to reduce carbon emissions and make a positive impact on the climate (Co-funded by the Erasmus+ programme of the European Union, 2016).

The quantification of the carbon handprint is based on the calculation of the carbon footprint, i.e. the assessment of the greenhouse gas (GHG) emissions over the product's life cycle (LCA). The calculation process consists of four stages: Identification of the operating environment, Defining LCA requirements, Quantification of the carbon handprint, Communication (Tiina, et al., 2018).

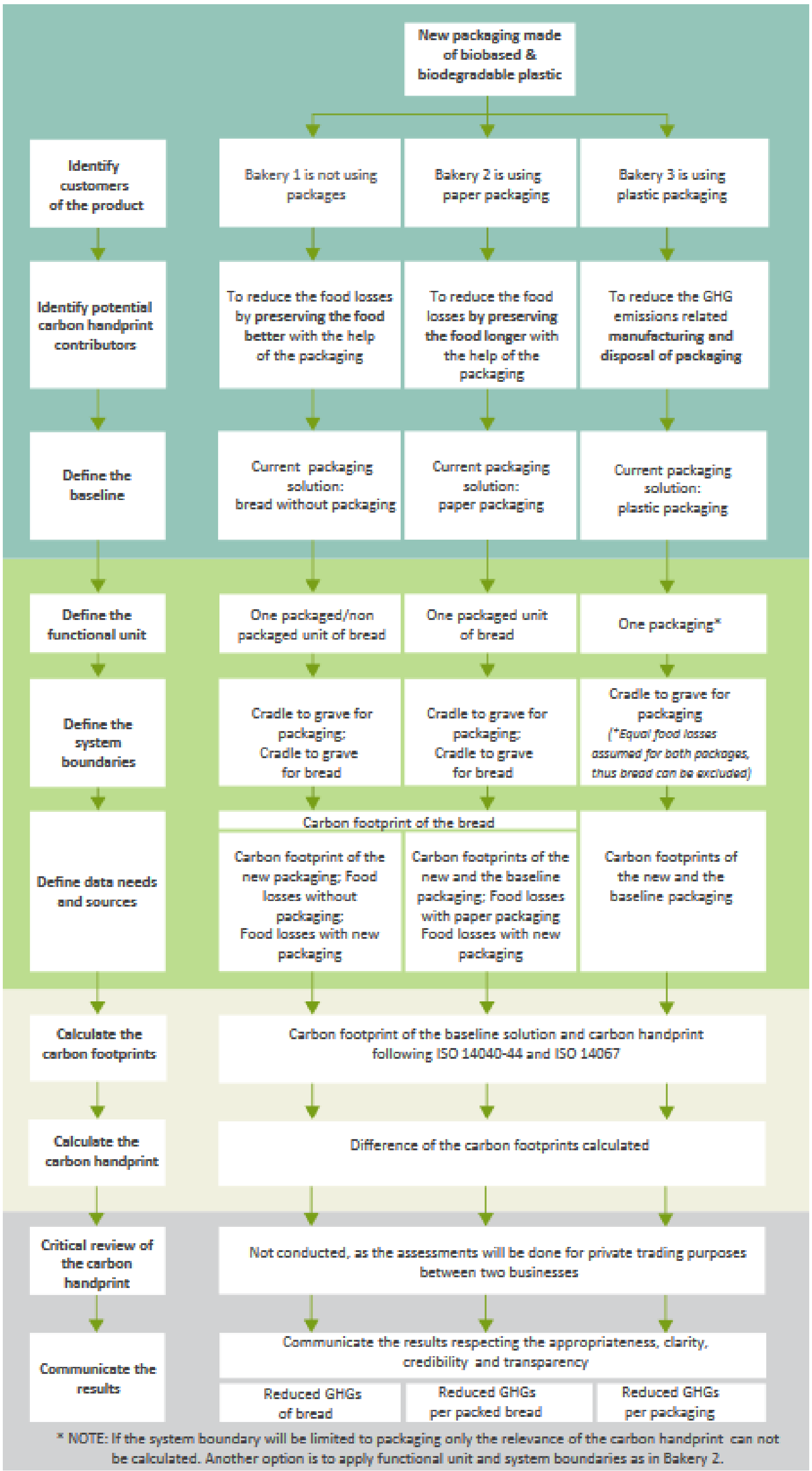
In the first step, the calculation process of a carbon handprint involves identifying the operating environment in which the organization or individual operates. This includes factors such as the location, type of industry, and size of the organization (Lakanen, et al., 2021).

The next step is to define the requirements for conducting a life cycle assessment (LCA), which is a methodology used to assess the environmental impacts of a product, service, or system (Kinnunen, Talvitie, Ottelin, Heinonen, & Junnila, 2022). This includes identifying the scope and boundaries of the LCA, as well as the data sources and impact categories to be considered.

The third stage involves quantifying the carbon handprint, which involves calculating the net amount of carbon dioxide emissions that are avoided or removed from the atmosphere because of the actions taken by the organization or individual. This can be done using various tools and methodologies, such as input-output analysis or environmental impact assessment (Lakanen, Kumpulainen, Helppi, Grönman, & Soukka, 2022).

The final stage is communication, which involves sharing the results of the carbon handprint calculation with stakeholders, such as employees, investors, customers, and the public. This can be done through various means, such as reports, presentations, or online platforms (Kiehle, 2021). The aim of this stage is to provide transparency and accountability, as well as to highlight the positive impact that the organization or individual is having on the environment. Figure 3.1 shows a fictional example of carbon handprint framework for bread packaging used in different bakeries. The template includes the four stages and ten steps.

Figure 3.1 A fictional example of carbon handprint framework for bread packaging.



Source: (Tiina, et al., 2018).

b. Recent method improvements

Carbon handprints are increasingly used by companies as an image promotion tool, using the evaluation of carbon handprints for marketing and communication, providing information and advice to decision makers and other interest stakeholders (Jenu, et al., 2020). As with any methodology, the calculation process for carbon handprint is constantly evolving and improving. Some recent developments and method improvements in this area include incorporating a broader range of impact categories, using more sophisticated data sources and modelling techniques, developing standardized approaches and reporting frameworks and engaging stakeholders and decision-makers (Ravesh, 2022).

In addition to carbon dioxide emissions, carbon handprint calculations can now also consider other environmental impacts, such as water use, land use, and biodiversity loss. This allows organizations and individuals to have a more comprehensive understanding of their environmental performance. Advances in technology have made it possible to use a wider range of data sources and modelling techniques to calculate carbon handprint (Burek, et al., 2022). For example, organizations can now use satellite imagery, machine learning algorithms, and other advanced tools to better understand their operating environment and the impacts of their actions. To improve the comparability and reliability of carbon handprint calculations, various organizations and initiatives are working to develop standardized approaches and reporting frameworks. These can provide guidance on how to conduct carbon handprint calculations, as well as how to present and communicate the results (Kiehle, 2021).

Another important aspect of carbon handprint is engaging with stakeholders and decision-makers. This can involve involving them in the calculation process, as well as sharing the results and discussing potential actions to reduce carbon emissions and improve environmental performance. By involving stakeholders, organizations and individuals can ensure that their carbon handprint calculations are relevant, meaningful, and impactful.

The role of ICT technology in reducing carbon emissions for other industries will be particularly important: through network communications, video conferencing and other technological means to reduce carbon emissions from unnecessary driving trips.

c. Methodology challenges

The concept of carbon handprint was introduced in 2016, but the calculation of the carbon handprint is extremely demanding for the researcher (Tiina, et al., 2018).

1. The calculation of the carbon handprint requires the researcher/company to have a deep understanding of the LCA or ISO 14076 standard.
2. The researcher needs to be familiar with the production process environment to set up the baseline scenario.

The researcher must have access to a wide range of data sources, including information on the organization's operations, supply chain, and the broader operating environment.

The calculation of carbon handprint involves complex modelling and analysis, which can be time-consuming and require specialized skills and expertise.

There may be a lack of standardization and guidance on how to conduct carbon handprint calculations, which can make it challenging for researchers to measure the environmental impact of an organization or an individual, consistently, and accurately (Lakanen, Kumpulainen, Helppi, Grönman, & Soukka, 2022).

d. Application area

Carbon handprint can be applied in a wide range of areas and industries, including manufacturing, agriculture, transportation, energy, among others (Ravesh, 2022). Some potential applications of carbon handprint include measuring and improving the environmental performance of organizations, developing sustainable products and services, encouraging sustainable behaviour by individuals, and supporting decision-making by governments and policy makers

Carbon handprint can be used by organizations to assess the environmental impacts of their operations, products, or services. This can help organizations identify areas where they can reduce their carbon footprint and improve their environmental performance. Applications to natural resources: a review of existing mineral resource assessment methods by Sonderegger et al. (2020). Drielsma et al (2016) proposed that the opportunity cost of resource availability should be incorporated into the life cycle sustainability assessment

Applications in agriculture: recommendations are given based on soil models in land use (Morais, et al., 2018),significant potential for orchard uptake and net storage of CO2 in the fruit industry identified through orchard modelling (Cerutti, et al., 2014) . Küsters et al. (2004)found the advantages of the LCA method for assessing the environmental preferences of arable agricultural production systems through a good environmental study of wheat production: 1. All relevant impacts can be considered and assessed simultaneously, 2. Correlation with the relevant impacts of the investigated system and the impacts of the given area is shown.

Carbon handprint can be used by organizations to design and develop products and services that have a positive impact on the environment. For example, an organization could use carbon handprint to assess the environmental impact of different design options and choose the option that has the lowest carbon footprint.

Carbon handprint can also be used by individuals to measure the environmental impact of their actions, such as the choices they make in their daily lives. This can help individuals understand the impact of their actions on the environment and encourage them to make more sustainable choices (Kuittinen & Häkkinen, 2020).

Carbon handprint can provide valuable information to governments and policy makers, who can use it to make informed decisions about environmental policies and regulations. For example, governments could use carbon handprint to assess the environmental impact of different policy options, and choose the option that has the lowest carbon footprint

Suitable for most fields, the product life cycle can be extended by different mechanisms to enhance product performance or service life to enable carbon handprint: Full and efficient use of materials and energy, reducing waste and reuse (Tiina, et al., 2018).

3.4 Life Cycle-Impact Assessment (LCIA)

a. Method description

Life Cycle Assessment (LCA) is an environmental impact assessment method set up in accordance with the international ISO 14040 standard: an environmental impact assessment of the life cycle of a specific product from raw material procurement, processing, manufacturing, distribution, use and disposal or recycling.

The LCA is divided into several phases, of which the Life Cycle Impact Assessment (LCIA) is the core of the LCA, i.e., the qualitative and quantitative assessment of the potential environmental impacts resulting from the basic flows obtained in the LCI (Nieuwlaar & Cleveland, 2004). LCIA consists of three steps: (i) qualitative classification, (ii) characterization of the data, and (iii) weighting (Ren & Liu, 2002).

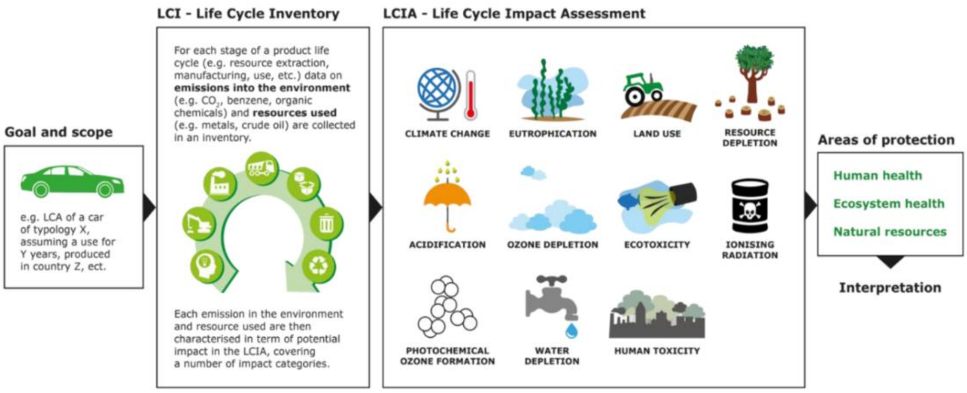
In the first step, qualitative classification, the potential environmental impacts of a product or system are identified and grouped into categories based on their type, severity, and relevance to the specific assessment. This step provides a high-level overview of the potential environmental impacts and helps to prioritize the areas that require further analysis (Bright, Cherubini, & Strømman, 2012).

In the second step, characterization of the data, the quantitative data on the potential environmental impacts of a product or system are collected and analysed (Li, 2006). This data may come from various sources, such as literature, databases, or experimental measurements, and may be expressed in different units or scales. In this step, the data are converted and standardized to enable comparison and aggregation across different impact categories.

In the final step, weighting, the data on the potential environmental impacts are weighted to reflect the relative importance of each impact category (Frischknecht, et al., 2016). This can be done using various methods, such as expert judgment, multicriteria decision analysis, or life cycle impact assessment methods. The weighted impacts are then aggregated to provide a single measure of the overall environmental performance of the product or system.

Overall, LCIA is an important step in LCA that enables the quantification and assessment of the potential environmental impacts of a product or system (Bulle, et al., 2019). It provides valuable information that can be used to identify and prioritize areas for improvement, to compare the environmental performance of different alternatives, and to support decision-making. Figure 3.2Figure 3.2 shows the LCA steps: goal and scope definition, life cycle inventory, life cycle impact assessment and interpretation.

Figure 3.2 A Life Cycle Assessment steps.



Source: (Sala, et al., 2016)

b. Recent method improvements

LCA has undergone significant development and refinement in recent years, and several method improvements have been proposed and implemented.

One major challenge in LCA is the availability and quality of data on the environmental impacts of products and systems (Margni, Rossier, Crettaz, & Jolliet, 2002). Recent efforts have focused on improving the coverage, accuracy, and transparency of data sources, such as ecoinvent and the Environmental

Product Declarations (EPD) database, and on developing new methods for estimating missing or uncertain data.

LCA is often used in conjunction with other assessment methods, such as Life Cycle Costing (LCC) or Social Life Cycle Assessment (SLCA), to provide a more comprehensive and holistic view of the environmental, economic, and social impacts of a product or system (Castro, Remmerswaal, & Reuter, 2003). Recent method improvements have focused on improving the integration and compatibility of LCA with these other methods, enabling more seamless and integrated analysis.

LCA traditionally focuses on a limited number of environmental impact categories, such as climate change or water scarcity. However, recent research has identified the need for new impact categories, such as the impacts on human health or biodiversity, and has developed new methods for assessing these impacts. These new categories and methods can provide a more comprehensive and nuanced view of the environmental impacts of a product or system (Owens, 2001).

LCA typically focuses on the life cycle of a product or system, but recent method improvements have emphasized the need to consider the temporal and spatial aspects of environmental impacts, such as the impacts over the long-term or the impacts in specific regions or ecosystems (Morais, et al., 2018). This can provide a more accurate and relevant assessment of the environmental impacts of a product or system.

Overall, recent method improvements in LCA have focused on improving the data availability and quality, increasing the integration with other assessment methods, developing new impact categories and methods, and considering temporal and spatial aspects. These improvements can help to provide a more comprehensive and accurate assessment of the environmental impacts of a product or system (Roy, y otros, A review of life cycle assessment (LCA) on some food products, 2009).

c. Methodology challenges

LCA is a powerful and widely-used tool, it also has several challenges and limitations that need to be carefully considered when using it. Some common challenges and limitations of LCA include: data availability and quality, boundary setting, normalization and weighting, representation of uncertainty and integration with other assessment methods (Bennett, Phipps, Strange, & Grey, 2004).

One major challenge in LCA is the availability and quality of data on the environmental impacts of products and systems. LCA typically requires data on a wide range of inputs and outputs, such as materials, energy, water, emissions, and waste, across the entire life cycle of a product or system. However, these data are often incomplete, uncertain, or difficult to obtain, which can limit the accuracy and reliability of the LCA results.

LCA typically focuses on a specific product or system, and the environmental impacts are assessed within defined boundaries, such as the life cycle of the product or system. However, choosing the appropriate boundaries and determining what should be included or excluded can be difficult and can have a significant impact on the results of the LCA (Roy, et al., 2009).

LCA typically quantifies the environmental impacts of a product or system in a limited number of impact categories, such as climate change or ozone depletion. These impacts are then normalized and weighted to reflect their relative importance and to enable comparison across different impact categories. However, the choice of normalization and weighting methods can be subjective and can affect the results of the LCA.

LCA typically includes assumptions and uncertainties in the data and methods used, and these uncertainties can have a significant impact on the results of the LCA (Cerutti, et al., 2014). However, representing and communicating these uncertainties can be challenging, and different methods and approaches have been proposed to address this issue.

LCA is often used in conjunction with other assessment methods, such as Life Cycle Costing (LCC) or Social Life Cycle Assessment (SLCA), to provide a more comprehensive and holistic view of the environmental, economic, and social impacts of a product or system (Morais, et al., 2018). However, integrating these different methods and dealing with the potential conflicts and inconsistencies between them can be challenging.

d. Application area

LCA has a wide range of applications, and it is often used in various sectors and contexts to support decision-making and to improve the environmental performance of products and systems.

Some common application areas for LCA include:

Product design and development: LCA is often used by manufacturers and designers to evaluate the environmental impacts of their products and to identify potential areas for improvement. LCA can provide valuable information about the environmental hotspots of a product and can help to optimize its design and materials to reduce its environmental impacts.

Environmental impact assessment: LCA is also used in environmental impact assessments (EIAs) to evaluate the potential environmental impacts of projects, such as infrastructure, energy, or waste management, and to compare different alternatives (Roy, et al., 2009). LCA can provide valuable information about the potential environmental impacts of a project and can help to identify and prioritize areas for mitigation or compensation.

Policy and regulation: LCA is also used by governments and policymakers to inform the development and implementation of environmental policies and regulations. LCA can provide quantitative data on the environmental impacts of different products, activities, or sectors, and can help to evaluate the effectiveness of different policy options in reducing these impacts.

Sustainable consumption and production: LCA is also used by consumers, businesses, and organizations to support sustainable consumption and production (SCP) and to reduce the environmental impacts of their activities. LCA can provide valuable information about the environmental impacts of different products and services, and can help to identify and prioritize areas for improvement in the supply chain (Llantoy, Chàfer, & Cabeza, 2020).

3.5 REMES-EU CGE Model

a. Method description

The Regional Equilibrium Model with focus on Energy System (REMES-EU) Computable General Equilibrium (CGE) Model is a computational general equilibrium model that is used to study the economic effects of policy changes in the European Union. It is part of the REMES (Regional and Sectoral Models) project, which is a joint effort by the European Commission and the Joint Research Centre to develop and maintain a suite of economic modelling tools (Wang, Wang, & Chen, 2009). The REMES-EU CGE model is a dynamic, multi-sectoral model that is used to analyse the impact of policy changes on different sectors of the economy, as well as on trade and the environment. It is a complex and powerful tool that is widely used by policymakers and researchers to evaluate the potential effects of policy changes on the European economy[4].

The mathematical formulation of REMES is based on the concept of Arrow-Debreu macroeconomic equilibrium structured in complementarity format (Bergman, Mäler, & Vincent, 2005). The complementarity format allows structuring an equilibrium in the form of weak inequalities, by establishing a logical connection between prices and market conditions.

A competitive equilibrium between all markets is described as a vector of activity levels, a vector of prices and a vector of total income, fulfilling the following conditions: zero profits, market clearing and income balance.

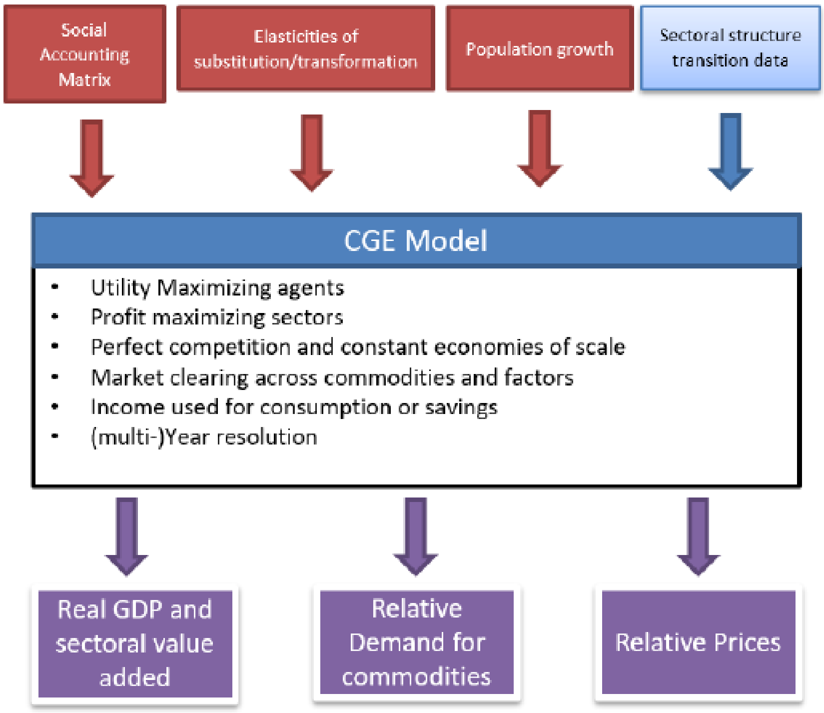
REMES considers five types of variables (Chisari & Miller, 2015):

1. Price related to anything that can be exchanged in the economy.
2. Activity levels which measure how much a sector or actor in the economy converts input factors into products or utility
3. Budget which is held by households and government and is related to their capacity of monetizing resources and must be equal to the sum of their expenditure and savings
4. Control variables which scale taxes, subsidies, and other transfers according to predefined conditions, to suggest policies to reach a predefined goal.

The main input data is structured as a Social Accounting Matrix (SAM), describing all the monetary flows between the different agents and sectors in a given base year. Moreover, each sector is endowed with a set of parameters, called elasticities of substitution, defining the responsiveness of the sectoral input mix (products, services, commodities, labour, and capital) to change in factors prices (Fu, Huang, Liu, & Zhai, 2021). Each of the five regions is characterized by having its own SAM that contains the amounts of all the exchanges between sectors, products, and actors in the model. Goods and services are exchanged both internally in the region and outside the region, through a trade field for each product or service in each SAM.
REMES provides economic simulations of possible scenarios resulting from the implementation of different kinds of policies as well as their impact on different sectorial activity levels and prices, also considering assumptions of the future state of technology and consumption trends (Babatunde, Begum, & Said, 2017). Typically, the main output takes the form of the evolution of value added in different sectors and regions, the composition value for inputs and outputs for each sector and the monetary flows between different actors and sectors in the economy. Figure 3.3 shows the REMES-EU model assumptions and structure.

Figure 3.3 REMES-EU model assumptions and structure

[4] https://www.ntnu.edu/web/iot/energy/energy-models-hub/remes



b. Recent method improvements

One recent method improvement in the use of these models is the incorporation of agent-based modelling approaches, which allow for the representation of the behaviour and decision-making of individual agents within the economy (Hermeling, Löschel, & Mennel, 2013). This can provide a more realistic and detailed representation of the economy and can help to capture the potential impacts of changes in individual behaviour on economic outcomes. Another recent method improvement is the use of machine learning techniques to improve the calibration and estimation of model parameters (Chen, Xue, Rose, & Haynes, 2016). This can help to improve the accuracy of the model and can make it easier to incorporate a larger number of variables and assumptions into the analysis.

Additionally, recent research has focused on improving the ability to represent uncertainty and to analyse the potential impacts of different scenarios or assumptions on economic outcomes. This can provide valuable insights for policymakers and other stakeholders who are considering different courses of action and need to understand the potential risks and uncertainties involved (Chen, Xue, Rose, & Haynes, 2016).

Overall, recent method improvements have focused on increasing the realism, accuracy, and flexibility of these models, and on improving their ability to provide valuable insights for decision-making.

c. Methodology challenges

One challenge in using the REMES-EU CGE Model is that it is a complex model with many variables and assumptions that need to be carefully specified to accurately reflect the real-world system being studied. This can make it difficult to set up and calibrate the model and can also lead to uncertainty or bias in the results if the assumptions or inputs are not carefully chosen (Liu, Tan, Yu, & Qi, 2017).

Another challenge is that CGE models like REMES-EU assume of equilibrium, meaning that they assume that all markets in the economy are in balance and that no individual agents can significantly influence prices or quantities (Lin & Jia, 2020). While this assumption can make the model easier to solve mathematically, it may not always accurately reflect the real world, where market imbalances and individual agents can have significant impacts on the economy.

Additionally, CGE models like REMES-EU can be computationally intensive, requiring significant computational resources to solve. This can make it difficult to run multiple scenarios or sensitivity analyses in a reasonable amount of time, limiting the ability to explore the full range of possible outcomes or to analyse the model's sensitivity to different assumptions (Fichefet & Maqueda, 1997).

Overall, the complexity and assumptions of CGE models like REMES-EU can make them challenge to use, but they can also provide valuable insights into the functioning of the economy when used carefully and appropriately.

d. Application area

The REMES-EU CGE model is typically used to analyze the economy-wide impacts of changes in the energy system, such as the adoption of new technologies or policies. This can include studying the effects of changes in energy prices, the deployment of renewable energy sources, or the implementation of carbon pricing or other emissions reduction policies (Dai, Masui, Matsuoka, & Fujimori, 2011).

The model can be used to analyze the impacts of these changes on various economic indicators, such as GDP, employment, trade, and prices, as well as on the energy sector itself (Bibas, et al., 2022). This can provide insights into the potential economic benefits or costs of different energy policies and can help inform decision-making about the design and implementation of these policies.

Additionally, the REMES-EU CGE model can be used to study the interactions between the energy system and other sectors of the economy, such as agriculture or transportation, and to analyze the potential impacts of these interactions on economic outcomes (Octaviano, Paltsev, & Gurgel, 2016). This can provide a more holistic view of the economy and can help to identify potential synergies or trade-offs between different policy goals. Overall, the REMES-EU CGE model is a valuable tool for studying the economy-wide impacts of changes in the energy system and can provide valuable insights for policymakers and other stakeholders.

3.6 Agent-Based Model

a. Method description

ABM is a theory-biased computer simulation technique that uses computer simulations to formulate testable hypotheses and explain phenomena and their causes through theory. Social emergence is a core concept of ABM, and the process of interaction between individual behaviours rising to the overall characteristics of society is called social emergence. "Agents" are the core elements of ABM. Agents should be independent individuals who are able to make behavioural decisions to achieve their goals autonomously and independently, while other agents may change their decisions. (Klabunde & Willekens, 2016). ABM's mode of thinking about phenomena at the collective level makes it easier to capture emergent phenomena relative to other modelling techniques and provides a description of the system that is closer to reality (Bonabeau, 2002).

It is a simulation technique used to study the behaviour of complex systems. In an agent-based model, individual agents are assigned certain behaviours and characteristics, and are placed within a virtual environment (Dullinger, y otros, 2020). The interactions between these agents are then simulated, allowing researchers to study the emergent behaviours and patterns that arise as a result. This method is often used to study systems that are made up of many interconnected components, such as economic systems, social networks, and biological ecosystems (Balbi & Giupponi, 2010). Agent-based modelling allows researchers to explore the complex interactions between these components and to better understand the underlying dynamics of the system. This can help to inform policy decisions and improve our understanding of how complex systems work.

b. Recent method improvements

Agent-based models are a type of computational modelling that are used to study complex systems. These models are built on the idea of simulating the behaviour of individual agents (i.e. autonomous entities that can make decisions and take actions) within a given system (Berger & Troost, 2014). The collective behaviour of the agents is then observed and analysed to gain insights about the system. In recent years, there have been several improvements and advancements in the field of agent-based modelling. Some of these developments include:

- The development of more sophisticated algorithms for simulating the behaviour of agents, including those that can adapt and learn over time.
- The use of more advanced computational techniques, such as machine learning and artificial intelligence, to improve the accuracy and efficiency of agent-based simulations.
- The development of new software and tools that make it easier to build, run, and analyse agent-based models.
- The use of agent-based modelling to study a wider range of complex systems, including social, economic, and biological systems.
- The integration of agent-based modelling with other modelling techniques, such as network analysis and spatial modelling, to provide a more comprehensive understanding of complex systems.

Overall, these developments have made it possible for researchers to use agent-based models to study complex systems in greater detail and with greater accuracy, leading to a better understanding of the underlying processes and dynamics of these systems (Angus & Parris, 2009).

c. Methodology challenges

Agent-based modelling is a computational modelling approach that involves the use of multiple agents to simulate the behaviour and interactions of autonomous entities in each system (Wu, Dai, Ge, Xi, & Wang, 2017). It is a powerful tool for studying complex systems, but it also comes with some challenges. Some of the challenges associated with agent-based modelling include the following:

- Developing accurate and realistic agents: To simulate a complex system, the agents used in an agent-based model must be able to represent the entities accurately and realistically being modelled. This can be difficult to achieve, particularly when the behaviour of the entities being modelled is complex or not well-understood.
- Determining appropriate rules and parameters: The rules and parameters that govern the behaviour of the agents in an agent-based model must be carefully chosen to accurately represent the system being modelled (Brady, Sahrbacher, Kellermann, & Happe, 2012). This can be challenging, particularly when the behaviour of the system is complex or not well-underlined.
- Verifying and validating the model: Once an agent-based model has been developed, it must be carefully verified and validated to ensure that it accurately represents the system being modelled. This can be a time-consuming and challenging process, particularly when the system being modelled is complex.
- Handling large-scale simulations: Agent-based models can involve many agents, which can make them computationally intensive to run. This can be a challenge, particularly when simulating large-scale or complex systems.

Analysing and interpreting the results: Once an agent-based model has been run, the resulting data must be carefully analysed and interpreted to gain insights into the behaviour of the system being modelled. This can be challenging, particularly when dealing with large amounts of data or complex behaviours (Jager, 2021).

d. Application area

Agent-based models are commonly used in a variety of fields, including economics, social sciences, computer science, and biology. Some of the specific application areas where agent-based modelling is commonly used include:

- Economics: Agent-based models are often used in economics to simulate the behaviour of individual economic agents, such as households, firms, or governments, and the interactions between them. These models can be used to study a wide range of economic phenomena, including market dynamics, resource allocation, and the emergence of social norms.
- Social sciences: Agent-based models are also used in social sciences to study the behaviour of individuals and groups and the emergence of collective phenomena. These models can be used to study topics such as the spread of social norms, the formation of social networks, and the evolution of social institutions (Jager, 2021).
- Biology: In biology, agent-based models are often used to simulate the behaviour of individual organisms and the interactions between them. These models can be used to study a wide range of biological phenomena, including the spread of diseases, the formation of ecological communities, and the evolution of species (Balbi & Giupponi, 2010).
- Computer science: Agent-based models are also used in computer science to study the behaviour of autonomous agents, such as robots or software agents, and the interactions between them. These models can be used to study a wide range of topics, including distributed systems, multi-agent systems, and artificial intelligence.

4.0 Challenges and needs

There are several challenges and needs that can arise when conducting appraisal methods, which are used to evaluate the value or worth of something (Natarajan, Padget, & Elliott, 2011). Some of these challenges and needs include:

- Determining the appropriate valuation approach: There are many different methods for valuing assets or projects and choosing the right one can be challenging. This may require considering factors such as the type of asset or project being evaluated, the purpose of the appraisal, and the availability of relevant data and information.
- Ensuring the accuracy and reliability of the valuation: Appraisal methods rely on assumptions and estimates, and it is important to ensure that these are based on accurate and up-to-date information (Wu, Dai, Ge, Xi, & Wang, 2017). This may require conducting thorough research and analysis and using appropriate techniques and tools to verify the assumptions and estimates used in the valuation.
- Communicating the valuation findings effectively: The results of an appraisal can be complex and technical, and it is important to communicate them clearly to stakeholders (Natarajan, Padget, & Elliott, 2011). This may require presenting the findings in a concise and accessible format and providing clear explanations of the assumptions and methods used in the valuation.
- Obtaining and managing data and information: Appraisal methods often rely on large amounts of data and information, which can be difficult to obtain and manage. This may require developing effective strategies for collecting and organizing data and ensuring that it is accurate and up to date.
- Addressing biases and subjective judgments: Appraisal methods can be subject to biases and subjective judgments, which can affect the accuracy and reliability of the valuation. This may require using appropriate techniques and tools to minimize the impact of biases and subjective judgments and ensuring that the valuation is based on objective and verifiable information.

- Dealing with uncertainty and risk: Appraisal methods often involve making assumptions and estimates about future events and conditions, which can introduce uncertainty and risk into the valuation. This may require developing appropriate strategies for dealing with uncertainty and risk, such as conducting sensitivity analyses or using scenario planning.
- Managing stakeholders and their expectations: Appraisal methods can have important implications for stakeholders, and it is important to manage their expectations and concerns effectively. This may require engaging with stakeholders and keeping them informed about the appraisal process and findings and addressing any concerns or issues that arise (Brady, Sahrbacher, Kellermann, & Happe, 2012).
- Ensuring compliance with relevant laws and regulations: Appraisal methods must be conducted in accordance with relevant laws and regulations, which can vary depending on the location and type of asset or project being evaluated (Berger & Troost, 2014). This may require understanding and complying with local, national, and international regulations, and obtaining any necessary approvals or permits.
- Managing conflicts of interest and maintaining objectivity: Appraisal methods must be objective and unbiased, and any conflicts of interest must be disclosed and managed appropriately. This may require developing policies and procedures for dealing with conflicts of interest and ensuring that the appraisal is conducted by qualified and independent professionals (Gutiérrez, et al., 2015).
- Providing ongoing support and guidance: Appraisal methods often involve complex technical and financial analyses, and stakeholders may need support and guidance to understand and use the results effectively (Angus & Parris, 2009). This may require providing ongoing training and support to stakeholders and developing clear and concise documentation of the appraisal process and findings.
- Continuously updating and improving the appraisal process: Appraisal methods are dynamic and constantly evolving, and it is important to keep up with the latest developments and best practices. This may require conducting regular reviews of the appraisal process, and implementing improvements and updates as needed.

Conducting effective appraisal methods requires a thorough understanding of the relevant valuation approaches and techniques, as well as the ability to address challenges and needs that may arise during the appraisal process.

5.0 References

Abler, D., Rodríguez, A., & Shortle, J. (1999). Parameter Uncertainty in CGE Modeling of the Environmental Impacts of Economic Policies. *Environmental and Resource Economics*, 75-94.

Acosta, L., Rounsevell, M., Bakker, M., Doorn, A., Gómez-Delgado, M., & Delgado, M. (2014). An Agent-Based Assessment of Land Use and Ecosystem Changes in Traditional Agricultural Landscape of Portugal. *Intelligent Information Management*.

Albizua, A., & Zografos, C. (2014). A Values-Based Approach to Vulnerability and Adaptation to Climate Change. Applying Q methodology in the Ebro Delta, Spain. *Environmental Policy and Governance*, Environmental Policy and Governance.

Alfie-Cohen, M., & Garcia-Becerra, F. (202). A multi-stakeholder participatory methodology to facilitate socio-ecological climate change vulnerability–adaptation–resilience strategies: application of the Q Method. *Mitigation and Adaptation Strategies for Global Change*, 14.

Angus, S., & Parris, B. (2009). Climate change impacts and adaptation in Bangladesh: An agent-based approach. *18th World IMACS*.

Antimiani, A., Costantini, V., & Paglialunga, E. (2015). The sensitivity of climate-economy CGE models to energy-related elasticity parameters: Implications for climate policy design. *Economic Modelling*, 38-52.

Aparcana, S., & Salhofer, S. (2013). Development of a social impact assessment methodology for recycling systems in low-income countries. *Int J Life Cycle Assess*, 1106–1115.

Armatas, C., Venn, T., & Watson, A. (2017). Understanding social–ecological vulnerability with Q-methodology: a case study of water-based ecosystem services in Wyoming, USA. *Sustainability Science*, 105-121.

Babatunde, K., Begum, R., & Said, F. (2017). Application of computable general equilibrium (CGE) to climate change mitigation policy: A systematic review. *Renewable and Sustainable Energy Reviews*, 61-71.

Balbi, S., & Giupponi, C. (2009). Reviewing Agent-Based Modelling of Socio-Ecosystems: A Methodology for the Analysis of Climate Change Adaptation and Sustainability. *University Ca' Foscari of Venice, Dept. of Economic*.

Balbi, S., & Giupponi, C. (2010). Agent-Based Modelling of Socio-Ecosystems: A Methodology for the Analysis of Adaptation to Climate Change. *International Journal of Agent Technologies and Systems*.

Baležentis, T., & Streimikiene, D. (2017). Multi-criteria ranking of energy generation scenarios with Monte Carlo simulation. *Applied energy, 185*, 862–871.

Barry, J., & Proops, J. (1999). Seeking sustainability discourses with Q methodology. *Ecological Economics*, 337-345.

Beaulieu, E., Goddéris, Y., Donnadieu, Y., Labat, D., & Roelandt, C. (2012). High sensitivity of the continental-weathering carbon dioxide sink to future climate change. *Nature Climate Change, 2*, 346–349.

Becker, H. (2001). Social impact assessment. *European Journal of Operational Research*, 311-321.

Bennett, R., Phipps, R., Strange, A., & Grey, P. (2004). Environmental and human health impacts of growing genetically modified herbicide-tolerant sugar beet: a life-cycle assessment. *Plant Biotechnology Journal*, 273-278.

Berger, T., & Troost, C. (2014). Agent-based Modelling of Climate Adaptation and Mitigation Options in Agriculture. *Journal of Agricultural Economics*, 323-348.

Bergman, L., Mäler, K.-G., & Vincent, J. (2005). Chapter 24 CGE Modeling of Environmental Policy and Resource Management. In *Handbook of Environmental Economics* (pp. 1273-1306).

Bibas, R., Cassen, C., Crassous, R., Guivarch, C., Hamdi-Cherif, M., Hourcade, J., . . . Waisman, H.-D. (2022). IMpact Assessment of CLIMate policies with IMACLIM-R 1.1. Model documentation version 1.1. *Model documentation version 1.1*.

Bonabeau, E. (2002). Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences*, 7280-7287.

Bosello, F. (2010). Adaptation, Mitigation and'Green'R&D to Combat Global Climate Change. Insights from an Empirical Integrated Assessment Exercise.

Bosello, F., & Cian, E. d. (2014). Documentation on the development of damage functions and adaptation in the WITCH model. *CMCC Research Paper*.

Bosello, F., Carraro, C., & De Cian, E. (2010). Climate policy and the optimal balance between mitigation, adaptation and unavoided damage. *Climate Change Economics, 1*, 71–92.

Bosetti, V., & Buchner, B. K. (2005). Using data envelopment analysis to assess the relative efficiency of different climate policy portfolios. *Available at SSRN 740306*.

Bosetti, V., & Drouet, L. (2005). Accounting for uncertainty affecting technical change in an economic-climate model.

Bosetti, V., & Tavoni, M. (2009). Uncertain R&D, backstop technology and GHGs stabilization. *Energy Economics, 31*, S18–S26.

Bosetti, V., Carraro, C., & Galeotti, M. (2006). Stabilisation targets, technical change and the macroeconomic costs of climate change control.

Bosetti, V., Carraro, C., & Galeotti, M. (2006). The dynamics of carbon and energy intensity in a model of endogenous technical change. *The Energy Journal*.

Bosetti, V., Carraro, C., De Cian, E., Duval, R., Massetti, E., & Tavoni, M. (2009). The incentives to participate in and the stability of international climate coalitions: a game theoretic approach using the witch model. *University Ca'Foscari of Venice, Dept. of Economics Research Paper Series*.

Bosetti, V., Carraro, C., Duval, R., Sgobbi, A., & Tavoni, M. (2009). The role of R&D and technology diffusion in climate change mitigation: new perspectives using the WITCH model.

Bosetti, V., Carraro, C., Galeotti, M., Massetti, E., & Tavoni, M. (2006). A world induced technical change hybrid model. *The Energy Journal*.

Bosetti, V., Carraro, C., Massetti, E., & Tavoni, M. (2008). International energy R&D spillovers and the economics of greenhouse gas atmospheric stabilization. *Energy Economics, 30*, 2912–2929.

Bosetti, V., Carraro, C., Massetti, E., Sgobbi, A., & Tavoni, M. (2009). Optimal energy investment and R&D strategies to stabilize atmospheric greenhouse gas concentrations. *Resource and Energy Economics, 31*, 123–137.

Bosetti, V., Marangoni, G., Borgonovo, E., Anadon, L. D., Barron, R., McJeon, H. C., . . . Friley, P. (2015). Sensitivity to energy technology costs: A multi-model comparison analysis. *Energy Policy, 80*, 244–263.

Bosetti, V., Massetti, E., & Tavoni, M. (2006). WITCH: Energy Patterns, Technology Options and CO2 Emissions. *Fondazione Eni Enrico Mattei, mimeo*.

Brady, M., Sahrbacher, C., Kellermann, K., & Happe, K. (2012). An agent-based approach to modeling impacts of agricultural policy on land use, biodiversity and ecosystem services. *Landscape Ecology*, 1363-1381.

Brannstrom, C. (2011). A Q-Method Analysis of Environmental Governance Discourses in Brazil's Northeastern Soy Frontier. *The Professional Geographer*, 531-549.

Brentrup, F., Küsters, J., Lammel, J., & Kuhlmann, H. (2002). Life Cycle Impact assessment of land use based on the hemeroby concept. *The International Journal of Life Cycle Assessment*, 339.

Bright, R., Cherubini, F., & Strømman, A. (2012). Climate impacts of bioenergy: Inclusion of carbon cycle and albedo dynamics in life cycle impact assessment. *Environmental Impact Assessment Review*, 2-11.

Brouwer, R., & van Ek, R. (2004). Integrated ecological, economic and social impact assessment of alternative flood control policies in the Netherlands. *Ecological Economics*, 1-21.

Buchner, B., & Carraro, C. (2004). Emission trading regimes and incentives to participate in international climate agreements. *European Environment, 14*, 276–289.

Buchner, B., & Carraro, C. (2005). Modelling climate policy: Perspectives on future negotiations. *Journal of Policy Modeling, 27*, 711–732.

Buchner, B., & Carraro, C. (2006). US, China and the economics of climate negotiations. *International Environmental Agreements: Politics, Law and Economics, 6*, 63–89.

Buchner, B., & Carraro, C. (2009). Parallel climate blocs, incentives to cooperation in international climate negotiations. *The design of climate policy*, 137–163.

Buckwell, A., Fleming, C., Muurmans, M., Smart, J., Ware, D., & Mackey, B. (2020). Revealing the dominant discourses of stakeholders towards natural resource management in Port Resolution, Vanuatu, using Q-method. *Ecological Economics*, 106781.

Bulle, C., Margni, M., Patouillard, L., Boulay, A.-M., Bourgault, G., De Bruille, V., . . . Jolliet, O. (2019). IMPACT World+: a globally regionalized life cycle impact assessment method. *The International Journal of Life Cycle Assessment*, 1653-1674.

Bumbudsanpharoke, W., Moran, D., & Dominic, C. (2009). Exploring perspectives of environmental best management practices in Thai agriculture: an application of Q-methodology. *Environmental Conservation*.

Bumbudsanpharoke, W., Moran, D., & Hall, C. (2009). Exploring perspectives of environmental best management practices in Thai agriculture: an application of Q-methodology. *Environmental Conservation*, 225-234.

Burek, J., Bauer, C., Kirchain, R., Moore, E., Gregory, J., & Norris, G. (2022). Assessing handprint potentials for business's eco-innovation. *Sustainable Production and Consumption*, 201-214.

Burniaux, J.-M., Nicoletti, G., & Oliveira-Martins, J. (1992). GREEN: A GLOBAL MODEL FOR QUANTIFYING THE COSTS OF POLICIES TO CURB CO2 EMISSIONS. *THE ECONOMIC COSTS OF REDUCING CO2 EMISSIONS (OECD ECONOMIC STUDIES NO 19)*.

Byrne, R., Byrne, S., & Ryan, R. (2017). Applying the Q-method to identify primary motivation factors and barriers to communities in achieving decarbonisation goals. *Energy Policy*, 40-50.

Byun, H., Shin, J., & Lee, C.-Y. (2018). Using a discrete choice experiment to predict the penetration possibility of environmentally friendly vehicles. *Energy*, 312-321.

Cai, Y., & Lontzek, T. (2019). The social cost of carbon with economic and climate risks. *Journal of Political Economy*, 2684-2734.

Cai, Y., Judd, K., & Lontzek, T. (2012). The Social Cost Of Abrupt Climate Change. *Work. Pap., Hoover Inst., Stanford Univ.*

Cai, Y., Judd, K., & Lontzek, T. (2012). The Social Cost of Stochastic and Irreversible Climate Change. *Work. Pap., Hoover Inst., Stanford Univ.*

Cai, Y., Judd, K., & Lontzek, T. (2013). The Social Cost of Stochastic and Irreversible Climate Change. *Working Paper*.

Carrara, S., & Marangoni, G. (2017). Including system integration of variable renewable energies in a constant elasticity of substitution framework: the case of the WITCH model. *Energy Economics, 64*, 612–626.

Carraro, C., & Buchner, B. K. (2004). Economic and environmental effectiveness of a technology-based climate protocol. *University Ca'Foscari of Venice, Dept. of Economics Research Paper Series Forthcoming, FEEM Working Paper*.

Carraro, C., & Egenhofer, C. (2007, January). *Climate and Trade Policy: Bottom-up Approaches Towards Global Agreement.* Edward Elgar Publishing.

Castro, M., Remmerswaal, J., & Reuter, M. (2003). Life cycle impact assessment of the average passenger vehicle in the Netherlands. *The International Journal of Life Cycle Assessment*, 297-304.

Cerutti, A., Beccaro, G., Bruun, S., Bosco, S., Donno, D., Notarnicola, B., & Bounous, G. (2014). Life cycle assessment application in the fruit sector: State of the art and recommendations for environmental declarations of fruit products. *Journal of Cleaner Production*, 125-135.

Chen, C., & Tavoni, M. (2013). Direct air capture of CO2 and climate stabilization: A model based assessment. *Climatic Change, 118*, 59–72.

Chen, W., Yin, X., & Zhang, H. (2016). Towards low carbon development in China: a comparison of national and global models. *Climatic Change, 136*, 95–108.

Chen, Z., Xue, J., Rose, A., & Haynes, K. (2016). The impact of high-speed rail investment on economic and environmental change in China: A dynamic CGE analysis. *Transportation Research Part A: Policy and Practice*, 232-245.

Chisari, O., & Miller, S. (2015). CGE Modeling: The Relevance of Alternative Structural Specifications for the Evaluation of Carbon Taxes' Impact and for the Integrated Assessment of Climate Change Effects: Simulations for Economies of Latin America and the Caribbean. *Inter-American Development Bank*.

Chovan, M. (2022). The importance of efficient designs in discrete choice experiments for environmental valuation.

Co-funded by the Erasmus+ programme of the European Union. (2016). *Carbon Handprints Manual.* Retrieved from https://ec.europa.eu/programmes/erasmus-plus/project-result-content/891f6f5e-5024-484a-a680-115f680fb661/Carbon%20Handprints%20Manual%20-%20English%20-%20Spanish%20-%20Lithuanian.pdf

Cools, M., Moons, E., Janssens, B., & Wets, G. (2009). Shifting towards environment-friendly modes: profiling travelers using Q-methodology. *Transportation*, 437-453.

Čop, T., & Njavro, M. (2022). Application of Discrete Choice Experiment in Agricultural Risk Management: A Review. *Sustainability*.

Cuppen, E., Bosch-Rekveldt, M., Pikaar, E., & Mehos, D. (2016). Stakeholder engagement in large-scale energy infrastructure projects: Revealing perspectives using Q methodology. *International Journal of Project Management*, 1347-1359.

Curry, R., Barry, J., & McClenaghan, A. (2013). Northern Visions? Applying Q methodology to understand stakeholder views on the environmental and resource dimensions of sustainability. *Journal of Environmental Planning and Management*, 624-649.

Dai, H., Masui, T., Matsuoka, Y., & Fujimori, S. (2011). Assessment of China's climate commitment and non-fossil energy plan towards 2020 using hybrid AIM/CGE model. *Energy Policy*, 2875-2887.

Daneshvar, E., Wicker, R., Show, P.-L., & Bhatnagar, A. (2022). Biologically-mediated carbon capture and utilization by microalgae towards sustainable CO2 biofixation and biomass valorization – A review. *Chemical Engineering Journal*, 130884.

De Cian, E., Bosetti, V., & Tavoni, M. (2012). Technology innovation and diffusion in “less than ideal” climate policies: An assessment with the WITCH model. *Climatic Change, 114*, 121–143.

Devarajan, S., Go, D., Robinson, S., & Thierfelder, K. (2011). Tax Policy to Reduce Carbon Emissions in a Distorted Economy: Illustrations from a South Africa CGE Model. *The B.E. Journal of Economic Analysis & Policy*.

Drielsma, J., Russell-Vaccari, A., Drnek, T., Brady, T., Weihed, P., Mistry, M., & Simbor, L. (2016). Mineral resources in life cycle impact assessment—defining the path forward. *The International Journal of Life Cycle Assessment*, 85-105.

Dullinger, I., Gattringer, A., Wessely, J., Moser, D., Plutzar, C., Willner, W., . . . Dullinger, S. (2020). A socio-ecological model for predicting impacts of land-use and climate change on regional plant diversity in the Austrian Alps. *Global Change Biology*, 2336-2352.

Engstroem, G. (2009). Assessing Sustainable Development in a DICE World.

Farajzadeh, Z., & Bakhshoodeh, M. (2015). Economic and environmental analyses of Iranian energy subsidy reform using Computable General Equilibrium (CGE) model. *Energy for Sustainable Developmentv*, 147-154.

Fichefet, T., & Maqueda, M. (1997). Sensitivity of a global sea ice model to the treatment of ice thermodynamics and dynamics. *Journal of Geophysical Research: Oceans*, 12609-12646.

Frischknecht, R., Fantke, P., Tschümperlin, L., Niero, M., Antón, A., Bare, J., . . . Jolliet, O. (2016). Global guidance on environmental life cycle impact assessment indicators: progress and case study. *The International Journal of Life Cycle Assessment*, 429-442.

Fu, Y., Huang, G., Liu, L., & Zhai, M. (2021). A factorial CGE model for analyzing the impacts of stepped carbon tax on Chinese economy and carbon emission. *Science of The Total Environment*.

Galeotti, M., & Carraro, C. (2004). Does Endogenous Technical Change Make a Difference in Climate Policy Analysis? A Robustness Exercise with the FEEM-RICE Model.

Goddéris, Y., François, L. M., Probst, A., Schott, J., Moncoulon, D., Labat, D., & Viville, D. (2006). Modelling weathering processes at the catchment scale: The WITCH numerical model. *Geochimica et Cosmochimica Acta, 70*, 1128–1147.

Goddéris, Y., Williams, J. Z., Schott, J., Pollard, D., & Brantley, S. L. (2010). Time evolution of the mineralogical composition of Mississippi Valley loess over the last 10 kyr: Climate and geochemical modeling. *Geochimica et Cosmochimica Acta, 74*, 6357–6374.

Grimsrud, K., Graesse, M., & Lindhjem, H. (2020). Using the generalised Q method in ecological economics: A better way to capture representative values and perspectives in ecosystem service management. *Ecological Economics*, 106588.

Gundlach, A., Ehrlinspiel, M., Kirsch, S., Koschker, A., & Sagebiel, J. (2018). Investigating people’s preferences for car-free city centers: A discrete choice experiment. *Transportation Research Part D: Transport and Environment*, 677-688.

Guo, N., Shi, C., Yan, M., Gao, X., & Wu, F. (2022). Modeling agricultural water-saving compensation policy: An ABM approach and application. *Journal of Cleaner Production*.

Gutiérrez, T., Rege, S., Marvuglia, A., Benetto, E., Bajo, J., Hernández, J., . . . Botti, V. (2015). Introducing LCA Results to ABM for Assessing the Influence of Sustainable Behaviours. *Trends in Practical Applications of Agents, Multi-Agent Systems and Sustainability*, 185-196.

Heinonen, J., & Ottelin, J. (2021). Carbon Accounting for Regenerative Cities. *Rethinking Sustainability Towards a Regenerative Economy*, 115-129.

Hermeling, C., Löschel, A., & Mennel, T. (2013). A new robustness analysis for climate policy evaluations: A CGE application for the EU 2020 targets. *Energy Policy*, 27-35.

Hermelingmeier, V., & Nicholas, K. (2017). Identifying Five Different Perspectives on the Ecosystem Services Concept Using Q Methodology. *Ecological Economics*, 255-265.

Hourcade, J.-C., Jaccard, M., Bataille, C., & Ghersi, F. (2006). Hybrid modeling: new answers to old challenges introduction to the special issue of the energy journal. *The Energy Journal*.

Hu, Z., Cao, J., & Hong, L. (2012). Robust Simulation of Global Warming Policies Using the DICE Model. *Management Science*, 2190-2206.

Hugé, J., Vande Velde, K., Benitez-Capistros, F., Japay, J., Satyanarayana, B., Nazrin Ishak, M., . . . Dahdouh-Guebas, F. (2016). Mapping discourses using Q methodology in Matang Mangrove Forest, Malaysia. *Journal of Environmental Management*, 988-997.

Jager, W. (2021). Using agent-based modelling to explore behavioural dynamics affecting our climate. *Current Opinion in Psychology*, 133-139.

Jenu, S., Deviatkin, I., Hentunen, A., Myllysilta, M., Viik, S., & Pihlatie, M. (2020). Reducing the climate change impacts of lithium-ion batteries by their cautious management through integration of stress factors and life cycle assessment. *Journal of Energy Storage*, 101023.

Ji, X., Wu, G., Lin, J., Zhang, J., & Su, P. (2022). Reconsider policy allocation strategies: A review of environmental policy instruments and application of the CGE model. *Journal of Environmental Management*.

Johnston, R., & Abdulrahman, A. (2017). Systematic non-response in discrete choice experiments: implications for the valuation of climate risk reductions. *Journal of Environmental Economics and Policy*, 246-267.

Josa, A., Aguado, A., Cardim, A., & Byars, E. (2007). Comparative analysis of the life cycle impact assessment of available cement inventories in the EU. *Cement and Concrete Research*, 781-788.

Judge, D., Deborah, D., & Deborah, D. (2018). Q Methodology: Teaching Strategy to Promote Student Engagement. *Nurse Educator*, Q Methodology: Teaching Strategy to Promote Student Engagement.

Kasurinen, H., Vatanen, S., Grönman, K., Pajula, T., Lakanen, L., Salmela, O., & Soukka, R. (2019). Carbon Handprint: Potential Climate Benefits of a Novel Liquid-Cooled Base Station with Waste Heat Reuse. *Energies*, 4452.

Kiehle, J. (2021). A carbon neutral campus. Tools of carbon footprint. *Master's thesis (University of OULU)*.

Kijak, R., & David, M. (2004). A Decision Support Framework for Sustainable Waste Management. *Journal of Industrial Ecology - Wiley*.

Kinnunen, A., Talvitie, I., Ottelin, J., Heinonen, J., & Junnila, S. (2022). Carbon sequestration and storage potential of urban residential environment – A review. *Sustainable Cities and Society*.

Klabunde, A., & Willekens, F. (2016). Decision-Making in Agent-Based Models of Migration: State of the Art and Challenges. *European Journal of Population*, 73-97.

Klang, A., Vikman, P.-Å., & Brattebø, H. (2003). Sustainable management of demolition waste—an integrated model for the evaluation of environmental, economic and social aspects. *Resources, Conservation and Recycling*, 317-334.

Kougias, I., Nikitas, A., Thiel, C., & Szabó, S. (2020). Clean energy and transport pathways for islands: A stakeholder analysis using Q method. *Transportation Research Part D: Transport and Environment*, 102180.

Kretschmer, B., & Peterson, S. (2010). Integrating bioenergy into computable general equilibrium models — A survey. *Energy Economics*, 673-686.

Kuittinen, M. (2019). Method for the whole life carbon assessment of buildings. *Ympäristöministeriön julkaisuja*.

Kuittinen, M., & Häkkinen, T. (2020). Reduced carbon footprints of buildings: new Finnish standards and assessments. *Buildings and Cities*, 182–197.

Küsters, J., Brentrup, F., Lammel, J., Barraclough, P., & Kuhlmann, H. (2004). Environmental impact assessment of agricultural production systems using the life cycle assessment (LCA) methodology II. The application to N fertilizer use in winter wheat production systems. *European Journal of Agronomy*, 265-279.

Lakanen, L., Grönman, K., Väisänen, S., Kasurinen, H., Soininen, A., & Soukka, R. (2021). Applying the handprint approach to assess the air pollutant reduction potential of paraffinic renewable diesel fuel in the car fleet of the city of Helsinki. *Journal of Cleaner Production*, 125786.

Lakanen, L., Kumpulainen, H., Helppi, O., Grönman, K., & Soukka, R. (2022). Carbon Handprint Approach for Cities and Regions: A Framework to Reveal and Assess the Potential of Cities in Climate Change Mitigation. *Sustainability*, 6534.

Le Hir, G., Donnadieu, Y., Goddéris, Y., Pierrehumbert, R. T., Halverson, G. P., Macouin, M., . . . Ramstein, G. (2009). The snowball Earth aftermath: Exploring the limits of continental weathering processes. *Earth and Planetary Science Letters, 277*, 453–463.

Lehrer, N., & Sneegas, G. (2018). Beyond polarization: using Q methodology to explore stakeholders' views on pesticide use, and related risks for agricultural workers, in Washington State's tree fruit industry. *Agriculture and Human Values*, 131-147.

Lemoine, D., & Rudik, I. (2020). Steering the Climate System: Using Inertia to Lower the Cost of Policy: Reply. *American Economic Review*, 1238-1241.

Li, Z. (2006). A new life cycle impact assessment approach for buildings. *Building and Environment*, 1414-1422.

Lin, B., & Jia, Z. (2020). Economic, energy and environmental impact of coal-to-electricity policy in China: A dynamic recursive CGE study. *Science of The Total Environment*.

Liu, Y., Tan, X.-J., Yu, Y., & Qi, S.-Z. (2017). Assessment of impacts of Hubei Pilot emission trading schemes in China – A CGE-analysis using TermCO2 model. *Applied Energy*, 762-769.

Llantoy, N., Chàfer, M., & Cabeza, L. (2020). A comparative life cycle assessment (LCA) of different insulation materials for buildings in the continental Mediterranean climate. *Energy and Buildings*.

Luderer, G., Bosetti, V., Jakob, M., Leimbach, M., Steckel, J. C., Waisman, H., & Edenhofer, O. (2012). The economics of decarbonizing the energy system—results and insights from the RECIPE model intercomparison. *Climatic Change, 114*, 9–37.

Luderer, G., Bosetti, V., Steckel, J., Waisman, H., Bauer, N., Decian, E., . . . Leimbach, O. S. (2009). The Economics of Decarbonization: Results from the RECIPE model intercomparison. *Potsdam Institute for Climate Impact Research, Potsdam, Germany*.

Mahat, P. (2021). *Carbon footprint of a refurbished smartphone retailer and carbon handprint of refurbished iPhone*. Retrieved from LUT University: https://lutpub.lut.fi/handle/10024/163282

Mangham, L., Hanson, K., & McPake, B. (2009). How to do (or not to do) … Designing a discrete choice experiment for application in a low-income country. *Health Policy and Planning*, 151-158.

Margni, M., Rossier, D., Crettaz, P., & Jolliet, O. (2002). Life cycle impact assessment of pesticides on human health and ecosystems. *Agriculture, Ecosystems & Environment*, 379-392.

Morais, T., Silva, C., Jebari, A., Álvaro-Fuentes, J., Domingos, T., & Teixeira, R. (2018). A proposal for using process-based soil models for land use Life cycle impact assessment: Application to Alentejo, Portugal. *Journal of Cleaner Production*, 864-876.

Natarajan, S., Padget, J., & Elliott, L. (2011). Modelling UK domestic energy and carbon emissions: an agent-based approach. *Energy and Buildings*, 2602-2612.

Ndunda, E., & Mungatana, E. (2013). Evaluating the welfare effects of improved wastewater treatment using a discrete choice experiment. *Journal of Environmental Management*, 49-57.

Nguyen, B., Boruff, B., & Tonts, M. (2018). Indicators of mining in development: A Q-methodology investigation of two gold mines in Quang Nam province, Vietnam. *Resources Policy*, 147-155.

Nieuwlaar, E., & Cleveland, C. (2004). Life Cycle Assessment and Energy Systems. 647-654.

Nijkamp, P., Wang, S., & Kremers, H. (2005). Modeling the impacts of international climate change policies in a CGE context: The use of the GTAP-E model. *Economic Modelling*, 955-974.

Notaro, S., Lovera, E., & Paletto, A. (2022). Consumers' preferences for bioplastic products: A discrete choice experiment with a focus on purchase drivers. *Journal of Cleaner Production*.

Nthambi, M., Markova-Nenova, N., & Wätzold, F. (2021). Quantifying Loss of Benefits from Poor Governance of Climate Change Adaptation Projects: A Discrete Choice Experiment with Farmers in Kenya. *Ecological Economics*.

Octaviano, C., Paltsev, S., & Gurgel, A. (2016). Climate change policy in Brazil and Mexico: Results from the MIT EPPA model. *Energy Economics*, 600-614.

Owens, J. (2001). Water Resources in Life-Cycle Impact Assessment: Considerations in Choosing Category Indicators. *Journal of Industrial Ecology*, 37-54.

Popov, A. A., Dobush, I. M., & Salnikov, A. S. (2022). A new extraction flow of the s mall-signal s witch-HEMT model based on the parasitic resistance scanning algorithm. *International Journal of RF and Microwave Computer-Aided Engineering, 32*, e23278.

Raux, C., Chevalier, A., Bougna, E., & Hilton, D. (2015). Mobility Choices and Climate Change: Assessing the Effects of Social Norms and Economic Incentives through Discrete Choice Experiments. *94th TRB Annual Meeting. Transportation and Climate Change - Impacts, Adaptation and Mitigation.*

Ravesh, A. (2022). PRODUCTIZING CARBON FOOTPRINT AND HANDPRINT FOR WOOD CONSTRUCTION. *Master's thesis (University of OULU)*.

Ren, W., & Liu, N. (2002, 9). Summary of the Method Research of Life Cycle Impact Assessment (LCIA). *Journal of Huazhong University of Science and Technology (Urban Science Edition)*.

Restrepo-Osorio, D., & Brown, J. (2018). A Q methodology application on disaster perceptions for adaptation and resiliency in an Andean watershed symposium: water and climate in Latin America. *Journal of Environmental Studies and Sciences*, 452-468.

Roy, P., Nei, D., Orikasa, T., Xu, Q., Okadome, H., Nakamura, N., & Shiina, T. (2009). A review of life cycle assessment (LCA) on some food products. *Journal of Food Engineering*, 1-10.

Roy, P., Nei, D., Orikasa, T., Xu, Q., Okadome, H., Nakamura, N., & Shiina, T. (2009). A review of life cycle assessment (LCA) on some food products. *Journal of Food Engineering*, 1-10.

Sala, S., Reale, F., Cristobal-Garcia, J., Marelli, L., Pant, R., & Commission), J. R. (2016). Life Cycle assessment for the impact assessment of policies. *EU publications*.

Ščasný, M., Zvěřinová, I., Czajkowski, M., Kyselá, E., & Zagórska, K. (2017). Public acceptability of climate change mitigation policies: a discrete choice experiment. *Climate Policy*, S111-S130.

Schwirplies, C., Dütschke, E., Schleich, J., & Ziegler, A. (2019). The willingness to offset CO2 emissions from traveling: Findings from discrete choice experiments with different framings. *Ecological Economics*.

Shaw, M., Pendleton, L., Cameron, D., Morris, B., Bachelet, D., Klausmeyer, K., . . . Roehrdanz, P. (2011). The impact of climate change on California's ecosystem services. *Climatic Change*, 465-484.

Shayegh, S., & Thomas, V. (2015). Adaptive stochastic integrated assessment modeling of optimal greenhouse gas emission reductions. *Climatic Change*, 1-15.

Shoyama, K., Managi, S., & Yamagata, Y. (2013). Public preferences for biodiversity conservation and climate-change mitigation: A choice experiment using ecosystem services indicators. *Land Use Policy*, 282-293.

Sonderegger, T., Berger, M., Alvarenga, R., Bach, V., Cimprich, A., Dewulf, J., . . . Young, S. (2020). Mineral resources in life cycle impact assessment—part I: a critical review of existing methods. *The International Journal of Life Cycle Assessment*, 784-797.

Swinscoe, T., Knoeri, C., Fleskens, L., & Barrett, J. (2014). Agent-based modelling of agricultural water abstraction in response to climate change and policies: In East Anglia, UK. *Social Simulation Conference*.

Sy, M., Rey-Valette, H., Simier, M., Pasqualini, V., Figuières, C., & De Wit, R. (2018). Identifying Consensus on Coastal Lagoons Ecosystem Services and Conservation Priorities for an Effective Decision Making: A Q Approach. *Ecological Economics*, 1-13.

Takanobu, K. (2009). Integrated Assessment for Setting Greenhouse Gas Emission Targets under the Condition of Great Uncertainty about the Probability and Impact of Abrupt Climate Change. *Journal of Environmental Informatics*, 89-99.

Tavoni, M., De Cian, E., Luderer, G., Steckel, J. C., & Waisman, H. (2012). The value of technology and of its evolution towards a low carbon economy. *Climatic Change, 114*, 39–57.

Tavoni, M., Sohngen, B., & Bosetti, V. (2007). Forestry and the carbon market response to stabilize climate. *Energy Policy, 35*, 5346–5353.

Tiina, P., Saija, V., Hanna, P., Kaisa, G., Heli, K., & Risto, s. (2018). *Carbon Handprint Guide*. Retrieved from VTT Technical Research Centre of Finland: https://cris.vtt.fi/ws/portalfiles/portal/22508565/Carbon_Handprint_Guide.pdf

Traeger, C. (2014). A 4-Stated DICE: Quantitatively Addressing Uncertainty Effects in Climate Change. *Environmental and Resource Economics*, 1-37.

Valentina, B., Marzio, G., & Alessandro, L. (2006). How consistent are alternative short-term climate policies with long-term goals? *Climate Policy*. Retrieved December 14, 2022, from https://www.tandfonline.com/doi/abs/10.1080/14693062.2006.9685603

Van Oijstaeijen, W., Van Passel, S., Back, P., & Cools, J. (2022). The politics of green infrastructure: A discrete choice experiment with Flemish local decision-makers. *Ecological Economics*.

Vanstockem, J., Vranken, L., Bleys, B., Somers, B., & Hermy, M. (2018). Do Looks Matter? A Case Study on Extensive Green Roofs Using Discrete Choice Experiments. *Sustainability*, 309.

Vargas, A., Diaz, D., & Aldana-Domínguez, J. (2019). Public discourses on conservation and development in a rural community in Colombia: an application of Q-methodology. *Biodiversity and Conservation*, 155-169.

Veronesi, M., Chawla, F., Maurer, M., & Lienert, J. (2014). Climate change and the willingness to pay to reduce ecological and health risks from wastewater flooding in urban centers and the environment. *Ecological Economics*, 1-10.

Wang, K., Wang, C., & Chen, J. (2009). Analysis of the economic impact of different Chinese climate policy options based on a CGE model incorporating endogenous technological change. *Energy Policy*, 2930-2940.

Wang, Y., Wang, Z., Wang, Z., Li, X., Pang, X., & Wang, S. (2021). Application of Discrete Choice Experiment in Health Care: A Bibliometric Analysis. *Frontiers in Public Health*.

Warren, R., Mastrandrea, M., Hope, C., & Hof, A. (2010). Variation in the climatic response to SRES emissions scenarios in integrated assessment models. *Climatic Change*, 671-685.

Wu, Z., Dai, E., Ge, Q., Xi, W., & Wang, X. (2017). Modelling the integrated effects of land use and climate change scenarios on forest ecosystem aboveground biomass, a case study in Taihe County of China. *Journal of Geographical Sciences*, 205-222.

Yang, Y., Son, K., Hung, F., & Tidwell, V. (2020). Impact of climate change on adaptive management decisions in the face of water scarcity. *Journal of Hydrology*.

Zabala, A., Sandbrook, C., & Mukherjee, N. (2018). When and how to use Q methodology to understand perspectives in conservation research. *Conservation Biology*, 1185-1194.

Zhao, X., Huning, A., Burek, J., Guo, F., Kropaczek, D., & Pointer, W. (2022). *The Role of Hybrid Energy Systems in Decarbonizing Industry: A Carbon Handprint–Based Case Study.* United States: Oak Ridge National Lab.(ORNL).

Zheng, C., Liu, Y., Bluemling, B., Chen, J., & Mol, A. (2013). Modeling the environmental behavior and performance of livestock farmers in China: An ABM approach. *Agricultural Systems*, 60-72.

Živojinović, I., & Wolfslehner, B. (2015). Perceptions of urban forestry stakeholders about climate change adaptation – A Q-method application in Serbia. *Urban Forestry & Urban Greening*, 1079-1087.

ANNEX: Case studies included in the best practices analysis

Method	Scope (Regional Or Global)	Country	Sector/Activity	Evaluated Policy	Reference
Q-Method					
Q-method	Regional	Serbia	Urban Forestry	Climate Change Adaptation	(Živojinović & Wolfslehner, 2015)
Q-method	Regional	Mexico	Socio-Ecological	Climate Change Adaptation	(Alfie-Cohen & Garcia-Becerra, 202)
Q-method	Regional	Norway	Ecological Economics	Ecosystem Services Conservation	(Grimsrud, Graesse, & Lindhjem, 2020)
Q-method	Regional	Ireland	Energy Types	CO2 Reduction	(Byrne, Byrne, & Ryan, 2017)
Q-method	Regional	Brazil	Agriculture	Deforestation	(Brannstrom, 2011)
Q-method	Regional	Colombia	Rural Community	Biodiversity Loss	(Vargas, Diaz, & Aldana-Domínguez, 2019)
Q-method	Regional	Thai	Agriculture	Pollution Control	(Bumbudsanpharoke, Moran, & Hall, 2009)
Q-method	Regional	Netherlands	Gas Exploration	Energy Efficiency	(Cuppen, Bosch-Rekveldt, Pikaar, & Mehos, 2016)
Q-method	Regional	Italy, UK, Hungary	Renewable Energy	Co2 Reduction	(Kougias, Nikitas, Thiel, & Szabó, 2020)
Q-method	Regional	Belgium	Public Transport	Co2 Reduction	(Cools, Moons, Janssens, & Wets, 2009)
Q-method	Regional	Netherlands	Biomass Energy	Co2 Reduction	(Curry, Barry, & McClenaghan, 2013)
Q-method	Regional	Latin America	Water And Climate	Ecosystem Services Conservation	(Restrepo-Osorio & Brown, 2018)
Q-method	Regional	Vanuatu	Natural Resource	Ecosystem Services Conservation	(Buckwell, y otros, 2020)
Q-method	Global	Sweden	Ecosystem Services	Ecosystem Services Conservation	(Hermelingmeier & Nicholas, 2017)
Q-method	Regional	Malaysia	Forest	Deforestation	(Hugé, et al., 2016)
Q-method	Regional	Coastal Lagoon	Ecosystem Services	Ecosystem Services Conservation	(Sy, et al., 2018)
Q-method	Regional	Vietnam	Gold Mines	Pollution Control	(Nguyen, Boruff, & Tonts, 2018)
Q-method	Regional	USA	Social–Ecological	Ecosystem Services Conservation	(Armatas, Venn, & Watson, 2017)
Q-method	Regional	UK	Ecological Economics	Co2 Reduction	(Barry & Proops, 1999)

Q-method	Regional	Spain	Social–Ecological	Climate Change Adaptation	(Albizua & Zografos, 2014)
Discrete Choice Experiment					
Discrete Choice Experiment	Regional	Czech Republic, Poland, UK	Climate Change Policies	Climate Change Adaptation	(Ščasný, Zvěřinová, Czajkowski, Kyselá, & Zagórska, 2017)
Discrete Choice Experiment	Regional	Kenyan	Climate Change Policies	Climate Change Adaptation	(Nthambi, Markova-Nenova, & Wätzold, 2021)
Discrete Choice Experiment	Regional	Kenyan	Treated Wastewater	Climate Change Adaptation	(Ndunda & Mungatana, 2013)
Discrete Choice Experiment	Regional	France	Public Transport	Co2 Reduction	(Raux, Chevalier, Bougna, & Hilton, 2015)
Discrete Choice Experiment	Regional	USA	Climate Change Policies	Climate Change Adaptation	(Johnston & Abdulrahman, 2017)
Discrete Choice Experiment	Regional	Croatia	Agriculture	Agricultural Risk Management	(Čop & Njavro, 2022)
Discrete Choice Experiment	Regional	Japan	Ecosystem Services	Ecosystem Services Conservation	(Shoyama, Managi, & Yamagata, 2013)
Discrete Choice Experiment	Regional	Belgium	Infrastructure	Climate Change Adaptation	(Van Oijstaeijen, Van Passel, Back, & Cools, 2022)
Discrete Choice Experiment	Regional	Korea	Vehicles	Climate Change Adaptation	(Byun, Shin, & Lee, 2018)
Discrete Choice Experiment	Regional	Italy	Bioplastic	Co2 Reduction	(Notaro, Lovera, & Paletto, 2022)
Discrete Choice Experiment	Regional	Germany	Public Transport	Co2 Reduction	(Schwirplies, Dütschke, Schleich, & Ziegler, 2019)
Discrete Choice Experiment	Regional	Germany	Car-Free City Centres	Pollution Control	(Gundlach, Ehrlinspiel, Kirsch, Koschker, & Sagebiel, 2018)
Discrete Choice Experiment	Regional	Belgium	Buildings	Climate Change Adaptation	(Vanstockem, Vranken, Bleys, Somers, & Hermy, 2018)
Discrete Choice Experiment	Regional	Swiss	Wastewater	Climate Change Adaptation	(Veronesi, Chawla, Maurer, & Lienert, 2014)
Carbon Handprint					
Carbon Handprint	Global	Finland	Energy (Diesel Fuel)	Pollution Control	(Lakanen, et al., 2021)

Carbon Handprint	Global	Finland	Base Station Technology	CO2 Reduction	(Kasurinen, et al., 2019)
Carbon Handprint	Global	USA	Industrial	CO2 Reduction	(Zhao, et al., 2022)
Carbon Handprint	Global	Finland	Multi-Sectoral	CO2 Reduction	(Mahat, 2021)
Carbon Handprint	Global	Finland, Island	Urban Residential Environment	Deforestation	(Kinnunen, Talvitie, Ottelin, Heinonen, & Junnila, 2022)
Carbon Handprint	Global	Finland	Urban Residential Environment	Co2 Reduction	(Lakanen, Kumpulainen, Helppi, Grönman, & Soukka, 2022)
Carbon Handprint	Global	Finland	Microalgae	Co2 Reduction	(Daneshvar, Wicker, Show, & Bhatnagar, 2022)
Carbon Handprint	Global	Finland	Buildings	Co2 Reduction	(Kuittinen, 2019)
Carbon Handprint	Global	Finland	A Carbon Neutral Campus	CO2 Reduction	(Kiehle, 2021)
Carbon Handprint	Global	Finland	Lithium-Ion Batteries	Co2 Reduction	(Jenu, et al., 2020)
Carbon Handprint	Global	Finland	Buildings	Co2 Reduction	(Kuittinen & Häkkinen, 2020)
Carbon Handprint	Global	Iceland, Finland	Regenerative Cities	Co2 Reduction	(Heinonen & Ottelin, 2021)
Carbon Handprint	Global	Finland	Buildings	Co2 Reduction	(Ravesh, 2022)
Carbon Handprint	Global	USA, Germany	Business's Eco-Innovation	Co2 Reduction	(Burek, et al., 2022)
Life Cycle-Impact Assessment					
Life Cycle-Impact Assessment	Global	Norway	Bioenergy	Co2 Reduction	(Bright, Cherubini, & Strømman, 2012)
Life Cycle-Impact Assessment	Global	Japan	Buildings	Pollution Control	(Li, 2006)
Life Cycle-Impact Assessment	Global	Global	Agriculture	Pollution Control	(Frischknecht, et al., 2016)
Life Cycle-Impact Assessment	Global	Canada, Zurich, USA, France	Multi-Sectoral	Pollution Control	(Bulle, et al., 2019)
Life Cycle-Impact Assessment	Global	EU	Land Use	Biodiversity Loss	(Brentrup, Küsters, Lammel, & Kuhlmann, 2002)

Life Cycle-Impact Assessment	Global	Swiss	Agriculture	Ecosystem Services Conservation	(Margni, Rossier, Crettaz, & Jolliet, 2002)
Life Cycle-Impact Assessment	Global	EU	Cement Inventories	Pollution Control	(Josa, Aguado, Cardim, & Byars, 2007)
Life Cycle-Impact Assessment	Global	Netherlands	Vehicle	Pollution Control	(Castro, Remmerswaal, & Reuter, 2003)
Life Cycle-Impact Assessment	Global	USA	Water Resource	Pollution Control	(Owens, 2001)
Life Cycle-Impact Assessment	Global	Portugal	Land Resource	Co2 Reduction	(Morais, et al., 2018)
Life Cycle-Impact Assessment	Global	Global	Agriculture	Co2 Reduction	(Cerutti, et al., 2014)
Life Cycle-Impact Assessment	Global	Japan	Food Industry	Co2 Reduction	(Roy, y otros, A review of life cycle assessment (LCA) on some food products, 2009)
Life Cycle-Impact Assessment	Global	UK Y Germany	Agriculture	Energy Efficiency	(Bennett, Phipps, Strange, & Grey, 2004)
Life Cycle-Impact Assessment	Global	Spain	Buildings	Energy Efficiency	(Llantoy, Chàfer, & Cabeza, 2020)
Agent Based Models					
Agent Based Model	Regional	Austrian	Land Use	Plant Diversity Loss	(Dullinger, y otros, 2020)
Agent Based Model	Regional	UK	Agriculture	Climate Change Adaptation	(Swinscoe, Knoeri, Fleskens, & Barrett, 2014)
Agent Based Model	Regional	Italy	Socio-Ecosystems	Climate Change Adaptation	(Balbi & Giupponi, 2010)
Agent Based Model	Regional	Germany	Agriculture	Climate Change Adaptation	(Berger & Troost, 2014)
Agent Based Model	Regional	Portugal	Agriculture	Ecosystem Services Conservation	(Acosta, et al., 2014)
Agent Based Model	Regional	Bangladesh	Climate Change	Climate Change Adaptation	(Angus & Parris, 2009)
Agent Based Model	Regional	Indian	Water Scarcity	Climate Change Adaptation	(Yang, Son, Hung, & Tidwell, 2020)
Agent Based Model	Regional	Germany	Agriculture	Climate Change Adaptation	(Gutiérrez, et al., 2015)

Agent Based Model	Regional	China	Agriculture	Climate Change Adaptation	(Guo, Shi, Yan, Gao, & Wu, 2022)
Agent Based Model	Regional	China	Agriculture	Climate Change Adaptation	(Zheng, Liu, Bluemling, Chen, & Mol, 2013)
Agent Based Model	Regional	China	Land Use	Biodiversity Loss	(Wu, Dai, Ge, Xi, & Wang, 2017)
Agent Based Model	Regional	Italy	Socio-Ecosystems	Climate Change Adaptation	(Balbi & Giupponi, 2009)
Agent Based Model	Global	Global	General	Climate Change Adaptation	(Jager, 2021)
Agent Based Model	Regional	UK	Domestic Energy	Co2 Reduction	(Natarajan, Padget, & Elliott, 2011)
Agent Based Model	Regional	EU	Agriculture Policy	Biodiversity Loss	(Brady, Sahrbacher, Kellermann, & Happe, 2012)
CGE Model					
CGE Model	Regional	Sweden	Multisector	Climate Change Adaptation	(Bergman, Mäler, & Vincent, 2005)
CGE Model	Regional	China	General	Climate Change Adaptation	(Wang, Wang, & Chen, 2009)
CGE Model	Regional	South Africa	Tax Policy	Co2 Reduction	(Devarajan, Go, Robinson, & Thierfelder, 2011)
CGE Model	Regional	Latin America, Caribbean	Tax Policy	Climate Change Adaptation	(Chisari & Miller, 2015)
CGE Model	Global	Global	Bioenergy	Climate Change Adaptation	(Kretschmer & Peterson, 2010)
CGE Model	Regional	Iranian	Energy Subsidies	Climate Change Adaptation	(Farajzadeh & Bakhshoodeh, 2015)
CGE Model	Regional	China	Carbon Tax	Co2 Reduction	(Fu, Huang, Liu, & Zhai, 2021)
CGE Model	Regional	China	Environmental Policy	Climate Change Adaptation	(Ji, Wu, Lin, Zhang, & Su, 2022)
CGE Model	Global	Global	Climate Change	Climate Change Adaptation	(Babatunde, Begum, & Said, 2017)
CGE Model	Regional	Italy	Energy	Climate Change Adaptation	(Antimiani, Costantini, & Paglialunga, 2015)
CGE Model	Global	EU	Climate Change Adaptation	Climate Change Adaptation	(Hermeling, Löschel, & Mennel, 2013)
CGE Model	Regional	Costa Rica	Economic Policies	Climate Change Adaptation	(Abler, Rodríguez, & Shortle, 1999)
CGE Model	Regional	China	High-Speed Rail Investment	Climate Change Adaptation	(Chen, Xue, Rose, & Haynes, 2016)
CGE Model	Regional	China	Emission Trading Schemes	Climate Change Adaptation	(Liu, Tan, Yu, & Qi, 2017)

CGE Model	Regional	China	Energy	Climate Change Adaptation	(Lin & Jia, 2020)
GTAP-E	Global	USA	Multi-Sectoral	CO2 Reduction	(Nijkamp, Wang, & Kremers, 2005)
ICES	Global	Global	Sea Ice	CO2 Reduction	(Fichefet & Maqueda, 1997)
GREEN	Global	EU	Multi-Sectoral	CO2 Reduction	(Burniaux, Nicoletti, & Oliveira-Martins, 1992)
Imaclim-R	Global	Global	Multi-Sectoral	CO2 Reduction	(Bibas, et al., 2022)
AIM	Regional	China	Energy	CO2 Reduction	(Dai, Masui, Matsuoka, & Fujimori, 2011)
EPPA	Global	Mexico, Brazil	Multi-Sectoral	CO2 Reduction	(Octaviano, Paltsev, & Gurgel, 2016)
DICE2007					
DICE2007	Global	USA, Zurich	CO2 Reduction	CO2 Reduction	(Cai, Judd, & Lontzek, 2012)
DICE2007	Global	USA	CO2 Reduction	CO2 Reduction	(Traeger, 2014)
DICE2007	Global	USA	CO2 Reduction	CO2 Reduction	(Shayegh & Thomas, 2015)
DICE2007	Global	Sweden	Energy	CO2 Reduction	(Engstroem, 2009)
DICE2007	Global	Japan	Climate Change	CO2 Reduction	(Takanobu, 2009)
DICE2007	Global	Global	Climate Change	CO2 Reduction	(Hu, Cao, & Hong, 2012)
DICE2007	Global	USA	Carbon Tax	CO2 Reduction	(Lemoine & Rudik, 2020)
DICE2007	Global	USA	Climate Change	Ecosystem Services Conservation	(Shaw, et al., 2011)
DICE2007	Global	USA	Carbon Tax	Co2 Reduction	(Cai, Judd, & Lontzek, 2012)
DICE2007	Global	Global	Economic Policies	Co2 Reduction	(Cai & Lontzek, 2019)
DICE2007	Global	Global	Economic Policies	Co2 Reduction	(Cai, Judd, & Lontzek, 2013)
DICE2007	Global	Netherlands, USA, UK	Climate Change	CO2 Reduction	(Warren, Mastrandrea, Hope, & Hof, 2010)
FEEMRICE					
FEEMRICE	Global	Italy	Technical Change	Co2 Reduction	(Bosetti & Drouet, 2005)
FEEMRICE	Global	Global	Investment	Co2 Reduction	(Bosello, 2010)
FEEMRICE	Global	Global	Trade Policy	Co2 Reduction	(Carraro & Egenhofer, 2007)
FEEMRICE	Global	Global	Technical Change	Co2 Reduction	(Galeotti & Carraro, 2004)
FEEMRICE	Global	Italy	Technical Change	Co2 Reduction	(Carraro & Buchner, 2004)

FEEMRICE	Global	Italy	Emission Trading Regimes and Incentives	Co2 Reduction	(Buchner & Carraro, 2004)
FEEMRICE	Global	Italy	Climate Policy	CO2 Reduction	(Valentina, Marzio, & Alessandro, 2006)
FEEMRICE	Global	USA, China	Emission Trading Regimes and Incentives	CO2 Reduction	(Buchner & Carraro, Modelling climate policy, 2005)
FEEMRICE	Global	Italy	Emission Trading Regimes and Incentives	CO2 Reduction	(Buchner & Carraro, 2009)
FEEMRICE	Global	Italy	Technical Change	Co2 Reduction	(Bosetti, Carraro, & Galeotti, 2006)
FEEMRICE	Global	Italy	Technical Change	Co2 Reduction	(Bosetti, Carraro, & Galeotti, 2006)
FEEMRICE	Global	USA, China	Climate Negotiations	Co2 Reduction	(Buchner & Carraro, 2006)
FEEMRICE	Global	USA, China	Climate Policy	Co2 Reduction	(Bosetti & Buchner, 2005)

The PATTERN project aims to improve practitioners' capacity for decision making on climate and environmental policies by developing a One-Stop Shop for the economic appraisal of policies and measures. With this One-Stop Shop and its different components, PATTERN will provide decision-makers, stakeholders, and the public with more realistic ability to systematically assess the options and their consequences. It will provide a basis for improving (i) methodologies, techniques and models for conducting economic appraisal of climate and environmental policies (ii) the broader policy evaluation framework and practices currently used in European countries and their regions and (iii) tailored analysis and engagement strategies structures for participation and co-creation with relevant stakeholders and key actors to enhance operational capacities of economic appraisal methods and improve the impact of European policies on climate and environment.

PATTERN

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