MAREA

Output O.T2.1.1
Conceptual model of Natural Capital Accounting

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Tin-Yu Lai[1], Liisa Saikkonen[1], Louise Forsblom[1], Jonne Kotta[2], Francisco R. Barboza[2]

Finnish Environment Institute[1], University of Tartu[2]

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Introduction of the conceptual model of natural capital accounting

The scope of natural capital can be various in different frameworks or contexts. Some refer to ecosystem assets and their provided ecosystem services (ESs), while others may have a broader scope to cover abiotic environmental resources (MAES et al., 2013; EEA and Petersen, 2019). However, regardless of how the scope is defined, natural capital accounting (NCA) aims to integrate the information of natural capital, which includes both asset and services information, into the accounting system. Such integration can make the environmental information comparable and compatible with the economic data that are compiled under the system of national accounting (EEA and Petersen, 2019, UN et al., 2014; 2021). The policy relevance of NCA has become recently more recognized. NCA was suggested as a tool to integrate the value of nature under the EU biodiversity strategy 2030 (EC, 2020). In addition, the Regulation on European Environmental Economic Accounts (EU 691/2011) is under revision to cover modules on ecosystem extent, condition, and service accounts, which serve as a basis for NCA (European Court of Auditors, 2019).

In the MAREA project, we cover the assets and services provided by both biotic and abiotic compartments of ecosystems as natural capital. We follow the guidelines from the System of Environmental-Economic Accounting – Central Framework (SEEA CF) and SEEA – Ecosystem Accounting (SEEA EA) Framework (UN et al., 2014; 2021). SEEA CF and SEEA EA provided guidelines to integrate human-nature systems under the accounting framework and developed the theoretical concept of NCA. However, the works done by different Work Packages (WPs) under this project provide more concrete examples to integrate human-nature systems, which can connect or contribute to NCA in different ways: WP1 develops models and high-resolution maps of ESs or the capability of ecosystems to provide ES, WP2 works on valuing the ESs and establishes the links between ESs and economic sectors, and the geoportal developed in WP4 provides a fundamental tool to reveal trade-offs and consider human impacts on ESs (Kotta et al., 2020). Taking the above-mentioned frameworks as the basis and the working experiences from each WP, WP2 further develops a conceptual model to link the products developed in each WP to NCA.

Figure 1 shows a schematic representation of the developed conceptual model. The steps located on the circle are the main activities developed in the MAREA project. The steps outside of the circle represent the necessary preparatory tasks and/or the linkage to the practical tasks needed to compile the natural capital accounts, which were beyond the working scope of MAREA. Steps 1, 2, 3, 6, and 7 require collaboration between WP2 and other WPs, and steps 4 and 5 are the sole ones under WP2. The following sections explain each step and provide working examples from MAREA.

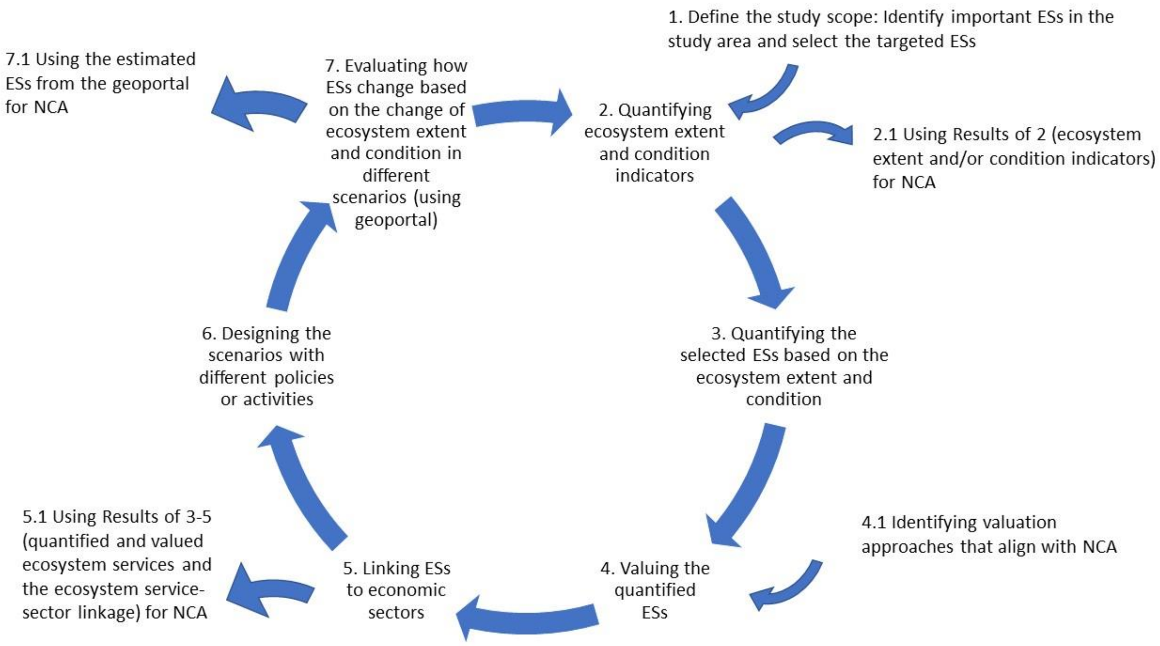

Figure 1 Schematic representation of the conceptual model for the natural capital accounting developed in WP2. (ES=Ecosystem service, NCA = natural capital accounting)

Components of the conceptual model

1. Define the study scope: Identify important ecosystem services in the study area and select the targeted ecosystem services

The importance of ESs can be defined from an ecological perspective, the demand and use of the ESs, and/or the relevant concerns of human society. Identifying the important ESs gives a hint on which ESs should be targeted. However, the selection of ESs for further quantification, valuation, and integration to NCA is also influenced by the availability of data and resources. WP1 has produced several maps of relevant ESs as classified according to the CICES classification. Although the final list of ES maps was influenced by current knowledge, data availability and suitability, the developed maps cover the most important ESs (See Deliverable D.T1.1.1 and Output O.T1.1). The ESs selected by WP2 are dependent on whether the ESs could be quantified in WP1 (e.g., global climate regulation services from blue carbon), the available economic data with the suitable valuation approaches, and the relevance of the ES to the society (e.g., increasing of outdoor recreational visits under COVID-19 pandemic (Fagerholm et al., 2021)). Table 1 lists a selection of ESs targeted in WP1 and WP2 to demonstrate the conceptual model. The full list of ES maps is available in D.T1.1.1.

Table 1 Examples of the study scope and selected ecosystem services (ESs).

Example of targeted ESs	Example of targeted habitats	Study area
Coastal filter: biodeposition of blue mussel (*Mytilus trossulus*) populations (Can be regarded as a type of water purification service in the SEEA EA)	Mussel reefs	The entire MAREA study area
The production yield of macroalgal biomass under farm conditions (=aquaculture provisioning services listed in the SEEA EA)	Macroalgal (*Ulva intestinalis* and *Fucus vesiculosus*) farms as artificial habitats (cultivation is taking place in the water column that is not a natural habitat for these species)	
Recreation and other cultural ESs	Common reed	Finnish coastal (cover partial MAREA study area)
	General marine and coastal ecosystems	Finland, Estonia, Latvia (Cover the entire MAREA study area)
Global climate regulation services (Also called blue carbon or carbon sequestration in WP1)	Seagrass meadows, mussel	The entire MAREA study area

2. Quantifying ecosystem extent and condition indicators

Some maps of ES (potential) supply (see Deliverable D.T1.1.1) produced by WP1 were based on the distribution of multiple habitats and species (see Output O.T1.1), which can be regarded as ecosystem extent based on the definition from SEEA EA and can be used to quantify the size of ecosystem extent (UN et al., 2021) (also see step 2.1). Depending on the indicators used in WP1, the maps can be used to further estimate either the supply or the potential supply of selected ESs. In addition to the (potential) supply of ESs, some of the maps in WP1 use the indicators that can indicate the capacity or opportunity of the ecosystem to provide ESs, such as the probability of the appearance of aquatic vegetation that indicates the potential to prevent erosion, the cover of seagrass, or biomass of specific species. These indicators correspond to the compositional or structural state characteristics type of ecosystem condition variables mentioned in the SEEA EA (UN et al., 2021). The habitat extent and condition play an important role in estimating ESs and their value, especially for some regulating and provisioning services (see more detailed explanation in step 3).

2.1 Using of ecosystem extent and/or condition indicators for natural capital accounting

In NCA, ecosystem extent and ecosystem condition accounts are two of the five core accounts. Ecosystem extent accounts record the size information on the area of a specific ecosystem type characterized by a distinct set of biotic and abiotic components and their interactions (UN et al., 2021). Therefore, the habitat maps produced in WP1 can serve as a good input for extent accounts.

Ecosystem condition account records the quality of an ecosystem measured in terms of its abiotic and biotic characteristics, which influence the capacity of the ecosystems to provide services (UN et al., 2021). Although the estimates and maps generated in WP1 provide a candidate list of the variables that could be included in ecosystem condition accounts for NCA, some further works likely need to be done before these estimates can be used for NCA. Some of the indicators that indicate the capacity of ES supply in WP1 are shown as between 0 and 1 (see D.T1.1.1), which either are scaled based on the lowest and highest observed values in the data or represent the probability of occurrence. However, SEEA EA (UN et al., 2021) states that scaling the selected ecosystem condition variables to ecosystem condition indicators between 0 and 1 should be based on the references level that can reflect good and bad ecosystem conditions. Also, NCA needs aggregated results to show the condition of an ecosystem extent in the table, but not in the map format.

There is an important perspective that needs to be considered to apply these ecosystem extent and condition indicators to NCA. NCA requires regular updates (e.g., every few years) in order to provide policy-relevant data or to allow comparison between periods. Therefore, the suitability of the indicators for use in NCA is influenced by how easily these ecosystem extents (habitat and species) and/or condition indicators can be re-quantified (e.g., every few years) to reflect the updated extent and condition for subsequent accounting rounds.

3. Quantifying the selected ecosystem services based on the ecosystem extent and condition

For different types of ESs, the role of ecosystem extent and condition in estimating the ESs may be different. In the case of some regulation services, for example, global climate regulation services from blue carbon, the information from ecosystem extent and condition can be used to quantify the actual supply and use flows of ESs in the physical term, either through modelling with the extent and/or condition indicators as part of the input data or through a proxy estimation based on ecosystem extent and condition results. For some other ESs, like fish provisioning or cultural ESs, the information from ecosystem extent and condition could only be used to estimate the potential ES supply or help to indicate the capacity or opportunity of ecosystems to provide ESs. For these ESs, the quantification of the actual supply flows of ESs in physical terms requires information on the demand side and using other approaches that can measure the ES supply and use directly. Table 2 gives some examples of the approaches to quantify the physical flows of the selected ESs (the last columns in Table 2) as well as the approaches that are applied in the MAREA project but can only estimate the potential ES supply or indicate the opportunity to provide ESs (the second column in Table 2). When there are multiple ways to measure the actual supply of a type of ESs, the priority order to use would be direct measuring, modelling, and then approximating based on ecosystem extent and condition features. The former ones could provide a more accurate estimation and thus more suitable for valuation and NCA.

The estimated actual ES supply, potential ES supply, or capacity and opportunity to provide ESs can link to different steps of NCA. Actual ESs supply can be used for ES supply and use accounts together with the information provided in step 5 (see more detail in step 5.1). The potential ES supply and the information on the capacity or opportunity of the ecosystems to provide ESs could be helpful to estimate the future flows of ESs, which could be used to estimate the value of the ecosystem assets (UN et al., 2021) (see more detail in step 7.1).

During the process of quantifying the selected ESs, the crucial point is that the unit used in the physical term should align with the unit used for valuation in step 4. For example, if the physical term of recreation services is measured in total length of visiting time, but the available valuation approach uses value per visit to measure the monetary value, it is not possible to conduct step 4. Therefore, even though the order of the steps is quantifying the physical terms of ESs first and then valuing the quantified ESs, the valuation approach and the forms of economic data used for valuation should already be considered at this stage.

Table 2 Approaches to quantify ES flows of the selected ESs

Example of targeted ESs	Approach to quantify potential ES supply or indicate the opportunity to supply ES	Approach to quantify actual ES supply
Coastal filter: biodeposition of blue mussel populations (Can be regarded as a type of water purification service in the SEEA EA)	Spatial modelling (boosted regression trees and dynamic energy budget modelling) based on earlier experimental evidence of these ecosystem services (indicators) from WP1 and WP4	
The production yield of macroalgal biomass under farm conditions (*Ulva intestinalis* and *Fucus vesiculosus*) (=aquaculture provisioning services listed in the SEEA EA)	Same as above	Require information of actual cultivation amount and only consider the amount provided by the farms that currently exist. (This estimation is not included in the MAREA project)
Global climate regulation services	Based on combining modelled biomasses of selected species with literature values on carbon sequestration (WP1) or the spatial modelling as above (WP4)	
Recreation and other cultural ES	Though coastal suitability index (CSI) that summarizes the suitable coastal features for developing cultural and recreational activities from WP1	Based on a questionnaire survey conducted by WP2
Aesthetic services	Areas with the low and high number of visible artificial objects are identified through viewshed analysis from WP1	Same as above

4 Valuing the quantified ecosystem services

Depending on the types of ESs and the estimation methods of ESs on their physical terms, this valuation step can be separated from the step of quantified ESs and conducted after that step (two-step procedures), but it is also possible to combine the two steps together for some services (one-step procedures). Taking the valuation of recreation services as an example, the two-step procedures could first estimate the number of visits to specific ecosystem types applying various approaches (e.g., counter, available statistics, social media or phone data (Venter et al., 2020)), and then use the transferred value of value per visits from existing studies to estimate the total value of the recreational services (Vačkář et al., 2018; UN et al., 2021). Two-step procedures are applicable when data of physical and monetary terms are collected e.g., from various sources, in different ways, or at different times. The example of climate regulation service valued in WP2 uses such two-step procedures as the physical terms of ES were estimated separately. As mentioned in step 3, this requires the unit alignment between quantifying ESs in physical terms and valuing quantified ESs.

For some types of ESs, the valuation approaches may require collecting the economic data and the correspondent data in physical terms simultaneously, i.e., conducting steps 3 and 4 together. For example, valuing the recreation services through the travel cost model also requires collecting the number of visits, which is one of the indicators used to measure the physical terms of the recreation services (UN et al., 2021). Therefore, steps 3 and 4 are conducted at the same time by collecting the data in the same survey, like how WP2 did for the recreation services in this project. The benefit of conducting steps 3 and 4 together is that the consistency between the physical and monetary measures of the services can be assured. However, it should be noted that maintaining the linkage between the physical value of the services and habitat and condition accounts is still important for NCA when conducting steps 3 and 4 together. Although some previous studies have tried to include a few environmental quality factors in valuing marine and coastal recreation services (e.g., Bertram et al., 2020; Lankia et al., 2019), the knowledge of the linkages between the demand for recreation-related services and the condition/habitat indicators can be improved (Saikkonen et al., in prep.; SYKE et al., 2021). Therefore, in WP2, several ecosystem condition indicators (e.g., the observed level of blue-green algae as an indicator of water quality, observed litter amount on the beach, observed biodiversity, and observed artificial objects) and some habitat types (e.g., common reed) are included in the questionary. Also, a georeferenced location was requested in the survey to make the survey results potentially linkable to the model products of condition or habitat indicators. The survey design in this project considered these two perspectives. Therefore, the estimation of recreation services can have a stronger link with ecosystem conditions and habitats to ensure its suitability for NCA.

4.1 Identifying valuation approaches that align with natural capital accounting

Each type of ES can be valued in several ways depending on the purpose of valuation. For NCA, comparability of the valuation results of ESs with the economic information recorded in the national accounting system is one of its key purposes (UN et al., 2021). Based on SEEA EA (UN et al., 2021), only the exchange value is considered, so not all the valuation approaches are applicable as some approaches value the consumer surplus. Therefore, it is required at the preparation stage to identify the valuation approaches that align with NCA requirements. The contributing partner has done this work for the selected ESs in another project (Saikkonen et al., in prep.; SYKE et al., 2021). Based on the review work of that project, the preferences order of valuation methods for NCA guided by the SEEA EA (UN et al., 2021), and the data availability, WP2 chooses at least one method to value the selected ESs. We select more than one valuation methods to explore the value differences for the same ES when different methods are applied.

5. Linking ecosystem services to economic sectors

The term, economic sectors, used in this project refers to the institutional sectors in the system of national accounting (SNA), which are formed by grouping the economic units that have similar purposes, objectives, and behaviours (UN et al., 2010). Economic units, also called institutional units, are the basic unit of the SNA and the ES user of NCA (UN et al., 2010;

UN et al., 2021). An economic unit is an economic entity that can engage in the full range of transactions and can own assets and incur liabilities on its own behalf (UN et al., 2010*),* such as household, legal or social entities (e.g., corporations and NGOs), and government (UN et al., 2010; UN et al., 2014). Following the classification in the SNA, the economic sectors for NCA can be classified as industry, household, government, and export (rest of the word). The latter three sectors are final consumption, and the industry sector can be further classified into different sub-sectors by economic activities (UN et al., 2021). In WP2, the Statistical classification of economic activities in the European Community (NACE)[1] Rev. 2 (EC, 2008) is used as the basis for the sub-sector classification of the industry sector.

WP2 links ESs to economic sectors in two ways: use perspective and impact perspective. In terms of use perspective, WP2 identifies (1) the sectors that use the ES provided by the Baltic Sea and (2) the sectors that have the potential to use the ES provided by the Baltic Sea, but the use of the ES does not currently happen. For example, the marine aquaculture sector using aquaculture provisioning services of rainbow trout belongs to (1). However, the marine aquaculture sector using aquaculture provisioning services of blue mussel belongs to (2), as farmed mussels for food or feed are not commercially produced in the Baltic Sea (Jernberg et al., in prep.), but many experimental actions are happening in the Baltic Sea (Baltic EcoMussel, 2003; Minnhagen et al., 2019). The linkages between the ES and economic sectors of (1) and (2) are based on the SEEA EA (UN et al., 2021) and other supplement references (see Output OT2.1.2 for the references of each ES). For both cases, not only the industry sub-sectors that directly use the ES as input but also the industry sub-sectors that use the outputs of the ES products from the direct-use sectors are identified. The final consumption sectors are only listed under direct-use sectors, as their indirect use of the ES requires detailed transaction data of each product, which is out of the scope of this project. During the work of establishing the links, it was noticed that the description in NACE Rev.2 was not clear enough to classify manufacturers of bio-based products to specific sectors as NACE Rev.2 was published in 2008 when the bio-based products were not so popular. For the case of manufacturers of bio-based products, we follow the sector classification in a Joint Research Centre (JRC) report (M'barek et al., 2018) that link the bio-based products producers to the sector that produces the equivalent products based on the chemical components. Output O.T2.1.2 shows the results of the linkage of eight types of selected ESs to the economic sectors. The selected ESs are part of the targeted ES in WP1 and WP2.

For linking the ES with economic sectors from an impact perspective, the linkage will be established based on the cumulative effects embedded in geoportal (Kotta et al., 2020). This is an ongoing work to develop the social-economic model in the geoportal with WP4 for feedback and trade-off analysis (part of the next derivable). Therefore, only an example is demonstrated here (see Table 3). One of the cumulative effects embedded in geoportal is the pressure of nutrient load, which, for example, has impacts on the biodeposition of blue mussel populations (part of water purification services) and the carbon sequestration of seagrass (part of global climate regulation services) (Kotta et al., 2020). The pressure is linked to different activities that contribute to the pressure of nutrient load based on the activity-

[1] NACE is derived from the French title "Nomenclature générale des Activités économiques dans les Communautés Européennes" (Statistical classification of economic activities in the European Communities).

pressure contributions presented in HELCOM ACTION report (2021), and the listed activities can be linked to sectors in NACE Rev.2.

Table 3 Example of linking the ES with economic sectors from the impact perspective

ES	Pressure in cumulative effects assessments	Pressure in HELCOM report	Activity in HELCOM report*	Sectors (NACE Rev. 2)
Biodeposition of blue mussel populations Carbon sequestration of seagrass	Nutrient load	Input of phosphorus to the Gulf of Finland	Agriculture	A 01 Crop and animal production, hunting and related service activities
			Forestry	A 02 Forestry and logging
			Storm water/overflows	Government or O 84 Public administration and defence; compulsory social security (Government act as collectively impacts from urban community)
			Scattered Dwellings	Household
			WWTP	E 37 Sewerage
			Industry	Requires collecting further information to identify if specific industries typically do not connect to the network of WWTP (either have their own WWT procedures or no treatment)
			Freshwater aquaculture	A 03.22 Freshwater aquaculture
			Marine aquaculture	A 03.21 Marine aquaculture
		Input of nitrogen to the Gulf of Finland	Agriculture	A 01 Crop and animal production, hunting and related service activities
			Forestry	A 02 Forestry and logging
			Stormwater/overflows	Government or O 84 Public administration and defence; compulsory social security (Government act as collectively impacts from urban communities)
			Scattered Dwellings	Household
			WWTP	E 37 Sewerage
			Industry	Requires collecting further information to identify if specific industries typically do not connect to the network of WWTP (either have their own WWT procedures or no treatment)
			Freshwater aquaculture	A 03.22 Freshwater aquaculture
			Marine aquaculture	A 03.21 Marine aquaculture
			Combustion	C 19.20 Manufacture of refined petroleum products D 35.11 Production of electricity (including producing electricity through thermal, nuclear, hydroelectric, gas, turbine, diesel and renewable) D 35.21 Manufacture of gas E 38.2 Waste treatment and disposal (including disposal of waste by incineration or combustion) *Required more literature on the full list of the sectors
			Transportation	H 49-52 Transportation and Storage

*Atmospheric deposition, Background, Airborne transboundary and Transboundary loads from non-CPs via rivers are not included

5.1 Using quantified and valued ecosystem services and the ecosystem service-sector linkage for natural capital accounting

Steps 3-5 can be used to compile supply and use tables of ESs in NCA. As the ES supply and use need to be balanced in the NCA context, only the estimation of the actual ES supply is needed (UN et al., 2021). The results from steps 3-4 can be used to compile the ES supply account in physical and monetary terms respectively, revealing the amount and value of certain ESs provided by specific ecosystem types based on their connection to habitat type (ecosystem extent). The information on which economic sectors use specific ES (step 5) could further help to allocate the supply of ES to different economic sectors to compile ES use accounts, showing the amount and value of certain ESs used by specific sectors.

6 Designing the scenarios with different policies or activities

With steps 1-4, it is possible to estimate and value the ESs at current (or recent) status. However, a one-time estimation and valuation of ESs cannot reveal the feedback influences of human activities on the ecosystem and the trade-offs among different ESs and other economic benefits. Such feedback influences and trade-offs can be revealed in NCA practice, by compiling the account repeatedly every few years. As the MAREA project did not plan to compile a set of accounts, we design some scenarios to investigate such feedback influences and trade-offs. For example, we design a scenario that specific areas would be designed as marine protected areas and a scenario that some nutrient abatement measures are implemented to evaluate how climate change regulation services provided by seagrass and mussel habitats would change. A business-as-usual scenario or a scenario that can consider some future supply and use of ESs would also be helpful to simulate future flows of ESs, which is a necessary step for valuing the ecosystem asset and compiling monetary ecosystem asset account (UN et al., 2021).

7 Evaluating how ecosystem services change based on the change of ecosystem extent and condition in different scenarios

After scenarios are designed, the geoportal (Kotta et al., 2020) is used to simulate the designed scenarios. The basic concept of the geoportal has been provided in D.T4.1.1. To apply the geoportal to simulate ESs change in physical and monetary terms, the socio-economic model tool in the geoportal (see D.T4.1.1) needs to integrate (1) the linkage between the ES and economic sectors from the impact perspective described in step 5 and (2) the valuation functions used in step 4 to value the ESs. The development of the socio-economic model tool and the integration works are one of the tasks in the next deliverables.

7.1 Using the estimated ecosystem services from the geoportal for natural capital accounting

Geoportal is an efficient tool applicable to NCA in two ways. First, it can simulate the level and change of different ESs under the same assumption scenario. This consistency among different ESs provided by the same ecosystem asset is necessary for valuing the ecosystem assets and revealing the trade-off among different ESs (UN et al., 2021). Second, it can be used to simulate the future flows of ESs. The future flows of ESs not only reflect the ability of an ecosystem to provide ESs in the future but also are the information required to estimate the net present value of an ecosystem asset and compile the monetary ecosystem account (UN et al., 2021). As the geoportal can estimate the ESs change over a year, applying the geoportal repeatedly can simulate the future flows of ESs, with consideration of the status of habitats, ecosystem conditions and the social-economic context with some scenarios that are properly designed.

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