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Preservation of Ocean Currents at Higher Policy Analysis Organizational Levels: An Economic Instrument for Climate Change Related Estimations

Jan Stenis¹, William Hogland²

¹Lunda Hydro AB, Vårlöksvägen 4, SE-387 92 Borgholm, Sweden
²Department of Biology and Environmental Science, Linnaeus University, SE-391 82 Kalmar, Sweden

Email address

jan.stenis@comhem.se (J. Stenis)

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Abstract

The present paper provides economic incentives for preserving the ocean currents in order to avoid possible continental climate changes. A cost structure is proposed for facilitating preservation of the ocean conveyor belt to prevent it from stop running on regional and global operating scales. The introduced methodology involves business administration theory and economics and employs the previously introduced equality principle and the model for Efficient Use of Resources for Optimal Production Economy (EUROPE) to impose shadow costs on ocean currents which induce economic incentives to maintain the ocean currents as is. A case study presents the practical application of the proposed theory in a Scandinavian and European context. It is concluded that the introduced methodology is useful for increasing the probability of the ocean conveyor belt being preserved and making the usage of major natural resources more efficient. Profitability increases, technology is advanced and environmental conditions improve when the EUROPE model is applied on activities that involve ocean currents at higher policy analysis levels by application of a monetary key factor which encompasses most aspects of interest. Furthermore, the equity of the distribution of advantages related to regional changes in the climate is improved. The developed methods are suitable information support tools for decision-making in the management of ocean currents. A more efficient and sustainable use of natural resources is enabled through economic incentives that promote source-reduction of material and immaterial spillages and other anthropogenic activities that possibly have a negative impact on the world's eco-systems in general and the ocean conveyor belt in particular.

1. Introduction

Ocean currents are directed movements of seawater that flow for great distances under the surface of the ocean. Together the ocean currents create the 'ocean conveyor belt' driven by differences in water density and temperature [1]. Vertical movements of ocean currents are known as upwelling and down welling [2].

The ocean conveyor belt to a large extent determines many regions' climate, defined as the slowly varying aspects of the atmosphere–hydrosphere–land surface system [3] by influencing the temperature of the regions. A most striking example is the Gulf Stream which gives northwest Europe a much more temperate climate than any other region at the same latitude.

The Gulf Stream is a warm Atlantic Ocean current that originates at Florida and follows the coastlines of the United States before crossing the Atlantic Ocean. The Gulf Stream makes the climate of Western and especially Northern Europe warmer than otherwise [4] see Fig. 1.



Figure 1. The branches of the Gulf Stream in the Atlantic Ocean [5].

The Gulf Stream is typically 100 km wide and 800-1,200 m deep. The current velocity is about 2.5 m/s corresponding to a constant water flow of approximately 0.25 km³/s. Compare with the average discharge of 0.000,209 km³ water/s of the Amazon river in South America, the largest river by discharge of water in the world [6] see Fig. 2. The average water temperature of the Florida current is above 13°C during the winter [7] but it undergoes wind-driven cooling that causes evaporation of the water and increases its salinity and density. When sea ice forms, salts are left out of the ice. These two processes produce water that is denser and colder in the North Atlantic Ocean where the water becomes so dense that it begins to sink down through less salty and less dense water. This down welling of cold, dense water forms the south going North Atlantic Deep Water stream [8].

The variation in temperature and salinity hence makes the Gulf Stream possible. Above and below 3.98°C the density of water is lower. The saltier the water is the heavier it is. Therefore the warm water in the Gulf Stream floats on top of the surrounding cooler Atlantic waters all the way from the Mexican Gulf to Northern Europe [9].

Thus, it is of utmost importance for the global climate in general and particularly the climate in Northern Europe that the continuous flow of warm water in the Gulf Stream up to the East coast of Greenland, where the water becomes colder and saltier and hence sinks, is maintained. The down welling in this area namely produces the East Greenland Current at the bottom of the ocean which usually is considered to be the major engine of the whole ocean conveyor belt [6].



Figure 2. The flows of the main Gulf Stream, the North Atlantic Current, the East Greenland Current, the North Cape Current and the average discharge of the Amazon River in South America (Sv) [6].

The North Atlantic Current of the Gulf Stream helps keep Ireland and the western coast of Great Britain a couple of degrees warmer than the east. Especially the western coastal islands of Scotland and almost Norway's entire coast are free of ice and snow thanks to the Gulf Stream. The Gulf Stream also warms the climate behind the Fennoscandia Shield. Otherwise, the climate in, for example, Sweden would have been as cold as in Alaska with arctic tundra. Thus, Scandinavia is inhabitable thanks to the Gulf Stream that constantly provides Northern Europe with heat energy corresponding to 6.779 millions large coal-fired 2 GW power stations (13° C * 0.25 km³ water/s * 4.18 kJ/kg water/K * 0.998 kg water/l / 2 GJ/s) if the temperature of the Gulf Stream is assumed to still be 13° C in surrounding Nordic waters otherwise assumed just to frees.

Put another way, the Gulf Stream supplies mainland Scandinavia with approximately 78 thousand times (13.56 PW / 174 GW) its energy demand. The human energy consumption of the Nordic countries namely is 130.8 million tonne of oil equivalent (toe) per year = 5494 PJ making a total for the continental part of Scandinavia of 174.2 GW since one toe = 42 GJ and Denmark annually consumes 17.5, Finland 32.3, Norway: 33.0 and Sweden 48.0 Mtoe [10] see Fig. 3.



Figure 3. The human energy consumption of the Nordic countries (Mtoe) [10].

Thus, the Gulf Stream provides Scandinavia with nearly 80 thousand times (14 PW / 174 GW) this peninsula's energy demand since the Gulf Stream constantly pumps almost 14 PW (13°C * 0.25 km³ water/s * 4.18 kJ/kg water/K * 0.998 kg water/l) up north if a temperature just above the freezing point is assumed for its surrounding Nordic waters. Similarly, the Gulf Stream provide the whole European Union with some six thousand times (14 PW / 2.3 TW) its need for energy since this union annually consumes 1700 Mtoe = 71,400 PJ = 2.3 TW and the Gulf Stream contains 14 PW, see Fig. 4.



Figure 4. The energy contents in the main flow of the Gulf Stream, the energy demand of the European Union and the energy demand of continental Scandinavia (GW).

If the Gulf Stream stops flowing, the Nordic countries would be required to produce extra energy to mitigate the resulting conditions. It is estimated that the Nordic countries' portion of the Gulf Stream energy is 8% of the total that reaches Western Europe. This gives a required extra energy supply of 1 PW (174.2 GW / 2.3 TW) * 13.558 PW = 8% * 13.558 PW = 1.03 PW = 1.03 PJ/s). In order to maintain current water temperatures surrounding Scandinavia, it is estimated that 224 Mm³/s water 11°C higher than the current temperature would be required (1.027 PJ/s / (11°C * 4.18 kJ/kg water/K * 0.998 kg water/l) [11].

In comparison, a typical nuclear power plant discharges around 40 m³/s cooling water into the receiving sea [11]. Thus, in total approximately 6 million nuclear plants' cooling water discharge is required in order to keep Scandinavia inhabitable (224 Mm³/s cooling water discharge / 40 m³ cooling water discharge 11°C higher than the surrounding water/s / nuclear power plant) provided that the Gulf Stream would stop to flow and cause the arctic tundra to grow in the Nordic countries. For example, Alaska is situated on the same latitude as Scandinavia. It is assumed that the heat transfer from the Gulf Stream to mainland Scandinavia when the warm stream-water cools is not specifically calculated for the geographical areas of interest. Also a possibly too high temperature difference of 13°C is assumed to exists between the Gulf Stream and its surrounding waters.

The methodology introduced in this paper facilitates the ambition to maintain the present climatological conditions. Top management is given a versatile tool for preserving, for example, the deep sea current of cold, salt water east of Greenland and economising on the water-flow spillages of mainly warm and salt water in the Gulf Stream. Here 'spillages' are defined as the deviated water flows that for different anthropogenic reasons begin to not contribute anymore to the flow in specifically the ocean currents that are crucial for upholding the ocean conveyor belt.

The ocean current preservation is enabled by the provided economic incentives. The presented model also provides a key factor that can be used as an indicator for how well the ocean currents are preserved in terms of the efficiency of the technology used and its environmental performance. Note that the model works regardless of the very kind of the applied technical solutions.

The proposed methodology in this paper emphasises the use of an earlier introduced economic tool principle that basically employs the allocation of fictive but expressive costs to less wanted residuals of different kinds. This novel economic instrument has previously been applied on various economic contexts and is the mathematical expression of a concept invented by the first author that is denoted the equality principle [12-18]. Here the equality principle in a modified way is applied to the problem of how to secure the prevailing flow in the ocean currents system so as to avoid major regional climate changes. Thereby, the model features shadow prices or shadow costs defined as a monetary value assigned to a good or service when the market price is unavailable or incomplete [19].

As regards combining shadow costs with optimisation of energy flows and the like can be mentioned that Palter [20] has studied how the Gulf Stream heat transport influences the climate of the entire Northern Hemisphere and Europe's climate on timescales of decades and longer and how the Gulf Stream's influence is mediated through feedback processes between the ocean, atmosphere, and cryosphere. Döös et al. [21] have presented a global stream function to analyse and quantify the entire world ocean conversion rate between cold/warm and fresh/saline waters while Laurian et al. [22] raise the question how a strong land–sea contrast can be maintained since Western Europe climate features a strong marine impact due to the prevailing westerlies. However, O'Hare [23] claims that the threat of Gulf Stream collapse and respective cooling over the North Atlantic region is reduced.

The present paper develops a new cost structure to provide economic incentives for preserving the ocean currents so as to avoid possible continental climate changes. Our novel idea to accomplish this has little in common with the environmental economists' traditional way of approaching these issues. Environmental economists usually study a phenomenon and try to estimate the shadow price of its residuals. This method gives adequate and in theory optimal incentives. Our approach to a minor extent relates to this traditional way of thinking. Instead it allocates logically fictive but useful shadow costs to the most important ocean currents. Thereby economic incentives are induced to preserve precisely the most crucial parts of the ocean conveyor belt to avoid major climate changes. Thus, the presented methodology represents a brand new concept as regards ocean current issues.

Considering this, few scholars seem to have studied the

economy of ocean current flows or developed models to obtain economic instruments that use shadow prices or shadow costs to optimize the performance of activities involving ocean current spillages. Most focus on the purely hydraulic, hydrological and meteorological aspects of ocean currents.

In particular, no studies seem to have been made of how just one monetary key factor can be used to monitor, measure and evaluate the performance of activities related to ocean current preservation. The present work hence represents a novel approach of substantial simultaneous importance for the global economy, the process of developing new technology and the environmental conditions worldwide to preserve the climate and protect the main ocean currents.

The objective of this study is to provide practical useful basic methods for managers at higher policy analysis levels to obtain guidelines on how to increase the cost efficiency of activities and schemes related to avoiding changes in the ocean currents by employment of the EUROPE model based on the equality principle [12-18]. And, evaluate the equity of the distribution of regional advantages related to temperature fluctuations.

2. Methodology

In this paper, a cost structure is proposed for economising on the water and energy spillages and the physical reductions of the major ocean currents that may jeopardise their normal flows and hence cause regional climate changes. A cost efficiency and equity point of view is employed with emphasis on the economy of climate changes due to possibly fluctuating ocean currents.

In the introduction, the hydrological and meteorological context is touched upon. Particularities of the European and Scandinavian economy expressed in energy terms related to the condition of ocean currents are reviewed and certain important alternative models explored.

The previously introduced equality principle and the tested EUROPE model is introduced and applied in this ocean context. Guidelines are given for how to apply the methodology introduced for improving the economy related to ocean current changes on different, larger geographical scales. General theory of business administration and economics are used.

The case study that follows concerns how to maintain specifically the certain flow within the Gulf Stream that is of major importance for keeping the ocean conveyor belt running. After a results and study features section the outcomes of the present study are discussed followed by suggestions for future works and a conclusions section. Finally, the major benefits of the current-preserving approach are listed and recommendations for top management are given.

The results in this paper provide an alternative way of approaching economic problems related to climate change issues. The basis is logical mathematics for portioning costs to unwanted or reduced ocean currents so as to improve the efficiency of resource usage that may jeopardize the stability of the ocean conveyor belt. Economising the ocean current flows is reinforced by using the EUROPE model to accomplish a reduction of unwanted water flow spillages.

The scientific methodology chosen combines the study of (a) what should be changed and how through, for example, case studies and (b) the development of theories and models based on the accumulation of relevant knowledge presented (in this case) in a scientific paper.

Both qualitative and quantitative methodologies are applied. Data are obtained by interviews and via 'neutral' numerical data that are obtained via the Internet and used primarily in the introduction and the case study. The research approach in this work is mainly analytical.

The validity of the developed methods to preserve the ocean currents is considered by the application of widely accepted theory of economics and business administration such as cost benefit-analysis and accounting, respectively. The reliability is considered to be ensured by consulting relevant standard works and theories of importance for the applied research approach.

The case study shows the practical value of the ocean-related research conducted here and exemplifies the model-usage. That is likely to reinforce the reliability of the achieved results.

3. The Europe Model

3.1. Basic Framework

The shift in paradigm proposed equates residual products such as material and energy wastes from industrial production with regular products as regards the allocation of revenues and costs. This approach is denoted the equality principle [12-18] and forms the scientific model basis for the model proposed.

The residuals of the different resources of interest, for example, the deviated or reduced flows in the branches of the Gulf Stream are regarded as a regular product output. This is expressed mathematically in Equation (1) which is traditionally used to allocate costs and revenues to resource residuals through multiplication by the total costs and sometimes revenues in question that are allocated by splitting them up in logical proportions. In section 4 in this paper the EUROPE model is applied in the ocean current context in order to exemplify its practical usage.

$$PF = A / (B + C) \tag{1}$$

SC = Corporate-internal shadow cost additionally allocated to<math>A = PF * TC (2)

TC = Total Costs = Fixed Costs + Variable Costs = FC + VC (3)

$$SC = (A * (FC + VC)) / (B + C)$$
 (4)

Where PF = the Proportionality Factor (without sort because PF is just a mathematical fraction), A = quantity of the residuals from a certain resource produced that are to be optimized, B = quantity of the regular resource output, C = sum of the quantities of all the different residual fractions stemming from 'the black box' of the studied system, $i = 1, 2 \dots n$ in order of estimated, descending and collocated economic and/or

environmental relevance. Unit: kg, litres, Joule, $\in,$ \$ or £, etcetera.

Equation (1) represents the economic implications of the equality principle, i. e. the model for Efficient Use of Resources for Optimal Production Economy (EUROPE) [12-18]. Depending on the circumstances, a suitable administrative unit must be defined in a logical way when Equation (1) is applied.

Such systems limits are set in flexible ways examples being increasing administrative levels all the way from the single company up to the entire planet Tellus. In this case the proposed theory is employed for the preservation of the global ocean current system: the ocean conveyor belt. The circumstances guide management when deciding on the physical scale on which to apply the EUROPE model so as to obtain a well-defined and limited surrounding for its use.

3.2. Theoretical Foundations

The smaller SC is the less of the purely fictive but incentive-increasing shadow cost, if fully considered, is to be allocated to A and its related activities. Thus, minimization of A is rewarded.

Shadow prices, or shadow costs, are obtained to induce strong economic incentives to economise the residuals that the shadow costs are allocated to. If the shadow costs are fully regarded, for example, the financial statements that actors presents, will hence be affected in a negative way that promote reduction at the source of their main residuals. In the ocean current context this corresponds to the desired preservation of the important water flow east of Greenland that likely keeps the ocean conveyor belt running. Thus, the equality principle is an economic instrument since it features the employment of economic incentives.

The shadow costs in the suggested approach are not intended to be regarded as real costs but are to a large extent a tool to improve the economy, the technology and the environment when the proposed model is applied on the projects of interest. The improvement is due to less residual products finally being produced as compared to not applying the EUROPE model for a certain purpose. The suggested cost levels may not necessarily be the optimum in a traditionally economic way of thinking but just help evaluators to improve the activities related to the issue of concern. For strictly economic reasons, the production apparatus of different industries or nations will be forced to become more efficient or improve its ratio of utilising its industrial inputs by applying source reduction that positively may affect the ocean currents.

4. Application of the Cost Structure on Ocean Currents

4.1. General Theory for Preservation of Ocean Currents

The water flow in the ocean currents and the possibly dangerous water flow spillage from these currents are inputs to Equation (1). Furthermore, the total cost for ocean currents flow reduction or changing directions (TC _{current}) is required. The aspect of energy content losses in the halted or deviated ocean currents are considered to be encompassed in the studied sea water volumes the model imply as heat energy capacity.

Equation (1) gives:

$$PF_{current} = 1 / [A_{current} / (B_{current} + C_{current})]$$
(5)

Where $A_{\text{current}} =$ quantity of the ocean current water flow to be preserved, $B_{\text{current}} =$ quantity of the total, regular, main ocean current water flow, $C_{\text{current}} =$ quantity of all the possibly dangerous flow-spillages from the regular, main ocean current or its reductions. Sort: millions m³ of sea water flow per second (Sv).

PF _{current} is multiplied with TC _{current} to obtain the shadow cost to allocate to a certain estimation and/or budget. This entity is denoted the current preservation and care keen cost (CUPCAKE). Compare Table 1.

CUPCAKE = Shadow cost allocated to
$$A_{\text{current}}$$
 = PF current
* TC current (6)

CUPCAKE will force the entities of interest to promote a preservation of the ocean currents and reduce the leakage of unwanted forms of water flows due to the economic incentives that are induced by a need to loan money. This borrowing in turn is due to the modified budget of these entities becoming expanded when CUPCAKE is added to the expenditures. And the more of CUPCAKE that is allocated to a certain unit, such as the budget of the European Union, the less cost-effective that unit's preservation of the important ocean currents in question will be, in relative terms. Thus, more economic incentives will be imposed on that unit to become more cost-effective and produce less negative outcome of all kinds that jeopardise the preservation of the ocean currents.

Furthermore, the climate will be more stabilised and the environment will be improved globally with, for example, less hurricanes and flooding. Thus, the total environmental degradation stemming from an increase of such produced ocean current spillages will decrease.

Table 1. The modified public finances [24] for the European Union (G \in).

EXPENDITURE	160
Smart and inclusive growth and jobs plus solidarity between EU regions	67
Agriculture and rural development plus sustainable growth: natural resources	58
Security and citizenship	2
Global Europe	8
Administration	9
Other special instruments	1
CUPCAKE per each of the currently 28 member countries in EU	15
TOTAL RECEIPTS	145
Proportion of Member States' gross national income (GNI) (75%)	108
Value added tax (VAT) (13%)	19
Customs duties on imports from outside the EU (11%)	16
Other (1%)	2
GENERAL GOVERNMENT BORROWING REQUIREMENT (GGBR) (9%)	15

CUPCAKE is inserted into the profit and loss accounts of the administrative units in question according to the general principles for a major trade bloc exhibited in Table 1. This fictive but useful shadow cost hence constitutes a versatile tool for managing, monitoring and evaluating ocean currents regardless of the actual technology used to possibly alter them.

4.2. Consequences of Application of the Theory

The CUPCAKE will force the trade bloc in question such as the European Union (EU) or the North Atlantic Free Trade Association (NAFTA) and the like to economise on, for example, its flow of substances dangerous for maintaining the ocean currents in a cost-effective way. This is accomplished through the economic incentive that is induced by an increase in the final need for loans and hence decreased cash assets that in turn lead to an increase in the final Public Sector Borrowing Requirement (PSBR). The preferable water input to the crucial currents is hence likely to be utilised in a more cost-effective way due to the economic incentive that is induced by a final profit decrease for the trade blocs. The reduced profitability is due to the employed shadow costs.

The more of the CUPCAKE that is allocated to a certain trade bloc's budget as a profit-reducing cost item, the less cost-effective that trade bloc's current-preservation is in relative terms. Economic incentives are hence imposed on that trade bloc to become more cost-effective and produce less final potentially dangerous water-flow spillages or not reduce the important currents in the ocean conveyor belt. Also, the environment will be improved, mainly in a regional and global context, due to less environmental degradation from side effects of the dangerous water-flow wastes. Examples of such side effects are unwanted atmospheric heating and river pollution connected to the utilization of the major industrial complexes in question.

Data from the trade bloc's public finances enables calculation of the optimal amount of the spillages of a branch or an industrial complex. Thus, the current-impact of a whole continent can simultaneously be improved from an economic and environmental point of view.

4.3. Weights

The application of the EUROPE model according to Equation (1) to the methods outlined above redistributes a portion of the costs for normal products, in this case the main, regular flow of, for example, the Gulf Stream, to spillages, in this case the important ocean sub-currents in an inverted way, by allocating the fictive shadow costs to the residuals in question, in this case the ocean current by-flows. The redistribution takes place in proportion to the relative size of the currents as compared with the total output of the producing unit of interest, in this case the ocean conveyor belt. This procedure must not necessarily result in any increase in the total cost for the involved actors and does not directly link the avoidance of all the different residuals with an economic incentive to reduce any expenditure, as expressed in the profit and loss accounts and budgets of different kinds. Nevertheless, weighting is in this study proposed to possibly be used so as to adapt the costs associated with a particular ocean current to its climate and environmental impact, based on scientific evidence and/or in terms of overall societal aims depending on the top managers' judgements or personal preferences.

For example, a factor 1.1 can be multiplied with the original shadow cost if a certain kind of dangerous water flow motivates a 10% mark up to provide an extra incentive to reduce its unsuitable existence. 'Environmental shadow prices' should hence be used combined with the cost allocation principle proposed in this paper in order to define general environmental standards.

However, if such environmental impact weighting is not applied, the proposed cost allocation principle is useful internally for redistributing costs connected to different water flows between various trade blocs by multiplying the obtained PF with the TC in question to arrive at a logical portion of the total cost mass to inverted be carried by a certain water flow A of greater importance. This results in a kind of competition between the different trade blocs which improves the environment and profits in general [12]. Thereby these major actors are given an economic incentive to maintain the important ocean currents and reduce the unwanted flows to enable improvement of their financial statements. Thus, the improvement incentive has impact on cost estimates, for example, and hence on budgets and on forecasts used as a decision basis for loan applications, and on information to the stakeholders of financial importance for the current task.

4.4. Multiple Currents

In the case of n currents regarded, the TC is calculated as follows:

$$TC_{n \text{ currents}} = \Sigma (TC_i * W_i)$$
(7)

i = 1, 2, ..., current *j*, where TC _n currents = total cost of the *n* currents stopping or changing directions, TC_i = total cost of current *i* stopping or changing direction employing Equation (3), W_i = the weight conferred to current *i* (without sort), W_i \geq 0, *j* = 1, 2, ..., *n* within a suitable production or administrative unit during a certain time period. Sort: \in , \gtrless or \pounds etcetera and Sv.

4.5. Summarized Theory

In summary, the theoretical findings of this study can be collocated in the general Equation (8) in the case of n ocean currents regarded:

CUPCAKE tot =
$$\Sigma ([1 / (A_i / (B_i + C_i))] * TC_i * W_i)$$
 (8)

i = 1, 2, ..., ocean current *j*, where CUPCAKE tot = total shadow cost of the *n* ocean currents stopping or changing directions, A_i = quantity of the important water flow in a certain ocean current *i*, B_i = quantity of the regular ocean current water main flow in question that produces, for example, A_i , C_i = quantity of all the possibly unwanted ocean current water flow spillages or losses of the regular ocean

current main flow B_i that have a negative impact on A_i , TC_i = Total societal cost of ocean current *i* stopping or changing direction employing Equation (3), W_i = the weight conferred to current *i* (without sort because it is just a mathematical value), $W_i \ge 0$, j = 1, 2, ..., n within a suitable and defined production or administrative unit during a certain time period. Sort: \in , \gtrless or \pounds etc. and Sv.

Equation (8) is useful for at higher administrative and larger geographical levels, such as the European Commission caring for the climate in Western Europe, simultaneously economising on the resource economy, advancing the technology used and improving the environmental conditions when undertaking ocean current-preserving projects of all kinds. Thereby, less CUPCAKE shadow costs allocated to certain trade bloc's accounting systems implies a more efficient handling of the ocean current in question since it then represents less disadvantageous but fictive costs that occur when applying the EUROPE model. All kinds of technological solutions to achieve the desired preservation are namely encapsulated in the proposed monetary units of the introduced model.

5. Case Study: The Gulf Stream and Its Impact on Scandinavia's Climate

5.1. Basic Data

This case study relates to the flow of the Gulf Stream particularly as regards its importance for preserving the prevailing climate in Scandinavia. The quantity of the important water from the Gulf Stream water flow heading southwards at the bottom of the ocean at the East coast of Greenland in the East Greenland Current = $A_{\text{current stop}} = 4 \text{ Sv}$, the quantity of the total, regular Gulf Stream water main flow in the North Atlantic Current = $B_{\text{current stop}} = 9$ Sv, the quantity of the 'spillages' from the regular Gulf Stream main flow at the East coast of Greenland that continue to flow towards North-East at the West coast of Norway in the North Cape Current = $C_{\text{current stop}} = 2$ Sv [25]. The worst case total GDP cost for the entire mainland Scandinavia if the Gulf Stream stops flowing and the land becomes uninhabitable = TC current stop = G₴ 1659 = G€ 1493, (exchange rate: $\exists 100 = €90$ July 2015), (GDP $_{\text{Denmark}}$ = G $\stackrel{\bullet}{\underset{\bullet}{\underset{\bullet}{331}}}$ 331, GDP $_{\text{Finland}}$ = G $\stackrel{\bullet}{\underset{\bullet}{\underset{\bullet}{3257}}}$ 257, GDP Norway = G $\stackrel{\frown}{\leftarrow}$ 513, GDP _{Sweden} = G $\stackrel{\frown}{\leftarrow}$ 558) [26].

Note that in 2005, British researchers [27] pointed to an approximately 30% decrease in the net flow of the northern Gulf Stream since 1957. Curry and Mauritzen [28] studied the freshening of the North Atlantic connected to Earth becoming warmer suggesting polar ice melting as precipitation increases in the high northern latitudes. Extra fresh water flooding the northern seas due to global warming could, in theory, divert the northward flowing Gulf Stream waters that pass the British Isles and Norway and instead make them to circulate toward the equator. This would seriously impact Europe's climate [29]. In this case study, however, the East Greenland Current (A current stop) is the object of interest to mainly preserve since the down welling causing this current usually is regarded as

constituting the very engine in the whole ocean conveyor belt all over the globe [6] even though a major diversion of particularly the North Cape Current ($C_{\text{current stop}}$) would make Scandinavia uninhabitable.

5.2. Data Collection

Data were collected from the public data-banks on the Internet of the European Union, the OECD and the Atlantic Meridional Overturning Circulation program (MOC) [30].

5.3. Application of the Methods Considered

The numerical values used are approximated to exemplify the consequences in practice of the presented general approach.

$$PF_{current stop} = 1 / (4 Sv / (9 Sv + 2 Sv)) = 2.75$$
(9)

CUPCAKE _{Gulf Stream} = PF _{current stop} * TC _{current stop} = 275 % * G
$$\in$$
 1493 = G \in 4106 (10)

CUPCAKE _{Gulf Stream} is the shadow cost to allocate to the European Union's estimations and/or budget so as to facilitate, for example, the European Commission's decision making. The amounts according to Equation 10 are to be put into its economic context as displayed in Table 1.

In 2013, the GDP of the European Union was G \ge 17,351 [26] = G \in 15,616. CUPCAKE _{Gulf Stream} hence constitutes 26.3 per cent of the GDP of EU.

This high portion of the GDP can be adjusted by application of a weight factor W $_{\text{Scandinavia}}$ according to the size of the GDP of Scandinavia in relation to the GDP of EU.

W _{Scandinavia} = GDP _{Scandinavia} / GDP _{EU} = G
$$\in$$
 1493 / G \in 15,
616 = approx. 10% (11)

Thus, the final shadow cost CUPCAKE _{Gulf Stream} turns out to be as follows:

CUPCAKE _{Gulf Stream} = PF _{current stop} * TC _{current stop} * W _{Scandinavia} =
$$275 \% * G \in 1493 * 10\% = G \in 411$$
 (12)

Then, CUPCAKE _{Gulf Stream} constitutes a more reasonable 2.6 per cent of the GDP $_{EU}$.

CUPCAKE _{Gulf Stream} is inserted into the profit and loss accounts of EU according to the general principle shown in Table 1. This fictive but useful shadow cost constitutes a tool for simultaneously managing, monitoring and evaluating all activities that influence the ambition to preserve the Gulf Stream as is in order to avoid evacuation of continental Scandinavia.

The resulting change of the General Government Borrowing Requirement (GGBR) becomes \notin 411 billion, approx. \notin 15 billion per each of the current 28 member countries in EU, when the whole of the EU situation is considered. This indicates that a substantial reduction of the impact of all the factors that negatively may affect the crucial parts of the Gulf Stream flow would be best in financial terms. It would also be beneficial for nature and technology.

In practice, this means to avoid, for example, oil spillages from oil drilling that may disturb or even destroy the very water pump just East of Greenland that is a precondition for the well-functioning of the ocean conveyor belt. Also different waste water discharges and solid wastes such as plastic wastes that constitutes 80% of marine debris and rapidly has been accumulating since the end of World War II [31] could have a negative impact on the ocean current systems. This impact can be mitigated as well by the introduced methodology based on monetary units which pedagogically covers all the technological aspects of the problem.

Environmental impact shadow price weighting is not employed in the case study. It would be possible to implement so as to make the major actors better utilize productively the resources of particular interest for top management to preserve the Gulf Stream. The multi-resource approach case is neither considered here due to the strictly mathematical triviality of the addition and the multiplication as expressed in Equation (3) and Equation (6) respectively. Furthermore, the equality principle approach in a modified way is here considered to be sufficiently outlined in the case studies to show how it generally can work in practice.

6. Results and Study Features

This study intends to apply economic theory on the unwanted or reduced flow of the especially important ocean currents. The results show viability for management of ocean currents as regards natural resources use that may have a negative impact on these currents.

The research shows utility when focusing on the economic and pollution aspects of producing activities' impact on the ocean conveyor belt. The paper explores the economics of the ocean currents and how to economise on this with an efficiency and resource economy view.

The methodology developed here enables a more efficient and sustainable use of natural resources. This is accomplished through providing economic incentives that promotes source-reduction of material and immaterial spillages and other anthropogenic activities that possibly degrade the world's eco-systems. The main features of the performed research are as follows:

- 1. The unwanted impact of ocean current residuals such as flow spillages and reductions related to energy-transport losses and other activities that may affect the ocean currents is improved. This impacts the health of the concerned population by simultaneously solving these problems;
- 2. It provides a tool for decision-makers to evaluate major exploitation projects that may affect the ocean conveyor belt through increasing the economic benefits for the major entities due to avoided climate changes. This may lead to the implementation of improved systems for control of nature's parameters that have impact on, for example, the Gulf Stream's functionality;
- 3. It enables the conducting of comparative analysis, in monetary terms, of the estimated, actual and prevented damages to the ocean conveyor belt expressed in monetary terms when industrial and other schemes of

importance for the important ocean currents are implemented;

- 4. It increases the efficiency in general of natural and energy resources and commodities use;
- 5. It increases the cost-effectiveness and global equity of activities related to the exploitation of natural and energy resources in the regional and global contexts connected to the usually desired preservation of the ocean conveyor belt as is in order to avoid climate changes.

7. Discussion

The case study investigated the practical application of the methodology. The results of the case study are useful to reduce the risk of climate change at higher administrative decision levels, for example, the European Commission considering the risk for a halted Gulf Stream and how to prevent this.

The case study focusing on the Gulf Stream intends to show the general possibility to apply the equality principle to unwanted or dangerously reduced ocean currents. Thereby the 'true' internal shadow prices, the fictive costs, are reasonable as compared to the budget of EU. This represents a fruitful possibility to adapt the proposed methodology to a practical context.

This statement is reinforced by the quantities of the estimated shadow costs that are put into the public finances of the European Union (Table 1) constituting a reasonable tenth of its total expenditures. This exemplifying value related to the important flow is calculated without employing environmental impact weighting due to the mathematical triviality.

No specific obstacles were encountered when applying the proposed methodology to higher organisational levels. Thus, the methodology suggested is generally applicable to higher policy analysis contexts involving ocean current aspects. It has here been tested on a higher administrative level. The different kinds of possible technological solutions that can be used to preserve the important ocean currents are also encapsulated in the immaterial monetary units used.

It is shown how the equality principle can be modified for application to traditional economics methods in order to provide a financial basis for environmentally friendly management of the ocean conveyor belt. Applying this principle according to the EUROPE model-equation (1) to the budgets on higher policy analysis organisational levels produces a negative impact on the bottom lines of, for example, the organizations' profit and loss accounts. This stems from the internal shadow cost assigned to the ocean current spillages in question. Thus, the suggested cost levels must not necessarily be the most optimal level in a traditional economic way but just help top management to improve the activities related to ocean currents.

The introduced methodology represents a viable alternative to traditional economic estimation methods, based on a mathematically adequate distribution principle, the equality principle. This approach, mathematically expressed by the EUROPE model, should be appreciated as a contribution to the existing arsenal of useful methods that are possible to apply on different areas when source reduction of different kinds of spillages is of interest.

A major advantage with the equality principle compared to other optimization methods is that it allocates incentive-increasing shadow costs based on its inherent logics. The easily understood mathematics decides how much of the total cost mass to allocate to the spillages of interest to reduce. Thereby, these spillages are compared to the total output from 'the black box' of the producing unit.

This mathematically adequate way of portioning costs constitutes the basis for evaluator's possibilities to review, monitor and evaluate their professional activities, in this case connected to the ambition to reduce ocean current spillages that may cause climate changes, also globally. The alternative models listed in the introduction consider the full societal costs of climate changes due to changes in the flow of the global ocean current system or consider the heat transport or salinity in these currents. Instead, it is here suggested to by a logical, mathematical division allocate incentive-increasing shadow costs in a way that for mathematical reasons ensure economic solutions as well as they provide a versatile management tool.

The case study resulted in a negative impact of in total G€ 411 on the European Union budget. This corresponds to approx. G€ 1.6 per Sv of the main Atlantic flow of the Gulf Stream (G€ 411 / 250 Sv) and approximately G€ 100 per Sv of the important water from the Gulf Stream water flow heading southwards at the bottom of the ocean at the East coast of Greenland in the East Greenland Current (G€ 411 / 4 Sv) [see Eqs. (9-12)]. If these shadow costs are calculated considering the burden to be carried by each of the current 28 member countries of EU, the shadow costs are approximately M€ 59 per Sv (G€ 1.6 per Sv / the 28 member countries of EU) of the main Atlantic flow of the Gulf Stream and G€ 3.7 per Sv (G€ 100 per Sv / the 28 member countries of EU) of the important water from the Gulf Stream water 'engine flow' heading southwards at the bottom of the ocean at the East coast of Greenland. These fictive but useful shadow costs per water flow unit may be substantial since environmental impact weights are not included.

CUPCAKE per each EU member country = approximately $G \in 15$ (G $\in 411 / 28$ member countries). This can be compared to the total expenditures of EU = G $\in 145$, se Fig. 5 and Table 1.



Figure 5. CUPCAKE's portion of the total expenditures of EU (G \in) [24].

The total estimated CUPCAKE value is somewhat high as compared to the expenditures of the European Union in 2015 according to Table 1. Nevertheless, the outcome is illustrative of the logical consequences when applying the equality principle on different geographical scales to accomplish preservation of ocean currents.

In the proposed model, costs are to a certain extent transferred from 'goods' to 'bads'. However, no common estimation method causes results that are absolutely valid. Therefore, the methodology presented here can be regarded as being generally useful for applying economic theory on activities related to the risk of climate changes. In particular, Equation (8) is useful since it represents a key factor for simultaneously reviewing, monitoring and evaluating the status of the resource economy, the technology used and the environmental conditions when undertaking projects of all kinds that impact the ocean conveyor belt.

The introduced approach appears to be applicable to any activity that has a negative impact on the ocean conveyor belt. This study intends to promote a new economic perspective by increasing the economic incentives to reduce the risk for changed ocean currents. Therefore, the financial impact of shadow prices on the expenditures and receipts of various budget levels will be promoted.

The introduced methodology directly links budgetary costs and the emergence of risk factors by redistributing costs between main ocean currents and minor stream-flows. Thus, the regional and global actors experience economic pressure to introduce environmentally friendly measures which emphasise source reduction of the dangerous activities for currents.

Forecasts, budgets and receipt and expenditures accounts for external use will be affected so as to internally create incentives to reduce the excessive occurrence of, for example, residuals and promote its utilization. Both appropriate official recommendations and voluntary environmental agreements are needed to assess residuals. Such developments promote the sustainability and the productivity of resource use which are of importance for ocean currents.

The findings contribute to a change in the perceived status of phenomena that may cause changes in the ocean conveyor belt. This is accomplished through emphasising the financial implications of the occurring but fictive expenditures and receipts due to the use of shadow prices. Hopefully, the basic approach advocated here will be adopted by, for example, international authorities such as the European Union, NAFTA, United Nations, OECD and the International Monetary Fund.

The major strength of the methodology is its general approach that provides an umbrella-solution based on commonly known economic theory for business administration and economics. The application of the model becomes independent of technological and ideological parameters since such phenomena together are encompassed in the flexible monetary terms used.

The weight factor approach considers the environmental impact on the regional climate of the actual ocean current spillages or reductions or the authorities' view. This is intended to enable environmental and other ambitions. The major claw of our model is its ability to induce industrial and environmental policy-changes and the redistribution of wealth in also a global context. The idea is to expressing reality in monetary terms that encompass most parameters of interest.

A weakness of the theory is its less good precision concerning the impact on actors that are affected by its implementation. However, the precision in the calculations when the proposed methodology is applied can be improved by auxiliary algorithms. Such devices may be used in combination with the EUROPE model to improve the scope and accuracy of the methodology.

A substantial result of implementing the introduced approach would be the influence on the distribution of wealth all around the globe regardless of political deadlocks and similar obstacles. For strictly economic reasons, the invented tool will namely reshuffle revenues and profits from the different activities connected to climate change through increasing the efficiency where most needed.

The actors on different major organisational levels showing the least cost-effective performance as regards ocean currents will encounter the heaviest economic incentives when the fictive shadow prices of the introduced model are applied. Thus, these less cost-efficient major actors are by time likely to improve their budgets more than others in relative terms.

The global distribution of wealth connected to the exploitation of natural and energy resources and other commodities that may influence the sustainability of the ocean currents will be affected as well. Thereby, those actors that display the least profitable production apparatus in terms of negative impact on the climate will hence benefit most from the results of this work. The economic incentives of the proposed model to optimize the existence of all kinds of unwanted ocean current spillages and changes are assumed to promote a stepwise equalization of the efficiency of the many national systems for production. Furthermore, global equity is promoted.

The major potential end users and applications of the proposed approach would be as follows:

- Major organisations, such as the European Union, the United Nations, OECD and the International Monetary Fund that want a tool for monitoring the environmental performance and correct it. They can improve the cost-effectiveness and impact on the climate and the environment in general when natural and energy sources are exploited;
- Trade bloc governments that want a tool for investment appraisal to evaluate the environmental performance of, for example, major plants. They can consider the international opinion to avoid, for example, international protest actions and mass hysteria;
- Governments that want to design innovative and fair environmental legislation;
- International environmental courts that decide upon punishments to nations' impact on ocean currents. This can be shown to have jeopardised the preservation of the climate;

- National authorities, such as EPAs that want to apply environmental legislation, and;
- Miscellaneous parties that want to estimate and monitor the ecological impact of different actors as regards the current emission and pollution levels, expressed in monetary terms.

The validity of the suggested methods is satisfactory because commonly used theory of business administration and economics are used. The extensive practical usage of the economic theory supports the validity. The reliability of the study is acceptable because the published studies support it. The case study highlights the practical value of the conducted research.

8. Suggestions for Future Works

The EUROPE model will be applied on the optimization of industrial activities that impact the ocean conveyor belt. Mathematical models will be developed to increase the precision of the estimations. It will be studied how to apply the EUROPE model on wastes such as oil spillages from ocean oil drilling, particularly in the vicinity of the East Greenland Current. The model will also be applied on plastic wastes that in large amounts may cause the Gulf Stream to stop or change directions.

9. Conclusions

The major conclusions based on the findings and the case studies are as follows:

1. The research has a substantial practical usefulness when focusing on top management's need to economise on the ocean-polluting residuals and spillages of energy-containing sea water from the important ocean currents that possibly can degrade the main ocean currents;

2. The findings will improve the cost-effectiveness and the equity primarily due to reduced risk for climate changes on the regional and continental scale. The preserving of a regional climate is emphasised on all higher policy analysis organisational levels of metrological importance;

3. The proposed introduction of economic incentives by the employment of shadow costs improves the utilization of natural and energy resources and the redistribution of wealth;

4. The findings make it possible for top managers to apply economic instruments in order to avoid evacuation of major peninsulas such as the Nordic countries due to currents stop running;

5. Major trade blocs such as the European Union and NAFTA obtain a versatile economic instrument to monitor, manage and preserve, for example, the crucial flow of the Gulf Stream.

10. Benefits

The major benefits of the study are as follows:

1. A principle for estimation of shadow costs related to the preservation of ocean currents;

- 2. Creation of incentives for the major actors to save costs due to halted ocean currents;
- 3. An innovative approach to solving the classical problem of simultaneously decreasing the negative impact of residuals on the environment and the general health of the population;
- 4. Increased profitability by redistribution of wealth globally due to a preserved climate;
- Environmental protection and an more efficient use of natural and energy resources;
- 6. Development of a tool for information support to enable ocean current decision-making;
- 7. Ocean current management at all larger geographical and higher organisational levels;
- 8. Theory based on commonly known concepts for business administration and economics.

Recommendations

Based on our analysis, the following recommendations as regards the ocean conveyor belt are made:

- 1. Use the EUROPE model before deciding to invest in major schemes for usage of natural and energy resources which may influence the main ocean current spillages and reductions;
- 2. Apply the EUROPE model on the management of residuals from all exploitation of natural resources and on spillages from activities that possibly can impact the ocean conveyor belt.

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