Monetization of oil spill impacts using environmental economics methods: A systematic review

By

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Abstract

Environmental economics is increasingly used in large-scale and severe accidents such as oil spills. Systematic reviews in this field are rare, if not non-existent, so there is a need to collect data concerning the investigation of (a) the non-market oil spill valuation techniques implemented, (b) the externalities (i.e., external costs and external benefits) resulting from the analysis and (c) the monetary estimates of the impacts analyzed in each research.

This MSc thesis aims to conduct a systematic review regarding the use of non-market valuation methods in the monetary valuation of oil spill impacts. The number of publications retrieved from the Scopus database fulfilling the criteria for abstract reading was 327. Following a thorough reading of every single abstract and indicative text screening where needed, 234 publications were excluded, and 93 were selected to be archived for full-text screening. At the final step, 33 publications formed the database of this review. The statistical analysis of the publications resulted in 66 different monetary estimates that vary by valuation approaches, units, and other distinct characteristics. Moreover, the database publications were analyzed based on 20 different variables to produce various statistics.

The ultimate purpose of the MSc thesis is to leave a legacy for future reference by showing, through statistical analysis, areas and incidents with limited availability of estimates or with significant differences between the findings of surveys. Thus, upcoming future research should fill these gaps and not reproduce them.

Small oil spill from private boat in Polychrono, Halkidiki on August 28th 2022 (unknown type of fuel).

Photo by: Nikolaos Asteriadis

1. Introduction

1.1 Brief historical overview

Environmental economics has been developing along the economic theory since the 18th century as all prominent classical economists have expressed, directly or indirectly, several views on managing environmental goods and services. Among them are some well-known personalities such as Adam Smith, who noted that the depletion of natural resources would lead to the cessation of economic development, and Karl Marx, according to whom progress was intertwined with the exploitation of natural resources [1].

Environmental economics saw significant progress after 1870, during the neoclassical period, when individuals like Arthur C. Pigou proposed specific policies to protect non-renewable natural resources by enacting legislation to prevent their unconscionable exploitation [2]. An equally important intervention was pointed out by economist John H. Gray in 1914, who claimed that due to current non-renewable resources exploitation affecting their future availability, an additional amount, called "user cost", should be added to the overall cost of production [3].

In 1931, the Journal of Political Economy accommodated a theory stated by Harold Hotelling (1895-1973), known as Hotelling's theory or Hotelling's rule, positioning that unreplenishable resources owners will only generate basic goods if this will result in a greater return than could be obtained through widely accessible tradeable assets like U.S. Treasury or other similar interest-bearing bonds. In other words, this hypothesis assumes that markets function effectively and non-renewable resources proprietors are only motivated by financial benefit [4]. Hotelling's rule was used to forecast the price of oil by determining the yield at which the owner will extract and sell it, depending on current interest rates.

In the mid-twentieth century John V. Krutilla published the "Conservation Reconsidered" in The American Economic Review (1967), in light of which, if people preferred a preserved condition to a developed one, then this preference was valid and belonged in the economic equation. Krutilla argued that in view of the diminishing availability of conserved natural landscapes, the conventional emphasis on resource

conservation for material production needs to be reevaluated [5]. In other words, Krutilla emphasized that protecting a landscape came at the expense of developing it, and vice versa, developing a landscape came at the expense of preserving it. As a result, the decision to develop was inherently financial.

In 1970, Ayres & Kneese formulated the "Material Balance Approach", according to which, since industrial wastes are harmful elements in the economic model and their emission to the environment is unavoidable, pollution produces externalities that are also harmful. Therefore, governments should take measures to control the degree and extent of pollution. This model highlighted three main characteristics of the natural environment; (1) the supply of raw materials, (2) the storage of wastes, and (3) the various services such as recreation, enjoying a landscape, etc. [6].

Another critical observation that kick-started the field of environmental valuation was that of Weisbrod in 1964, who characterized national parks as irreplaceable goods as their demolition and conversion into industrial sites is cost-prohibitive in recreating them. He also added that some households, despite not using the parks, would be willing to pay a certain sum of money to keep them working. This amount of money was characterized as an option value, with its central element being that it cannot be calculated by any market mechanism [7].

1.2 Legislative frameworks

The first environmental valuation reports appeared in the legislative framework of the USA in the 1930s with the "Flood Control Act," which refers to the non-measurable economic figures. In 1950, the Green Book got published aiming to determine the value of recreational areas, which led later, around 1979, to the development of the travel cost method (will be discussed in the section below) by the Water Resource Council. These were the first steps towards environmental valuation, although the most remarkable growth came after 1964, as mentioned above with the option value, and specifically during the '70s and '80s with examples such as the President's Executive Order 12292/1981 on maximizing Net Social Benefit, or the Electric Consumers Protection Act in 1986 about costs of environmental impacts during the operation of hydroelectric projects [1].

The most critical environmental assessment and policy legislative act was CERCLA in 1980, according to which federal and state agencies became responsible for managing the state's natural resources and had to take steps to assess and repair environmental damage and identify those responsible carriers [8]. It was an extension of the Natural Resource Damage Assessment (known as NRDA), which stands for the process of the public's claim for environmental assets damage against the responsible organization and of the pursuit of compensation for the harm done. CERCLA, along with the Ohio case that established the contingent valuation according to which environmental assessments should take non-use values into account [9], [10], formed the basis for the Oil Pollution Act (OPA) that the US Congress voted in 1990 after the Exxon Valdez accident to estimate the total damage caused to the marine ecosystem by the oil spill.

OPA was originally a legislation designed to prevent oil spills from facilities and vessels, enforce the removal of spilled oil, and assign liabilities for the cleanup cost and damages. It resulted in significant changes in the upstream and downstream (production, transportation, and distribution) sectors of oil industries as it required specific operating procedures, defined responsible parties, implemented damages measurement processes, and established a fund for damages, cleanup, and removal costs [11].

Under OPA, three components of the environmental liability are distinguished, based on 33 USC § 2706(d): *"(1) primary restoration, which includes the costs of restoring, rehabilitating, replacing or acquiring the equivalent of the damaged natural resources, (2) compensation for interim losses, which is the diminution in value of those natural resources pending recovery of the resources to baseline and (3) the reasonable cost of assessing those damages"* [12], [13].

Overseas, in the European Union, environmental valuation techniques were put to use in 1973 in the Netherlands, where the contingent valuation method established the tolerable noise level and, a year later, was used to estimate the cost of air pollution [14]. Gradually, various methods began to be applied in countries such as Germany, Norway, and the United Kingdom for air pollution issues, environmental and human health impacts from road construction works, and noise pollution issues from large-scale projects.

Integration efforts in Europe intensified after 1990 when the British government proposed using environmental valuation methods in cost-benefit analysis. Cost-benefit analysis is a unique and powerful tool as it allows governments to make decisions that reflect ordinary people's preferences. The founders of this analysis were Nicholas Kaldor and John Hicks back in the 1930s, and their main target was to evaluate resources that market-based methods could not handle due to externalities [15]. At first, CBA was used as a business tool to evaluate policy decisions, commercial transactions, and project investments, though it started gaining a reputation in the environmental stage after 1950 when it was used in a study entitled "Proposed Practices for Economic Analysis of River Basin Projects" [16]. After that, CBA aroused interest in Europe in the early 1980s, with Asian, African, and other developing countries following.

In 1994, the European Union issued the "Directions for the EU on Environmental Indicators and Greek National Accounting – The Integration of Environmental and Economic Information Systems", where the immediate need to expand the use of monetary valuations methods of environmental damages was declared [17], with an emphasis on the necessity to use market mechanisms to a greater extent during the coexistence of environmental and economic policies for the transition to an environmentally sustainable course [18].

In general, the directives of the European Union that incorporate principles of environmental economics are 85/337/EEC on the environmental impact assessment of various public and private project plans, 96/61/EC on the integrated prevention and control of pollution, 2000/60/EC on the establishment of a policy in the management of water resources, 2002/49/EC on the assessment and management of environmental noise and 2004/35/EC on environmental responsibility regarding the prevention and restoration of environmental damage [1].

Directive 85/337/EEC, which is not anymore in force, provides, in addition to the qualitative description of the effects in the environment of various plans, the description of the preventive measures in order to reduce, avoid or compensate for the adverse consequences to the environment due to the project at hand [19].

Directive 2000/60/EC on Community policy in the field of water resources recognizes the value of the use and services of water and provides an economic analysis of them. It aims towards using value-performance financial tools at services offered by water resources and is taken into account during pricing policy to encourage rational consumption of the specific natural resource [19].

Directive 2002/49/EC on assessing and managing environmental noise refers specifically to using cost-benefit analysis as a criterion for evaluating noise reduction measures [19].

Then, directive 2004/35/EC on the environmental responsibility regarding the avoidance and recovery of ecological harm, is the formation of a framework for the environmental responsibility relying on the "polluter pays" tenet, with a focus on preventing and remediating environmental damage [19].

1.3 Basic theoretical framework of environmental valuation

As perceived, in the last 30 years, environmental valuation, which stands for the section of environmental economics that tries to assign monetary values on different consequences., either positive or negative [20], started taking part in the economic assessment of nearly any kind of accident that can cause harm to the environment.

Valuation of environmental goods is based on individuals' (or households') willingness to pay to enjoy an environmental good or willingness to accept compensation in order to accept its loss. The value being evaluated each time can be divided into two categories; use and non-use values. Use values affect people directly and can be associated with food production, flood regulation, recreational opportunities, potable water provision, etc. Non-use environmental values derive from people being satisfied knowing that someone else has access to nature's benefits, or sometimes they are derived from people's ethical position on the importance of other species, which they may never co-exist with [20]–[22].

The willingness to pay (or WTP) mentioned above is an anthropocentric, budget-constrained measure that reflects the consumer's choice for a change in welfare, whether

this change will be mirrored by use or a non-use value. Informally, a limit price represents the greatest amount a consumer is willing to pay to obtain some specified good. This concept and a related concept, the compensation threshold or willingness to accept, are helpful in the context of discrete choice theory [23].

When analyzing and monetizing the damages of a harmful to the environment accident, there are two distinguished types of costs, one about cleanup and restoration and one that is labeled as indirect damages [24], including costs to tourism, house prices, fishing industries, recreational purposes, harm to the wildlife, etc. When no price market is available, several indirect and direct approaches can monetize the impacts using the willingness to pay (WTP) or willingness to accept approach via surveys. The indirect methods, also called revealed preference methods, use observations on purchase options to assess non-market values. However, there are many cases where these methods cannot provide the estimates needed to analyze an environmental policy because their values are based on a behavioral footprint and, therefore, are ineffective for estimating non-use values. [25]. These methods also focus on past facts, which limits their utility for future circumstances.

On the other hand, stated preference methods can be used to estimate approximately all types of values, but their validity is controversial. These methods are usually based on surveys and derive values by asking people to choose between different environmental policies that will yield better environmental results [25]. Since they were first used for the damage assessment of the Alaskan oil spill in the early 1990s, there has been an intense research debate about the validity of stated preference methods among economists and other related academic sections [21]. In more recent assessments, the results of stated preference methods valuation were often similar to those from revealed preference valuation. They are congruent with binding plebiscites on environmental measures and comply with predictions derived from classical economic theory [26]. This indicates that approaches based on expressed preferences can deliver reliable estimates of non-market values in environmental assessment [25].

As shown in Figure 1, some of these methods are the hedonic price analysis, travel cost analysis, contingent valuation, and choice experiments, all of which monetize an accident by giving a value to an item that was directly or indirectly affected [22].

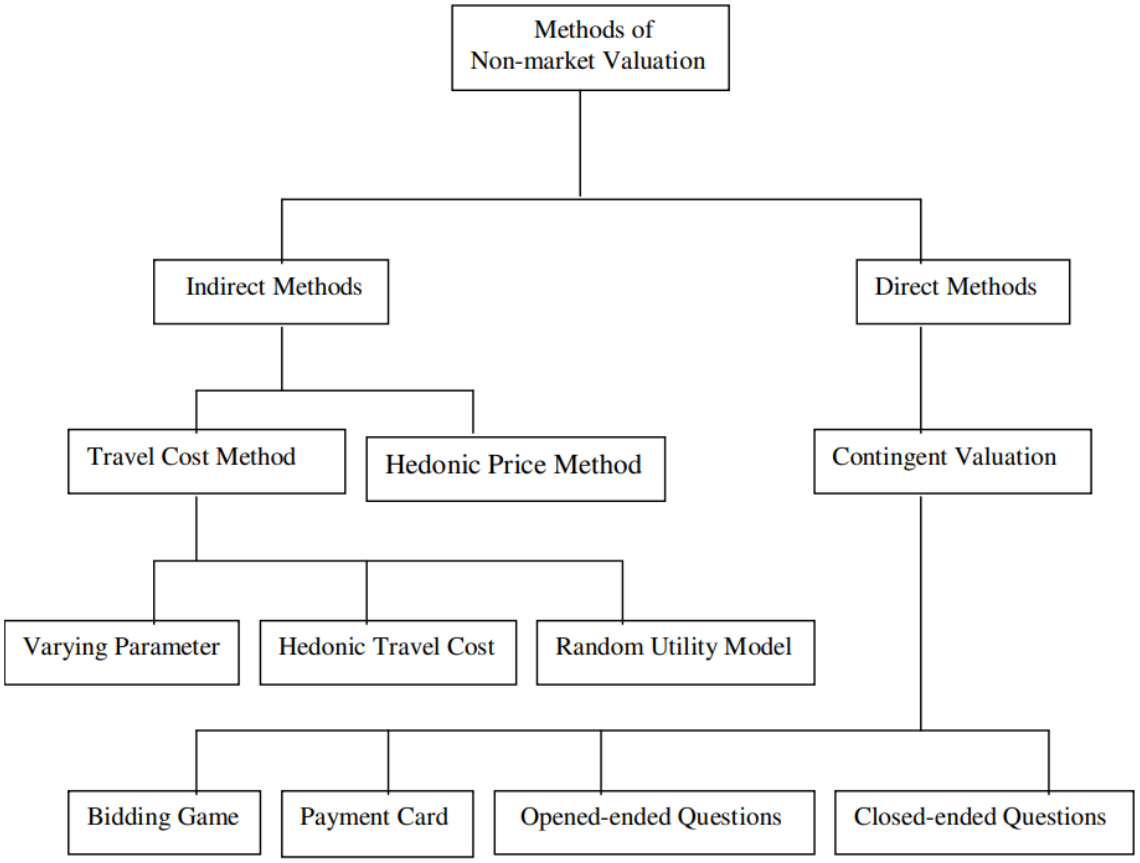

Figure 1. The relationship between different specific non-market valuation techniques for NTFPs, i.e., non-timber forest products (Source: adapted from Sarker and McKenney, 1992) [27].

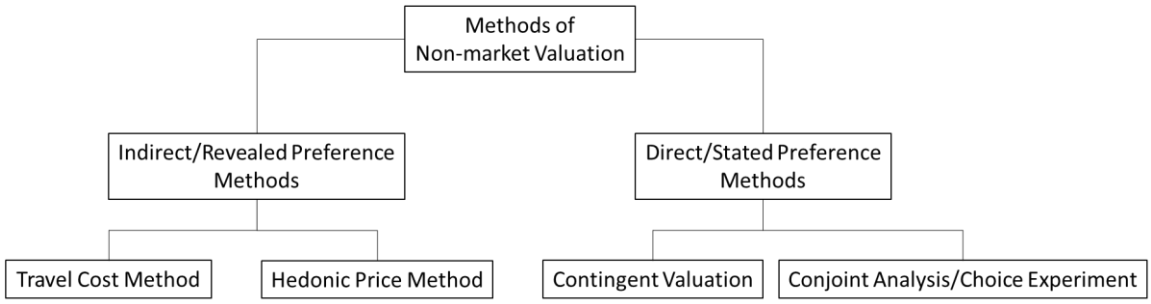

Figure 2. Valuation Methods Examined in this Systematic Review

The hedonic price method determines the implicit price of a non-market good by comparing its worth to an alternative good or service. One way to evaluate specific environmental features is, for instance, through housing prices. Most environmental applications of this method use analysis through regression to decompose house prices into individual contributions derived from crucial features such as the number of bedrooms, location, distance from schools, the air quality of the area, or amenities provided by the area. This creates estimates of the hedonic values (also known as implicit prices [28]) of the aforementioned features. The hedonic price method is based on the fact that housing characteristics have implicit prices, and interested buyers are looking for a specific level of a particular characteristic. Consumers could be willing to spend more for a property in a country park than one near an oil-polluted beach. [29].

The travel cost method entails gathering data on the expenses each individual incurred when going to the recreation area or amenity. This “price” that visitors pay is specific to each individual and is derived by adding the expenses of each person’s trip from their starting point to the amenity. A demand curve can be approximated using the observed travel costs related to the number of individuals using the amenity, and as a result, a price can be determined for the non-price amenity [28]. This demand curve estimates consumer surplus in relation to visiting a place or considers how visitation rates and the consumer surplus may change if the entrance fee to this area increases. A problem this method can face is that people may travel to a place for many different reasons, not only for recreational purposes. Thus, researchers calculate the ratio of time spent at the survey location [26].

Contingent valuation (CV), which is based on surveys, is a widely used approach for putting monetary values on environmental products and services that aren't financially tradeable [30]. At first, surveys usually asked people to simply state the maximum price they were willing to pay. More since then, it has been common to present a set of monetary values and ask people whether they would be willing to pay this amount, either annually or as a lump sum. The amount varies between participants, allowing statistical models to calculate mean willingness to pay results [26].

A choice experiment (or choice modeling method or conjoint analysis) is also a survey-based non-market valuation method used to classify individual preferences. The

respondents of the survey are asked to choose between two or more alternatives. The researcher anticipates that this choice will be made by comparing the different qualities of the available commodities and selecting the one that offers the highest utility [31]. This approach is predicated on the idea that a good's utility, whether it be public or private, is determined by its qualities rather than the good itself [32]. The final estimation model can be applied to forecast market share or estimate welfare. In addition, it can also be applied for beneficial determination of regulations throughout the intended audience or the willingness to pay for new products [33], [34].

Figure 3 shows the suggested questions, as stated by Baker (2014) [25], a researcher should ask to decide which non-market valuation method they will be using for an environmental survey.

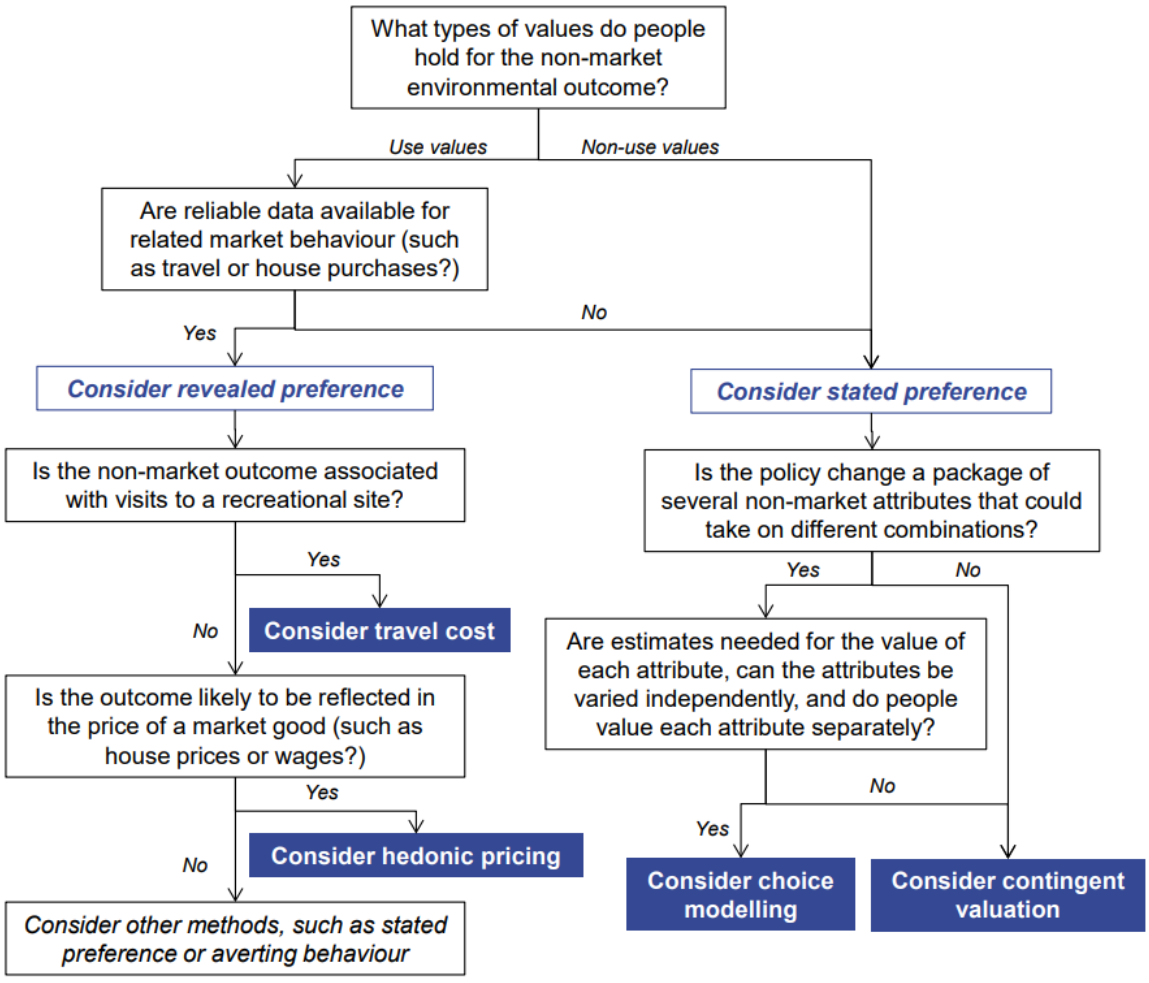

Figure 3 Selecting a non-market valuation method – Initial questions (Baker, 2014) [25]

Some other methods are also mentioned as "direct" in various references, but they obtain information about the monetary damage costs of pollution and are more commonly used by people who are not environmental economists. One of them is the production damage measures which directly measure a deleterious effect of a production process or an accident. Another one is the avoided cost measures which calculate the amount of money that is not spent to mitigate the harm on an asset but to reverse it to its original state. Last but not least is the health cost measures which directly measure the effects of pollution on human health [22].

1.4 Environmental valuation of oil spills

The use of non-market valuation started becoming a big thing in the environmental sector, especially in large-scale incidents requiring precise decision-making to protect natural resources and human health as much as possible.

An oil spill is one of the well-known types of accidents that have overall adverse effects on the environment. Oil spills, aside from commercial vessels and at docks, are usually formed by barges, refineries, tankers, storage facilities, pipelines and drilling rigs mishaps mainly in water body, e.g., ocean, lakes, rivers and bays.

Valuing oil spill environmental impacts with non-market methods was gaining more and more limelight after every single accident in the last decades, especially due to the fact that analyzing the restoration cost of a region was not always taking some ecosystem values into account. The goal of the environmental valuation of an oil spill accident is to develop a monetary measurement of the benefit or the cost to the welfare of the society that is being hurt by the oil spill [35], depending on whether the valuation target is related to environmental amelioration initiatives or degradation’s effects.

Some of the oil spill accidents that led to the development of these non-market valuation methods and are mentioned in the present thesis are BP's Deepwater Horizon Oil Spill (2010), which stands as the largest accidental oil spill in history with 134 million gallons of released oil, the Exxon Valdez oil spill (1989), the Prestige oil spill (2002), the Nestucca oil spill (1988), the Bohai Bay oil spill (2011) and more.

The BP's Deepwater Horizon oil spill is worth a brief overview as it led to a multi-billion damage to natural resources. One of the most critical environmental valuations of the 134 million gallons oil spill was conducted using a stated preference survey to 5,148 adults randomly selected for face-to-face or phone interviews. The main target of this interview was to assess people's willingness to pay a one-time tax to prevent similar to the 2010 BP oil spill effects in the future [36]. All these kinds of questionnaires do not just state the question mentioned above, asking for the respondent to fill in a number, but they include a detailed description of the accident, the environmental medium, and injuries reports about natural resources and wildlife like deaths of various species and lost recreational time for tourists due to beach contaminations. Apart from these, there is also a detailed description of the proposed program for preventing a similar future accident, followed by a fill-in form for the amount each person or household is willing to pay in extra taxes for a suggested prevention program to be implemented.

This study was undertaken by state and federal trustees of the Gulf's natural resources under the guidance of the US National Oceanic and Atmospheric Administration (NOAA), with environmental economist Richard Carson being one of the principal investigators [36]. According to the final estimate, the average household was willing to pay 153 USD for the preventative program. By multiplying this number with the total US households, it comes out that the value of BP's oil spill damage to natural resources stands at 17.2 billion USD.

These non-market valuations are crucial, otherwise the monetary assessment of large-scale accidents would just include the cost to the responsible. In this case, it is BP which announced in 2016 that the Deepwater Horizon oil spill cost 61.6 billion USD [37], a sum that includes the compensation to the families of the 11 workers who died that day, the cleanup costs and the value of the 4.9 million barrels of oil that got lost. As it seems the actual cost of this oil spill should be 28% higher for a total of 78.8 billion USD, and these are the findings of just one out of numerous studies and surveys that were conducted post-2010.

Another major accident was the Exxon Valdez oil spill. It was the biggest oil accident in the US until the Deepwater Horizon disaster, counting about *"11 million*

gallons of crude oil spilled into Alaska's Prince William Sound on March 24, 1989", by an oil tanker owned by Exxon Shipping Company. It led to many environmental valuation studies that kickstarted the use of non-market methods more than any other incident. As mentioned before, the Exxon Valdez oil spill was the reason why the US Congress voted for the Oil Pollution Act (OPA) in 1990. Pockets of crude oil are still present in certain areas over 30 years after the oil slick, which killed hundreds of thousands of seabirds, seals, whales, and otters, and swept 1,300 kilometers of coastline. The cleanup effort involved more than 11,000 Alaskans, government responders, and Exxon workers. Exxon spent around 2 billion USD on cleaning expenses and another 1.8 billion USD to restore the environment and compensate those who were harmed by the accident. [38].

Several environmental valuations took place, with most of them being applied more than ten years after the incident, but the first, which served as a basis for all subsequent studies, was a contingent valuation survey held in 1991. The participants who answered the questionnaire were 1203 with the mean WTP standing at 79.2 1990 USD dollars (equals to 164.25 2021 USD) per household for a one-time federal tax to Prince Williams Sound Protection Fund that will develop an escort ship program to prevent damage from another spill that would have the same effect on the environment [39]. The respondents had to choose between a range of prices for the program by valuing the spill's effect on wildlife and, more specifically, the number of seabirds found dead.

As already made clear, this thesis aims to conduct a systematic review of monetization of oil spill impacts using the above-mentioned environmental valuation methods. This brief introduction to the legislative frameworks, the definitions of some non-market environmental valuation methods, and their linkage with oil spill accidents' monetization are followed by section 2, which provides the materials and background information about the systematic review's methodology and the final database aside with the procedure of constructing it. Section 3 will present the aggregate results of the obtained data, and statistically categorize the selected variables. Lastly, section 4 states the conclusions of the systematic review.

2. Systematic review method

2.1 Origin and theoretical framework

Systematic reviews have marked the past 40 years as an information consolidation method or tool from various existing studies and publications on a given topic. The original target of systematic reviews, considered a secondary search, was to summarize and collect prior research and knowledge for future reference. They were initially used in 1753, in a simple form that was introduced as "literature review", by James Lind, who published a paper to provide a summary of evidence on scurvy [40] and began gaining more reputation in the early 20th century when reviews were conducted in several fields such as medicine, education, agriculture, social sciences, and physics. The benefits and impacts of systematic reviews tend to be vital as it has been proved that human lives and natural resources have been saved by distinguishing useless, unnecessary, and harmful processes [41].

Nowadays, systematic reviews are widely established as the most credible source of information from research. They are treated as top-tier evidence across various essential organizations, such as the Oxford Centre for Evidence-Based Medicine [42].

Systematic reviews are highly structured and follow a standard process. The main elements of a well-structured systematic review are synthesis, summarization, combination, analysis, commenting, and criticism. The process can be broken down into a series of smaller, more manageable steps [43]. Systematic reviews are conducted for specific purposes: (1) identifying information on a topic or identifying literature gaps, (2) synthesizing conclusions on an ambiguous topic, and (3) providing assistance to researchers in terms of decision-making. They use precise and reproducible methods to retrieve all available literature related to a certain inquiry to answer a specified question. Hence, systematic reviews require prerequisite methodologies for literature searching with predetermined inclusion and exclusion criteria that should be reported in a fully detailed review protocol. The search technique and the conclusions that may be derived from the study will be guided by this specific review question. A tightly-framed question will produce a tight and exact search string, thus very few studies. Performing an overly narrow search also increases the chances of not including essential studies.

On the other hand, a broad question can generate an inaccurate search, with many false positive results. Therefore, the question must be carefully and precisely drafted to guide the literature search properly. Systematic review searches require to be transparent and minimize any bias while collecting the most pertinent bibliographic evidence, such as published articles, which are necessary to answer the review question [44]. Any written work, including scientific dissertations, book chapters, papers, web pages, etc., might be considered an "article." Several studies may be included in publications, or multiple publications may quote the same research. Failure to include relevant publications could significantly influence and bias the results. This can also occur over time as new studies are published. In fact, it is unlikely to detect absolutely all relevant publications during a database synthesis [44].

2.2 Bias and errors

Conducting a rigorous synthesis of evidence for a systematic review involves minimizing the risk of error and bias in all stages. Errors during the search include vague search terms, misspellings, and syntax errors, e.g., improper use of Boolean operators and inappropriate search terms. Such problems can be minimized by evaluating the search strategy from third parties such as a team supervisor. Apart from that, minimizing bias may require using sources besides the standard academic electronic libraries, using multiple databases and search tools, and communicating with organizations or individuals who may be relevant to the topic [45].

There are several types of bias that can occur. Linguistics bias suggests that key studies are more probable to be written and submitted in English, making their access easier than those published in other languages [46]. A second prevailing bias is linked with timing. It involves the chance that research that support the theory are more likely to be published earlier than those that contradict its assertions [47].

2.3 Overview and integration of the steps of a systematic review

2.3.1 Research questions

Several publications provide a step-by-step guide for conducting a systematic review [43], [48]–[50]. The first step is to identify which is the research question. The systematic review presented in this MSc dissertation aims to analyze the monetization of oil spill impacts using environmental economics methods, also known as non-market methods. In this case, the main research questions addressed by this review are:

i. What are the main environmental valuation techniques used to monetize all kinds of impacts from an oil spill?
ii. Which are the valuation items used in non-market methods to monetize impacts from a severe disaster like an oil spill?
iii. What is the environmental cost (valuation estimates) of past or hypothetical future oil spills?

2.3.2 Data collection strategy

The second step of the review is to define the data collection strategy and the inclusion and exclusion criteria. This is to ensure that the search produces only the needed data to perform the review synthesis. The fundamental part of the data collection strategy step is specifying the search terms. A search string that is effective in finding relevant publications leads to the desired result of maximum relevant findings, and therefore there will be no need to run the search again and again with different terms and mix up similar publications. In addition, a well-structured search string can be reused as is for future modifications and updates, saving time and resources.

Initial search terms are usually generated from the query elements. Several databases should be sought to identify as many related publications as possible. Ideally, a decision on which databases would be most appropriate to answer the review's questions should be made. This choice mainly depends on the field of interest (e.g., biology, social sciences, environmental engineering, etc.) and their ability to reduce various types of bias as previously described. The number of results an electronic database gives should not indicate the relevance of publications, and therefore, it should not be a rejection or

acceptance criterion [26]. While some databases, like Google Scholar, provide free access, others need a membership or offer free access through educational institutions (such as Scopus). Hence, institutional subscriptions may be required for access to electronic bibliographic databases. The most extensive online databases are Scopus, Web of Science (WoS), and Google Scholar. The Scopus was the preferred selection as it includes most of the publications indexed in WoS and has more exclusive journals in all fields [51]. Apart from that, Google Scholar tends to include many gray literature, keynotes, extended abstracts, etc.

The last part of the data collection strategy is selecting a bibliographic data management software. User may export search results to a computer or an online database using a variety of reference management programs. Creating an efficient workflow of the publications for collecting, organizing, storing, and sharing purposes, can save plenty of time later during the writing process. Some standard bibliographic management software is EndNote and Reference Manager, which require a paid subscription, and Zotero and Mendeley, which are free to use. The decision should preferably be made at the start of the project, during scoping, as it is likely to be impacted by the resources available and the author's experience with each program, while the collection of bibliographic references starts along with the first steps of the systematic review. For this specific review, Zotero was chosen mainly because it is free to use and offers direct integration with Word and a wide variety of citation styles.

2.3.3 Search for studies

Next up is searching for studies. It is a complicated and susceptible process because it must retrieve as many potentially relevant studies as possible. The sensitivity and accuracy of the publications returned by the search strings are sometimes traded off while implementing the search technique [52]. Increasing the sensitivity of a search process usually decreases its accuracy, meaning that more irrelevant articles are retrieved, which may increase the time spent evaluating the relevance of the results. This makes clear that search strategy development is often an iterative process that takes lots of tries until reaching an optimal point. It is expected that during the search process, the search string is

altered repeatedly by adding or removing keywords and modifying the syntax with different operators, to get the best results.

It is suggested that the search process should start using a search string that is expected to return the most significant possible number of relevant documents. After that, more subsequent search strings can be constructed to supplement the first results [53]. The final list of the different search terms merged into search strings should return as many studies that are pertinent (sensitivity) while also minimizing the amount of results that are irrelevant (accuracy). The search strings must perfectly adapt to the chosen search engine's characteristics. Scopus offers a detailed video tutorial showing the whole process of searching for documents (Scopus Tutorial) as well an "Access and uses Support Center" page containing all necessary information about searching for a document, Boolean and proximity operators, finding exact or approximate phrases and words, filtering the search results and combining different search strings.

A continuous and comparative process of reviewing and assessing the search results might assist in improving the search strategy. If the search strategy does not specify some returned publications, then the team or individual conducting the systematic review should consider why [54]. While the search engine tries to include the most relevant studies possible, it will inadvertently include some publications that are beyond the focus of the review. As a consequence, the final search will return a collection of articles that will include both pertinent and non-relevant results. Let's say the amount of search results is too great for the team or person in charge of the review to handle with its current resources. In that case, using specific tools provided by some online databases, to improve returned results may be considered to discard some irrelevant publications. On the other hand, there is always a risk in using such tools as they may remove relevant publications. This can happen because most of the aforementioned tools filter the results through the journal category, not the publication category.

Once a search is completed, new studies may be published, making the research a diligent effort. Therefore, it is vital that the initial searches are well documented and stored, if possible. There are two primary factors that should alter in a search procedure. The first can arise when the synthesis of the studies database spans a long-time interval. In this case,

the review's conclusions might get outdated even before the review is published. The second reason arises when the conclusions synthesis report has already been published, and there is a need to revise because even newer studies must be considered. In this case, the search protocol, i.e., search strategy, should be checked to determine if the team or individual in charge of the review should add new terms for additional sources [55].

For this specific review, the first Scopus search procedure began with a broad scoping of publications linked to the environmental valuation of oil spills using the string:

TITLE-ABS-KEY ("oil spill" AND economic AND value*)

A total of 290 document results were returned, and the first refinement was to limit them to those written in English by editing the search string as follows:

TITLE-ABS-KEY ("oil spill" AND economic AND valu*) AND (LIMIT-TO (LANGUAGE, "English"))

This resulted in a total of 277 documents. The asterisk (*) is used in a word so that the search engine will include different suffixes. For example, when typing "valu*" Scopus will return results for "value", "valuation", "valuable" etc.

After a thorough inspection of a significant part of these results, it came out that most of them were analyzing the costs of oil spill accidents using market-based methods. In contrast, non-market valuation methods had no significant participation, but still, there were some exceptions. The next step to filter and enrich these exceptions was to fit more specific keywords to include the environmental valuation methods for which this systematic review was initially designed. As mentioned, this review aims to analyze the use of stated and revealed preference valuation methods on oil spill impacts. This means that the keywords that need to be implemented into the Scopus search string are contingent

valuation, choice experiment (or conjoint analysis), hedonic price, travel cost, WTP and WTA. Initially, a separate search string was used to check the results of these keywords linked to oil spills:

TITLE-ABS-KEY ("oil spill" AND ("contingent value*" OR "choice exp*" OR "choice model*" OR "conjoint analysis" OR hedonic OR "travel cost" OR wtp OR "will* to pay" OR "wta" OR "will* to accept"))

This sentence returned 91 document results which were cut down to 89 when limited to the English language. The only issue now was that these results could not stand as the only database for the review because many of the 277 results from the first string were not included in this search. For these purposes, Scopus has a combination function for different queries, and after using it to embed the first search string into the second, the final search string stood as follows:

(TITLE-ABS-KEY ("oil spill" AND economic AND valu*)) OR (TITLE-ABS-KEY ("oil spill" AND ("contingent valu*" OR "choice exp*" OR "choice model*" OR "conjoint analysis" OR hedonic OR "travel cost" OR wtp OR "will* to pay" OR "wta" OR "will* to accept"))) AND (LIMIT-TO (LANGUAGE, "English")).

After deciding not to exclude any publication type, 327 of them met the requirements for abstract reading. Following a thorough reading of every single abstract of these publications, depending on the main inclusion and exclusion criteria which are whether the publications contain any economic value or not, 93 publications were chosen to be preserved for full-text screening after 234 were disregarded.

During this process, some publications were restricted and could not be accessed with the Aristotle University of Thessaloniki Institutional Login. After a broad web search, some of them were found and included in the full-text screening:

- A total of 14 publications were excluded because they did not offer free access to any database.
- 13 publications were of general environmental valuation methods content without providing any values,
- 1 was written in the Korean language, but Scopus did not filter it out,
- 3 of them had economic values but were not associated with oil spill accidents, neither hypothetical nor actual,
- and 29 publications had economic values resulting from market methods.

The 33 remaining publications formed this review's final database, as in Table 1. The whole filtering process of the literature, starting from the first two primary searches until the final database of 33 publications, is described in Figure 4.

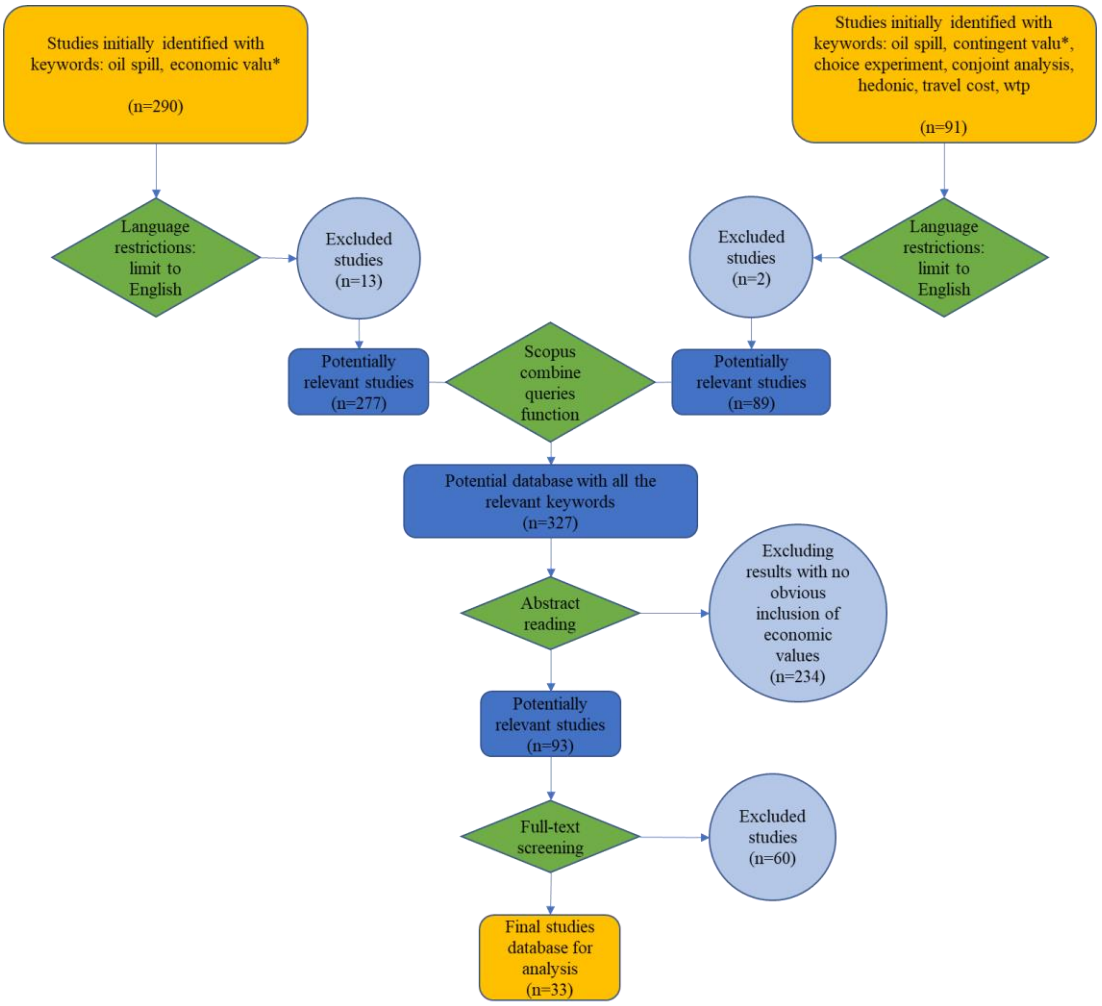

Figure 4. Filtering of literature

Table 1. The dataset publications

ID	TITLE	REFERENCE
1	A Contingent Valuation Study of an Accidental Oil Spill Along the Belgian Coast	[56]
2	A probabilistic approach for a cost-benefit analysis of oil spill management under uncertainty: A Bayesian network model for the Gulf of Finland	[57]
3	A revealed preference approach to valuing non-market recreational fishing losses from the Deepwater Horizon oil spill	[58], [59]
4	Behavioral economics, benefit-cost analysis, and the WTP versus WTA choice	[60]
5	Contingent valuation and lost passive use: Damages from the Exxon Valdez oil spill (Book Chapter)	[61]
6	Contingent valuation: Flawed logic?	[62], [63]
7	Convergent validity of stated preference methods to estimate willingness-to-pay for seafood traceability: The case of Gulf of Mexico oysters	[64]
8	Decoupling the value of leisure time from labor market returns in travel cost models	[65]
9	Diagnosing Insensitivity to Scope in Contingent Valuation	[66]
10	Does college education nourish egoism?	[67]
11	Economic impacts of cancelled recreational trips to Northwest Florida after the Deepwater Horizon oil spill	[68], [69]
12	Economic Valuation of Environmental Damages due to the Prestige Oil Spill in Spain	[70]
13	Estimating the value of lost recreation days from the Deepwater Horizon oil spill	[71]
14	How Sensitive Are Environmental Valuations to Economic Downturns?	[72]
15	Indirect assessment of economic damages from the Prestige oil spill: Consequences for liability and risk prevention	[73]
16	International Public Preferences and Provision of Public Goods: Assessment of Passive Use Values in Large Oil Spills	[74]
17	Managing coastal area resources by stated choice experiments	[75]
18	Measuring the value of water quality improvements in Lake Tai, China	[76]
19	Non-use value in natural resource damage assessments: The Nestucca oil spill	[77]
20	Putting a value on injuries to natural assets: The BP oil spill	[36]
21	Social and ecological impacts of the Hebei Spirit oil spill on the west coast of Korea: Implications for compensation and recovery	[78]
22	The effects of the BP Deepwater Horizon oil spill on housing markets	[79]
23	The public value of building large oil spill response vessels in Korea	[80]
24	The public value of reducing the incidence of oil spill accidents in Korean Rivers	[81]
25	The public willingness to pay for reducing the incidence of Hazardous chemical spill accidents by half in South Korea	[82]
26	Tourism for surf and marsh fishing in coastal Louisiana: effects of site closure, travel cost decrease, and entrance fee increase	[83]
27	Valuation of oil spill risk reductions in the Arctic	[84]
28	Valuing local endangered species: The role of intra-species substitutes	[85]
29	Valuing the attributes of remediation of maritime oil spills: An empirical case study in South Korea	[86]
30	Valuing the benefits of improved marine environmental quality under multiple stressors	[87]
31	Willingness to pay among households to prevent coastal resources from polluting by oil spills: A pilot survey	[88]
32	Willingness to pay for shrimp attributes and evidence of stigma following the Gulf Coast oil spill	[89]
33	Public Attitudes on Funding Oil Pollution Cleanup in the Chinese Bohai Sea	[90]

The systematic review then moves on to data extraction, which records key study features in a controlled and uniform manner using information from journal articles and reports. [91]. It is expected that in non-financed projects, a single table in a simple platform like Microsoft Excel, LibreOffice Calc, or Google Spreadsheets is used to capture the data that will eventually be summarized and analyzed. Besides them, there are plenty of applications with paid subscriptions that offer many tools to help with data organization, while the data extraction task can become very time-consuming and repetitive when done by hand. Intelligent software like covidence identifies and extracts information automatically. Nonetheless, during the full-text screening of the final 33 publications, several data were extracted and organized in twenty-one (21) variables as shown and described in Table 2 using a simple Microsoft Excel sheet.

All these publications consist of studies using different methods and approaches. Therefore, there is a variety of different monetary measures that must be transformed to be analyzed in the following section. Due to this paper being a systematic review and not an independent and specific study, in the field of the oil and gas industry, which uses the USD as the main currency worldwide, all the values were transformed into 2021 USD equivalent, using the following formula [92]:

$$\text{Value}\ (\text{USA}_{2021}) = \text{Value}\ (Country_{year}) * \frac{\text{PPP}\ (\text{USA}_{year})}{\text{PPP}\ (Country_{year})} * \frac{\text{CPI}\ (\text{USA}_{2021})}{\text{CPI}\ (\text{USA}_{year})}$$

Where:

- the country stands for the origin of the study,
- year refers to the year the study was conducted,
- PPP is the purchasing power parity of the country of interest (i.e., *"the measurement of prices in different countries that uses the prices of specific goods to compare the absolute purchasing power of the countries' currencies"* [93]) and
- CPI is the consumer price index (i.e., *"a measure of the average change over time in the prices paid by consumers for a representative basket of consumer goods and services"* [94]).

Both indices (PPP and CPI) were retrieved by the World Bank [95], [96]. In Table 3 below, some indicative original and converted values, as well as the type of conversion along with the CPI and PP indices, are presented. All these monetary values are accompanied by unit values such as per household (HH), per year, per kilometer (km), per square kilometer (km^2), per specie (i.e., seabird, shrimp), per individual, etc., which will be discussed in the following section 3.3 alongside with the final 66 unique monetary values and other data.

Table 2. Variables used for the analysis

VARIABLE	DESCRIPTION	TYPE
ID	No. of publication in the final database	Discrete
YEAR OF PUBLICATION	Publication year of the article	Discrete
ORIGIN OF PUBLICATION	The country of the valuation studied	Nominal
ORIGIN OF SPILL INCIDENT	The country of the spill evaluated	Nominal
CONTINENT OF CASE STUDY	The continent the origin of the publication belongs to	Nominal
JOURNAL	Title of the journal	Nominal
VALUATION METHOD	Stated preference, revealed preference	Nominal
VALUATION APPROACH	Hedonic price, travel cost, contingent valuation, choice experiment	Nominal
TYPE OF VALUE	Total value, use value, non-use value	Nominal
ELICITATION APPROACH	Willingness to pay (WTP), willingness to accept (WTA), compensating measures, total economic value (TEV)	Nominal
DATA COLLECTION METHOD	Personal interviews, internet-based surveys, phone surveys, value transfer, e-mail	Nominal
YEAR OF SURVEY	Year of the data collection campaign	Discrete
VALUATION UNIT	Per household, per individual, per measurement unit, etc.	Nominal
ORIGINAL VALUE	Original monetary estimate	Continuous
TRANSFORMED VALUE	Transformed monetary estimate	Continuous
EXTERNALITIES	External costs, external benefits	Nominal
JUSTIFICATION	Justification of the valuation unit	Nominal
VALUATION ITEM	Water quality, human health, wildlife, air quality, housing market, recreational use, landscape quality, coastal damages, etc.	Nominal
ENVIRONMENTAL MEDIUM	Open sea, land, lake, river, ocean, etc.	Nominal
SPATIAL SCALE	Local, National	Nominal

Table 3. Indicative monetary values conversion

ID	ORIGINAL VALUE	TYPE OF CONVERSION	PPP (USA YEAR OF STUDY)	PPP (COUNTRY & YEAR OF STUDY)	CPI (USA 2021)	CPI (USA YEAR OF STUDY)	CONVERTED VALUE
1	90.3	2001 EUR to 2021 USD	1.00	0.89	124.27	83.43	150.67
5	79.2	1990 USD to 2021 USD	1.00	1.00	124.27	59.92	164.25
9	1086.00	2013 NOK to 2021 USD	1.00	9.03	124.27	106.83	139.90
18	141.00	2008 CNY to 2021 USD	1.00	3.18	124.27	98.74	55.82
29	174.61	2019 KRW to 2021 USD	1.00	864.63	124.27	117.24	0.21

In the next section, the aggregate results of the data obtained from the full-text screening of the final dataset's publications will be presented, and a statistical categorization of all the selected variables will be made. The traits of the contained studies will be summarized, and data will be brought together to produce something that has more excellent value all at once than the total of its parts. This process, combined with a thorough commentation on the results, constitutes the final step of the systematic review.

3. Results and discussion

3.1 Year of publication, origin, and scientific journal

As shown in Figure 5 below, nine publications (27.3%) were published between 2000 and 2009, and twenty-four studies (72.7%) were published between 2010 and 2020. Although there were some studies before 2000, such as the Exxon Valdez oil spill or the Nestucca oil spill, they were published in more recent journals, and this is why Scopus did not return any pre-2000 papers.

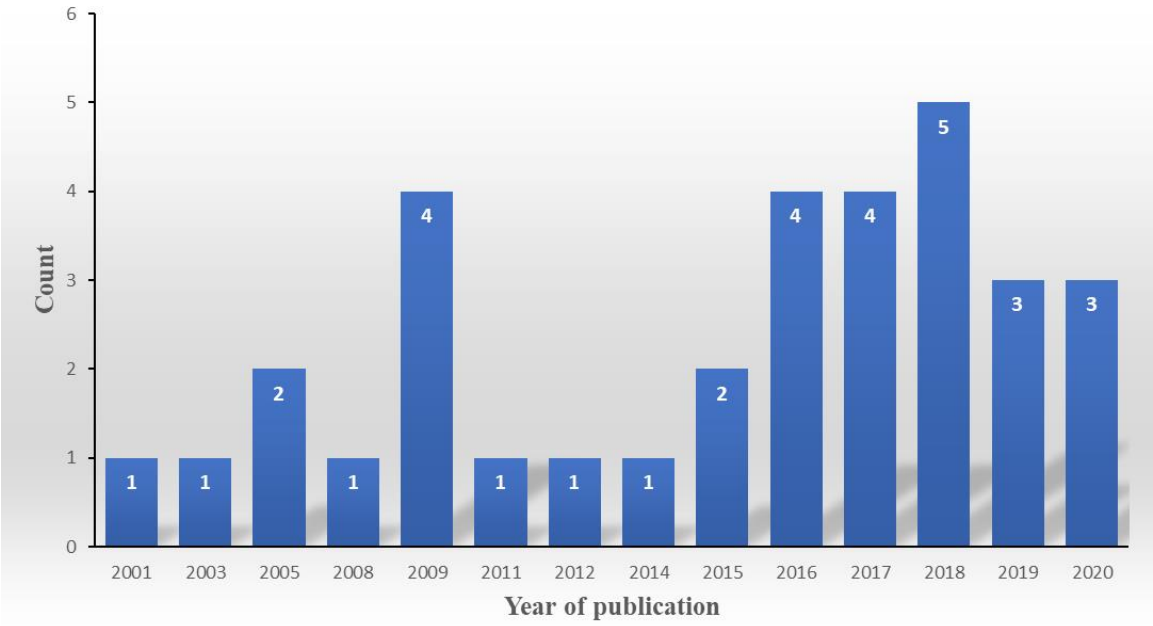

Figure 5. Publication year

Further, the majority of publications have studied oil spill incidents in North America (14 cases or 42.4%), Europe (11 cases or 33.3%), and Asia (8 cases or 24.3%). More specifically, oil (and chemical) spills have been studied in the USA (14 cases or 42.4%), Spain (5 cases or 15.2%), South Korea (5 cases or 15.2%), China (3 cases or 9.1%), Norway (2 cases or 6.1%), Germany (1 case or 3%), Finland (1 case or 3%), Estonia (1 case or 3%) and Belgium (1 case or 3%) as shown in Figure 6.

Comparing Figure 6 with Figure 7, it is inferred that some studies were published in a different country from the origin of the studied spill. For example, publication no. 4 [60] assesses the BP Deepwater Horizon oil spill (USA). However, it was published by

Simon Fraser University in Canada in cooperation with Civil Service College in Singapore. Publication no. 10 [67] presents a contingent valuation study of the Exxon Valdez oil spill in Alaska, USA, but Sogang University in South Korea published it. Publication no. 17 [75] evaluates natural goods of a coastal environment using a spill management practice in the German North Sea, and it is published by the Yantai Institute of Coastal Zone Research for Sustainable Development in China in cooperation with Institute for Coastal Research GKSS Center in Germany. Publication no. 27 [84] uses data from a contingent valuation study in Lofoten, Norway, to assess the value of ecosystem services at risk from oil spills in the Arctic, and it was published by KTH Royal Institute of Technology in Sweden, in cooperation with Enveco Environmental Economics Consultancy and The Beijer Institute of Ecological Economics, both in Sweden.

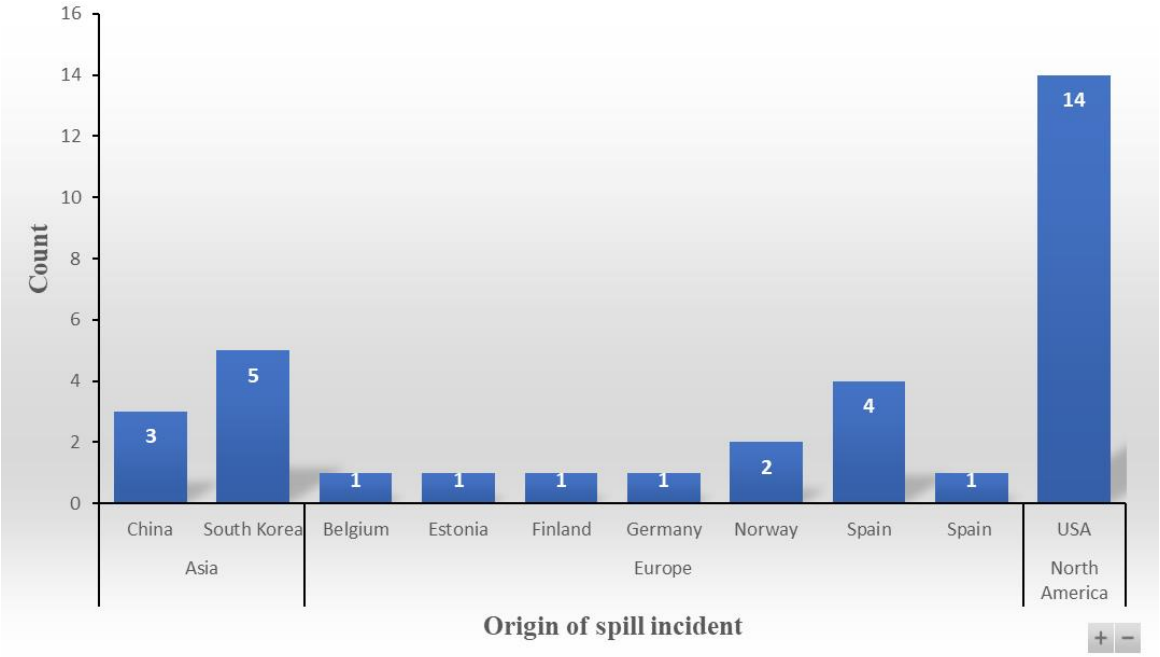

Figure 6. Origin of spill incident

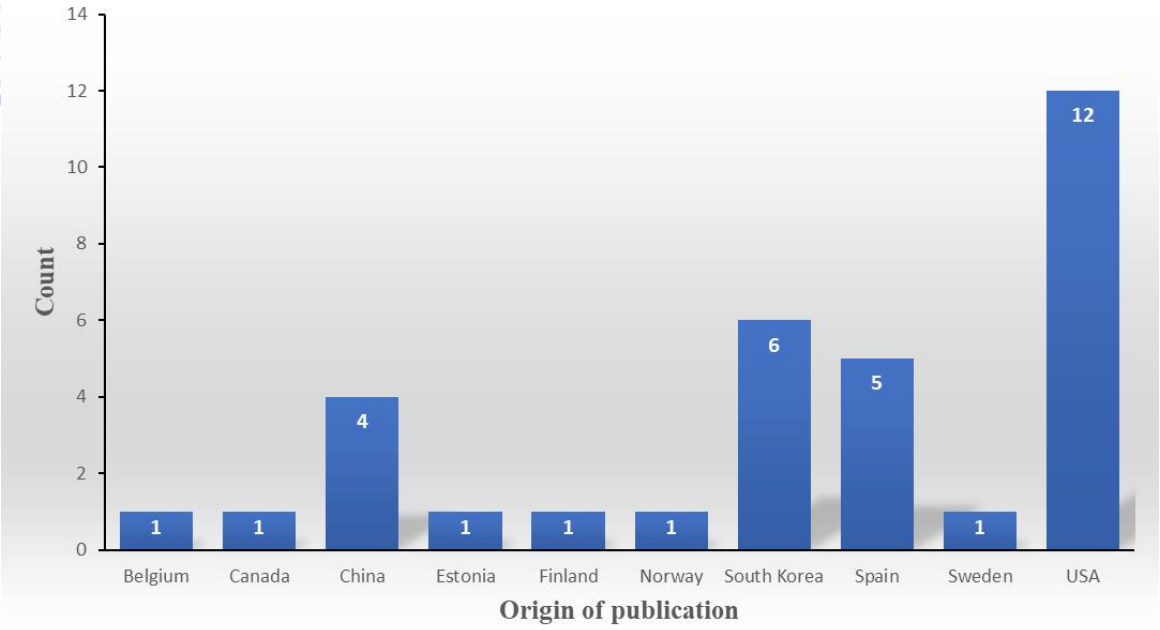

Figure 7. Origin of publication

This again proves the worldwide importance of environmental, economic and social impacts of oil spills and the wide range of use of hypothetical accident scenarios to minimize the chances of them actually happening.

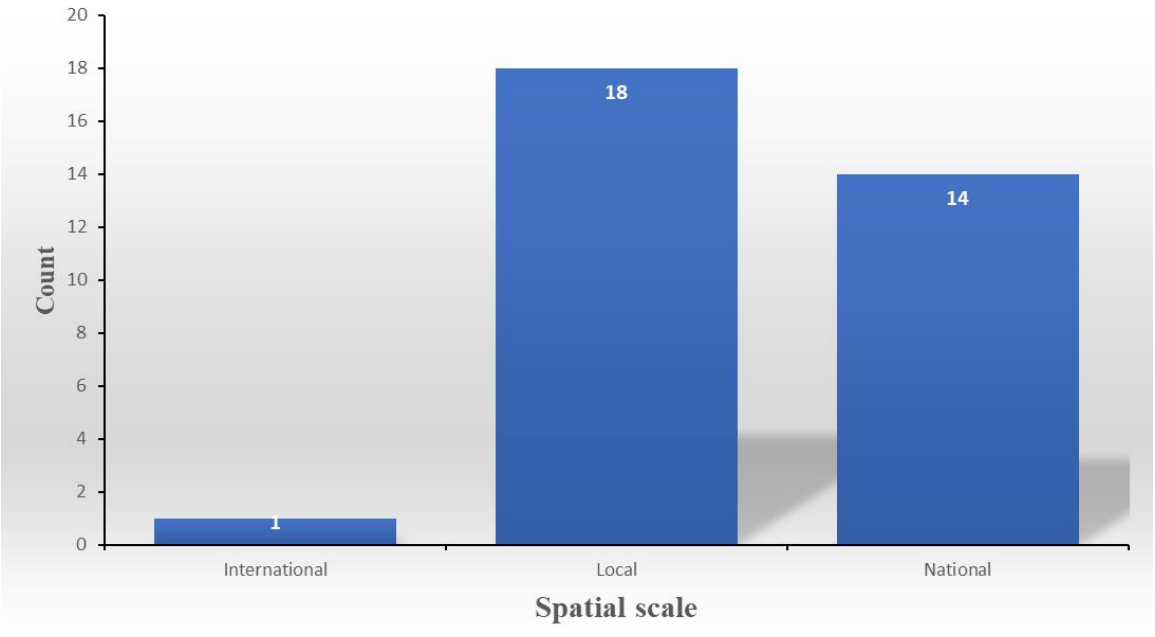

Figure 8. Spatial scale of studies

All the studies from the final database are published in journals of various disciplines, as shown in Table 4. As regards environmental, economic and natural resources journals, three papers have been published in "Environmental and Resource Economics", two in "Ecological Economics", two in "Journal of Environmental Economics and Policy", two in "Journal of Environmental Management", two in "Sustainability (Switzerland)" and one paper in each of the following journals:

- "Environmental Economics and Policy Studies",
- "International Review of Environmental and Resource Economics",
- "Journal of Environmental Economics and Management",
- "Journal of the Association of Environmental and Resource Economists",
- "Marine Resource Damage Assessment: Liability and Compensation for Environmental Damage",
- "Science of the Total Environment" and
- "The Stated Preference Approach to Environmental Valuation: Volume III: Applications: Benefit-Cost Analysis and Natural Resource Damage Assessment".

The rest of the journals concerned about the fields of marine and coastal research (6 publications), general scientific content (3 publications), general economic content (2 publications), oil spills and disasters (2 publications).

Table 4. Ranking of journals per papers published

JOURNAL TITLE	FREQUENCY	PERCENT
ENVIRONMENTAL AND RESOURCE ECONOMICS	3	9.1
ECOLOGICAL ECONOMICS	2	6.1
JOURNAL OF COASTAL RESEARCH	2	6.1
JOURNAL OF ENVIRONMENTAL ECONOMICS AND POLICY	2	6.1
JOURNAL OF ENVIRONMENTAL MANAGEMENT	2	6.1
SCIENCE	2	6.1
SUSTAINABILITY (SWITZERLAND)	2	6.1
2005 INTERNATIONAL OIL SPILL CONFERENCE, IOSC 2005	1	3.0
AQUACULTURE ECONOMICS AND MANAGEMENT	1	3.0
DISASTERS	1	3.0
ECONOMICS BULLETIN	1	3.0
ENVIRONMENTAL ECONOMICS AND POLICY STUDIES	1	3.0

JOURNAL TITLE	FREQUENCY	PERCENT
ESTUARINE, COASTAL AND SHELF SCIENCE	1	3.0
INTERNATIONAL REVIEW OF ENVIRONMENTAL AND RESOURCE ECONOMICS	1	3.0
JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT	1	3.0
JOURNAL OF HOUSING ECONOMICS	1	3.0
JOURNAL OF THE ASSOCIATION OF ENVIRONMENTAL AND RESOURCE ECONOMISTS	1	3.0
JOURNAL OF ZHEJIANG UNIVERSITY: SCIENCE A	1	3.0
MARINE POLICY	1	3.0
MARINE POLLUTION BULLETIN	1	3.0
MARINE RESOURCE DAMAGE ASSESSMENT: LIABILITY AND COMPENSATION FOR ENVIRONMENTAL DAMAGE	1	3.0
OCEAN AND COASTAL MANAGEMENT	1	3.0
REGIONAL SCIENCE POLICY AND PRACTICE	1	3.0
SCIENCE OF THE TOTAL ENVIRONMENT	1	3.0
THE STATED PREFERENCE APPROACH TO ENVIRONMENTAL VALUATION: VOLUME III: APPLICATIONS: BENEFIT-COST ANALYSIS AND NATURAL RESOURCE DAMAGE ASSESSMENT	1	3.0

3.2 Valuation methods, items, and externalities

This section presents the main findings regarding the first research question (i.e., what are the main environmental valuation techniques used to monetize all kinds of impacts from an oil spill). Stated preference (or direct) methods have been used in twenty-six cases (78.8%) [36, 56, 57, 60–62, 64, 66, 67, 70, 72, 74–78, 80–82, 84–90], revealed preference (or indirect) methods in six cases (18.2%) [58, 65, 68, 71, 79, 83], and benefit transfer method in one case (3%) [73], as shown in Table 5.

More than half of the studies have been conducted using the contingent valuation approach [56, 57, 60–62, 64, 66, 67, 70, 72, 74, 76–78, 80–82, 84, 85], seven (21.2%) studies have applied choice experiments [36, 75, 86–90], five (15.2%) studies have used travel cost approach [58, 65, 68, 71, 83], one (3%) used benefit transfer approach [73] and

one (3%) used hedonic price method [79] to monetize impacts from oil spills, as shown in table 6.

Table 5. Valuation methods used in monetizing oil spill impacts

VALUATION METHOD	FREQUENCY	PERCENT
STATED PREFERENCE	26	78.8
REVEALED PREFERENCE	6	18.2
BENEFIT TRANSFER	1	3.0

Table 6. Valuation approaches used in monetizing oil spill impacts

VALUATION APPROACH	FREQUENCY	PERCENT
CONTINGENT VALUATION	19	57.6
CHOICE EXPERIMENT	7	21.2
TRAVEL COST	5	15.2
BENEFIT TRANSFER	1	3.0
HEDONIC PRICE	1	3.0

Figure 9 below states that the WTP (willingness to pay) elicitation approach was used in thirty-one out of thirty-three studies (93.9%), whereas WTA (willingness to accept) was used in one (3%) publication. There was one publication (id 26 from table 1 [83]) whose study used consumer surplus to monetize the welfare losses from the closure of three recreational sites. It is an approach resulting from the willingness to pay, as it happens when the consumer is willing to pay more than possible for a product or service. In this case, paying for a trip to those sites is impossible as they are closed, and this is how consumer surplus emerges.

Further, twenty-five studies (75.8%) calculated total values, whereas eight (24.2%) calculated use values. Choice experiment studies calculated total values (6 cases) and use value (1 case), contingent valuation studies calculated total values (18 cases) and use values (1 case), hedonic price method studies calculated use value (1 case), travel cost method studies calculated use values (5 cases) and the benefit transfer method study calculated total value (1 case).

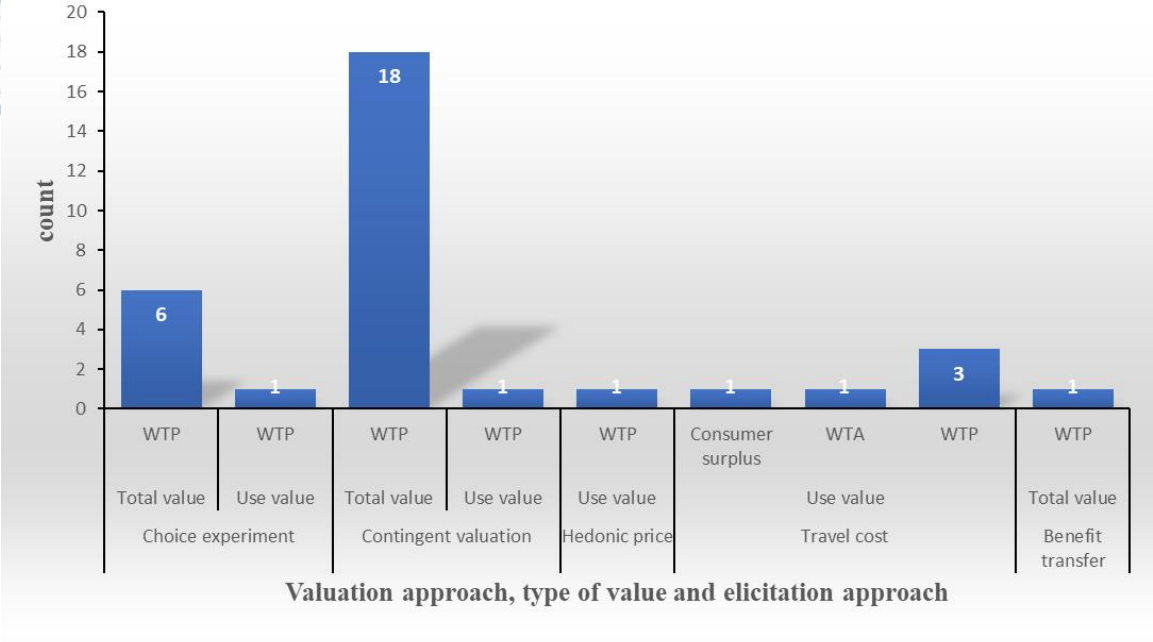

Figure 9. Elicitation approach per type of value and valuation approach

Figure 10 distinguishes the valuation approaches for estimating external costs and benefits. Talking about the valuation of oil spills, one would expect that studies would monetize just external costs. This is partially correct as most of the studies monetize various environmental assets in order to valuate the oil accident. Nonetheless, some studies do not valuate the accident but the benefits of not encountering it. The main external benefits monetized by several studies [64, 76, 80–82, 84, 86, 87] have to do with improvements in the quality of water, construction of protective vessels, and reduction of oil and chemical spill incidents. In contrast, external costs are mainly associated with injuries and deaths of animals and humans, water contamination, coasts and beaches, and degradation of the quality of life.

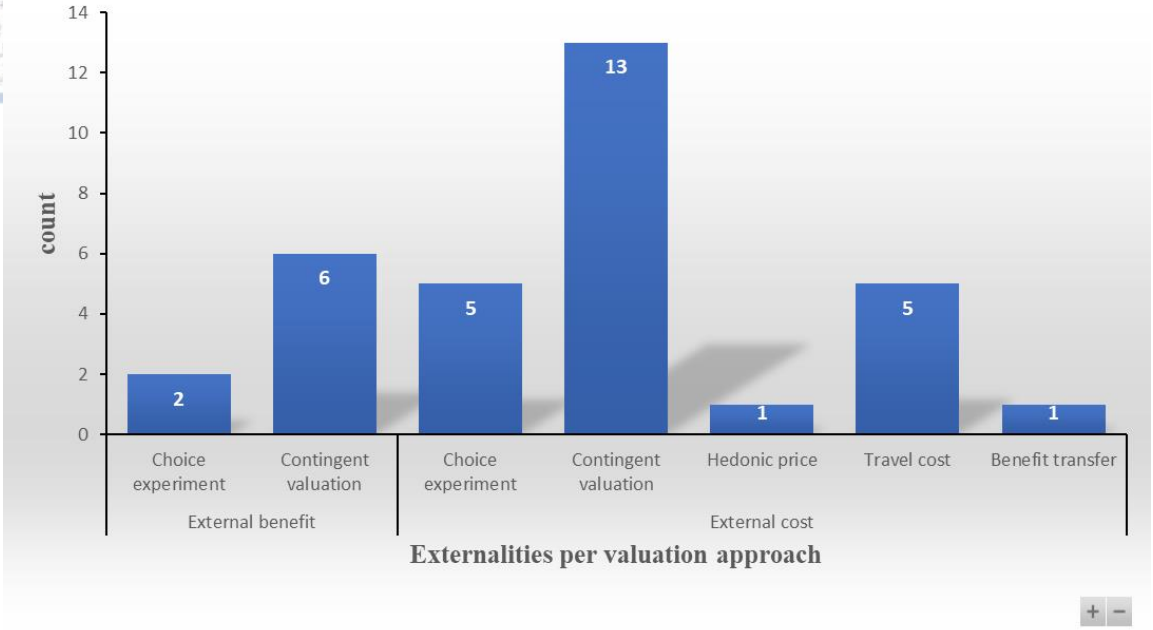

Figure 10. Externalities per valuation approach

As presented in table 7, fourteen publications are monetizing oil spill impacts with non-market methods using wildlife elements, such as mammals, reptiles, birds, fish, crabs, shrimps, seals, fauna, and ducks, as valuation items. One of them estimates external benefits, and the rest thirteen external costs. Thirteen publications use general nature elements to monetize impacts from oil spills, such as beaches, coasts, marshes, air, and water. Five of them estimate external benefits and eight external costs. Last but not least, fourteen publications use quality of life elements such as recreation, fishing, human injuries, human meals, housing values, and human well-being to monetize oil spill impacts. Two of them estimate external benefits, and twelve of them external costs.

Table 7. Number of valuation studies and externalities per valuation item

VALUATION ITEM	EXTERNAL BENEFITS	EXTERNAL COSTS	REFERENCES
WILDLIFE	**1**	**13**	
MAMMALS	1	3	[61], [70], [84], [85]
REPTILES		1	[85]
BIRDS	1	9	[56], [61], [62], [66], [70], [77], [84], [85], [88], [90]
FISH	1	2	[56], [84], [85]
CRABS		1	[56]
SHRIMPS		2	[56], [89]
SEALS		1	[66]
FAUNA		3	[70], [72], [74]
DUCKS		1	[75]
NATURE	**5**	**8**	
BEACHES		5	[56], [74], [75], [88], [90]
MARSHES		1	[62]
AIR (POLLUTION)		1	[67]
COASTS		5	[67], [74], [75], [78], [90]
WATER	5		[76], [80], [81], [84], [86]
QUALITY OF LIFE	**2**	**12**	
RECREATION		8	[57], [58], [62], [65], [68], [71], [74], [83]
FISHING		2	[58], [73]
HUMAN INJURIES		2	[36], [60]
OYSTER MEALS	1		[64]
HOUSING VALUES		1	[79]
HUMAN WELL-BEING	1		[87]

Another variable from table 2 worth being statistically categorized is the environmental medium of each study's oil spill or spill incident. Nearly half of the studies from the database (15 cases or 45.5%) concern gulfs, mainly the Gulf of Mexico, which makes sense because of the Deepwater Horizon oil spill. Six cases (18.2%) are related to coasts, five cases (15.2%) to oceans, three cases (9.1%) to open seas, and one case (3%) each involves archipelago, closed sea, lake, and river, as stated in figure 11. Table 8 below categorizes each valuation item to the case study's environmental medium per the monetized externalities.

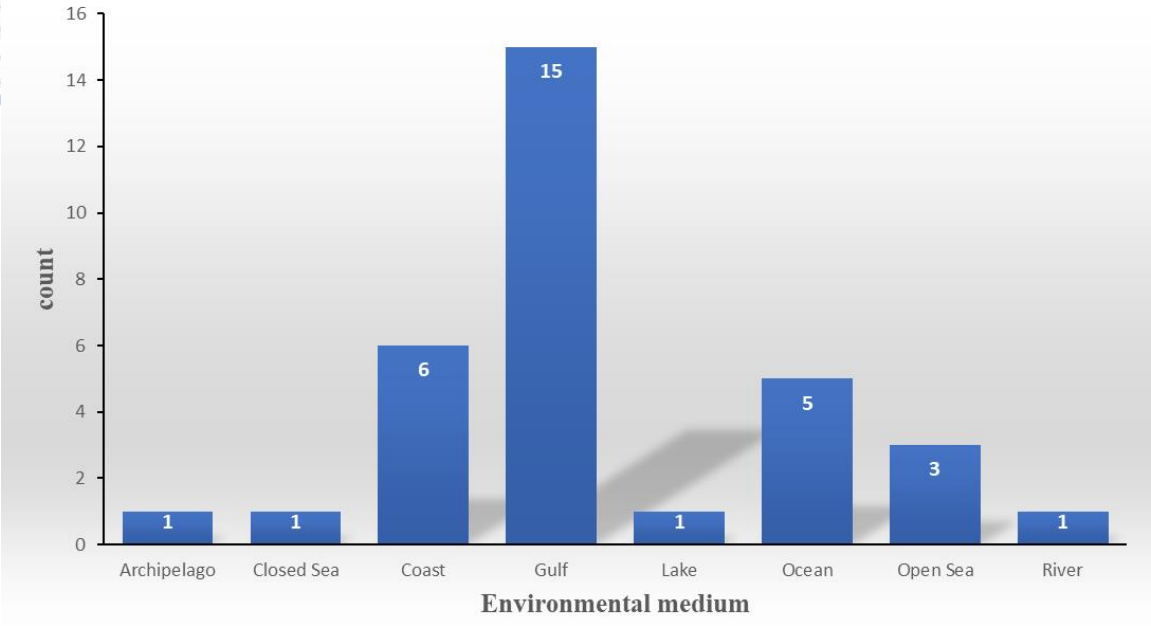

Figure 11. Environmental medium per study

Table 8. Externalities per environmental medium and valuation item

ENVIRONMENTAL MEDIUM, EXTERNALITIES & VALUATION ITEM	COUNT	REFERENCE
ARCHIPELAGO	**1**	
EXTERNAL COST	**1**	[66]
BIRDS, SEALS	1	
CLOSED SEA	**1**	
EXTERNAL BENEFIT	**1**	[87]
HUMAN WELL-BEING	1	
COAST	**6**	
EXTERNAL BENEFIT	**1**	[86]
WATER QUALITY	1	
EXTERNAL COST	**5**	
BEACHES, BIRDS	1	[88]
BIRDS, FISH, CRABS, SHRIMPS, BEACHES	1	[56]
BIRDS, REPTILES, FISH, MAMMALS	1	[85]
FAUNA, COASTS, BEACHES	1	[74]
RECREATION	1	[83]
GULF	**15**	
EXTERNAL BENEFIT	**1**	[64]
OYSTER MEALS	1	
EXTERNAL COST	**14**	

ENVIRONMENTAL MEDIUM, EXTERNALITIES & VALUATION ITEM	COUNT	REFERENCE
AIR POLLUTION, COASTS	1	[67]
BIRDS, MAMMALS	1	[61]
COASTS	1	[78]
COASTS, BEACHES, BIRDS	1	[90]
FISHING, RECREATION	1	[58]
HOUSING VALUES	1	[79]
HUMAN INJURIES	2	[36], [60]
MARSHES, BIRDS, RECREATION	1	[62]
RECREATION	3	[65], [68], [71]
RECREATION, NATURE	1	[57]
SHRIMPS	1	[89]
LAKE	**1**	
EXTERNAL BENEFIT	**1**	[76]
WATER QUALITY	1	
OCEAN	**5**	
EXTERNAL BENEFIT	**1**	
FISH, BIRDS, MAMMALS, WATER	1	[84]
EXTERNAL COST	**4**	
BIRDS	1	[77]
BIRDS, FAUNA, MAMMALS	1	[70]
FISHING, RECREATION	1	[73]
NATURE, FAUNA	1	[72]
OPEN SEA	**3**	
EXTERNAL BENEFIT	**2**	
POLLUTION	1	[80]
WATER QUALITY	1	[82]
EXTERNAL COST	**1**	
COASTS, BEACHES, DUCKS	1	[75]
RIVER	**1**	
EXTERNAL BENEFIT	**1**	[81]
WATER QUALITY	1	

The last two tables refer to the second question of the review, i.e., which are the valuation items used in non-market methods to monetize impacts from a severe disaster like an oil spill. There are at least twenty items and thirty different item combinations in this review's database, which non-market methods use via surveys to monetize the impacts of oil spills. Out of fifteen gulf-related studies, one (6.7%) monetizes external benefits by valuing oyster meals and fourteen (93.3%) monetize external costs by valuing air, coasts,

beaches, fishing, recreation, housing values, human injuries, nature, birds, mammals, shrimps and marshes. Out of six coast-related studies, one (16.7%) monetizes external benefits by valuing water quality and five (83.3%) monetize external costs by valuing beaches, coasts, recreation and a wide range of wildlife such as birds, fish, crabs, shrimps, reptiles, mammals, and fauna. Out of five ocean-related studies, one (20%) monetize external benefits by valuing fish, birds, mammals and water, and four (80%) monetize external costs by valuing birds, fauna, mammals, recreation, fishing and nature. Out of three open sea related studies, two (67%) monetize external benefits by valuing pollution and water quality, and one (33%) monetize external costs through coasts, beaches and ducks. There is one study for each closed sea, lake and river, monetizing external benefits through human well-being and water quality, as well as one archipelago-related study monetizing external costs through birds and seals.

3.3 Monetary estimates

As for the third research question i.e., what is the environmental cost (valuation estimates) of past or hypothetical future oil spills, the conversion formula along with some indicative monetary estimates have already been stated in table 3 of section 2.3.3, although here there will be a more detailed categorization of the data collected from the database's publications.

As illustrated in figure 12, out of thirty-three results of the search, eleven different combinations of valuation units were retrieved. Fifteen studies (45.5%) calculated values in USD, and more specifically, one (3%) in billion USD declination, seven (21.2%) in USD per HH (household), five (15.2%) in USD per individual, and two (6%) in USD per trip. One study (3%) calculated values in CAD per HH, two studies (6%) in CNY per HH, and two (6%) studies in NOK per HH. Four studies (12.1%) calculated values in KRW, out of which three (9.1%) were about KRW per HH and one (3%) about KRW per individual. The remaining nine studies (27.3%) studies calculated values in EUR with eight cases (24.2%) in EUR per HH and one case (3%) in EUR per individual.

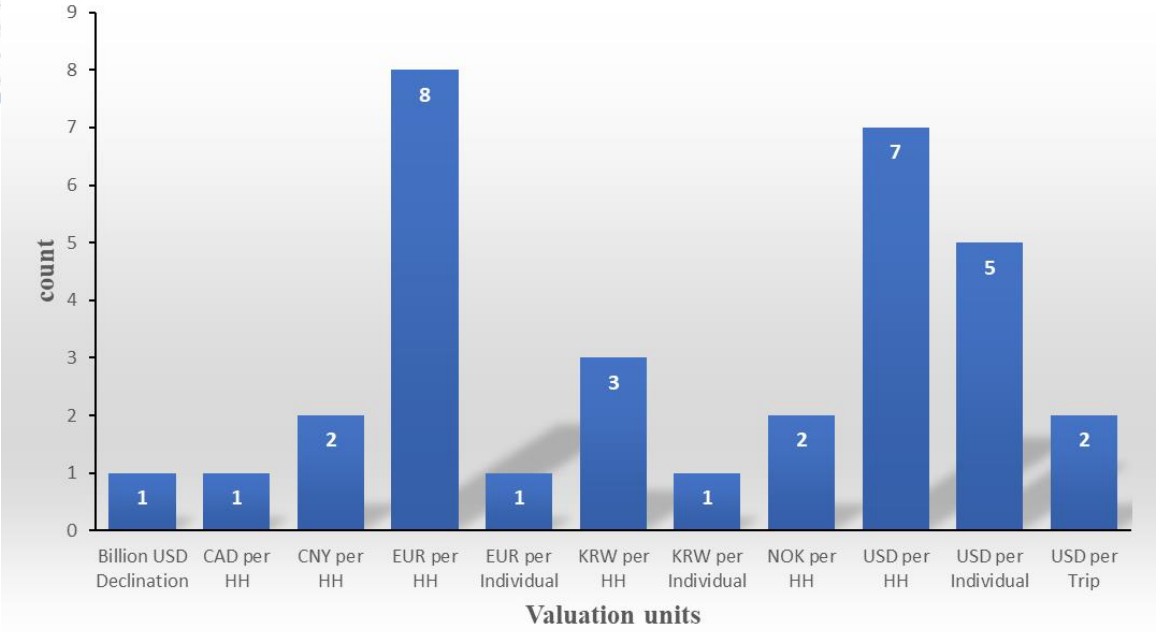

Figure 12. Valuation units

To answer the third research question, table 9 was created, where all the monetary estimates are shown. In total, sixty-six estimates from thirty-three publications were calculated, two estimates per publication on average, although some of them had more than two estimates. For example, publication no. 15 [73] monetizes six different scenarios and publications no. 9 and 29 [66, 86] monetize four different scenarios each.

Table 9. Summary of studies' monetary estimates

REFERENCE	VALUATION UNIT	JUSTIFICATION	SCENARIOS	ORIGINAL VALUE	2021 USD EQUIVALENT
[56]	EUR per HH	Contribution to a fund	Light scenario	90.3	150.67
			Moderate scenario	99.5	166.02
			Severe scenario	104.5	174.37
[57]	EUR per HH	Escort ship plan		85.19	120.69
[58] [59]	USD per Trip	Prevent DHOS	By shore fishing	66.17	76.97
			By for-hire fishing	79.66	92.66
			By private fishing	19.34	22.50
[60]	USD per HH	One-time tax	Protection against similar to DHOS	153.00	175.12
[61]	USD per HH	One-time tax	Prince William Sound Protection Fund	79.2	164.25
[62] [63]	USD per HH	Tax increase	Two groups of assets	153.00	172.74
			One group of assets	136.00	153.54

REFERENCE	VALUATION UNIT	JUSTIFICATION	SCENARIOS	ORIGINAL VALUE	2021 USD EQUIVALENT
[64]	USD per Individual	Consuming Oyster meals		1.82	2.26
[65]	USD per Trip	Average time cost	Income-based approach	390.00	445.87
			Individual specific approach	354.00	404.71
[66]	NOK per HH	Prevent oil spill	Small oil spill	1086.00	139.90
			Medium oil spill	1418.00	182.67
			Large oil spill	1639.00	211.14
			Very large oil spill	1869.00	240.77
[67]	USD per Individual	Prevent oil spill	High school individual to prevent an oil spill in Alaska water	70.00	160.39
			College individual to prevent an oil spill in Alaska water	65.00	148.94
[68] [69]	USD per HH	Trip expenditures	Stop going to GOM	1706.96	2056.26
[70]	EUR per HH	Prevent oil spill	Similar to Prestige	40.51	73.98
[71]	USD per Individual	Lost recreational day	June 2010-January 2011	37.23	46.26
			February 2011-November 2011	40.41	48.68
[72]	EUR per HH	Prevent oil spill	2006	60.36	110.24
			2009	26.92	47.31
[73]	USD per HH	Prevent oil spill	Similar to Exxon Valdez oil spill	53.61	70.06
			Hypothetical oil spill on California coast	76.45	99.91
	EUR per HH		Conserve Galicia from an oil spill	114.00	203.42
			Similar to the Exxon Valdez oil spill	71.94	128.37
			Similar to the hypothetical oil spill of California in Spain	102.6	183.07
			Similar to the Galicia oil spill in Spain	114.00	203.42
[74]	EUR per HH	Prevent oil spill	Spanish HH	124.37	218.57
			UK HH	80.87	143.85
			Austrian HH	89.08	133.35
[75]	EUR per HH	Prevent oil spill	German North Sea beaches	157.3	250.09
[76]	CNY per HH	Environmental fee	Water quality in Lake Tai	141.00	55.82
[77]	CAD per HH	Prevent oil spill	Similar to the Nestucca oil spill	80.00	133.63

[36]	USD per HH	Tax increase	Program to avoid fewer injuries	136.00	158.19
			Program to avoid more injuries	153.00	177.97
[78]	USD per HH	Long term tax	Restoration of coastal environments	4324.00	6.93
			1992	55.25	64.27
			2013	141.16	164.19
[79]	Billion USD	Decline in housing values		4.4	5.03
[80]	KRW per HH	Vessels construction		3721.00	4.89
[81]	KRW per HH	Reduce oil spill accidents in Korean rivers		6188.00	8.13
[82]	KRW per HH	Reduce chemical spill accidents in South Korea		3830.00	4.85
[83]	USD per Individual	Welfare loss	Closure of Grand Isle	2102.00	2373.17
			Closure of Elmer's Island	686.00	774.50
			Closure of Port Fourchon	592.00	668.37
[84]	NOK per HH	Reduce oil spill accidents	Probability of oil spill	887.6	115.92
			Probability and impacts of oil spill	809.4	105.70
[85]	EUR per Individual	Conservation program	Aware of intra-species substitutes	19.34	34.87
			Not aware of intra-species substitutes	18.17	32.76
[86]	KRW per Individual	Additional income tax	1% recovery of contaminated sea areas	174.61	0.21
			1% recovery of contaminated coast distance	193.73	0.24
			1% reduction in resident health risk	95.04	0.12
			1% recovery of marine ecosystem	22.74	0.03
[87]	EUR per HH	Improve water quality	Estonian marine waters	65.00	144.72
[88]	EUR per HH	Protection from an oil spill	Specific coastal resources	29.1	45.42
[89]	USD per Individual	Bid per half a pound of shrimp	Domestic shrimp	1.07	1.33
			Wild-caught shrimp	0.82	1.02
			Gulf coast shrimp	1.19	1.48
[90]	CNY per HH	Count of assets saved	Km^2 of water to be cleaned	0.7	0.26
			Km of beach to be cleaned	0.7	0.26
			Seabirds to be saved	0.00744	0.00

Considering the aforementioned data, it is evident that there is divergence between the estimates. For example, an estimated trip expenditure to stop going to the Gulf of Mexico was $2056.26 per HH (2021 USD equivalent) [68]. In contrast, another study estimated $175.12 (2021 USD equivalent) as a one-time tax for protection against a similar to Deepwater Horizon oil spill incident [60]. Both studies tried to evaluate the same oil spill, but the final estimations differed significantly. This is attributed to many factors and mainly to the fact that many different valuation approaches were used. Table 10 presents the number of value estimates per valuation method. Each valuation method has its peculiarities regarding the accuracy and quality of the results, which is one reason why this systematic review is helpful.

Further, some other factors contributing to the divergence between the estimates are the hypotheses made by the authors, the adverse effects examined by the study, the influence scope of these impacts, the size of the affected population, and the particular characteristics of each environmental study. Apart from that, monetary values vary not only depending on the valuation technique or the particular methodological assumption adopted by the researchers but also on the valuation unit of each study. Understandably, utilizing lost recreational time as a valuation item for evaluating the effects of an oil spill is very different from considering human injuries or, even worse, human life losses.

Table 10. Monetary estimates per valuation approach

Valuation units	Choice Experiment	Contingent Valuation	Hedonic Price	Travel cost	Benefit transfer
Billion USD					
decline in housing values			1		
CAD per HH					
prevent oil spill		1			
CNY per HH					
count of assets saved	1				
environmental fee		1			
EUR per HH					
contribution to a fund		1			
escort ship plan		1			
improve water quality	1				
prevent oil spill	1	3			
protection from an oil spill	1				
EUR per Individual					
conservation program		1			
KRW per HH					
reduce chemical spills accidents		1			
reduce oil spill accidents		1			
vessels construction		1			
KRW per Individual					
additional income tax	1				
NOK per HH					
prevent oil spill		1			
reduce oil spill accidents		1			
USD per HH					
long term tax		1			
one-time tax		2			
prevent oil spill					1
tax increase	1	1			
trip expenditures				1	
USD per Individual					
bid per half a pound of shrimp	1				
consuming oyster meals		1			
lost recreational day				1	
prevent oil spill		1			
welfare loss				1	
USD per Trip					
average time costs				1	
prevent DHOS				1	

4. Conclusions

Environmental economics is increasingly used to meet the need for evaluating impacts on non-tradeable natural resources from severe incidents like oil spills, as well as the environmental liability assessment. The rapid increase in production, refining, and transportation of oil & gas leads to an equally rapid rise of accidents and spills, polluting natural resources and affecting the environment. As a result, more and more studies are being published trying to evaluate environmental goods that are affected but not accounted for by classical economic valuation. A systematic review of these studies can bring together the information published so far and help upcoming researchers by showing them the needs in each field and ways they can conduct their research.

This systematic review aimed to investigate the following:

1. The main non-market valuation techniques used for monetizing oil spill impacts.
2. The main externalities related to these accidents.
3. The monetization of these external costs and benefits.

The number of publications retrieved from the Scopus database fulfilling the criteria for abstract reading was 327. Following a thorough reading of every single abstract and indicative text screening where needed, 234 publications were excluded, and 93 were selected to be archived for full-text screening. At the final step, 33 publications formed the database of this review. The statistical analysis of the publications resulted in 66 different monetary estimates. It turns out that many different methods have been used with the vast majority of them concerning contingent valuation surveys followed by choice experiments, travel cost and hedonic price methods. The statistical study' conclusions demonstrate a variety of value factors as well.. The economic values that correspond to them vary depending on the valuation method, the topic of each environmental assessment, and its unique characteristics. More specifically, monetary estimates range from less than 1 USD per person up to more than 2,300 USD per person. This extensive range of estimates is the proof of importance of all the statistical analysis presented above.

The ultimate purpose of the systematic review is to leave a legacy for future reference by showing, through statistical analysis, areas and incidents with limited availability of estimates or with significant differences between the findings of surveys. Thus, upcoming future research should fill these gaps and not reproduce them.

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