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Value transfer in ecosystem accounting applications

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Abstract:	Ecosystem accounting is a statistical framework that aims to track the state of ecosystems and ecosystem services, with periodic updates. This framework follows the statistical standard of the System of Environmental Economic Accounting Ecosystem Accounting (SEEA EA). SEEA EA is composed of physical ecosystem extent, condition and ecosystem service supply-use accounts and monetary ecosystem service and asset accounts. This paper focuses on the potential use of the "Value Transfer" (VT) valuation method to produce the monetary ecosystem service accounts taking advantage of experience with rigorous benefit transfer methods that have been developed and tested over many years in environmental economics. Although benefit transfer methods have been developed primarily for welfare analysis, the underlying techniques and advantages are directly applicable to monetary exchange values required for ecosystem accounting. The compilation of regular accounts is about to become a key area of work for the National Statistical Offices worldwide as well as for the EU Member States in particular, due to the anticipated amendment to regulation on European environmental economic accounts introducing ecosystem accounts. On this basis, accounting practitioners have voiced their concerns in a global consultation during SEEA EA revision, about three issues in particular: the lack of resources, the need for guidelines and the challenge of periodically updating the accounts. We argue that VT can facilitate empirical applications that assess ecosystem services in monetary terms, especially at national scales and in situations with limited expertise and resources available. VT is a low-cost valuation approach in line with SEEA EA requirements able to provide periodic, rigorous and consistent estimates for use in accounts. While some methodological challenges remain, it is likely that VT can help to implement SEEA EA at scale and in time to respond to the pressing need to incorporate nature into mainstream decision-making processes.
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Title page

Value transfer in ecosystem accounting applications

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October 31st 2022

Dear Editor,

I am enclosing herewith the revised manuscript entitled “Value transfer in ecosystem accounting” for publication in Journal of Environmental Management. This is an original discussion paper and it has not been submitted elsewhere. The submission is supported by all co-authors.

In this round of submission, I am including the highlights of the manuscript and the acknowledgments section. I am submitting one clean version excluding the authors’ names and a clean version with authors details (including the acknowledgments). Also, please note that the revised manuscript with track changes reveal the name of authors (so this version is not for review). Moreover, you may notice a few discrepancies between the clean manuscript and the manuscript with track changes. This is due to final minutes amendments in the document that haven’t been part of track changes list.

We think that *Journal of Environmental Management* offers the ideal medium through which to share our insights with the rest of the scientific community.

I am in your disposal for further questions related to my submission.

Sincerely,

Grammatikopoulou Ioanna

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Dear reviewer 1,
I would like to thank you for your great support into our work and your constructive comment.

Reviewer #1: Congratulations! I have read your work with great interest. Although each section is argued, I noticed a slight hesitation in the conclusions. Please argue how VT can help to respond decision-making processes.

We thank the reviewer for the positive response to our paper and helpful suggestion for improvement. In response, we have added new paragraphs to section 2.2 of the paper, in line with your recommendation. This added paragraph highlights the specific role of EA and VT within decision-making processes, such as those associated with environmental accounting mandates recently established by the European Commission, and the proposed strategy for a U.S. System of Natural Capital Accounting and Associated Environmental-Economic Statistics.

We think these arguments fit better in section 2.2 than in the concluding section.

Dear reviewer 2,
I would like to thank you for your feedback. Please see below my response under each of your points.

Reviewer #2: 1. Your article contains footnotes, please include these instructions in the main text, JEMA seems to have no footnote format.

We thank the reviewer for this helpful suggestion. In response, all footnotes have been incorporated into the main text or eliminated.

2. (abstract section) "When compiling ecosystem and ecosystem services accounts in line with SEEA EA, two metrics are required: the physical metrics of the accounts and the associated monetary metrics. This paper focuses on the potential use of the "Value Transfer" (VT) valuation method to produce the monetary metrics for the SEEA EA implementation, parallel to the rigorous benefit transfer methods that have been developed in environmental economics." Your study focuses on the potential use of the "Value Transfer" (VT) valuation method to produce the monetary metrics for the SEEA EA implementation. Costanza et al. (2007) (Twenty years of ecosystem services: How far have we come and how far do we still need to go?) pointed out that one of the limitations of the economic method is that the accounted ES monetary value is not equal to market value. Another limitation is that monetary method is based on human preference (subjectivity). So how do you overcome these limitations because you also focus on benefit transfer methods that have been developed in environmental economics.

We thank the reviewer for this comment. The objective of this paper is to discuss the capacity of VT to provide values to support ecosystem accounting (EA), based on exchange values that are compatible with the System of National Accounts. It is unfortunately beyond the scope of this paper to consider the different purposes for which different valuation metrics are appropriate (whether for benefit-cost analysis or EA). These issues have already been discussed extensively, including in the Costanza reference mentioned above. VT is based, by definition, on economic welfare or exchange values assessed using different methods, i.e. price-based, cost-based, revealed-preference or stated-preference based. The theoretical and conceptual properties of the original, primary study values carry through to any transfers of those values. Some valuation methods reveal values that approximate the market value of an ES benefit (e.g. agricultural production). Other methods like the stated preference methods capture both use and non-use values. However, as correctly pointed out by the reviewer, ALL economic values are based on human subjective preferences. The issues raised in this comment relate to fundamental dimensions of economic valuation and accounting rather than properties of VT. Although we can add a paragraph discussing this issue if absolutely necessary, we feel that it is outside the scope of this paper and should not be included, for the sake of brevity.

3. "(in Johnston et al., 2015) ", please delete "in" and check all format of the citation in this study.

We thank the reviewer for noticing this problem and have revised the paper accordingly.

4. (table 1) "Source: Own elaboration" what do you mean "Own elaboration"? maybe "this study"? Also, please use the table format of JEMA.

This description was included to reflect the fact that the content of the table was developed by the study authors, not taken from an external reference. However, we realize that this was confusing, and have deleted this description from the table. . The table format has also been revised, as requested.

5. (section 2.1) "VT approaches use research results from pre-existing monetary valuation studies at one or more sites or policy contexts to predict value estimates or other related economic information for other sites or policy contexts that are not yet studied but share similar biophysical and socioeconomic conditions." It seems that the VT method is only suitable for other sites with similar biophysical and socioeconomic conditions, but in fact very few areas meet similar biophysical and socioeconomic conditions at the same time, which ignores the local characteristics of some places, it is easy to cause the bias of the estimation, and this also means that it is difficult to generalize the VT method. This contradicts the later point in your article that VT is a general method.

We thank the reviewer for highlighting this apparent inconsistency and regret that the original paper was not more clear on this topic. We have made revisions to multiple sections of the paper to clarify this issue. Among these, we have edited the text quoted above (p. 4 in the revised manuscript) to highlight that close "similarity" is *not* required for VT and is not part of the core definition of VT–VT can be implemented over similar OR dissimilar sites. VT is simply defined as follows (p. 4): "VT approaches use research results from pre-existing monetary valuation studies at one or more sites or policy contexts to predict value estimates or other related economic information for other sites or policy contexts."

However, on average (but not always), transfers between sites that are more similar tend to be more accurate. This relationship is not absolute and is a matter of degree, as discussed by Johnston et al. (2021). We have edited the paper to make this point more clear, for example on page 6, which states:

"It is generally expected that benefit transfers will be more accurate, on average, when the policy and original study areas are more similar, in terms of ES benefits, size, policy context and populations (Carolus et al. 2020). However, the degree to which similarity is required for accurate transfers depends on the transfer method applied—as some methods (e.g., meta-analysis) have greater capacity to adjust for contextual differences than other methods (e.g., unadjusted unit value transfer) (Johnston et al. 2021). The literature provides many examples of transfers implemented over sites with relatively large differences in site characteristics (e.g., different European countries, Czajkowski et al. 2017). Moreover, even unit-value transfers can incorporate some types of adjustments that, ideally, improve accuracy."

Through edits such as these throughout the paper, we have clarified that relationships between site similarity and benefit transfer accuracy are complex, and that VT does not require sites to be perfectly identical. Also, some methods such as meta-analysis allow adjustments that can support accurate transfers even when sites differ across important dimensions. We hope these changes address the reviewer's concern.

6. (section 3.1) In "Several VT approaches are available for EA and their validity and reliability is largely context dependent" and table 1, you presented the applicability of VT method. I would suggest you add some specific examples on what types of VT are suitable for EA. List one-to-one correspondence in the paragraph or in the table.

We thank the reviewer for this comment. Because the accuracy of VT is context and data dependent, it is not possible to derive a fixed, one-to-one match between specific EA needs and the type of transfers that can be applied. This determination requires practitioners to explore the context and data available for each type of value to be estimated. We have edited the paper (p. 9) to make this point explicit, explaining that *"Several VT approaches are available for EA and their validity and reliability is largely context dependent - for example depending on factors such as the type of values to be estimated, the supporting body of valuation information, and site characteristics (Johnston et al. 2021). Hence, it is not possible to derive a fixed, one-to-one match between specific EA needs and the type of transfers that can be applied."* Given these limitations, any specific one-to-one examples we could provide in Table 1 would not be generalizable and hence of limited use to readers.

7. (discussion section) you proposed the challenges of VT method. I would also suggest you to add how current studies like what cases, data, method or models can help overcome these challenges. Also, you mentioned the systematic factors that influence transfer errors (especially valuation method and ES type). I'm confused that when you use VT to account ES value of different ecosystems and services, how do you avoid double counting if you need to assess the total value? Because some subtypes of ecosystem services like NPP and carbon sequestration are both the product of photosynthesis. If you add their values directly, it will generate double counting. Therefore, I wonder how do you overcome this limitation.

We thank the reviewer for raising this important point, which we have now addressed in the revised manuscript. Of course, double-counting is not an issue that is specific to VT - it is a concern for any type of valuation method. Fortunately, the same types of procedures that already exist in EA and welfare analysis can be applied when using VT for EA, to ensure that double counting does not occur. We have added a new paragraph on page 17 of the revised manuscript to address this issue explicitly:

"Another well-known challenge that can arise in welfare analysis or EA is double-counting (Boyd and Banzhaf 2006; Fisher et al. 2009). As described by Johnston and Russell (2011, p. 2243), "consistent estimates of ecosystem service benefits require differentiation of intermediate ecosystem functions from final ecosystem services, so that the benefit of each distinct ecosystem condition or process, to each human beneficiary, is counted once and only once." As is the case with welfare analysis, the validity of any EA framework requires structures, accounting mechanisms and rules to ensure that relevant exchange values are not double-counted. This is primarily a concern for the underlying development of guidelines that determine what values should be counted as part of EA, rather than VT which primarily concerns how those values are estimated using existing data. Procedures of this type have been established for welfare and ecosystem services analysis (e.g., Fisher et al. 2009; Bateman et al. 2011; Johnston and Russell 2011). In EA double counting is avoided in the structuring of physical ecosystem service supply-use tables upon which valuation for the monetary ecosystem service accounts is based (UN, 2021))."

Highlights

1. The compilation of regular ecosystem accounts will become a key area of work for the National Statistical Offices worldwide
2. Practitioners will require guidelines on methods so to provide periodic accounts, given resource constraints
3. We argue that the Value Transfer method can facilitate the compilation of ecosystem service monetary accounts especially at national scale.
4. We call for future empirical applications of Value Transfer for ecosystem accounting purposes

Revised manuscript (Clean version) Click here to view linked References

Abstract

Ecosystem accounting is a statistical framework that aims to track the state of ecosystems and ecosystem services, with periodic updates. This framework follows the statistical standard of the System of Environmental Economic Accounting Ecosystem Accounting (SEEA EA). SEEA EA is composed of physical ecosystem extent, condition and ecosystem service supply-use accounts and monetary ecosystem service and asset accounts. This paper focuses on the potential use of the “Value Transfer” (VT) valuation method to produce the monetary ecosystem service accounts taking advantage of experience with rigorous benefit transfer methods that have been developed and tested over many years in environmental economics. Although benefit transfer methods have been developed primarily for welfare analysis, the underlying techniques and advantages are directly applicable to monetary exchange values required for ecosystem accounting. The compilation of regular accounts is about to become a key area of work for the National Statistical Offices worldwide as well as for the EU Member States in particular, due to the anticipated amendment to regulation on European environmental economic accounts introducing ecosystem accounts. On this basis, accounting practitioners have voiced their concerns in a global consultation during SEEA EA revision, about three issues in particular: the lack of resources, the need for guidelines and the challenge of periodically updating the accounts. We argue that VT can facilitate empirical applications that assess ecosystem services in monetary terms, especially at national scales and in situations with limited expertise and resources available. VT is a low-cost valuation approach in line with SEEA EA requirements able to provide periodic, rigorous and consistent estimates for use in accounts. While some methodological challenges remain, it is likely that VT can help to implement SEEA EA at scale and in time to respond to the pressing need to incorporate nature into mainstream decision-making processes.

Keywords: value transfer, value generalization, benefit transfer, ecosystem accounting, natural capital accounting

1. Introduction

Ecosystem Accounting (EA) is a framework for integrating ecosystems with the System of National Accounts. The first version of this framework, as official methodological guidelines for member states, has been standardized in the System of Environmental-Economic Accounting (SEEA), which has been proposed and supported by the United Nations (UN) since 1993 (UN, 1993). The SEEA Ecosystem Accounting (SEEA EA) chapters 1-7 on biophysical accounts were adopted as a statistical standard by the UN Statistical Commission in March 2021 (UN, 2021; UNCEEA, 2021). The long-term aim of the SEEA EA is to integrate physical and monetary measures of ecosystem services (ES) and ecosystem assets by developing ecosystem accounts consistent with the System of National Accounts (SNA), using the same accounting principles. This implies that monetary valuation of ES and ecosystem assets using exchange values are required (Obst et al. 2016, UN, 2021). In this paper, we argue that the Value Transfer method (VT) (also known as benefit transfer) can facilitate and accelerate empirical applications of monetary valuation of ES for national accounts.

SEEA EA Chapters 8-11 on valuation and accounting treatments were recognized by the UN Statistical Division as describing "internationally recognized statistical principles and recommendations for the valuation of ecosystem services and assets in a context that is coherent with the concepts of System of National Accounts" (UN, 2021). The UN Statistical Commission called for promptly resolving the outstanding methodological aspects of Chapters 8-11 identified in the SEEA EA research agenda (UNCEEA, 2021). The agenda calls for testing and development of several VT issues as discussed in this paper, i.e., "application of value transfer techniques for accounting purposes, in particular considering alignment with exchange value concepts, consistency with data collected in physical terms on extent, condition and service flows and advancement of the potential of value generalization techniques" (UN 2021, p.351). Value transfer guidance is briefly provided in the SEEA EA (section 9.5) and identified as a research and development need (UN, 2021). The use of value transfer in ecosystem accounts is also referred to as "value generalization" (NCAVES and MAIA, 2022).

The global consultation of the SEEA EA provided further detailed comments by countries, National Statistical Offices (NSO) and international institutions regarding the barriers to applying monetary valuation methods, which also concern VT. These comments, addressed concerns such as: implementation barriers relating to VT; the complexity of valuation model assumptions adapted for accounting purposes; the institutional and market feasibility assumptions required in the transfer of exchange values; limitations on value estimates which were designed for other purposes and then transferred for the purpose of national accounts; requirements for reliability of estimates and documentation of uncertainty; documentation with respect to compatibility of primary studies used in meta-analysis used for VT; and lack of guidance on methods to generalize values (UN, 2020).

Summarizing these comments, EA practitioners are faced with three general areas of concern in applying monetary valuation methods: (1) the lack of financial resources and expertise to evaluate in physical and in monetary terms the ES included in the accounts, (2) the lack of consistent and clear guidelines that facilitate the process of account compilation, in particular regarding monetary valuation methods (i.e., which method to be used, how and when), and (3) the challenge of producing sufficiently reliable and consistent periodic updates of the monetary accounts.

In this paper, we argue that VT methods may facilitate EA practitioners' work to address these concerns and thereby enrich EA practice. VT approaches may provide a suitable means to obtain the value information required for EA, particularly in cases where time and financial resources are limited, as they are cost-effective and well tested in the context of policy and project appraisal (Johnston et al. 2021). While the practice of transferring values from one site to another has already been used in EA applications (e.g., in Vysna et al. 2021; La Notte et al. 2012; Gundimeda 2012, 2006; Remme et al. 2018; Sumarga et al., 2015), it is rarely acknowledged as such, and is typically done on a case-by-case and ad hoc basis. Moreover, mapping for physical supply-use accounts is a form of value generalization using a model often calibrated on a sample of sites in the accounting area (UN, 2022). Providing guidance for and recognizing the use of VT—grounded in prior work and guidelines from the benefit transfer literature (Johnston et al. 2021)—would help promote consistency and rigor across EA applications and facilitate greater uptake of VT in EA. The substantive knowledge developed over the past 30 years of applied VT research, summarized in Richardson et al. (2015), Johnston et al. (2018, 2021), and Johnston and Rosenberger (2010), among others, provides a solid starting point for such guidance. In concept, the general mechanisms for VT apply similarly to many types of economic value information—including exchange values typically considered within EA. VT application in EA can be developed in a way that enables consistent and periodic updates of monetary accounts with relatively low resource demands. At the same time, it is important to recognize that VT has typically been applied in other contexts than EA (e.g., to transfer information on welfare values rather than exchange values).

A number of guidelines for conducting value transfers for environmental economic applications and project appraisal already exist. Richardson et al. (2015) focus on guidelines for transferring welfare estimates of ES and Johnston et al. (2021) provide guidelines for VT in general (and for assessing the validity and credibility of transfers), whereas Johnston and Bauer (2019) provide guidance on transferring ES values for large-scale applications. Although many of these guidelines apply to EA applications, they are not specific to EA, and these publications are largely silent on what adaptations to VT methods might be required for EA applications.

Grounded in this prior work, our objective is to explore two main questions: How might VT be relevant for EA applications, and how can VT methods respond to the concerns raised by account compilers? By opening this discussion, we aim to stimulate further research into the potential use of VT in EA. We also hope to flag the need for context-specific guidelines that facilitate further implementation of EA. We believe that bringing together the national accounting and environmental economics communities can help to operationalize VT research and enrich both EA and VT research.

2. How Value Transfer works and why it fits to Ecosystem Accounting scope

2.1 An overview of the method

VT approaches use research results from pre-existing monetary valuation studies at one or more sites or policy contexts to predict value estimates or other related economic information for other sites or policy contexts. Two main approaches have commonly been used with two common variations within each (Johnston et al., 2015):

1. Unit value transfer:

    1.1. Simple, single unadjusted value transfer.

    1.2. Adjusted unit value transfer, to account for factors such as currency or income differences between sites.

2. Value function transfer:

    2.1 Single-site or single-study value function transfer, which employs an estimated function from a single primary study, with data often but not always drawn from one study site.

    2.2 Value transfer using data-synthesis methods such as meta-analysis, which combine information from multiple prior studies across different sites to produce broadly applicable "umbrella" value functions.

Unit value transfer has been applied in multiple contexts, including a global valuation of ecosystem services (Costanza et al. 1997, 2014) and national valuations of the contribution of natural ecosystem capital to the economy (Kubiszewski et al. 2013, Frélichová et al. 2014, Ferrini et al. 2014 and 2015, Niquisse and Cabral 2017). Because transfers of this type allow few (and generally simple) adjustments to the transferred values, they "are usually chosen only when there is insufficient data to support other approaches for the given policy-site application" (Johnston et al. 2021). Although some global and national transfers of this type have been criticized for violating core principles of economic theory for welfare analysis and benefit transfer (Bockstael et al. 2010; Johnston and Wainger 2015; Johnston et al. 2021), some (although perhaps not all) of these critiques might be less relevant when considering exchange values of the type considered within accounting.

Meta-analysis VT has been applied for assessments of ES provided by many natural systems such as wetlands (e.g. Ghermandi et al. 2010, Poudel et al. 2020, Vedogbeton and Johnston 2020), forests (e.g. Chiabai et al. 2011; Grammatikopoulou and Vačkářová, 2021), mangroves (e,g, Brander et al. 2012) and lakes (Reynaud and Lanzanova 2017), as well as many other types of ES and environmental changes. Schmidt et al. (2016) developed meta-analysis value transfer functions for 12 ES based on 194 case studies using 839 monetary ES values. It has also been applied extensively to values for environmental changes such as water quality improvements (Johnston et al. 2017, 2019; Newbold et al. 2018; Moeltner 2019).

VT research has demonstrated that quality control and best practices are important for valid and reliable value transfers (Richardson et al., 2015; Johnston et al. 2021). Value transfer accuracy reflects both of these concepts (Rosenberger 2015). Within the context of VT, validity implies that value estimates or other transferred quantities are unbiased. This is usually interpreted as a lack of statistically significant generalization (or transfer) error. Reliability concerns the variance of the value-transfer prediction, often measured as average generalization error: the (mean) difference between a primary study value and a value produced via value transfer. It is generally expected that value transfers will be more accurate, on average, when the policy and original study areas are more similar, in terms of ES benefits, size, policy context and populations (Carolus et al. 2020). However, the degree to which similarity is required for accurate transfers depends on the transfer method applied—as some methods (e.g., meta-analysis) have greater capacity to adjust for contextual differences than other methods (e.g., unadjusted unit value transfer) (Johnston et al. 2021). The literature provides many examples of transfers implemented over sites with relatively large differences in site characteristics (e.g., different European countries, Czajkowski et al. 2017). Moreover, even unit-value transfers can incorporate some types of adjustments that, ideally, improve accuracy. For example, La Notte et al. (2021) tested the unit transfer value for habitat and species maintenance estimates in Europe and they enhanced the simple unit transfer value with a sophisticated statistical analysis of biophysical and socio-economic comparability of policy sites and study sites.

Reviews of VT studies tend to suggest that value function transfers are more accurate than unit transfers, in general, where policy sites differ from study sites to a large degree—although this finding does not apply universally to all possible applications (Rosenberger and Stanley 2006; Bateman et al. 2011a; Ferrini et al., 2014, Rosenberger 2015; Johnston et al., 2021). Hence, as noted by Johnston et al. (2021), the degree to which high degrees of similarity are required must be considered in context. Points of attention include the type of ecosystem service benefit valued and the availability of substitutes, the scope or size of the study and policy sites or the ecosystem service that is valued, the (ecological, social, economic, and political) context of the ecosystem service, and how these issues are expected to affect the exchange value in question. Recent developments in academic practice such as open access publishing, regularly updated valuation databases and improvements in AI-based analysis may facilitate new VT research and increase its cost-effectiveness—for example by reducing the difficulty of compiling research metadata.

There is an important difference in purpose and scale between welfare valuation studies often used as inputs in VT studies and EA applications where only exchange value measures (e.g. market prices) are compatible with national accounts. Welfare valuation often includes willingness to pay (WTP) and willingness to accept (WTA) measures that reflect underlying theoretical constructs such as compensating or equivalent variation, or related measures such as consumer surplus. Only exchange values can be used for SEEA EA accounts that aim to be compatible with other economic data from SNA (Obst et al., 2016; UN, 2021a). Moreover, most EA applications require values that are used for large accounting areas, covering a whole country in case of national accounts, although the majority of examples in the research literature reflect local or regional examples. Illustrative examples of national-scale VT applications are provided by Ferrini et al. (2015), as related to the UK National Ecosystem Assessment, and Wheeler (2015), for US water quality benefits. However, most VT research is focused on WTP changes evaluated over smaller sub-national scales, and applied to ex-ante project evaluation. Nonetheless, there is no reason in principle why the VT method cannot produce transferrable exchange values for large spatial areas and ex-post assessment.

2.2 Policy context of Ecosystem Accounting and the contribution of Value Transfer

EA is likely to become a key area of work for National Statistical Offices (NSOs) worldwide, yet there is limited capacity to satisfy the rising policy demands. EA is built on a strong framework and its implementation will support the control and reporting activity for several global environmental and sustainability initiatives (UN, 2021). EA is expected to support climate mitigation and adaptation, as well as biodiversity conservation and other related policy objectives.

At the moment, the policy pull for EA implementation is the strongest in the EU. As of July 2022, the European Commission has adopted the technical proposal to amend the Regulation 691/2011 on European environmental economic accounts to include three new modules of environmental accounts, one of them being ecosystem accounts. This would make regular reporting of EA mandatory for EU Member States. The proposed amendment under negotiation suggests that the Commission would need to carry out a methodological and feasibility study on the monetary valuation of ecosystem services before further reporting of monetary values is included in the Regulation. When the proposal is adopted by the Parliament and the Council, countries and NSOs may have to use quick, standardized, and easy-to-use methods, as implementing new valuation work for each individual country and accounting period is likely to become financially and practically unfeasible because of capacity and resource gaps at the NSOs and individual countries. EA will be required at national level and compiled as a periodic exercise with a permanent mandate and budgets to generate new and collect existing datasets.

Moreover, the White House Office of Science and Technology Policy (OSTP) in August 2022 released a national strategy report to develop statistics for environmental economics decisions. The reports highlight the aim to incorporate nature into national economic accounts through the development of natural capital accounts (Link 1). As in EU context, this development will require a regular implementation of EA.

The report of the plenary of Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) flags the inability of valuation studies to reach out to policy processes and call for co-production of valuation knowledge, proper guidance and standardization of valuation methods. This standardization is what national EA initiatives require (IPBS, 2022, pp6 and pp18) and what SEEA EA framework aims to cover.

VT lies very much within the scope of the aforementioned policy objectives. In this paper, we argue that VT can contribute to fill resource gaps in the interim until monetary valuation of ES becomes part of the regular national statistics reporting (NCAVES and MAIA 2022, p.120) and can be an important valuation tool for early operationalizing monetary ecosystem accounts. VT can provide a cost-effective, transparent framework that could allow periodic and consistent updates, while also allowing for stepwise updating of valuation estimates to improve precision, as available data and capacity increase. Similar arguments for the use of VT have been made by the US Environmental Protection Agency (EPA) when considering measurement of the ecological benefits of proposed federal rules, which must be accompanied by a formal Benefit-Cost Analysis (BCA) (Iovanna and Griffiths 2006 in Richardson et al., 2015; Newbold et al., 2018; Wheeler, 2015). US EPA commonly relies on value transfers (e.g., for estimating the nonmarket benefits of water quality improvements and supporting BCA) for purposes of regulatory analysis (Wheeler, 2015). Globally, VT can offer standardized and low-cost means of predicting values for EA applications in both developed and developing countries, contingent upon a suitable body of primary studies from which to draw VT estimates.

3 How can Value Transfer support implementation of Ecosystem Accounting

EA applications demand clear and consistent guidelines to ensure validity, reliability and comparability across space and time, yet existing guidelines are still experimental, providing limited advice on which method should be used for given ES. EA applications are also still in an exploratory phase and there are only a few best practice examples to be shared among countries (Hein et al. 2020; Vallecillo et al., 2018; 2019, La Notte et al., 2021). Structured and consistent monetary accounts remain a challenge for practitioners.

Below we discuss how VT addresses the three major areas of practitioners' concern related to the production of monetary ecosystem accounts: lack of capacity, need for clear guidelines and need for systematic/ periodic accounts within limited resources available.

3.1. A capacity-tailored method

Accounting practitioners require methods and approaches that are compatible with available human and financial resources (including expertise) at the NSO. VT can accommodate both simple and more complex modeling approaches, providing flexibility to EA implementation subject to reliability requirements and available capacity. Building capacity in VT skills and applying VT can be less demanding than for primary valuation approaches, which require more specific expertise. Note, however, that some VT methods require considerable expertise. For example, development and estimation of a new meta-regression analysis requires considerable expertise to compile metadata and estimate statistical models. However, once a meta-regression model has been estimated, the subsequent use of the model for VT applications requires less specialized expertise. Examples are provided in Johnston and Wainger (2015) and Johnston and Bauer (2019).

Data for application of VT for EA purposes can be compiled and made available. While NSOs are aware of relevant data sources for the SNA and the biophysical accounts of the SEEA EA, this is not the case for the monetary accounts. However, open access datasets that report economic values of ES for various ecosystems, which were used for VT applications, are already available. The most widely used databases include the Ecosystem Service Valuation Database (ESVD) (de Groot et al., 2012) and the Environmental Valuation Reference Inventory (EVRI) database. Screening these valuation databases for exchange value (e.g. replacement costs or production function estimates) compatible estimates would be a starting point for VT EA applications.

Several VT approaches are available for EA and their validity and reliability is largely context dependent - for example depending on factors such as the type of values to be estimated, the supporting body of valuation information, and site characteristics (Johnston et al. 2021). Hence, it is not possible to derive a fixed, one-to-one match between specific EA needs and the type of transfers that can be applied. For EA, the context is driven by the spatial unit of the biophysical accounts and in VT key elements to consider include the scale of the monetary analysis (e.g., local vs national), and the characteristics of the ecosystem services (La Notte et al., 2019). The selection of VT approach depends on the level of accuracy required (i.e., validity and reliability) (Zulian et al., 2018), following a tiered approach (Brander et al., 2018). VT offers flexibility in this respect. Furthermore, different VT approaches may be considered appropriate for different types of values for theoretical or conceptual reasons, as demonstrated in VT applications in other areas of public policy. For example, unit value transfers are standard practice for estimating the value of statistical life (VSL) (Johnston and Rosenberger 2010; Lindhjem and Navrud 2015). Another example is the use of meta-analysis approach in cases where selection of the studies used for VT may be biased, as it can provide a means to evaluate and correct the systematic effects of these selection biases (Rosenberger and Johnston 2009). When one selects primary studies for VT, implicit assumptions are typically made that the underlying body of literature provides an unbiased sample of the population of empirical estimates (i.e., no selection biases) and that these estimates provide an unbiased representation of true values (i.e., no measurement error). If these assumptions do not hold, the result will be systematic biases in the resulting value transfers (Hoehn 2006; Rosenberger and Johnston 2009). Examples such as these suggest that VT approaches should be determined on a case-by-case basis (Johnston et al. 2021). No single VT approach is superior for all possible applications and contexts.

Table 1 presents an overview of the primary VT approaches with respect to a set of selected operational features that are important for EA. Some features such as the budget may drive choices of statistical institutes to invest in VT. The possibility to compare areas and adjust for spatially explicit factors is key to the use of valuation in accounting. EA requires systematic compilation over time and thus needs to provide updated estimates. The last feature is related to the requirement for models that are amenable to the automated production of accounts.

Table 1: Selection criteria

Operational features	Relevance for EA	Unit value transfer	Single- study function transfer	Meta-analysis transfer
Resources (e.g. budget and time)	Relevant	Low requirement in resources	Low requirement in resources	High requirement in case of estimating a new meta-analysis; Low in case of applying a pre-existing meta-analysis
Similarity between study and policy area especially in the ES features	Relevant	Is required	Partly required	Partly required, but less so than other types of VT
Coherence with spatial factors/features	Very relevant	Not possible	Possible	Possible
Periodic updating	Very relevant	Possible	Possible	Possible
Automation	Relevant	Possible	Possible	Possible

3.2. A well-studied method with clear and available guidelines

Methods for VT have been continually improved and validated over 30 years of applied research and methodological developments. Johnston and Rosenberger (2010) and Johnston et al. (2018) describe the historical developments of the method and provide a thorough discussion of key methodological challenges. Johnston et al. (2015) provide a comprehensive overview of methods. Richardson et al. (2015), Ferrini et al. (2015) and Johnston and Wainger (2015) discuss the role of benefit transfer in ES valuation. The authors provide examples of applications to show which values for ES and ecosystem changes were estimated using transfers. The work by Johnston et al. (2017 and 2018) refers to spatial considerations in transfer applications. Guidelines on applications, validity and credibility are provided in Johnston et al. (2021).

3.2.1 Towards standardizing the process of the selection of studies and database structure

The selection of primary studies for VT determines the validity and reliability of any VT application (Johnston et al. 2021) and in particular of a meta-analysis transfer. The increasing number of primary valuation studies in the literature (and the progression of study methods over time) provides a solid foundation for VT EA applications, particularly in certain areas where many primary studies have been conducted. Their selection is most transparent when using a systematic review approach, i.e., a stepwise methodology that aims to collect, assess and synthesize existing research data based on a priori eligibility criteria and a priori methodological protocol (Richardson et al. 2015). Guidelines and procedures for literature reviews of this type in economics are provided by Stanley et al. (2013) and Johnston et al. (2021). For the time being, there is no available literature review protocol for developing VT valuations to produce monetary EA (Vačkářů and Grammatikopoulou, 2018) but we can anticipate that, besides the review protocol, a structured reporting within primary studies can help to reduce transfer errors, by providing more complete information to support data synthesis (Plummer 2009 in Richardson 2015; Loomis and Rosenberger 2006). As noted in past applications of valuation meta-analysis (e.g., Brander et al., 2007; Lara-Pulido et al., 2018), there is a great variation in the way values are reported in primary studies. Johnston et al. (2005, 2017) discuss how different water quality monetary measures reported in primary study can be reconciled for VT approaches. After primary study screening and selection, a database of selected studies must be developed (i.e., key features of each study to be used in VT are recorded). A typical dataset will include the monetary estimates, the ES type and characteristics, the size or scope of the ES or environmental change that was valued by the study, the geospatial extent of the area over which the change occurred, the primary beneficiaries (e.g. residents or tourists) and extent of the market over which values were measured, the local economic features (e.g. GDP) and ideally the geographical features of the area, and other variables that are expected to influence values (e.g., availability of substitutes). The complexity of the database will vary with the VT techniques used.

Ideally, database compilation to support VT should follow a structured process to homogenize the information that is extracted from each study, something that will remain necessary as long as studies do not follow a standard reporting protocol. Current open-source databases (e.g., ESVD) and empirical application studies (e.g., Grammatikopoulou and Vačkářová, 2021) outline a possible way for structuring such databases. Johnston et al. (2021) provide guidelines for data adjustments to harmonize information across studies. This is a time-consuming process and requires expertise. Although existing valuation databases provide a good starting point for VT, the information in these databases is rarely sufficient to support all the information needs of a VT (Johnston et al. 2015).

A distinct requirement for VT EA applications is to identify (e.g., in the study database) whether a study estimates exchange or welfare values (or both). This is in part determined by the valuation method used in each study, a study characteristic that is usually recorded in existing databases.

Around three quarters of value estimates in the ESVD database are produced using methods directly compatible with the SEEA EA guidelines, i.e. market-based, cost-based and revealed preference methods (e.g. travel cost). However, further revisions to the original study data and estimates may be required to produce suitable exchange values. For example, travel cost data can be used to estimate welfare values but can also contain travel expense data which is required to derive exchange values.

3.2.2 Literature evidence on accuracy and transfer errors

Evaluations of VT validity and reliability require an understanding of the errors that are expected from VT—ideally as a function of VT method, ES type, ecosystem extent and conditions and other potentially relevant factors. As described by Johnston et al. (2021), "a transfer is typically considered valid if it provides a statistically unbiased estimate of the true value at the policy site. Reliable transfers, in contrast, are associated with lower transfer errors or variances (Bishop and Boyle 2019; Rosenberger 2015). Both are elements of the accuracy of transfer estimates." In theory, VTs can be subject to measurement errors and generalization errors. Measurement errors arise in VT due to underlying errors in the original study site value information (Rosenberger and Stanley 2006). In practice, VT accuracy is typically characterized by assessing transfer or generalization error, using convergent validity tests that quantify the difference between transferred empirical estimates (secondary estimates) and primary-study estimates of the same value (Rosenberger and Stanley 2006; Johnston and Rosenberger 2010; Johnston et al. 2015). It is assumed that the primary valuation at a policy site provides an unbiased estimate, or that biased studies have been eliminated by quality control during the selection of studies for transfer (Johnston et al. 2015, 2021). Of course, evaluations of this type can only be conducted for cases where a primary study has *already been conducted* for the policy site, so that a primary-study estimate of value is available. VT is generally required only when suitable primary-study estimates are *not available* to measure the value of interest. Hence, for actual VT applications, the transfer error is almost always unknown.

For EA applications, an ideal benchmark primary valuation study with which to assess value transfer accuracy would typically be a high-quality study over a representative sample of the national population (or with statistical adjustments to obtain representative estimates), following all best practices assumed to promote unbiased value estimation. Over the long run, VT measurement errors for EA applications can be reduced by increasing the validity and reliability of primary valuation studies in the literature that can support these transfers.

The VT literature has summarized evidence on the size of transfer errors across multiple applications, from which generalizable conclusions may be drawn about the type of errors that might be expected across different contexts (Brouwer and Spaninks 1999; Rosenberger and Stanley 2006; Rosenberger and Johnston 2009; Kaul et al. 2013; Ferrini et al 2014, Rosenberger 2015). For example, Rosenberger (2015) reports median transfer errors of 36% for value function transfers and 45% for unit VT (means are 65% and 140%, respectively). Although one might argue that these measures of central tendency are within the error tolerances of at least some applications, of potentially greater concern is the variance of these error estimates across studies, and the extent to which these errors vary systematically across different types of transfer methods and applications. However, it should be emphasized that these estimates are typically drawn from transfers of welfare rather than exchange values—hence their applicability to exchange values is currently unknown.

Because of the need for accuracy and validity varies across applications, there is no universal test or maximum error that dictates the acceptability of VT (Johnston et al. 2021). The accuracy of most estimates used today for national accounting cannot be quantified (IMF 2001). However, it is generally accepted that many of these accounting measures are inaccurate. As noted by Barton et al. (2019, p. 69), "GDP revisions can be quite large (e.g., Ghana 60%, China 15%, Netherlands 7%)," implying errors of similar magnitudes (at a minimum) in the initial estimates. Errors of this level thus fall within the degree of VT errors commonly observed in the literature.

The accuracy requirement for VT applied to EA may initially be similar to, or lower than, known uncertainty in GDP estimates. However, the purposes of EA require accuracy that is sufficient for trend detection in physical ecosystem service supply-use tables. SEEA EA is silent on whether trend detection of monetary ES value is required, but if so, the accuracy requirements for value transfer will be higher than what is expected from GDP measures.

3.2.3 Accommodating spatial heterogeneity

Values of ES can vary substantially across space, depending on the ecological and socio-economic context in given locations (Ferrini et al. 2015; Johnston and Wainger 2015; Glenk et al. 2020). This variation is inevitable, but VT provides various approaches to adjust transferred values for these contextual differences (e.g., Bateman et al. 2011a; Ferrini et al. 2015; Johnston et al., 2017, 2019). In the same way that spatial heterogeneity in primary values requires attention in VT applications, EA requires attention to spatial dimensions when creating aggregated ecosystem accounts (Addicott and Fenichel, 2019). In terms of biophysical accounts, joint effects of the extent (size) and condition (state) of individual ecosystems differ across space, which in turn leads to variability and spatial heterogeneity in ecosystem functions and ecosystems' potential to supply services (ecosystem service supply), independent of the beneficiaries from these services (ecosystem service demand). The spatial configuration of beneficiaries relative to ecosystems then (often) determines whether potential supply turns into an actual flow of ES (Olander et al. 2018). In terms of the monetary valuation related to ES, other spatial factors are also relevant (Schaafsma 2015, Glenk et al. 2020). For example, the values related to ES tend to decrease with increasing distance between beneficiaries and the provided services, an effect known as distance decay (Sutherland and Walsh 1985; Hanley et al. 2003; Bateman et al. 2006). Furthermore, availability and proximity of substitutes and complements to a given environmental good or service is also likely to affect its economic value, among many other factors that can vary over space (see Glenk et al. 2020; De Valck and Rolfe 2018). Finally, the economic value of ES is likely to be influenced by the size and characteristics of the population of beneficiaries: for example ecosystems in densely populated areas often (but not always) generate higher values than in remote, sparsely populated areas (Brander et al. 2012). This is because there are a greater number of potential beneficiaries in close proximity to the services that are provided. Cultural factors, social norms and actual and perceived rights to ecosystem services in the local context where primary studies are conducted might also influence estimated values (e.g., Barton et al. 2019; Dallimer et al. 2014; Rogers and Burton 2017; Bakhtiari et al. 2018, Badura et al. 2019).

Recent VT studies have addressed some of these spatial aspects directly, although this is an area of ongoing work. Brander et al. (2012), for example, account for ecosystem availability (to capture substitution effects) and population density (to account for market differences). Similar to Bateman et al. (2011a), Johnston et al. (2019) show that including distance decay in a VT can decrease the transfer error in VT applications. Interestingly, the proposed methodology in Johnston et al. (2019) does not require primary studies to provide spatial data – it uses external data sources and GIS to estimate average distances between sample populations and environmental changes in individual primary valuation studies, and then incorporates this information into the meta-analytic VT function. Although the possibility of complementing primary valuation studies with external spatial data (e.g., GIS data) represents a great opportunity to foster the application of VT, it also raises the need to have trained researchers to conduct EA. An increasing number of valuation studies model spatial dimensions of environmental and ES values, including the effects of substitutes (that vary over space), distance and geopolitical boundary effects, in both design and analysis (e.g., De Valck et al. 2017; Logar and Brouwer 2018; Schaafsma et al. 2012, 2013; Schaafsma and Brouwer 2019, Badura et al. 2019).

The growing availability of geo-referenced information and big data analytics provide an ideal setting to develop spatially explicit VT approaches for EA. Existing global tools for spatial ecosystem mapping and accounting (e.g., INVEST, ARIES) mention VT, but do not yet include fully operational valuation modules for all services (and are not designed for EA). Although key spatial information is already collected and standardized in tools such as these, deploying VT for accounting remains the crucial step to support EA practitioners. Moreover, some of the underlying value-prediction techniques in tools such as INVEST and ARIES do not comply with best-practice standards for VT such as those outlined in Johnston et al. (2021). Hence, before applying such tools for EA, it is important to consider the properties of the underlying VT techniques that are used to predict ES values.

3.3 A replicable method that can facilitate periodic accounts

Accounts must be compiled with a certain periodicity to ensure a regular presentation of EA data to decision makers. This periodicity in the SNA is the accounting period. In EA, the use of an annual frequency may not be ideal, considering for example large scale changes in ecosystems that can only be tracked over long periods (e.g., three or five years). The periodicity of updating biophysical and monetary metrics should depend on the speed of change in ecosystem extent, condition and ecosystem service supply (assuming the purpose of trend detection). Slow change may require less frequent updating. The need for periodic estimations in all types of accounts and all terms of assessment increases the necessity for regularly updated information inputs. If new data (for both the monetary and physical accounts) cannot be collected every accounting period, modelling (for the physical accounts) and VT (for the monetary accounts) provide useful alternatives (UN, 2015).

4 Methodological challenges

As reviewed above, VT methods offer a promising means to advance EA applications. Nonetheless, certain VT methodological challenges relevant to EA applications remain to be addressed.

First, there is a need for standardized design and reporting in primary valuation studies for VT and accounting purposes[1]. The intrinsic characteristic of EA requires a structure, accounting mechanisms and rules that are consistent through space and time. In the case of ES accounts (which is the only module in EA that requires monetary valuation), the Supply and Use Tables are framed across a specific structure of Ecosystem Types (on the supply side) of Economic Units (on the use side) and throughout a list of service flows. A clear identification of all these components requires a reporting protocol for primary studies to facilitate the provision of reliable input data for EA. Important information would include sensitivity (i.e., parameterization where possible) of values to ecosystem extent, condition and relevant spatial variables, population characteristics and institutional contexts, as well as standardization in units of measurement. To this end, it may be necessary for primary study reporting and databases to be updated in line with the EA classifications, i.e. type of ecosystem assets, type of ES by CICES, harmonization of units of measurement etc.

Database and model application updates during the periodic processes of EA can help accommodate changes in values that can occur over time. These temporal changes, if unaccommodated, can lead to reduced VT accuracy (Johnston et al., 2018). Regardless of the approach of the type of VT applied, it is also crucial that original primary study estimates represent valid measures of economic value and that these valid measures can be updated as needed over time. A literature review protocol that describes a clear and consistent structure of the review process would help to ensure replicability (Haddaway et al. 2015).

A further discussion is required regarding the acceptable level of transfer error for EA. It speaks in favor of VT that many of the transfer accuracy levels found in the literature are in the same order of magnitude as the accuracy of estimates for standard national accounting. While in general we would advocate for (meta-analytic) function transfer, more information is needed about transfer accuracy when applied to EA (validity, transfer and generalization errors), the systematic factors that influence transfer errors (especially valuation method and ES type), and the possible adjustments towards error minimization. Additional research will likely be required to identify systematic patterns in transfer errors as a function of methods and ES types, when applied to the type of values required for national accounting. This research can be used to establish standard guidelines for VT used within accounting practice, similar to those provided by Johnston et al. (2021) for use in more traditional VT applications.

Much of VT and valuation research has concerned welfare-based value estimates. Further research could also investigate how VT accuracy varies when different types of values are predicted. Similarly, while the primary focus of EA is exchange values, VT EA applications might provide an opportunity to test the empirical differences between the exchange and welfare value concepts. Information of this type could help to inform calibrations that could be used to transform information on welfare values to information on exchange values. Prospective methods of this type could help researchers to empirically assess how exchange values differ from welfare ones and perhaps what adjustments to welfare values could be made to obtain exchange values needed for accounting. Approaches such as these could possibly complement the simulated exchange value approach (Caparros et al., 2017) as the only current approach able to 'generate' exchange values from welfare values. Furthermore, it is foreseeable that complementary accounts in welfare values might be constructed for specific policy questions, wherein VT could play a role (see SEEA EA ch.12 in UN, 2021; Turner, Badura and Ferrini 2019).

Another well-known challenge that can arise in welfare analysis or EA is double-counting (Boyd and Banzhaf 2006; Fisher et al. 2009). As described by Johnston and Russell (2011, p. 2243), "consistent estimates of ecosystem service benefits require differentiation of intermediate ecosystem functions from final ecosystem services, so that the benefit of each distinct ecosystem condition or process, to each human beneficiary, is counted once and only once." As is the case with welfare analysis, the validity of any EA framework requires structures, accounting mechanisms and rules to ensure that relevant exchange values are not double-counted. This is primarily a concern for the underlying development of guidelines that determine *what values should be counted as part of EA*, rather than VT which primarily concerns how those values are estimated using existing data. Procedures of this type have been established for welfare and ecosystem services analysis (e.g., Fisher et al. 2009; Bateman et al. 2011b; Johnston and Russell 2011), and similar approaches are required for EA (regardless of whether VT is applied). Nonetheless, to ensure validity, any VT procedure used for EA should be designed to ensure that each relevant ecosystem service value is counted only once.

5 Conclusion

VT was developed as a "feasible means to provide information on economic values to support decision-making when time, funding and other practical constraints impede the use of original valuation studies" (Johnston et al. 2021). In the same way that Newbold et al. (2018) argue that VT is an essential part of all prospective cost benefit analysis in assessing US federal regulations, we argue that VT will be needed in EA. From this perspective, VT should not be considered as a standalone valuation method, but rather as a general approach needed when seeking to combine multiple single study values for large-scale, repeated applications such as EA. However, while rudimentary VT applications are already embedded in EA pilot studies, they typically lack the rigor, standardization and body of research literature that supports VT applications in cost-benefit analysis. We argue that EA practitioners can learn much from the decades of research and methodological development on VT in other fields.

VT is well placed for supplying monetary values for EA and as such accelerate EA implementation. VT offers a feasible solution to valuation applied at national scale; it can be based on SNA-compatible exchange values alone and provide a transparent approach for periodic and consistent updating of EA.

To ensure that VT can provide values to be aggregated and integrated into SNA accounts, it is crucial that different biophysical measures of ES (per ha, per user, etc.) could be consistently retrieved and transferred from available study sites. This overcomes the misalignment of economic or jurisdictional data with ecological spatial units. VT for EA should also explicitly account for the spatial heterogeneity in values in aggregated accounts. This feature can either be available in the primary studies or being rooted in the VT method. Moreover, to accommodate the need for periodical update of the accounts, VT needs to be consistently and transparently repeated and adapted to the nature of temporal changes in ecosystems and socio-economic conditions.

In summary, we argue that VT provides a promising means to accelerate EA applications. Nonetheless, despite extensive research and evidence on applications of VT for welfare applications, additional work is required to operationalize VT in EA. One area of further work is the provision of structured guidelines and protocols that would ensure proper applications, i.e. starting from protocols that would outline processes for the design, implementation and reporting of primary studies, to protocols for producing and updating databases of primary studies, and finally to guidelines that would delineate the methodological steps for VT in the EA context. Future efforts should also be placed on empirical applications of VT for EA purposes, in order to provide systematic evidence on how VT performs in practice and the methodological challenges in its application. These recommendations are in line with those mentioned under the US national strategy that refer to the need for 'reliable, repeatable and scalable monetary valuation' towards developing guidance and standards for ecosystems and the need for harmonization of EA approaches using lessons learned from empirical applications, i.e. 'early-stage pilot and prototype account' (Link 1 in p.50). Some challenges remain, but it is likely that VT can help to respond to the pressing need to incorporate nature into mainstream decision-making processes.

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Link1: https://www.whitehouse.gov/wp-content/uploads/2022/08/Natural-Capital-Accounting-Strategy.pdf

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Value transfer in ecosystem accounting applications

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Abstract

Ecosystem accounting is a statistical framework that aims to track the state of ecosystems and ecosystem services, with periodic updates. This framework follows the statistical standard of the System of Environmental Economic Accounting Ecosystem Accounting (SEEA EA). SEEA EA is composed of physical ecosystem extent, condition and ecosystem service supply-use accounts and monetary ecosystem service and asset accounts. This paper focuses on the potential use of the "Value Transfer" (VT) valuation method to produce the monetary ecosystem service accounts taking advantage of experience with rigorous benefit transfer methods that have been developed and tested over many years in environmental economics. Although benefit transfer methods have been developed primarily for welfare analysis, the underlying techniques and advantages are directly applicable to monetary exchange values required for ecosystem accounting. The compilation of regular accounts is about to become a key area of work for the National Statistical Offices worldwide as well as for the EU Member States in particular, due to the anticipated amendment to regulation on European environmental economic accounts introducing ecosystem accounts. On this basis, accounting practitioners have voiced their concerns in a global consultation during SEEA EA revision, about three issues in particular: the lack of resources, the need for guidelines and the challenge of periodically updating the accounts. We argue that VT can facilitate empirical applications that assess ecosystem services in monetary terms, especially at

national scales and in situations with limited expertise and resources available. VT is a low-cost valuation approach in line with SEEA EA requirements able to provide periodic, rigorous and consistent estimates for use in accounts. While some methodological challenges remain, it is likely that VT can help to implement SEEA EA at scale and in time to respond to the pressing need to incorporate nature into mainstream decision-making processes.

Keywords: value transfer, value generalization, benefit transfer, ecosystem accounting, natural capital accounting

1. Introduction

Ecosystem Accounting (EA) is a framework for integrating ecosystems with the System of National Accounts. The first version of this framework, as official methodological guidelines for member states, has been standardized in the System of Environmental-Economic Accounting (SEEA), which has been proposed and supported by the United Nations (UN) since 1993 (UN, 1993). The SEEA Ecosystem Accounting (SEEA EA) chapters 1-7 on biophysical accounts were adopted as a statistical standard by the UN Statistical Commission in March 2021 (UN, 2021; UNCEEA, 2021). The long-term aim of the SEEA EA is to integrate physical and monetary measures of ecosystem services (ES) and ecosystem assets by developing ecosystem accounts consistent with the System of National Accounts (SNA), using the same accounting principles. This implies that monetary valuation of ES and ecosystem assets using exchange values are required (Obst et al. 2016, UN, 2021). In this paper, we argue that the Value Transfer method (VT) (also known as benefit transfer) can facilitate and accelerate empirical applications of monetary valuation of ES for national accounts.

SEEA EA Chapters 8-11 on valuation and accounting treatments were recognized by the UN Statistical Division as describing "internationally recognized statistical principles and recommendations for the valuation of ecosystem services and assets in a context that is coherent with the concepts of System of National Accounts" (UN, 2021). The UN Statistical Commission called for promptly resolving the outstanding methodological aspects of Chapters 8-11 identified in the SEEA EA research agenda (UNCEEA, 2021). The agenda calls for testing and development of several VT issues as discussed in this paper, i.e., "application of value transfer techniques for accounting purposes, in particular considering alignment with exchange value concepts, consistency with data collected in physical terms on extent, condition and service flows and advancement of the potential of value generalization techniques" (UN 2021, p.351). Value transfer guidance is briefly provided in the SEEA EA (section 9.5) and identified as a research and development need (UN, 2021). The use of value transfer in ecosystem accounts is also referred to as "value generalization" (NCAVES and MAIA, 2022).

The global consultation of the SEEA EA provided further detailed comments by countries, National Statistical Offices (NSO) and international institutions regarding the barriers to applying monetary valuation methods, which also concern VT. These comments, addressed concerns such as: implementation barriers relating to VT; the complexity of valuation model assumptions adapted for accounting purposes; the institutional and market feasibility assumptions required in the transfer of exchange values; limitations on value estimates which were designed for other purposes and then transferred for the purpose of national accounts; requirements for reliability of estimates and documentation of uncertainty; documentation with respect to compatibility of primary studies used in meta-analysis used for VT; and lack of guidance on methods to generalize values (UN, 2020).

Summarizing these comments, EA practitioners are faced with three general areas of concern in applying monetary valuation methods: (1) the lack of financial resources and expertise to evaluate in physical and in monetary terms the ES included in the accounts, (2) the lack of consistent and clear guidelines that facilitate the process of account compilation, in particular regarding monetary valuation methods (i.e., which method to be used, how and when), and (3) the challenge of producing sufficiently reliable and consistent periodic updates of the monetary accounts.

In this paper, we argue that VT methods may facilitate EA practitioners' work to address these concerns and thereby enrich EA practice. VT approaches may provide a suitable means to obtain the value information required for EA, particularly in cases where time and financial resources are limited, as they are cost-effective and well tested in the context of policy and project appraisal (Johnston et al. 2021). While the practice of transferring values from one site to another has already been used in EA applications (e.g., in Vysna et al. 2021; La Notte et al. 2012; Gundimeda 2012, 2006; Remme et al. 2018; Sumarga et al., 2015), it is rarely acknowledged as such, and is typically done on a case-by-case and ad hoc basis. Moreover, mapping for physical supply-use accounts is a form of value generalization using a model often calibrated on a sample of sites in the accounting area (UN, 2022). Providing guidance for and recognizing the use of VT—grounded in prior work and guidelines from the benefit transfer literature (Johnston et al. 2021)—would help promote consistency and rigor across EA applications and facilitate greater uptake of VT in EA. The substantive knowledge developed over the past 30 years of applied VT research, summarized in Richardson et al. (2015), Johnston et al. (2018, 2021), and Johnston and Rosenberger (2010), among others, provides a solid starting point for such guidance. In concept, the general mechanisms for VT apply similarly to many types of economic value information—including exchange values typically considered within EA. VT application in EA can be developed in a way that enables consistent and periodic updates of monetary accounts with relatively low resource demands. At the same time, it is important to recognize that VT has typically been applied in other contexts than EA (e.g., to transfer information on welfare values rather than exchange values).

A number of guidelines for conducting value transfers for environmental economic applications and project appraisal already exist. Richardson et al. (2015) focus on guidelines for transferring welfare estimates of ES and Johnston et al. (2021) provide guidelines for VT in general (and for assessing the validity and credibility of transfers), whereas Johnston and Bauer (2019) provide guidance on transferring ES values for large-scale applications. Although many of these guidelines apply to EA applications, they are not specific to EA, and these publications are largely silent on what adaptations to VT methods might be required for EA applications.

Grounded in this prior work, our objective is to explore two main questions: How might VT be relevant for EA applications, and how can VT methods respond to the concerns raised by account compilers? By opening this discussion, we aim to stimulate further research into the potential use of VT in EA. We also hope to flag the need for context-specific guidelines that facilitate further implementation of EA. We believe that bringing together the national accounting and environmental economics communities can help to operationalize VT research and enrich both EA and VT research.

2. How Value Transfer works and why it fits to Ecosystem Accounting scope

2.1 An overview of the method

VT approaches use research results from pre-existing monetary valuation studies at one or more sites or policy contexts to predict value estimates or other related economic information for other sites or policy contexts. Two main approaches have commonly been used with two common variations within each (Johnston et al., 2015):

1. Unit value transfer:

    1.1. Simple, single unadjusted value transfer.

    1.2. Adjusted unit value transfer, to account for factors such as currency or income differences between sites.

2. Value function transfer:

    2.1 Single-site or single-study value function transfer, which employs an estimated function from a single primary study, with data often but not always drawn from one study site.

    2.2 Value transfer using data-synthesis methods such as meta-analysis, which combine information from multiple prior studies across different sites to produce broadly applicable “umbrella” value functions.

Unit value transfer has been applied in multiple contexts, including a global valuation of ecosystem services (Costanza et al. 1997, 2014) and national valuations of the contribution of natural ecosystem capital to the economy (Kubiszewski et al. 2013, Frélichová et al. 2014, Ferrini et al.

2014 and 2015, Niquisse and Cabral 2017). Because transfers of this type allow few (and generally simple) adjustments to the transferred values, they "are usually chosen only when there is insufficient data to support other approaches for the given policy-site application" (Johnston et al. 2021). Although some global and national transfers of this type have been criticized for violating core principles of economic theory for welfare analysis and benefit transfer (Bockstael et al. 2010; Johnston and Wainger 2015; Johnston et al. 2021), some (although perhaps not all) of these critiques might be less relevant when considering exchange values of the type considered within accounting.

Meta-analysis VT has been applied for assessments of ES provided by many natural systems such as wetlands (e.g. Ghermandi et al. 2010, Poudel et al. 2020, Vedogbeton and Johnston 2020), forests (e.g. Chiabai et al. 2011; Grammatikopoulou and Vačkářová, 2021), mangroves (e,g, Brander et al. 2012) and lakes (Reynaud and Lanzanova 2017), as well as many other types of ES and environmental changes. Schmidt et al. (2016) developed meta-analysis value transfer functions for 12 ES based on 194 case studies using 839 monetary ES values. It has also been applied extensively to values for environmental changes such as water quality improvements (Johnston et al. 2017, 2019; Newbold et al. 2018; Moeltner 2019).

VT research has demonstrated that quality control and best practices are important for valid and reliable value transfers (Richardson et al., 2015; Johnston et al. 2021). Value transfer accuracy reflects both of these concepts (Rosenberger 2015). Within the context of VT, validity implies that value estimates or other transferred quantities are unbiased. This is usually interpreted as a lack of statistically significant generalization (or transfer) error. Reliability concerns the variance of the value-transfer prediction, often measured as average generalization error: the (mean) difference between a primary study value and a value produced via value transfer. It is generally expected that value transfers will be more accurate, on average, when the policy and original study areas are more similar, in terms of ES benefits, size, policy context and populations (Carolus et al. 2020). However, the degree to which similarity is required for accurate transfers depends on the transfer method applied—as some methods (e.g., meta-analysis) have greater capacity to adjust for contextual differences than other methods (e.g., unadjusted unit value transfer) (Johnston et al. 2021). The literature provides many examples of transfers implemented over sites with relatively large differences in site characteristics (e.g., different European countries, Czajkowski et al. 2017). Moreover, even unit-value transfers can incorporate some types of adjustments that, ideally, improve accuracy. For example, La Notte et al. (2021) tested the unit transfer value for habitat and species maintenance estimates in Europe and they enhanced the simple unit transfer value with a sophisticated statistical analysis of biophysical and socio-economic comparability of policy sites and study sites.

Reviews of VT studies tend to suggest that value function transfers are more accurate than unit transfers, in general, where policy sites differ from study sites to a large degree—although this finding does not apply universally to all possible applications (Rosenberger and Stanley 2006;

Bateman et al. 2011a; Ferrini et al., 2014, Rosenberger 2015; Johnston et al., 2021). Hence, as noted by Johnston et al. (2021), the degree to which high degrees of similarity are required must be considered in context. Points of attention include the type of ecosystem service benefit valued and the availability of substitutes, the scope or size of the study and policy sites or the ecosystem service that is valued, the (ecological, social, economic, and political) context of the ecosystem service, and how these issues are expected to affect the exchange value in question. Recent developments in academic practice such as open access publishing, regularly updated valuation databases and improvements in AI-based analysis may facilitate new VT research and increase its cost-effectiveness—for example by reducing the difficulty of compiling research metadata.

There is an important difference in purpose and scale between welfare valuation studies often used as inputs in VT studies and EA applications where only exchange value measures (e.g. market prices) are compatible with national accounts. Welfare valuation often includes willingness to pay (WTP) and willingness to accept (WTA) measures that reflect underlying theoretical constructs such as compensating or equivalent variation, or related measures such as consumer surplus. Only exchange values can be used for SEEA EA accounts that aim to be compatible with other economic data from SNA (Obst et al., 2016; UN, 2021a). Moreover, most EA applications require values that are used for large accounting areas, covering a whole country in case of national accounts, although the majority of examples in the research literature reflect local or regional examples. Illustrative examples of national-scale VT applications are provided by Ferrini et al. (2015), as related to the UK National Ecosystem Assessment, and Wheeler (2015), for US water quality benefits. However, most VT research is focused on WTP changes evaluated over smaller sub-national scales, and applied to ex-ante project evaluation. Nonetheless, there is no reason in principle why the VT method cannot produce transferrable exchange values for large spatial areas and ex-post assessment.

2.2 Policy context of Ecosystem Accounting and the contribution of Value Transfer

EA is likely to become a key area of work for National Statistical Offices (NSOs) worldwide, yet there is limited capacity to satisfy the rising policy demands. EA is built on a strong framework and its implementation will support the control and reporting activity for several global environmental and sustainability initiatives (UN, 2021). EA is expected to support climate mitigation and adaptation, as well as biodiversity conservation and other related policy objectives.

At the moment, the policy pull for EA implementation is the strongest in the EU. As of July 2022, the European Commission has adopted the technical proposal to amend the Regulation 691/2011 on European environmental economic accounts to include three new modules of environmental accounts, one of them being ecosystem accounts. This would make regular reporting of EA mandatory for EU Member States. The proposed amendment under negotiation suggests that the Commission would need to carry out a methodological and feasibility study on the monetary valuation of ecosystem services before further reporting of monetary values is included in the

Regulation. When the proposal is adopted by the Parliament and the Council, countries and NSOs may have to use quick, standardized, and easy-to-use methods, as implementing new valuation work for each individual country and accounting period is likely to become financially and practically unfeasible because of capacity and resource gaps at the NSOs and individual countries. EA will be required at national level and compiled as a periodic exercise with a permanent mandate and budgets to generate new and collect existing datasets.

Moreover, the White House Office of Science and Technology Policy (OSTP) in August 2022 released a national strategy report to develop statistics for environmental economics decisions. The reports highlight the aim to incorporate nature into national economic accounts through the development of natural capital accounts (Link 1). As in EU context, this development will require a regular implementation of EA.

The report of the plenary of Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) flags the inability of valuation studies to reach out to policy processes and call for co-production of valuation knowledge, proper guidance and standardization of valuation methods. This standardization is what national EA initiatives require (IPBS, 2022, pp6 and pp18) and what SEEA EA framework aims to cover.

VT lies very much within the scope of the aforementioned policy objectives. In this paper, we argue that VT can contribute to fill resource gaps in the interim until monetary valuation of ES becomes part of the regular national statistics reporting (NCAVES and MAIA 2022, p.120) and can be an important valuation tool for early operationalizing monetary ecosystem accounts. VT can provide a cost-effective, transparent framework that could allow periodic and consistent updates, while also allowing for stepwise updating of valuation estimates to improve precision, as available data and capacity increase. Similar arguments for the use of VT have been made by the US Environmental Protection Agency (EPA) when considering measurement of the ecological benefits of proposed federal rules, which must be accompanied by a formal Benefit-Cost Analysis (BCA) (Iovanna and Griffiths 2006 in Richardson et al., 2015; Newbold et al., 2018; Wheeler, 2015). US EPA commonly relies on value transfers (e.g., for estimating the nonmarket benefits of water quality improvements and supporting BCA) for purposes of regulatory analysis (Wheeler, 2015). Globally, VT can offer standardized and low-cost means of predicting values for EA applications in both developed and developing countries, contingent upon a suitable body of primary studies from which to draw VT estimates.

3 How can Value Transfer support implementation of Ecosystem Accounting

EA applications demand clear and consistent guidelines to ensure validity, reliability and comparability across space and time, yet existing guidelines are still experimental, providing limited advice on which method should be used for given ES. EA applications are also still in an exploratory phase and there are only a few best practice examples to be shared among countries (Hein et al. 2020; Vallecillo et al., 2018; 2019, La Notte et al., 2021). Structured and consistent monetary accounts remain a challenge for practitioners.

Below we discuss how VT addresses the three major areas of practitioners' concern related to the production of monetary ecosystem accounts: lack of capacity, need for clear guidelines and need for systematic/ periodic accounts within limited resources available.

3.1. A capacity-tailored method

Accounting practitioners require methods and approaches that are compatible with available human and financial resources (including expertise) at the NSO. VT can accommodate both simple and more complex modeling approaches, providing flexibility to EA implementation subject to reliability requirements and available capacity. Building capacity in VT skills and applying VT can be less demanding than for primary valuation approaches, which require more specific expertise. Note, however, that some VT methods require considerable expertise. For example, development and estimation of a new meta-regression analysis requires considerable expertise to compile metadata and estimate statistical models. However, once a meta-regression model has been estimated, the subsequent use of the model for VT applications requires less specialized expertise. Examples are provided in Johnston and Wainger (2015) and Johnston and Bauer (2019).

Data for application of VT for EA purposes can be compiled and made available. While NSOs are aware of relevant data sources for the SNA and the biophysical accounts of the SEEA EA, this is not the case for the monetary accounts. However, open access datasets that report economic values of ES for various ecosystems, which were used for VT applications, are already available. The most widely used databases include the Ecosystem Service Valuation Database (ESVD) (de Groot et al., 2012) and the Environmental Valuation Reference Inventory (EVRI) database. Screening these valuation databases for exchange value (e.g. replacement costs or production function estimates) compatible estimates would be a starting point for VT EA applications.

Several VT approaches are available for EA and their validity and reliability is largely context dependent - for example depending on factors such as the type of values to be estimated, the supporting body of valuation information, and site characteristics (Johnston et al. 2021). Hence, it is not possible to derive a fixed, one-to-one match between specific EA needs and the type of transfers that can be applied. For EA, the context is driven by the spatial unit of the biophysical accounts and in VT key elements to consider include the scale of the monetary analysis (e.g., local vs national), and the characteristics of the ecosystem services (La Notte et al., 2019). The selection of VT approach depends on the level of accuracy required (i.e., validity and reliability) (Zulian et al., 2018), following a tiered approach (Brander et al., 2018). VT offers flexibility in this respect. Furthermore, different VT approaches may be considered appropriate for different types of values for theoretical or conceptual reasons, as demonstrated in VT applications in other areas of public policy. For example, unit value transfers are standard practice for estimating the value of statistical life (VSL) (Johnston and Rosenberger 2010; Lindhjem and Navrud 2015). Another example is the use of meta-analysis approach in cases where selection of the studies used for VT may be biased, as it can provide a means to evaluate and correct the systematic effects of these selection biases (Rosenberger and Johnston 2009). When one selects primary studies for VT, implicit assumptions are typically made that the underlying body of literature provides an unbiased sample of the population of empirical estimates (i.e., no selection biases) and that these estimates provide an unbiased representation of true values (i.e., no measurement error). If these assumptions do not hold, the result will be systematic biases in the resulting value transfers (Hoehn 2006; Rosenberger and Johnston 2009). Examples such as these suggest that VT approaches should be determined on a case-by-case basis (Johnston et al. 2021). No single VT approach is superior for all possible applications and contexts.

Table 1 presents an overview of the primary VT approaches with respect to a set of selected operational features that are important for EA. Some features such as the budget may drive choices of statistical institutes to invest in VT. The possibility to compare areas and adjust for spatially explicit factors is key to the use of valuation in accounting. EA requires systematic compilation over time and thus needs to provide updated estimates. The last feature is related to the requirement for models that are amenable to the automated production of accounts.

Table 1: Selection criteria

Operational features	Relevance for EA	Unit value transfer	Single- study function transfer	Meta-analysis transfer
Resources (e.g. budget and time)	Relevant	Low requirement in resources	Low requirement in resources	High requirement in case of estimating a new meta-analysis; Low in case of applying a pre-existing meta-analysis
Similarity between study and policy area especially in the ES features	Relevant	Is required	Partly required	Partly required, but less so than other types of VT
Coherence with spatial factors/features	Very relevant	Not possible	Possible	Possible
Periodic updating	Very relevant	Possible	Possible	Possible

Automation	Relevant	Possible	Possible	Possible

3.2. A well-studied method with clear and available guidelines

Methods for VT have been continually improved and validated over 30 years of applied research and methodological developments. Johnston and Rosenberger (2010) and Johnston et al. (2018) describe the historical developments of the method and provide a thorough discussion of key methodological challenges. Johnston et al. (2015) provide a comprehensive overview of methods. Richardson et al. (2015), Ferrini et al. (2015) and Johnston and Wainger (2015) discuss the role of benefit transfer in ES valuation. The authors provide examples of applications to show which values for ES and ecosystem changes were estimated using transfers. The work by Johnston et al. (2017 and 2018) refers to spatial considerations in transfer applications. Guidelines on applications, validity and credibility are provided in Johnston et al. (2021).

3.2.1 Towards standardizing the process of the selection of studies and database structure

The selection of primary studies for VT determines the validity and reliability of any VT application (Johnston et al. 2021) and in particular of a meta-analysis transfer. The increasing number of primary valuation studies in the literature (and the progression of study methods over time) provides a solid foundation for VT EA applications, particularly in certain areas where many primary studies have been conducted. Their selection is most transparent when using a systematic review approach, i.e., a stepwise methodology that aims to collect, assess and synthesize existing research data based on a priori eligibility criteria and a priori methodological protocol (Richardson et al. 2015). Guidelines and procedures for literature reviews of this type in economics are provided by Stanley et al. (2013) and Johnston et al. (2021). For the time being, there is no available literature review protocol for developing VT valuations to produce monetary EA (Vačkářů and Grammatikopoulou, 2018) but we can anticipate that, besides the review protocol, a structured reporting within primary studies can help to reduce transfer errors, by providing more complete information to support data synthesis (Plummer 2009 in Richardson 2015; Loomis and Rosenberger 2006). As noted in past applications of valuation meta-analysis (e.g., Brander et al., 2007; Lara-Pulido et al., 2018), there is a great variation in the way values are reported in primary studies. Johnston et al. (2005, 2017) discuss how different water quality monetary measures reported in primary study can be reconciled for VT approaches. After primary study screening and selection, a database of selected studies must be developed (i.e., key features of each study to be used in VT are recorded). A typical dataset will include the monetary estimates, the ES type and characteristics, the size or scope of the ES or environmental change that was valued by the study, the geospatial extent of the area over which the change occurred, the primary beneficiaries (e.g. residents or tourists) and extent of the market over which values were measured, the local economic features (e.g. GDP) and ideally the geographical features of the area, and other variables that are expected to influence values (e.g., availability of substitutes). The complexity of the database will vary with the VT techniques used.

Ideally, database compilation to support VT should follow a structured process to homogenize the information that is extracted from each study, something that will remain necessary as long as studies do not follow a standard reporting protocol. Current open-source databases (e.g., ESVD) and empirical application studies (e.g., Grammatikopoulou and Vačkářová, 2021) outline a possible way for structuring such databases. Johnston et al. (2021) provide guidelines for data adjustments to harmonize information across studies. This is a time-consuming process and requires expertise. Although existing valuation databases provide a good starting point for VT, the information in these databases is rarely sufficient to support all the information needs of a VT (Johnston et al. 2015).

A distinct requirement for VT EA applications is to identify (e.g., in the study database) whether a study estimates exchange or welfare values (or both). This is in part determined by the valuation method used in each study, a study characteristic that is usually recorded in existing databases. Around three quarters of value estimates in the ESVD database are produced using methods directly compatible with the SEEA EA guidelines, i.e. market-based, cost-based and revealed preference methods (e.g. travel cost). However, further revisions to the original study data and estimates may be required to produce suitable exchange values. For example, travel cost data can be used to estimate welfare values but can also contain travel expense data which is required to derive exchange values.

3.2.2 Literature evidence on accuracy and transfer errors

Evaluations of VT validity and reliability require an understanding of the errors that are expected from VT—ideally as a function of VT method, ES type, ecosystem extent and conditions and other potentially relevant factors. As described by Johnston et al. (2021), "a transfer is typically considered valid if it provides a statistically unbiased estimate of the true value at the policy site. Reliable transfers, in contrast, are associated with lower transfer errors or variances (Bishop and Boyle 2019; Rosenberger 2015). Both are elements of the accuracy of transfer estimates." In theory, VTs can be subject to measurement errors and generalization errors. Measurement errors arise in VT due to underlying errors in the original study site value information (Rosenberger and Stanley 2006). In practice, VT accuracy is typically characterized by assessing transfer or generalization error, using convergent validity tests that quantify the difference between transferred empirical estimates (secondary estimates) and primary-study estimates of the same value (Rosenberger and Stanley 2006; Johnston and Rosenberger 2010; Johnston et al. 2015). It is assumed that the primary valuation at a policy site provides an unbiased estimate, or that biased studies have been eliminated by quality control during the selection of studies for transfer (Johnston et al. 2015, 2021). Of course, evaluations of this type can only be conducted for cases where a primary study has *already been conducted* for the policy site, so that a primary-study estimate of value is available. VT is generally required only when suitable primary-study estimates are *not available* to measure the value of interest. Hence, for actual VT applications, the transfer error is almost always unknown.

For EA applications, an ideal benchmark primary valuation study with which to assess value transfer accuracy would typically be a high-quality study over a representative sample of the national population (or with statistical adjustments to obtain representative estimates), following all best practices assumed to promote unbiased value estimation. Over the long run, VT measurement errors for EA applications can be reduced by increasing the validity and reliability of primary valuation studies in the literature that can support these transfers.

The VT literature has summarized evidence on the size of transfer errors across multiple applications, from which generalizable conclusions may be drawn about the type of errors that might be expected across different contexts (Brouwer and Spaninks 1999; Rosenberger and Stanley 2006; Rosenberger and Johnston 2009; Kaul et al. 2013; Ferrini et al 2014, Rosenberger 2015). For example, Rosenberger (2015) reports median transfer errors of 36% for value function transfers and 45% for unit VT (means are 65% and 140%, respectively). Although one might argue that these measures of central tendency are within the error tolerances of at least some applications, of potentially greater concern is the variance of these error estimates across studies, and the extent to which these errors vary systematically across different types of transfer methods and applications. However, it should be emphasized that these estimates are typically drawn from transfers of welfare rather than exchange values—hence their applicability to exchange values is currently unknown.

Because of the need for accuracy and validity varies across applications, there is no universal test or maximum error that dictates the acceptability of VT (Johnston et al. 2021). The accuracy of most estimates used today for national accounting cannot be quantified (IMF 2001). However, it is generally accepted that many of these accounting measures are inaccurate. As noted by Barton et al. (2019, p. 69), “GDP revisions can be quite large (e.g., Ghana 60%, China 15%, Netherlands 7%),” implying errors of similar magnitudes (at a minimum) in the initial estimates. Errors of this level thus fall within the degree of VT errors commonly observed in the literature.

The accuracy requirement for VT applied to EA may initially be similar to, or lower than, known uncertainty in GDP estimates. However, the purposes of EA require accuracy that is sufficient for trend detection in physical ecosystem service supply-use tables. SEEA EA is silent on whether trend detection of monetary ES value is required, but if so, the accuracy requirements for value transfer will be higher than what is expected from GDP measures.

3.2.3 Accommodating spatial heterogeneity

Values of ES can vary substantially across space, depending on the ecological and socio-economic context in given locations (Ferrini et al. 2015; Johnston and Wainger 2015; Glenk et al. 2020). This variation is inevitable, but VT provides various approaches to adjust transferred values for these contextual differences (e.g., Bateman et al. 2011a; Ferrini et al. 2015; Johnston et al., 2017, 2019). In the same way that spatial heterogeneity in primary values requires attention in VT applications, EA requires attention to spatial dimensions when creating aggregated ecosystem accounts (Addicott and Fenichel, 2019). In terms of biophysical accounts, joint effects of the extent (size) and condition (state) of individual ecosystems differ across space, which in turn leads to variability and spatial heterogeneity in ecosystem functions and ecosystems' potential to supply services (ecosystem service supply), independent of the beneficiaries from these services (ecosystem service demand). The spatial configuration of beneficiaries relative to ecosystems then (often) determines whether potential supply turns into an actual flow of ES (Olander et al. 2018). In terms of the monetary valuation related to ES, other spatial factors are also relevant (Schaafsma 2015, Glenk et al. 2020). For example, the values related to ES tend to decrease with increasing distance between beneficiaries and the provided services, an effect known as distance decay (Sutherland and Walsh 1985; Hanley et al. 2003; Bateman et al. 2006). Furthermore, availability and proximity of substitutes and complements to a given environmental good or service is also likely to affect its economic value, among many other factors that can vary over space (see Glenk et al. 2020; De Valck and Rolfe 2018). Finally, the economic value of ES is likely to be influenced by the size and characteristics of the population of beneficiaries: for example ecosystems in densely populated areas often (but not always) generate higher values than in remote, sparsely populated areas (Brander et al. 2012). This is because there are a greater number of potential beneficiaries in close proximity to the services that are provided. Cultural factors, social norms and actual and perceived rights to ecosystem services in the local context where primary studies are conducted might also influence estimated values (e.g., Barton et al. 2019; Dallimer et al. 2014; Rogers and Burton 2017; Bakhtiari et al. 2018, Badura et al. 2019).

Recent VT studies have addressed some of these spatial aspects directly, although this is an area of ongoing work. Brander et al. (2012), for example, account for ecosystem availability (to capture substitution effects) and population density (to account for market differences). Similar to Bateman et al. (2011a), Johnston et al. (2019) show that including distance decay in a VT can decrease the transfer error in VT applications. Interestingly, the proposed methodology in Johnston et al. (2019) does not require primary studies to provide spatial data – it uses external data sources and GIS to estimate average distances between sample populations and environmental changes in individual primary valuation studies, and then incorporates this information into the meta-analytic VT function. Although the possibility of complementing primary valuation studies with external spatial data (e.g., GIS data) represents a great opportunity to foster the application of VT, it also raises the need to have trained researchers to conduct EA. An increasing number of valuation studies model spatial dimensions of environmental and ES values, including the effects of substitutes (that vary over space), distance and geopolitical boundary effects, in both design and analysis (e.g., De Valck et al. 2017; Logar and Brouwer 2018; Schaafsma et al. 2012, 2013; Schaafsma and Brouwer 2019, Badura et al. 2019).

The growing availability of geo-referenced information and big data analytics provide an ideal setting to develop spatially explicit VT approaches for EA. Existing global tools for spatial ecosystem mapping and accounting (e.g., INVEST, ARIES) mention VT, but do not yet include fully operational valuation modules for all services (and are not designed for EA). Although key spatial information is already collected and standardized in tools such as these, deploying VT for accounting remains the crucial step to support EA practitioners. Moreover, some of the underlying value-prediction techniques in tools such as INVEST and ARIES do not comply with best-practice standards for VT such as those outlined in Johnston et al. (2021). Hence, before applying such tools for EA, it is important to consider the properties of the underlying VT techniques that are used to predict ES values.

3.3 A replicable method that can facilitate periodic accounts

Accounts must be compiled with a certain periodicity to ensure a regular presentation of EA data to decision makers. This periodicity in the SNA is the accounting period. In EA, the use of an annual frequency may not be ideal, considering for example large scale changes in ecosystems that can only be tracked over long periods (e.g., three or five years). The periodicity of updating biophysical and monetary metrics should depend on the speed of change in ecosystem extent, condition and ecosystem service supply (assuming the purpose of trend detection). Slow change may require less frequent updating. The need for periodic estimations in all types of accounts and all terms of assessment increases the necessity for regularly updated information inputs. If new data (for both the monetary and physical accounts) cannot be collected every accounting period, modelling (for the physical accounts) and VT (for the monetary accounts) provide useful alternatives (UN, 2015).

4 Methodological challenges

As reviewed above, VT methods offer a promising means to advance EA applications. Nonetheless, certain VT methodological challenges relevant to EA applications remain to be addressed.

First, there is a need for standardized design and reporting in primary valuation studies for VT and accounting purposes[1]. The intrinsic characteristic of EA requires a structure, accounting mechanisms and rules that are consistent through space and time. In the case of ES accounts (which is the only module in EA that requires monetary valuation), the Supply and Use Tables are framed across a specific structure of Ecosystem Types (on the supply side) of Economic Units (on the use side) and throughout a list of service flows. A clear identification of all these components requires a reporting protocol for primary studies to facilitate the provision of reliable input data for EA.

Important information would include sensitivity (i.e., parameterization where possible) of values to ecosystem extent, condition and relevant spatial variables, population characteristics and institutional contexts, as well as standardization in units of measurement. To this end, it may be necessary for primary study reporting and databases to be updated in line with the EA classifications, i.e. type of ecosystem assets, type of ES by CICES, harmonization of units of measurement etc.

Database and model application updates during the periodic processes of EA can help accommodate changes in values that can occur over time. These temporal changes, if unaccommodated, can lead to reduced VT accuracy (Johnston et al., 2018). Regardless of the approach of the type of VT applied, it is also crucial that original primary study estimates represent valid measures of economic value and that these valid measures can be updated as needed over time. A literature review protocol that describes a clear and consistent structure of the review process would help to ensure replicability (Haddaway et al. 2015).

A further discussion is required regarding the acceptable level of transfer error for EA. It speaks in favor of VT that many of the transfer accuracy levels found in the literature are in the same order of magnitude as the accuracy of estimates for standard national accounting. While in general we would advocate for (meta-analytic) function transfer, more information is needed about transfer accuracy when applied to EA (validity, transfer and generalization errors), the systematic factors that influence transfer errors (especially valuation method and ES type), and the possible adjustments towards error minimization. Additional research will likely be required to identify systematic patterns in transfer errors as a function of methods and ES types, when applied to the type of values required for national accounting. This research can be used to establish standard guidelines for VT used within accounting practice, similar to those provided by Johnston et al. (2021) for use in more traditional VT applications.

Much of VT and valuation research has concerned welfare-based value estimates. Further research could also investigate how VT accuracy varies when different types of values are predicted. Similarly, while the primary focus of EA is exchange values, VT EA applications might provide an opportunity to test the empirical differences between the exchange and welfare value concepts. Information of this type could help to inform calibrations that could be used to transform information on welfare values to information on exchange values. Prospective methods of this type could help researchers to empirically assess how exchange values differ from welfare ones and perhaps what adjustments to welfare values could be made to obtain exchange values needed for accounting. Approaches such as these could possibly complement the simulated exchange value approach (Caparros et al., 2017) as the only current approach able to 'generate' exchange values from welfare values. Furthermore, it is foreseeable that complementary accounts in welfare values might be constructed for specific policy questions, wherein VT could play a role (see SEEA EA ch.12 in UN, 2021; Turner, Badura and Ferrini 2019).

Another well-known challenge that can arise in welfare analysis or EA is double-counting (Boyd and Banzhaf 2006; Fisher et al. 2009). As described by Johnston and Russell (2011, p. 2243), "consistent estimates of ecosystem service benefits require differentiation of intermediate ecosystem functions from final ecosystem services, so that the benefit of each distinct ecosystem condition or process, to each human beneficiary, is counted once and only once." As is the case with welfare analysis, the validity of any EA framework requires structures, accounting mechanisms and rules to ensure that relevant exchange values are not double-counted. This is primarily a concern for the underlying development of guidelines that determine *what values should be counted as part of EA*, rather than VT which primarily concerns how those values are estimated using existing data. Procedures of this type have been established for welfare and ecosystem services analysis (e.g., Fisher et al. 2009; Bateman et al. 2011b; Johnston and Russell 2011), and similar approaches are required for EA (regardless of whether VT is applied). Nonetheless, to ensure validity, any VT procedure used for EA should be designed to ensure that each relevant ecosystem service value is counted only once.

5 Conclusion

VT was developed as a "feasible means to provide information on economic values to support decision-making when time, funding and other practical constraints impede the use of original valuation studies" (Johnston et al. 2021). In the same way that Newbold et al. (2018) argue that VT is an essential part of all prospective cost benefit analysis in assessing US federal regulations, we argue that VT will be needed in EA. From this perspective, VT should not be considered as a standalone valuation method, but rather as a general approach needed when seeking to combine multiple single study values for large-scale, repeated applications such as EA. However, while rudimentary VT applications are already embedded in EA pilot studies, they typically lack the rigor, standardization and body of research literature that supports VT applications in cost-benefit analysis. We argue that EA practitioners can learn much from the decades of research and methodological development on VT in other fields.

VT is well placed for supplying monetary values for EA and as such accelerate EA implementation. VT offers a feasible solution to valuation applied at national scale; it can be based on SNA-compatible exchange values alone and provide a transparent approach for periodic and consistent updating of EA.

To ensure that VT can provide values to be aggregated and integrated into SNA accounts, it is crucial that different biophysical measures of ES (per ha, per user, etc.) could be consistently retrieved and transferred from available study sites. This overcomes the misalignment of economic or jurisdictional data with ecological spatial units. VT for EA should also explicitly account for the spatial heterogeneity in values in aggregated accounts. This feature can either be available in the primary studies or being rooted in the VT method. Moreover, to accommodate the need for periodical update of the accounts, VT needs to be consistently and transparently repeated and adapted to the nature of temporal changes in ecosystems and socio-economic conditions.

In summary, we argue that VT provides a promising means to accelerate EA applications. Nonetheless, despite extensive research and evidence on applications of VT for welfare applications, additional work is required to operationalize VT in EA. One area of further work is the provision of structured guidelines and protocols that would ensure proper applications, i.e. starting from protocols that would outline processes for the design, implementation and reporting of primary studies, to protocols for producing and updating databases of primary studies, and finally to guidelines that would delineate the methodological steps for VT in the EA context. Future efforts should also be placed on empirical applications of VT for EA purposes, in order to provide systematic evidence on how VT performs in practice and the methodological challenges in its application. These recommendations are in line with those mentioned under the US national strategy that refer to the need for 'reliable, repeatable and scalable monetary valuation' towards developing guidance and standards for ecosystems and the need for harmonization of EA approaches using lessons learned from empirical applications, i.e. 'early-stage pilot and prototype account' (Link 1 in p.50). Some challenges remain, but it is likely that VT can help to respond to the pressing need to incorporate nature into mainstream decision-making processes.

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Link1: https://www.whitehouse.gov/wp-content/uploads/2022/08/Natural-Capital-Accounting-Strategy.pdf

Revised manuscript (with track changes) Click here to view linked References

Value transfer in ecosystem accounting applications

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Abstract

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Ecosystem accounting is a statistical framework that aims to track the state of ecosystems and ecosystem services, with periodic updates. This framework follows the statistical standard of the System of Environmental Economic Accounting Ecosystem Accounting (SEEA EA). ~~When compiling ecosystem and ecosystem services accounts in line with~~ SEEA EA is composed of physical ecosystem extent, condition and ecosystem service supply-use accounts and monetary ecosystem service and asset accounts. ~~two metrics are required: the physical metrics of the accounts and the associated monetary metric~~This paper focuses on the potential use of the "Value Transfer" (VT) valuation method to produce the monetary ecosystem service accounts~~metrics~~ taking advantage of~~for the SEEA EA implementation, parallel~~ experience with~~experiences~~~~to~~ ~~the~~ rigorous benefit transfer methods that have been developed and tested over many years in environmental economics. Although benefit transfer~~these~~ methods have been developed primarily for welfare analysis, the underlying techniques and advantages are directly applicable to ~~the~~ monetary exchange values~~metrics~~ required for ecosystem accounting. The compilation of regular accounts is about to become a key area of work for the National Statistical Offices worldwide as well as for the EU Member States in particular, due to the anticipated amendment to regulation on ~~on~~ European environmental economic accounts introducing ecosystem accounts. On this basis, accounting practitioners have voiced their concerns in a global consultation during SEEA EA revision, about three issues in particular: the lack of resources, the need for guidelines and the challenge of periodically updating the accounts. We argue that VT can facilitate empirical applications that assess ~~ecosystem and~~ ecosystem services in monetary terms, especially at national scales and in situations with limited expertise and resources available. VT is a low-cost valuation approach in line with SEEA EA requirements able to provide periodic, rigorous and consistent estimates for use in accounts. While some methodological challenges remain, it is likely that VT can help to implement SEEA EA at scale and in time to respond to the pressing need to incorporate nature into mainstream decision-making processes.

Keywords: value transfer, value generalization, benefit transfer, ecosystem accounting, natural capital accounting

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1. Introduction

Ecosystem Accounting (EA) is a framework for integrating ecosystems with the System of N~~n~~ational A~~a~~ccounts~~ing and reporting systems~~. The first version of this framework, as official methodological guidelines for member states, has been standardized in the System of Environmental-Economic Accounting (SEEA), which has been proposed and supported by the United Nations (UN) since 1993 (UN, 1993). The SEEA Ecosystem Accounting (SEEA EA) chapters 1-7 on biophysical accounts were adopted as a statistical standard by the UN Statistical Commission in March 2021 (UN, 2021; UNCEEA, 2021). The long-term aim of the SEEA EA is to integrate physical and monetary measures of ~~ecosystems and~~ ecosystem services (ES) and ecosystem assets by developing ecosystem accounts consistent with the System of National Accounts (SNA), using the same accounting principles. This implies that monetary valuation of ES and ecosystem assets using exchange values are required (Obst et al. 2016, UN, 2021). In this paper, we argue that the Value Transfer method (VT) (also known as benefit transfer) can~~is promising for~~ facilitat~~eing~~ and accelerat~~eing~~ empirical applications of monetary valuation of~~in~~ ES for national accounts. ~~, especially at the national scale.~~

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SEEA EA Chapters 8-11 on valuation and accounting treatments were recognized by the UN Statistical Division as describing "internationally recognized statistical principles and recommendations for the valuation of ecosystem services and assets in a context that is coherent with the concepts of System of National Accounts" (UN, 2021). The UN Statistical Commission called for promptly resolving the outstanding methodological aspects of Chapters 8-11 identified in the SEEA EA research agenda (UNCEEA, 2021). The agenda calls for testing and development of several VT issues as discussed in this paper, i.e., "~~"~~application of value transfer techniques for accounting purposes, in particular considering alignment with exchange value concepts, consistency with data collected in physical terms on extent, condition and service flows and advancement of the potential of value generalization techniques”~~.~~ (UN 2021, p.351). Value transfer guidance is briefly provided in the SEEA EA (section 9.5) and identified as a research and development need (UN, 2021). The use of value transfer in ecosystem accounts is also referred to as “value generalization” (NCAVES and MAIA, 2022).

The global consultation of the SEEA EA provided further detailed comments by countries, National Statistical Offices (NSO) and international institutions regarding the barriers to applying monetary valuation methods, which also concern VT. These comments addressed concerns such as: implementation barriers relating to VT; the complexity of valuation model assumptions adapted for accounting purposes; the institutional and market feasibility assumptions required in the transfer of exchange values; limitations on value estimates which were designed for other purposes and then transferred for~~to~~ the purpose of national accounts; requirements for reliability of estimates and documentation of uncertainty; documentation with respect to compatibility of primary studies used in meta-analysis used for VT; and lack of guidance on methods to generalize values (UN, 2020).

Summarizing these comments, EA practitioners are faced with three general areas of concern in applying monetary valuation methods: (1) the lack of financial resources and expertise to evaluate in physical and in monetary terms the ES included in the accounts, (2) the lack of consistent and clear guidelines that facilitate the process of account compilation, in particular regarding monetary valuation methods (i.e., which method to be used, how and when), and (3) the challenge of producing sufficiently reliable and consistent periodic updates of the monetary accounts.

In this paper, we argue that VT methods may facilitate EA practitioners' work to address these ~~above-mentioned~~ concerns and thereby enrich EA practice. VT approaches may provide a suitable means to obtain the value information required for EA, particularly in cases where time and financial resources are limited, as they are~~it is~~ cost-effective and well tested in the context of policy and project appraisal (Johnston et al. 2021). While the practice of extrapolating~~transferring~~ values from sample of~~one~~ sites to an accounting areas~~another~~ has ~~been~~ already been used in EA applications (e.g., in Vysna et al. 2021; La Notte et al. 2012; Gundimeda 2012, 2006; Remme et al. 2018; Sumarga et al., 2015), it is rarely acknowledged as such, and is typically done on a case-by-case and ad hoc basis. Moreover, physical ecosystem service supply mapping for physical supply-use accounts is a form of value generalization using a model often calibrated on a sample of sites in the accounting area (United Nations 2022). Providing guidance for and recognizing the use of VT—grounded in prior work and guidelines from the benefit transfer literature (Johnston et al. 2021)—would help promote consistency and rigor across EA applications and facilitate greater uptake of VT in EA. The substantive knowledge developed over the past 30 years of applied VT research, summarized~~summarised~~ in Richardson et al. (2015), Johnston et al. (2018, 2021), and Johnston and Rosenberger (2010), among others, provides a solid starting point for such guidance. In concept, the general mechanisms for VT apply similarly to many types of economic value information—including exchange values typically considered within EA. VT application in EA can be developed in a way that enables consistent and periodic updates of monetary accounts ~~with relatively low resource demands~~. At the same time, it is important to recognize that VT has typically been applied in other contexts than EA (e.g., to transfer information on welfare values rather than exchange values). Hence, VT practice and guidance may require adaptation to the EA context, for example to accommodate any distinct challenges that might emerge when seeking to transfer exchange values.

A number of guidelines for conducting value transfers for environmental economic applications and project appraisal already exist. Richardson et al. (2015) focus on guidelines for transferring welfare estimates of ES and Johnston et al. (2021) provide guidelines for VT in general (and for assessing the validity and credibility of transfers), whereas~~and~~ Johnston and Bauer (2019) provide guidance on transferring ES values for large-scale applications.[1] Although many of these guidelines apply to EA applications, they are not specific to EA, and these publications are largely silent on what adaptations to VT methods might be required for EA applications.

~~[1] As illustrated by Johnston and Bauer (2019), "large-scale" applications can involve transfers of value (a) related to environmental conditions or changes occur over large geospatial areas and/or (b) that predict values realized by people over large geospatial areas, or large "extent of the market". Both (a) and (b) can involve one continuous geospatial area (e.g., one state in a country) or multiple distinct areas combined (e.g., multiple states or countries, not necessarily contiguous).~~

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Grounded in this prior work, our objective is to explore two main questions: How might VT be relevant for EA applications, and how can VT methods respond to the concerns raised by account compilers? By opening this discussion, we aim to stimulate further research into the potential use of VT in EA. We also hope to flag the need for context-specific guidelines that could facilitate further implementation of EA. We believe that bringing together the national accounting and environmental economics communities can help to operationalize VT research and methods for accounting purposes and can thereby potentially enrich both EA and VT research.

The remainder of the paper is structured as follows; section 2 depicts an overview of the VT method and discusses *why* the VT method fits with the EA scope, section 3 outlines *how* VT corresponds to several EA areas of concern. Section 4 discusses the current methodological challenges of the VT method. The last section presents some concluding remarks.

2. How Value Transfer works and why it fits to Ecosystem Accounting scope

2.1 An overview of the method

VT approaches use research results from pre-existing monetary valuation studies at one or more sites or policy contexts to predict value estimates or other related economic information for other sites or policy contexts that are not yet studied but share similar biophysical and socioeconomic conditions. TTo this end, two main approaches have commonly been used with two common variations within each (in Johnston et al., 2015):

1. Unit value transfer:

    1.1. Simple, single unadjusted value transfer.

    1.2. Adjusted unit value transfer, in order to account for factors such as currency or income differences between sites.

2. Value function transfer:

    2.1 Single-site or single-study benefit function transfer, which employs an estimated function from a single primary study, with data often but not always drawn from one study site.[2] [2]

[2] As discussed by Johnston et al. (2021), similar functions can also be derived by individual studies that collect and pool data from multiple sites to estimate a single benefit function. An example is the use of data collected from recreational choices over multiple sites to estimate a single random utility model (RUM) of recreation demand, which can then be used to produce estimates of WTP.

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2.2 V~~Meta-analysis v~~alue transfer using data-synthesis methods such as meta-analysis, which combine~~synthesizes~~ information from multiple~~a set of~~ prior studies across different sites to produce broadly applicable "umbrella" benefit functions.[3] ~~[3]~~

Unit value transfer has been applied in multiple contexts, including a global valuation of ecosystem services (Costanza et al. 1997, 2014) and national valuations of the contribution of natural ecosystem capital to the economy (Kubiszewski et al. 2013, Frélichová et al. 2014, Ferrini et al. 2014 and 2015~~.~~, Niquisse and Cabral 2017). Because transfers of this type allow few (and generally simple) adjustments to the transferred values, they "are usually chosen only when there is insufficient data to support other approaches for the given policy-site application" (Johnston et al. 2021). Although some global and national transfers of this type have been criticized for violating core principles of economic theory for welfare analysis and *benefit* transfer (Bockstael et al. 2010; Johnston and Wainger 2015; Johnston et al. 2021)[4] ~~[4]~~, some (although perhaps not all) of these critiques might be less relevant when considering exchange values of the type considered within accounting.

Meta-analysis VT has been applied for assessments of ES provided by many natural systems such as wetlands (e.g. Ghermandi et al. 2010, Poudel et al. 2020, Vedogbeton and Johnston 2020), forests (e.g. Chiabai et al. 2011; Grammatikopoulou and Vačkářová, 2021), mangroves (e,g, Brander et al. 2012) and lakes (Reynaud and Lanzanova 2017), as well as many other types of ES and environmental changes. Schmidt et al. (2016) developed meta-analysis value transfer functions for 12 ES based on 194 case studies using 839 monetary ES values. It has also been applied extensively to values for environmental changes such as water quality improvements (Johnston et al. 2017, 2019; Newbold et al. 2018; Moeltner 2019).

VT research has demonstrated that quality control and best practices are~~is~~ important~~necessary~~ for valid and reliable[5] ~~[5]~~ value transfers (Richardson et al., 2015; Johnston et al. 2021)~~.~~. Benefit transfer accuracy reflects both of these concepts (Rosenberger 2015). Within the context of VT, validity implies that value estimates or other transferred quantities are unbiased. This is usually interpreted as a lack of statistically significant generalization (or transfer) error. Reliability concerns the

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[3] ~~As described by Johnston et al. (2021), benefit functions also be derived using structural models, grounded in economic theory, that use data from multiple prior valuation studies to calibrate preference parameters (Smith et al. 2002, 2006; Smith and Pattanayak 2002; Van Houtven et al. 2011; Phaneuf and Van Houtven 2015). In concept, approaches of this type could be adapted for the transfer of exchange rather than welfare values. However, the primary advantage of these methods emphasized in prior work is the transfer of neoclassical welfare measures with desired theoretical properties. Parallel advantages could possibly apply to exchange values, but to our knowledge have not yet been demonstrated for applications of this type. Hence, we leave the possible exploration of structural exchange value transfers for future work.~~

[4] ~~For example, see the discussion of benefit scaling in Johnston et al. (2021), applicable to such large-scale applications.~~

[5] ~~Both validity and reliability are important features of VT quality control. Validity implies that value estimates or other transferred quantities are statistically identical across study and policy contexts (i.e., there is no statistically significant transfer error). Reliability is measured as average generalization error—or the (mean) difference between a primary study value and a value produced via benefit transfer.~~

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variance of the benefit-transfer prediction, often measured as average generalization error: the (mean) difference between a primary study value and a value produced via benefit transfer. It is generally expected that benefit transfers will be more accurate, on average, when the policy and original study areas are where a key issue is that the policy and original study areas should moregenerally be similar, in terms of ES benefits, size, policy context and populations (Carolus et al. 2020). However, the degree to which similarity is required for accurate transfers depends on the transfer method applied—as some methods (e.g., meta-analysis) have greater capacity to adjust for contextual differences than other methods (e.g., unadjusted unit value transfer) (Johnston et al. 2021). The literature provides many examples of transfers implemented over sites with relatively large differences in site characteristics (e.g., different European countries, Czajkowski et al. 2017). Moreover, even unit-value transfers can incorporate some types of adjustments that, ideally, improve accuracy. For example, La Notte et al. (2021) tested the unit transfer value for habitat and species maintenance estimates in Europe and they enhanced the simple unit transfer value with a sophisticated statistical analysis of biophysical and socio-economic comparability of policy sites and study sites.

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Reviews of VT studies tend to suggest that value function transfers are less problematic and more accurate than unit transfers, in general, where policy sites differ from study sites to a large degree—although this finding does not apply universally to all possible applications (Rosenberger and Stanley 2006; Bateman et al. 2011; Ferrini et al., 2014, Rosenberger 2015; Johnston et al., 2021). Hence, as noted by Johnston et al. (2021), the degree to which high degrees of similarity are required must be considered in context. Points of attention include the type of ecosystem service benefit valued and the availability of substitutes, the scope or size of the study and policy sites or the ecosystem service that is valued, the (ecological, social, economic, and political) context of the ecosystem service, and how these issues are expected to affect the exchange value in question. Recent developments in academic practice such as open access publishing, regularly updated valuation databases and improvements in AI-based analysis may facilitate new VT research and increase its cost-effectiveness—for example by reducing the difficulty of compiling research metadata.

There is an important difference in purpose and scale between welfare valuation studies often used as inputs in VT studies and EA applications where only exchange valuemarket measures (e.g. marketexchange prices) are compatible with national accountsapplicable. Welfare valuation often includes willingness to pay (WTP) and willingness to accept (WTA) measures that reflect underlying theoretical constructs such as obtained as consumer surplus or compensating or /equivalent variation, or related measures such as consumer surplus. Only exchange values can be used for SEEA EA accounts that aim to be compatible with other economic data from SNA (Obst et al., 2016; UN, 2021a). Moreover, most EA applications require values that are used for large accounting areas, covering a whole country in case of national accounts, although the majority of examples in the research literature reflect local or regional examples[6].[6] Illustrative examples of national-scale VT applications are provided by Ferrini et al. (2015), as related to the UK National Ecosystem Assessment, and Wheeler (2015), for US water quality benefits. However, most VT research is predominantly focused on WTP changes evaluated over smaller sub-national scales, and applied to used for ex-ante project evaluation purposes. Nonetheless, there is no reason in principle why the VT method cannot produce transferrable exchange values for large spatial areas and ex-post assessment.

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2.2 Policy context of Ecosystem Accounting and the contribution of Value Transfer

EA is likely to become a key area of work for National Statistical Offices (NSOs) worldwide, yet there is limited capacity to satisfy the rising policy demands. EA is built on a strong framework and its implementation will support the control and reporting activity for several global environmental and sustainability initiatives (UN, 2021). EA is expected to support climate mitigation and adaptation, as well as biodiversity conservation and other related policy objectives.

At the moment, the policy pull for EA implementation is the strongest in the EU, where the European Commission (Eurostat) is developing an amendment to Regulation 691/2011 on European environmental economic accounts to include three new modules of environmental accounts, one of them being ecosystem accounts. This would make regular reporting of EA mandatory for EU Member States. The most recent amendment proposal only requires reporting of physical ecosystem accounts (EC 2022). The amendment requires EUROSTAT tocarry out a methodological and feasibility study on the monetary valuation of ecosystem services before further reporting of monetary values is included in the Regulation. In futureTo this end, If adopted, countries and NSOs maywill have to use quick, standardized, and easy-to-use methods, as implementing new valuation work for each individual country and accounting period is likely to become financially and practically unfeasible because of capacity and resource gaps at the NSOs and individual countries. EA will be required at national level and compiled as a periodic exercise looking at large values by National Statistical Officesinstitutions with a permanent mandate and budgets to generate new and collect existing datasets. We argue that VT can contribute to fill resource gaps in the interim until monetary valuation of ES becomes a part of regular national statistics production (p.120, NCAVES and MAIA 2022). It can be an and become an important valuation tool for early operationalizing monetary ecosystem accountsEA. VT can provide a cost-effective, transparent framework that could allow periodic and consistent updates of monetary EA, while also allowing for stepwise updating of valuation estimates to improve precision, as available data and capacity increase. Similar arguments for the use of VT have been madewere followed by the US Environmental Protection Agency (EPA) when considering measurement ofto assess the ecological benefits of proposed federal rules, which must be accompanied by a formal Benefit-

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[6] Illustrative examples of national-scale VT applications are provided by Ferrini et al. (2015), as related to the UK National Ecosystem Assessment. Examples of VT applications for nationwide assessment of US water quality benefits are provided in Wheeler (2015).

Cost Analysis (BCA) (Iovanna and Griffiths 2006 in Richardson et al., 2015; Newbold et al., 2018; Wheeler, 2015). US EPA commonly relies on value transfers (e.g., for estimating the nonmarket benefits of water quality improvements and supporting BCA) for purposes of regulatory analysis (WheelerUS EPA, 2015).

At the moment, the policy pull for EA implementation is the strongest in the EU. As of July 2022, the European Commission has adopted the technical proposal to amend the Regulation 691/2011 on European environmental economic accounts to include three new modules of environmental accounts, one of them being ecosystem accounts. This would make regular reporting of EA mandatory for EU Member States. The proposed amendment under negotiation suggests that the Commission would need to carry out a methodological and feasibility study on the monetary valuation of ecosystem services before further reporting of monetary values is included in the Regulation. When the proposal is adopted by the Parliament and the Council, countries and NSOs may have to use quick, standardized, and easy-to-use methods, as implementing new valuation work for each individual country and accounting period is likely to become financially and practically unfeasible because of capacity and resource gaps at the NSOs and individual countries. EA will be required at national level and compiled as a periodic exercise with a permanent mandate and budgets to generate new and collect existing datasets.

Moreover, the White House Office of Science and Technology Policy (OSTP) in August 2022 released a national strategy report to develop statistics for environmental economics decisions. The reports highlight the aim to incorporate nature into national economic accounts through the development of natural capital accounts (Link 1). As in EU context, this development will require a regular implementation of EA.

The report of the plenary of Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) flags the inability of valuation studies to reach out to policy processes and call for co-production of valuation knowledge, proper guidance and standardization of valuation methods. This standardization is what national EA initiatives require (IPBS, 2022, pp6 and pp18) and what SEEA EA framework aims to cover.

VT lies very much within the scope of the aforementioned policy objectives. In this paper, we argue that VT can contribute to fill resource gaps in the interim until monetary valuation of ES becomes part of the regular national statistics reporting (NCAVES and MAIA 2022, p.120) and can be an important valuation tool for early operationalizing early monetary ecosystem accounts. VT can provide a cost-effective, transparent framework that could allow periodic and consistent updates, while also allowing for stepwise updating of valuation estimates to improve precision, as available data and capacity increase. Similar arguments for the use of VT have been made by the US Environmental Protection Agency (EPA) when considering measurement of the ecological benefits of proposed federal rules, which must be accompanied by a formal Benefit-Cost Analysis (BCA) (Iovanna and Griffiths 2006 in Richardson et al., 2015; Newbold et al., 2018; Wheeler, 2015). US EPA commonly relies on value transfers (e.g., for estimating the nonmarket benefits of water quality improvements and supporting BCA) for purposes of regulatory analysis (Wheeler, 2015). Globally, VT can offer standardized and low-cost means of predicting values for EA applications in both developed and developing countries, contingent upon a suitable body of primary studies from which to draw VT estimates.

3 How can Value Transfer support implementation of Ecosystem Accounting

EA applications demand clear and consistent guidelines to ensure validity, reliability and comparability across space and time, yet existing guidelines are still experimental, providing limited advice on which method should be used for given ES. EA applications are also still in an exploratory phase and there are only a few best practice examples to be shared among countries (Hein et al. 2020; Vallecillo et al., 2018; 2019, La Notte et al., 2021)). Structured and consistent monetary accounts remain a challenge for practitioners. .

Below we discuss how VT addresses the three major areas of practitioners' concern related to the production ofwhere it comes to producing monetary ecosystem accounts: lack of capacity, need for clear guidelines and need for systematic/ periodic accounts within limited resources available.

3.1. A capacity-tailored method

Accounting practitioners requireneed methods and approaches that are compatible with available human and financial resources (including expertise) at the NSO. VT can accommodate both simple and more complex modelling approaches, providing flexibility to EA implementation subject to reliability requirements and available capacity. Building capacity in VT skills and applying VT can beis often significantly less demanding than for primary valuation approaches, which require more specific expertise[7].[7] Note, however, that some VT methods require considerable expertise. For example, development and estimation of a new meta-regression analysis requires considerable

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[7] Note, however, that some types of VT methods require considerable expertise. For example, development and estimation of a new meta-regression analysis for economic values requires considerable expertise to compile metadata, estimate statistical models, etc. However, once a meta-regression model has been estimated, the subsequent *use* of the model for VT applications is fairly standardized and requires less expertise. Examples are provided in Johnston and Wainger (2015) and Johnston and Bauer (2019).

expertise to compile metadata and estimate statistical models. However, once a meta-regression model has been estimated, the subsequent use of the model for VT applications requires less specialized expertise. Examples are provided in Johnston and Wainger (2015) and Johnston and Bauer (2019).

Data for application of VT for EA purposes can be compiled and made available~~ with relatively little effort~~. While NSOs are aware of relevant data sources for the SNA and the biophysical accounts of the SEEA EA, this is not the case for the monetary accounts. However, open access datasets that report economic values of ES for various ecosystems, which were used for VT applications, are already available. The most widely used databases include the Ecosystem Service Valuation Database (ESVD) (de Groot et al., 2012) and the Environmental Valuation Reference Inventory (EVRI) database. Screening these valuation databases for exchange value (e.g. replacement costs or production function estimates) compatible estimates would be a starting point for VT EA applications.

Several VT approaches are available for EA and their validity and reliability is largely context dependent - for example depending on factors such as the type of values to be estimated, the supporting body of valuation information, and site characteristics (Johnston et al. 2021). Hence, it is not possible to derive a fixed, one-to-one match between specific EA needs and the type of transfers that can be applied. For EA, the context is driven by the spatial unit of the biophysical accounts and in VT ~~the ~~key elements to consider include~~is~~ the scale of the monetary analysis (e.g., local vs national), and the characteristics of the ecosystem services (La Notte et al., 2019). The selection of VT approach depends on the level of accuracy require~~me~~d~~nt~~ (i.e., validity and reliability) (Zulian et al., 2018), following a tiered approach (Brander et al., 2018). VT offers flexibility in this respect. Furthermore, different VT approaches may be considered appropriate for different types of values for theoretical or conceptual reasons, as demonstrated in VT applications in other areas of public policy. For example, unit value transfers are standard practice for estimating the value of statistical life (VSL) (Johnston and Rosenberger 2010; Lindhjem and Navrud 2015). Another example is the use of meta-analysis approach in cases where selection of the studies used for VT may~~is expected to~~ be biased[8], as it can provide a~~the~~ means to evaluate and correct the systematic effects of these selection biases (Rosenberger and Johnston 2009). When one selects primary studies for VT, implicit assumptions are typically made that the underlying body of literature provides an unbiased sample of the population of empirical estimates (i.e., no selection biases) and that these estimates provide an unbiased representation of true values (i.e.,

[8] ~~On average, VT is expected to be no more accurate than the underlying sample of study-site data that supports it, or to the extent that any underlying biases can be corrected during the transfer process (Johnston et al. 2015). However, it is important to recognize that "the relationship between the original accuracy of study-site value estimates and the accuracy of value transfers is neither monotonic nor straightforward" (Johnston et al. 2021). When one selects primary studies for VT, implicit assumptions are typically made that the underlying body of literature provides an unbiased sample of the population of empirical estimates (i.e., no selection biases) and that these estimates provide an unbiased representation of true values (i.e., no measurement error). If these assumptions do not hold, the result will be systematic biases in the resulting value transfers (Hoehn 2006; Rosenberger and Johnston 2009).~~

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no measurement error). If these assumptions do not hold, the result will be systematic biases in the resulting value transfers (Hoehn 2006; Rosenberger and Johnston 2009). E~~These e~~xamples such as these suggest that ~~it should be decided on a case-by-case basis which~~ VT approaches should be determined on a case-by-case basis ~~is most suitable, as recommended more generally by (~~Johnston et al. ~~(~~2021). No single VT approach is superior for all possible applications and contexts.

Table 1 presents an overview of the primary VT ~~each~~ approaches with respect to a set of selected operational features that are important for EA. Some features such as the budget may drive choices of statistical institutes to invest in VT. The possibility to compare areas and adjust for spatially explicit factors is key to the use of valuation in accounting. EA requires systematic compilation over time and thus needs to provide updated estimates. The last feature is related to the requirement for models that are amen~~d~~able to the automated production of accounts.

Table 1: Selection criteria

Operational features	Relevance for EA	Unit value transfer	Single- study f~~F~~unction transfer	Meta-analysis transfer
Resources (e.g. budget and time)	Relevant	Low requirement in resources	Low requirement in resources	High requirement in case of estimating a new meta-analysis; Low in case of applying a pre-existing meta-analysis
Similarity between study and policy area especially in the ES features	Relevant	Is required	Partly required	Partly required, but less so than other types of VT
Coherence with spatial factors/features	Very relevant	Not possible	Possible	Possible
Periodic updating	Very relevant	Possible	Possible	Possible
Automation	Relevant	Not possible	Possible	Possible

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3.2. A well-studied method with clear and available guidelines

Methods for VT have been continually improved and validated over 30 years of applied research and methodological developments. Johnston and Rosenberger (2010) and Johnston et al. (2018) describe the historical developments of the method and provide a thorough discussion of key methodological challenges. Johnston et al. (2015) provide a comprehensive overview of methods. Richardson et al. (2015), Ferrini et al. (2015) and Johnston and Wainger (2015) discuss the role of benefit transfer in ES valuation. The authors provide examples of applications to show which values for ES and ecosystem changes were estimated using transfers. The work by Johnston et al. (2017 and 2018) refers to spatial considerations in transfer applications. Guidelines on applications, validity and credibility are provided in Johnston et al. (2021).

3.2.1 Towards standardizing the process of the selection of studies and database structure

The selection of primary studies for VT determines the validity and reliability of any VT application (Johnston et al. 2021) and in particular of a meta-analysis transfer. The increasing number of primary valuation studies in the literature (and the progression of study methods over time) provides a solid foundation for VT EA applications, particularly in certain areas where many primary studies have been conducted. Their selection is most transparent when using a systematic review approach, i.e., a stepwise methodology that aims to collect, assess and synthesize existing research data based on a priori eligibility criteria and a priori methodological protocol (Richardson et al. 2015). Guidelines and procedures for literature reviews of this type in economics are provided by Stanley et al. (2013) and Johnston et al. (2021). For the time being, there is no available literature review protocol for developing VT valuations to produce monetary EA (Vačkářů and Grammatikopoulou, 2018) but we can anticipate that, besides the review protocol, a structured reporting withinof primary studies can help is the effective way to reduce transfer errors, by providing more complete information to support data synthesis (Plummer 2009 in Richardson 2015; Loomis and Rosenberger 2006). As noted in past applications of valuation meta-analysis (e.g., Brander et al., 2007; Lara-Pulido et al., 2018), there is a great variation in the way values are reported in primary studies. Johnston et al. (2005, 2017) discuss how different water quality monetary measures reported in primary study can be reconciled for VT approaches. After primary study screening and selection, a database of selected studies must be developed (i.e., key features of each of the study to be used in VT are recorded). A typical dataset will include the monetary estimates, the ES type and characteristics, the size or scope of the ES or environmental change that was valued by the study, the geospatial extent of the area over which the change occurred, the primary beneficiaries (e.g. residents or tourists) and extent of the market over which values were measured, the local economic features (e.g. GDP) and ideally the geographical features of the area (i.e. availability of substitute), and other variables that are expected to influence values (e.g., availability of substitutes). The complexity of the database will vary with the VT techniques used. This step is often emphasized for meta-analysis where multiple studies need to be included and further elaborated with statistical analysis (e.g. Brander et al 2007).

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Ideally, the database compilation to support VT should follow a structured process to homogenize the information that is extracted from each study, something that will remain necessary as long as studies do not follow a standard reporting protocol. Current open-source databases (e.g., ESVD) and empirical application studies (e.g., Grammatikopoulou and Vačkářová, 2021) outline a possible way for structuring such databases. Johnston et al. (2021) provide guidelines for data adjustments to harmonize information across studies. This is a time-consuming process and requires expertise. Although existing valuation databases provide a good starting point for VT, the information in these databases is rarely sufficient to support all the information needs of a VT (Johnston et al. 2015).

A distinct requirement for VT EA applications is to identify (e.g., in the study database) whether a study estimates exchange orand welfare values (or both). This is in part determined by the valuation method used in each study, a study characteristic that is usually recorded in existing databases. For example, 3821 out of 4768 value estimates in the ESVD database are produced using methods directly compatible with the SEEA EA guidelines, i.e. market-based, cost-based and revealed preference methods (e.g. travel cost). However, further revisions to the original study data and estimates may be required to produce suitable exchange valuesin some cases. For example, travel cost data can be used to estimate welfare values but can also contain travel expense data which is required to derive exchange values.

3.2.2 Literature evidence on accuracy and transfer errors

Evaluations of VT validity and reliability require an understanding of the errors that are expected from VT—ideally as a function of VT method, ES type, ecosystem extent and conditions and other potentially relevant factors. As described by Johnston et al. (2021), "a transfer is typically considered valid if it provides a statistically unbiased estimate of the true value at the policy site. Reliable transfers, in contrast, are associated with lower transfer errors or variances (Bishop and Boyle 2019; Rosenberger 2015). Both are elements of the accuracy of transfer estimates." In theory, VTs can be subject to measurement errors and generalization errors. Measurement errors are errors that arise in VT due to underlying errors in the original study site value information (Rosenberger and Stanley 2006). In practice, VT accuracy is typically characterized by assessing the transfer or generalization error, using convergent validity tests that quantify the difference between transferred empirical estimates (secondary estimates) and primary-study estimates of the same value (Rosenberger and Stanley 2006; Johnston and Rosenberger 2010; Johnston et al. 2015)[9] .[9] It is assumed that the primary valuation at a policy site provides an unbiased estimate, or that biased studies have been eliminated by quality control during the selection of studies for transfer (Johnston et al. 2015, 2021). Of course, evaluations of this type can only be conducted for

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[9] Of course, evaluations of this type can only be conducted for cases where a primary study has *already been conducted* for the policy site, so that a primary-study estimate of value is available. VT is generally required only when suitable primary-study estimates are *not available* to measure the value of interest. Hence, for actual VT applications, the transfer error is almost always unknown.

cases where a primary study has already been conducted for the policy site, so that a primary-study estimate of value is available. VT is generally required only when suitable primary-study estimates are not available to measure the value of interest. Hence, for actual VT applications, the transfer error is almost always unknown.

ForIn the case of an EA applications, an ideal benchmark primary valuation study with which to assess value transfer accuracy would typically be a high-quality study overwith a representative sample of the national population (or with statistical adjustments to obtain representative estimates), following all best practices assumed to promote unbiased value estimation. — this should be the long-term aim of monetary valuation conducted for the purpose of EA. Over the long run, VT measurement errors for EA applications can be reduced by increasing the validity and reliability of primary valuation studies in the literature that can support theseprovide the source data for transfers. However, bBecause our paper objective is on the use of VT for EA, in what follows we also focus primarily on accuracy and errors related directly to the VT process—not those inherent in the original primary study estimates.

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The VT literature has summarised evidence on the size of transfer errors across multiple applications, from which generalizable conclusions may be drawn about the type of errors that might be expected across different contexts (Brouwer and Spaninks 1999; Rosenberger and Stanley 2006; Rosenberger and Johnston 2009; Kaul et al. 2013; Ferrini et al 2014, Rosenberger 2015). For example, Rosenberger (2015) reports median transfer errors of 36% for value function transfers and 45% for unit VT (means are 65% and 140%, respectively). Although one might argue that these measures of central tendency are within the error tolerances of at least some applications, of potentially greater concern is the variance of these error estimates across studies, and the extent to which these errors vary systematically across different types of transfer methods and applications. However, it should be emphasized that these estimates are typically drawn from transfers of welfare rather than exchange values—hence their applicability to exchange values is currently unknown.

Because theBecause of the need for accuracy and validity varies across applications, there is no universal test or maximum error that dictates the acceptability of VT (Johnston et al. 202115). The accuracy of most estimates used today for national accounting cannot be quantified (IMF 2001). However, it is generally accepted that many of these accounting measures are inaccurate. As noted by Barton et al. (2019, p. 69), "GDP revisions can be quite large (e.g., Ghana 60%, China 15%, Netherlands 7%)," implying errors of similar magnitudes (at a minimum) in the initial estimates. Errors of this level thus fall within the degree of VT errors commonly observed in the literature.

The accuracy requirement for VT applied to EA may initially be similar to, or lower than, known uncertainty in GDP estimates. However, the purposes of EA require accuracy that is sufficient for trend detection in physical ecosystem service supply-use tables. SEEA EA is silent on whether trend detection of monetary ES value is required, but if so, the accuracy requirements for value transfer will be higher than what is expected from GDP measures.

3.2.3 Accommodating spatial heterogeneity

Values of ES can vary substantially across space, depending on the ecological and socio-economic context in given locations (Ferrini et al. 2015; Johnston and Wainger 2015; Glenk et al. 2020). This variation is inevitable, but VT provides various approaches~~a meanss~~ to adjust transferred values for these contextual differences (e.g., Bateman et al. 2011; Ferrini et al. 2015; Johnston et al., 2017, 2019~~and Wainger 2015~~). In the same way that spatial heterogeneity in primary values requires attention in VT applications, EA requires attention to~~needs to consider~~ spatial dimensions~~variation~~ when creating aggregated ecosystem accounts (Addicott and Fenichel, 2019). In terms of biophysical accounts, joint effects of the extent (size) and condition (state) of individual ecosystems differ across space, which in turn leads to variability and spatial heterogeneity in ecosystem functions and ecosystems' potential to supply services (ecosystem service supply), independent of the beneficiaries from these services (ecosystem service demand). The spatial configuration of beneficiaries relative to ecosystems then (often) determines whether potential supply turns into an actual flow of ES (Olander et al. 2018). In terms of the monetary valuation related to ES, other spatial factors are also relevant (Schaafsma 2015, Glenk et al. 2020). For example, the values related to ES tend to decrease with increasing distance between beneficiaries and the provided services, an effect known as distance decay (Sutherland and Walsh 1985; Hanley et al. 2003; Bateman et al. 2006). Furthermore, availability and proximity of substitutes and complements to a given environmental good or service is also likely to affect its economic value, among many other factors that can vary over space (see Glenk et al. 2020; De Valck and Rolfe 2018). Finally, the economic value of ES is likely to be influenced by the size and characteristics of the population of beneficiaries: for example ecosystems in densely populated areas often (but not always) generate higher values than in remote, sparsely populated areas (Brander et al. 2012). This is because there are a greater number of potential beneficiaries in close proximity to the services that are provided. Cultural factors, social norms and actual and perceived rights to ecosystem services in the local context where primary studies are conducted~~,~~ might also influence ~~the~~ estimated values (e.g., Barton et al. 2019; Dallimer et al. 2014; Rogers and Burton 2017; Bakhtiari et al. 2018, Badura et al. 2019).

R~~Several r~~ecent VT studies have addressed m~~s~~ome of these spatial aspects directly, although this is an area of ongoing work. Brander et al. (2012), for example, account for ecosystem availability (to capture substitution effects) and population density (to account for market differences). Similar to Bateman et al. (2011), Johnston et al. (2019) show that including distance decay in a VT can decrease the transfer error in VT applications. Interestingly, the proposed methodology in Johnston et al. (2019) does not require primary studies to provide spatial data – it uses external data sources and GIS to estimate average distances between sample populations and environmental changes in individual primary valuation studies, and then incorporates this information into the meta-analytic

VT function. Although the possibility of~~to~~ complementing primary valuation studies with external spatial data (e.g., GIS data)~~GIS~~ represents a great opportunity to foster the application of VT, it also raises the need to have trained researchers to conduct EA. An increasing number of valuation studies model spatial dimensions of environmental and ES values, including the effects of substitutes (that vary over space), distance and geopolitical boundary effects, in both design and analysis (e.g., De Valck et al. 2017; Logar and Brouwer 2018; Schaafsma et al. 2012, 2013; Schaafsma and Brouwer 2019, Badura et al. 2019). While most of these studies are stated preference approaches which are not eligible for SEEA EA, Caparros et al (2017) ~~proposed the~~ simulate ~~accounting compatibled~~ exchange value (SEV) ~~s~~ by combining data on recreation demand from a~~as an approach to derive exchange prices~~ ~~from~~ stated~~revealed~~ preference valuation with~~studies~~ a cost function for recreation supply. The SEV method~~This~~ can ~~potentially~~ extend the number of compatible monetary approaches for EA, although applications of the simulated exchange value thus far have been~~remain~~ limited to recreational services ~~and a limited number of sites~~ (Grilli et al 2021) and a limited number of sites.

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The growing availability of geo-referenced information and big data analytics provide an ideal setting to develop spatially explicit VT approaches~~strategies~~ for EA. Existing global tools for spatial ecosystem mapping and accounting (e.g., INVEST, ARIES) mention VT, but do not yet include fully operational valuation modules for all services (and are not designed for EA). Although key spatial information is already collected and standardized in tools such as these, deploying VT for accounting remains the crucial step to support EA practitioners. Moreover, some of the underlying value-prediction techniques in tools such as INVEST and ARIES do not comply with best-practice standards for VT such as those outlined in Johnston et al. (2021). Hence, before applying such tools for EA, it is important to consider the properties of the underlying VT techniques that are used to predict ES values.

3.3 A replicable method that can facilitate periodic accounts

Accounts must be compiled with a certain periodicity to ensure a regular presentation of EA data to decision makers. This periodicity in the SNA is the accounting period. In EA, the use of an annual frequency may not be ideal, considering for example large scale changes in ecosystems that can only be tracked over long periods (e.g., three or five years). The periodicity of updating biophysical and monetary metrics should depend on the speed of change in ecosystem extent, condition and ecosystem service supply (assuming the purpose of trend detection). Slow change may require less frequent updating. The need for periodic estimations in all types of accounts and all terms of assessment increases the necessity for regularly updated information inputs. If new data (for both the monetary and physical accounts) cannot be collected every accounting period, modelling (for the physical accounts) and VT (for the monetary accounts) ~~may~~ provide useful alternatives (UN, 2015) .

4 Methodological challenges

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As reviewed above, VT methods offer a promising means to advance EA applications. Nonetheless, certain VT methodological challenges relevant to EA applications remain to be addressed.

First, there is a need for standardized design and reporting in primary valuation studies for VT and accounting purposes[10]. The intrinsic characteristic of EA requires a structure, accounting mechanisms and rules that are consistent through space and time. In the case of ES accounts (which is the only module in EA that requires monetary valuation), the Supply and Use Tables are framed across a specific structure of Ecosystem Types (on the supply side) of Economic Units (on the use side) and throughout a list of service flows. A clear identification of all these components requires a reporting protocol for primary studies to facilitate the provision of reliable input data for EA. Important information would include sensitivity (i.e., parameterization where possible) of values to ecosystem extent, condition and relevant spatial variables, population characteristics and institutional contexts, as well as standardization in units of measurement. To this end, it may be necessary for primary study reporting and databases to be updated in line with the EA classifications, i.e. type of ecosystem assets, type of ES by CICES, harmonization of units of measurement etc.

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Database and model application updates during the periodic processes of EA can help accommodate changes in values that can occur over time. These temporal changes, if unaccommodated, can lead to reduced VT accuracy (Johnston et al., 2018). Regardless of the approach of the type of VT applied, it is also crucial that original primary study estimates represent valid measures of economic value and that these valid measures can be updated as needed over time. A literature review protocol that describes a clear and consistent structure of the review process would help to ensure replicability (Haddaway et al. 2015).

A further discussion is required regarding the acceptable level of transfer error for EA. It speaks in favor of VT that many of the transfer accuracy levels found in the literature are in the same order of magnitude as the accuracy of estimates for standard national accounting. While in general we would advocate for (meta-analytic) function transfer, more information is needed about transfer accuracy when applied to EA (validity, transfer and generalization errors), the systematic factors that influence transfer errors (especially valuation method and ES type), and the possible adjustments towards error minimization. Additional research will likely be required to identify

[10] ~~The intrinsic characteristic of EA is to have a structure that must be consistent not only through space and time, but also in the underpinning accounting mechanism and rules. In the case of ES accounts (which is the only module in EA that requires monetary valuation), the Supply and Use Tables are framed across a specific structure of Ecosystem Types (on the supply side) of Economic Units (on the use side) and throughout a list of service flows. A clear identification of all these components needs a reporting protocol that primary studies have to follow. This will later facilitate the provision of reliable input data into the valuation datasets.~~

systematic patterns in transfer errors as a function of methods and ES types, when applied to the type of values required for national accounting. This research can be used to establish standard guidelines for VT used within accounting practice, similar to those provided by Johnston et al. (2021) for use in more traditional VT applications.

Much of VT and valuation research has concerned welfare-based value estimates. Further research could also investigate how VT accuracy varies when different types of values are predicted. Similarly, while the primary focus of EA is exchange values, VT EA applications might provide an opportunity to test the empirical differences between the exchange and welfare value concepts. Information of this type could help to inform calibrations that could be used to transform information on welfare values to information on exchange values. P~~That is, p~~rospective methods of this type could help researchers to empirically assess how exchange values differ from welfare ones and perhaps what adjustments to welfare values could be made to obtain exchange values needed for accounting. Approaches such as these could possibly complement ~~(or validate)~~ the simulated exchange value approach as the only current approach using~~able to 'generate' exchange values~~ with input from~~from~~ a demand function derived from stated preferences ~~welfare values (i.e., simulated exchange approach~~). Furthermore, it is foreseeable that complementary accounts in welfare values might be constructed for specific policy questions, wherein VT could play a role (see SEEA EA ch.12 in UN, 2021; Turner, Badura and Ferrini 2019).

Another well-known challenge that can arise in welfare analysis or EA is double-counting (Boyd and Banzhaf 2006; Fisher et al. 2009). As described by Johnston and Russell (2011, p. 2243), "consistent estimates of ecosystem service benefits require differentiation of intermediate ecosystem functions from final ecosystem services, so that the benefit of each distinct ecosystem condition or process, to each human beneficiary, is counted once and only once." As is the case with welfare analysis, the validity of any EA framework requires structures, accounting mechanisms and rules to ensure that relevant exchange values are not double-counted. This is primarily a concern for the underlying development of guidelines for physical and monetary accounts that provide~~defining~~ non-overlapping definitions of~~terminingе what~~ ecosystem services ~~values~~ for the purpose of valuation in~~should be counted as part of~~ EA (NCAVES and MAIA 2022).~~, rather than~~ VT is~~which~~ primarily concerned withs how those values are estimated using existing data. Procedures of this type have been established for welfare and ecosystem services analysis (e.g., Fisher et al. 2009; Bateman et al. 2011; Johnston and Russell 2011), and similar guidance will be~~approaches are~~ required for monetary accounts in EA (regardless of whether VT is applied). Nonetheless, to ensure validity, any VT procedure used for EA should be designed to ensure that each relevant ecosystem service value is counted only once.

5 Conclusion

VT was developed as a "feasible means to provide information on economic values to support decision-making when time, funding and other practical constraints impede the use of original

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valuation studies" (Johnston et al. 2021). In the same way that Newbold et al. (2018) argue that VT is an essential part of all prospective cost benefit analysis in assessing US federal regulations, we argue that VT will be needed in EA~~ecosystem services accounting~~. From this perspective, VT should not be considered as a standalone valuation method, but rather as a general approach needed when seeking to combine multiple single study values for large-scale, repeated applications such as EA. However, while rudimentary~~l~~ VT applications are already embedded in EA pilot studies, they typically lack the rigor, standardization and body of research literature that supports VT applications in cost-benefit analysis. We argue that EA practitioners can learn much from the decades of research and methodological development on VT in other fields.

VT is well placed for supplying monetary values for EA and as such accelerate EA implementation. VT offers a feasible solution to valuation applied at national scale; it can be based on SNA-compatible exchange values alone and provide a transparent approach for periodic and consistent updating of EA.

To ensure that VT can provide values to be aggregated and integrated into SNA accounts, it is crucial that different biophysical measures of ES (per ha, per user, etc.) could be consistently retrieved and transferred from available study sites. This~~,~~ overcomes the misalignment of economic or jurisdictional data with ecological spatial units. VT for EA should also explicitly account for the spatial heterogeneity in values in aggregated accounts. This feature can either be available in the primary studies or being rooted in the VT method. Moreover, to accommodate the need for periodical update of the accounts, VT needs to be consistently and transparently repeated and adapted to the nature of temporal changes in ecosystems and socio-economic conditions.

In summary, we argue that VT provides a promising means to accelerate EA applications. Nonetheless, despite expansive research and evidence on applications of VT for welfare applications, additional work is required to operationalize VT in EA. One area of further work is the provision of structured guidelines and protocols that would ensure proper applications, i.e. starting from protocols that would outline processes for the design, implementation and reporting of primary studies, to protocols for producing and updating ~~a~~ databases of primary studies, and finally to guidelines that would delineate the methodological steps for VT in the EA context. Future efforts should also be placed on ~~further~~ empirical applications of VT for EA purposes, in order to provide systematic evidence on how VT performs in practice and the methodological challenges in its application. Some challenges remain, but it is likely that VT can help to respond to the pressing need to incorporate nature into mainstream decision-making processes~~.~~.

In summary, we argue that VT provides a promising means to accelerate EA applications. Nonetheless, despite extensive research and evidence on applications of VT for welfare applications, additional work is required to operationalize VT in EA. One area of further work is the provision of structured guidelines and protocols that would ensure proper applications, i.e. starting from protocols that would outline processes for the design, implementation and reporting

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of primary studies, to protocols for producing and updating databases of primary studies, and finally to guidelines that would delineate the methodological steps for VT in the EA context. Future efforts should also be placed on empirical applications of VT for EA purposes, in order to provide systematic evidence on how VT performs in practice and the methodological challenges in its application. These recommendations are in line with those mentioned under the US national strategy that refer to the need for 'reliable, repeatable and scalable monetary valuation' towards developing guidance and standards for ecosystems and the need for harmonization of EA approaches using lessons learned from empirical applications, i.e. 'early-stage pilot and prototype account' (Link 1 in p.50). Some challenges remain, but it is likely that VT can help to respond to the pressing need to incorporate nature into mainstream decision-making processes.

flags the inability of valuation studies to reach out to policy processes and call for co-production of valuation knowledge, proper guidance and standardization of valuation methods. This standardization is what national EA initiatives require (REF, pp6 and pp18) and what SEEA EA framework aims to cover. VT lies very much within the scope of these objectives. Within the,, thatThis requirement will be more apparent

GloballyAt the global context VT can offer standardized and low-cost means of predicting values for valuation in EA applications performed also in both developed and developing countries, contingent upon a suitable body of primary studies from which to draw VT estimates.

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Footnotes

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- As illustrated by Johnston and Bauer (2019), "large-scale" applications can involve transfers of value (a) related to environmental conditions or changes occur over large geospatial areas and/or (b) that predict values realized by people over large geospatial areas, or large "extent of the market". Both (a) and (b) can involve one continuous geospatial area (e.g., one state in a country) or multiple distinct areas combined (e.g., multiple states or countries, not necessarily contiguous).
- As discussed by Johnston et al. (2021), similar functions can also be derived by individual studies that collect and pool data from multiple sites to estimate a single benefit function. An example is the use of data collected from recreational choices over multiple sites to estimate a single random utility model (RUM) of recreation demand, which can then be used to produce estimates of WTP.
- As described by Johnston et al. (2021), benefit functions also be derived using structural models, grounded in economic theory, that use data from multiple prior valuation studies to calibrate preference parameters (Smith et al. 2002, 2006; Smith and Pattanayak 2002; Van Houtven et al. 2011; Phaneuf and Van Houtven 2015). In concept, approaches of this type could be adapted for the transfer of exchange rather than welfare values. However, the primary advantage of these methods emphasized in prior work is the transfer of neoclassical welfare measures with desired theoretical properties. Parallel advantages

could possibly apply to exchange values, but to our knowledge have not yet been demonstrated for applications of this type. Hence, we leave the possible exploration of structural exchange value transfers for future work.

For example, see the discussion of benefit scaling in Johnston et al. (2021), applicable to such large-scale applications.

Both validity and reliability are important features of VT quality control. Validity implies that value estimates or other transferred quantities are statistically identical across study and policy contexts (i.e., there is no statistically significant transfer error). Reliability is measured as average generalization error – or the (mean) difference between a primary study value and a value produced via benefit transfer.

Illustrative examples of national-scale VT applications are provided by Ferrini et al. (2015), as related to the UK National Ecosystem Assessment. Examples of VT applications for nationwide assessment of US water quality benefits are provided in Wheeler (2015).

Note, however, that some types of VT methods require considerable expertise. For example, development and estimation of a new meta-regression analysis for economic values requires considerable expertise to compile metadata, estimate statistical models, etc. However, once a meta-regression model has been estimated, the subsequent *use* of the model for VT applications is fairly standardized and requires less expertise. Examples are provided in Johnston and Wainger (2015) and Johnston and Bauer (2019).

On average, VT is expected to be no more accurate than the underlying sample of study-site data that supports it, or to the extent that any underlying biases can be corrected during the transfer process (Johnston et al. 2015). However, it is important to recognize that "the relationship between the original accuracy of study-site value estimates and the accuracy of value transfers is neither monotonic nor straightforward" (Johnston et al. 2021). When one selects primary studies for VT, implicit assumptions are typically made that the underlying body of literature provides an unbiased sample of the population of empirical estimates (i.e., no selection biases) and that these estimates provide an unbiased representation of true values (i.e., no measurement error). If these assumptions do not hold, the result will be systematic biases in the resulting value transfers (Hoehn 2006; Rosenberger and Johnston 2009).

Of course, evaluations of this type can only be conducted for cases where a primary study has *already been conducted* for the policy site, so that a primary study estimate of value is available. VT is generally required only when suitable primary study estimates are *not available* to measure the value of interest. Hence, for actual VT applications, the transfer error is almost always unknown.

The intrinsic characteristic of EA is to have a structure that must be consistent not only through space and time, but also in the underpinning accounting mechanism and rules. In the case of ES accounts (which is the only module in EA that requires monetary valuation), the Supply and Use Tables are framed across a specific structure of Ecosystem Types (on the supply side) of Economic Units (on the use side) and throughout a list of service flows. A clear identification of all these components needs a reporting protocol that primary studies have to follow. This will later facilitate the provision of reliable input data into the valuation datasets.

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Declaration of interests

☒The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: