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Keywords: welfare, shadow prices, inclusive wealth, exchange values, natural capital, cultural and heritage capital, human capital, intangible capital, economic measurement

JEL classification: A13, D62, E01, E22, I30, Q51, Q57

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Accounting for missing capitals: approaches to valuation

Diane Coyle & Julia Wdowin[1]

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Economists increasingly make the case for the measurement of missing capitals for better welfare, wealth, sustainability and productivity measures. Shadow prices represent the value of missing capital assets in economic welfare terms. This paper reviews the value concepts underlying shadow prices and the choice of estimation in practice. Four missing capital types are explored here: natural, cultural and heritage, human, and intangible capitals. We discuss the distinction between the concepts of exchange values and shadow prices intended to capture the social welfare value of assets when these differ from exchange values for reasons such as the presence of externalities. Exchange value estimates are consistent with SNA principles, while shadow prices seek to internalise the value of non-market elements such as externalities. We first clarify the distinction and also the relation of consumer surplus to shadow prices. In addressing the question of how to value non-market benefits and costs and, thus, how to estimate shadow prices, we also provide a mapping from missing capital asset categories to valuation methods and the theory of value they embed. Finally, we discuss issues relating to asset category overlaps as well as complementarities between categories in generating welfare, presenting some key unresolved questions.

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Section 1: Introduction

One of the fundamental issues in national accounting as it evolves is the question of which currently excluded capital assets should be included within the production and asset boundaries – the 'missing capitals'. This question is related to both the changing nature of the economy, and thus a better understanding of the full range of inputs required for economic activity, and also a concern for

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measurement of the economy 'Beyond GDP'. This concern reflects the desire for a measure of economic activity that can account for sustainability and other aspects of social welfare. The inclusion of missing capitals in national accounting, and thus the potential extension of the asset boundary to include them, is at the centre of the current debate about the bounds of what is understood as economic activity.

Contemplating the expansion of the asset and production boundary to include missing capitals and the services they provide requires both conceptual clarity and appropriate measurement methods. The missing capitals provide a range of non-market benefits (or capital services).[2] Two tasks come into play. The specific assets need to be defined and classified, including accounting for overlaps or double counting, and they need to be valued to provide a money metric. Underlying these technical and methodological choices there is a necessary prior decision regarding the theory of value. Whilst there has been significant progress around definition and valuation across different domains such as natural, human and intangible capitals, the endeavour lacks a consistent framework mapping categories of asset to valuation methods and the value theory they embed, a lack of consistency that is reflected in the literature. This paper proposes such a framework, aiming to bring some clarity to the discussion.

One important issue concerns the purpose of valuation of missing capitals. One possible aim is, as just noted, extending national income accounting to include missing capital services that are in fact inputs into economic production and consumption. This is often termed comprehensive (or inclusive) wealth accounting. This extension could be achieved in a manner broadly consistent with the System of National Accounts (SNA) principles: estimates could be calculated at exchange values – as in the System of Environmental Economic Accounting (SEEA) – and so consistent with the SNA. Alternatively, values could be estimated at shadow prices, for a broader social welfare aggregate. This would be the aim of some advocates for going Beyond GDP. Another possible aim is social cost-benefit analysis (CBA). CBA is rooted in basic microeconomic theory (albeit generally ignoring the well-known aggregation problems in social choice), but the aim in such exercises is to conduct an appraisal of the likely social return to a policy intervention or an investment. In this case, the use of shadow prices is closer to the purpose of the exercise, although in policy practice exchange values may be used.

In either case, the approach to valuation of the missing capitals is a key issue as these often have significant non-market elements. These may be externalities, as with many forms of natural capital,

[2] There is also a range of tangible assets that are excluded from the SNA asset boundary and whose measurement does not pose particular challenges, for instance, consumer durables such as antiques and collectible items or used goods such as used cars are excluded from GDP. National accountants tend towards accounting for capital that impacts GDP under SNA 2008.

such as the carbon sequestration or cooling services provided by trees which might also have a commercial value as timber. In the case of intangible assets, such as data, there will be spillovers due to non-rivalry. The SNA framework adheres to the use of exchange values for all included assets. For the majority of economic activity included within the SNA production boundary, exchange values are calculated based on observed market prices or via a 'sum of costs', although the exchange values of some other items, such as public services, are calculated using different methods. For example, they are often imputed. In any case, exchange values (however estimated) are explicitly marginal concepts and exclude option values or externalities. Consistency with the SNA would require using exchange values for the missing capitals in extending the asset and production boundary. In what follows, we will use the term *exchange values* to refer to this marginal, market-adjacent concept of value. The rationale for their use in national accounting is that they represent the underlying microeconomic price theory where the market outcome reflects the marginal cost and benefit of the products in question.[3]

By contrast, *shadow prices* are estimates of the social welfare value of capital assets (or their related capital services) that do not have a market price, or whose exchange value does not include other external social costs and benefits.[4] It should be noted that the term 'shadow prices' is sometimes used in the literature to refer to what we term exchange values in this paper. We will reserve the term shadow prices to refer to wider social welfare values.

As noted, for the purpose of social CBA, shadow prices are required, although methods of estimating them using market behaviour (such as revealed preference or time-based methods) may be preferred when feasible. An alternative construct of welfare is sometimes used in place of the social welfare functions of neoclassical theory: Total Economic Value (TEV). This deviates from conventional narrower neoclassical microeconomic welfare foundations,[5] which many of its users in fact consider an advantage.

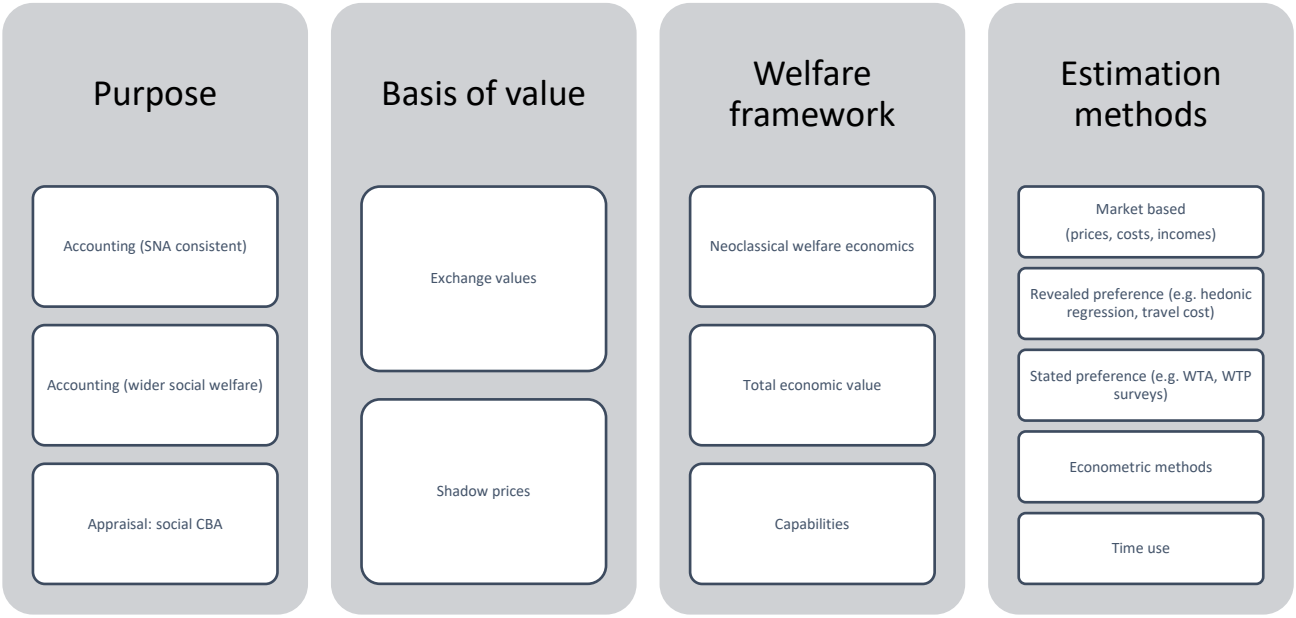
A range of different valuation methods is available to measure the value of missing capital assets. It is not uncommon for different valuation methods to be used to answer the same question – for example to measure the value of a dataset – but the methods used may actually be addressing different conceptions of the value. Or, one method might capture some consumer surplus, while another method used in the same case captures none. That is, exchange values and shadow prices are

[3] In practice statistical offices may often use average rather than marginal prices for pragmatic reasons.
[4] Shadow prices are sometimes referred to as accounting prices (as in Dasgupta, 2021); but non-economists find this confusing terminology so we will use the term shadow prices throughout.
[5] The TEV framework has a neoclassical basis since value to all TEV components derives from individual preferences and utility. However, utility can be derived from a broader set of values such as non-use, option or existence values.

sometimes estimated using the same methods, with these estimates then being directly compared. A further issue relates to how consumer surplus is defined once the analysis involves a social demand curve, not just a private demand curve, as well as whether average or marginal changes to social welfare are involved (see Section 5).

We discuss below some of the issues involved in the estimation methodologies, related to some of the variation in the literature as regards the concept being estimated. We aim to clarify when different methods are used, with the aim of providing a conceptually consistent framework for moving 'Beyond GDP' appropriate to the aims of the exercise; broadening the current SNA to include some additional missing capitals is a different aim from constructing an aggregate measure of social welfare, which differs again from carrying out a social cost-benefit analysis. Figure 1 below sets out these different dimensions; there is not a simple mapping between the columns.

Figure 1: Dimensions of value framework



We start by distinguishing between exchange values and shadow prices, discussing how these terms are used in the literature. We move onto an overview of welfare constructs to set out the theoretical basis for shadow prices. We next review existing valuation methods for natural, cultural and heritage, human and intangible capitals assets, and analyse what social welfare values would mean in the context of each of these asset domains, and what concept is addressed with the use of different estimation methods. An elaboration of the available estimation methods by capital asset type follows. Finally, we raise some questions relating to overlaps and disaggregating assets as well as complementarities and interactions in generating value between different asset categories within an inclusive wealth framework.

Section 2: Shadow prices and exchange values

The discussion throughout this paper hinges on the distinction between different concepts of economic value. The key distinction is between *exchange values*, capturing marginal private costs and benefits,[6] as used in the SNA; and *shadow prices*, capturing social costs and benefits. An exchange value reflects the price at which a given service and associated asset would be exchanged between buyer and seller if a market for the service existed;[7] if an observed price is unavailable, market outcomes such as costs or incomes are used, or other valuation methods including imputations and approaches based on revealed and stated preference.[8] The key point is that exchange values are conceptually marginal, and exclude externalities, optionality or other dependencies of value that go beyond the individual economic agent.[9] Estimates of exchange values are needed to be compatible with the SNA framework and the SEEA extension. It is thus assumed that exchange values can meaningfully be applied to non-market benefits to provide a broader set of economic accounts. In this context, the term 'shadow prices' is sometimes used in the wider literature but this nomenclature risks some confusion. To be clear, the use of shadow prices in the sense in which we use the term here, reflective of changes in social welfare, is conceptually inconsistent with the SNA accounting framework. While national accounting is moving towards including a wider range of assets, these are therefore valued at market price equivalent or exchange values (Nakamura, Soloveichik, and Martin, 2024).

The widespread interest in a social welfare-based complementary approach to aggregate economic measurement, comprehensive wealth accounting (Obst, 2018), requires using shadow prices. Within the comprehensive wealth accounting framework, shadow prices are defined as "the marginal contribution of capital assets to social well-being," (Yamaguchi, 2020). They are not conceptually equivalent to market price equivalent values (representing marginal revenue and cost in a competitive market) except in precise circumstances (UN et al, 2014, 5.26; Fenichel, Obst, Wentland, 2024). Shadow prices, in the comprehensive wealth literature, are marginal values in the sense that they reflect the social welfare change associated with a marginal change in the relevant capital asset but this is different from the value of the marginal individual transaction in the national accounts

[6] Public sector purchases are treated as private costs and benefits in the SNA context.
[7] Although market transactions, and thus also exchange values, are not always the best measure of value for use in the SNA, for example because of their potentially volatile nature.
[8] Exchange values can be derived from either observed market prices or an aggregate value of sum of costs. However, standard national accounts are not compiled only on the basis of observed market prices, where in some cases observed market prices are unavailable. In these cases, the market price equivalent values for items that are included in GDP (and other produced statistics) are used. Public services, such as health or education, as well as other imputed items, included in GDP and other statistics, are valued using different valuation techniques.
[9] Although note that market prices may include monopoly rents.

conceptualisation (UN et al, 2014, 5.26). This means that in the literature, estimates of shadow prices are conceptualised as average, not marginal, changes in social welfare associated with the given asset or service.

Thus, shadow prices measure the overall costs and benefits associated with a given capital asset or service, for example taking into account externalities. Fenichel et al (2024) set out the conditions under which the exchange value and shadow price concepts (in their case proxied by the change in consumer surplus) are identical, namely that exchange values are adjusted using an ideal index to capture intertemporal changes in 'true' income; they propose using some of the methods typically applied to non-market asset valuation to estimate social welfare reflective exchange values for use in national accounting. Taylor et al (2024) put forward a similar argument, concluding that in particular circumstances, for example looking at a product price in a perfect market, there may be no conceptual difference in measuring an exchange price for non-market activities and a shadow price for the same activity. However, the wedge between conventional exchange value estimates and the estimates of the social welfare reflected in a shadow price generally remains. Fundamentally, Fenichel et al (2024) and Taylor et al (2024) highlight the importance of understanding the scope of non-market valuation methods in relation to *particular* services, chiming with the basic premise of this paper; and these authors similarly highlight the need for a suitable taxonomy of assets with which to align non market valuation studies. We return to the classification issue below.

In summary, there are two main questions to be considered when defining exchange values and shadow prices. Firstly, the scope of the valuation of the asset or capital service, i.e. whether externalities are included or not; and secondly, whether valuations of assets or capital services are marginal or average/total valuations. National accounting is based on exchange values, which in theory are marginal valuations (although in practice do not always reflect marginal valuations); and, by definition exchange values exclude externalities. On the other hand, shadow prices necessarily include externalities. Moreover, most of the shadow price literature converges on these being marginal valuations with respect to social welfare; but they could also be conceived in terms of average valuation , for example for an accounting system or other purpose. In this paper, we mainly focus on shadow prices as marginal valuations to social welfare, but discuss the possibility of average valuations in Section 5.

Therefore, whether the marginal valuation of, for example, air quality is considered an exchange value or a shadow price depends on whether it is classified within the given framework as an externality or a (natural) capital service in its own right, and, additionally, on the particular framework being used requiring shadow prices to be marginal, not average, valuations. On the other hand, the existence of

externalities is key to the definition of shadow prices, so the consumer surplus associated with a market product does not involve a shadow price.

There is a range of alternative approaches taken in the literature to extending economic aggregates to measure social welfare.

In terms of accounting and the construction of broader Beyond GDP aggregates, shadow prices map most directly onto the latter two segments of the six distinct possible accounting approaches set out by Heys et al (2019) in their 'spectrum' of aggregate (accounting) measures ((1) GDP Minus; (2) Current GDP; (3) Future GDP; (4) Welfare Minus; (5) Welfare; (6) Well-being), namely 'welfare' and 'well-being'. Whilst the third and fourth approaches, 'Future GDP' and 'Welfare Minus', respectively, include missing capitals, these are measured consistently with SNA accounting principles.

There are two possible approaches to viewing how a move to shadow prices could be situated on the more elaborate six-part 'spectrum of welfare measures' proposed by Heys et al (2019). The first is to view shadow prices as a complementary but distinct approach to accounting, and thus each part of the spectrum could be estimated at both sets of prices from the third approach onwards, 'Future GDP', which includes missing capitals. Alternatively, shadow prices could represent a new pillar, 'Welfare Plus', which would sit between the fifth approach 'Welfare' and the sixth 'Well-being'. In this scenario, a switch from the exchange values that underlie the ONS measure of 'democratic income' in the 'Welfare' segment to social welfare values would apply before the final 'well-being' segment that groups dashboard and indicator measures.

Another approach adds estimates of consumer surplus to GDP (e.g. Brynjolfsson et al, 2020; Hulten and Nakamura, 2020; Schreyer 2021). This type of approach can be considered as extending the use of hedonic price indices for some goods, used to calculate consumer price indices in standard national accounts statistics (Coyle, 2024). Hedonic adjustments, or other quality adjustments for activities such as public services, capture quality improvements by estimating the marginal value of certain measurable product characteristics on the assumption that market price reflects these quality changes; the consumer achieves higher utility than the observed price and quantity would indicate. This estimated marginal value is added to the measured real output by reducing of the deflator. For an accounting purpose, this approach raises the question about how to account for a wide range of public or collective goods, not just digital goods; should similar estimates of consumer welfare be added for others such as public parks or even infrastructure?

However, as there is in any case a range of approaches in the growing literature, for example different approaches to adding consumer surplus associated with digital services (see also Schreyer, 2021) or

environmental services (see Fenichel et al, 2024) whose market price is zero, it is worth briefly revisiting the underlying economic theory. Before that discussion, we briefly note some issues related to economic ownership.

Section 3: Economic ownership

An important question in shifting the perspective from valuation of the private costs and benefits of assets to a social welfare perspective relates to economic ownership of assets. An economic owner is the institutional unit that receives the benefits associated with an asset and simultaneously bears the associated risks. There is a question about identifying who is the economic owner (institutional unit) in a social welfare context, i.e. when the analysis extends across various 'units'?

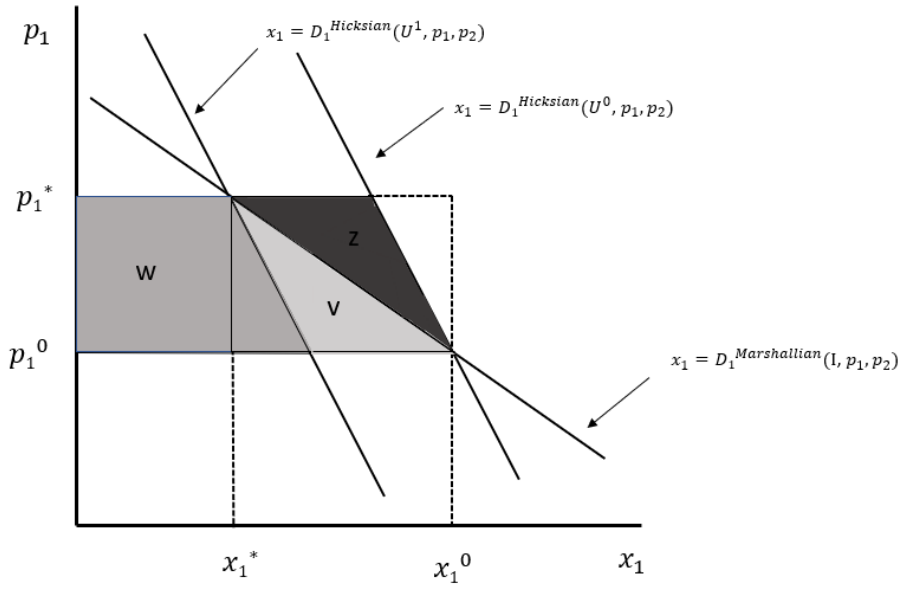
The SNA can be understood as using exchange values that map onto a particular economic owner. But to take into account externalities, exchange values would need to map onto all economic owners involved. This underlies the approach of the SEEA-EEA, which accounts for the non-SNA benefits of ESS, but, in valuing externalities, applies exchange values to all economic units. For example, even without being an economic owner of a certain ESS, such as a coral reef, one can receive benefits from it such as beauty, water filtration, recreation or carbon sequestration. The SNA attributes all of the value of a capital asset to the owner, even though other economic units are getting some non-monetary benefits. The SEEA-EEA, on the other hand by incorporating externalities, includes exchange values to *all* economic units receiving benefits. Valuing such benefits at exchange values expands the aggregate measure at the 'extensive' margin without expanding it at the 'intensive' margin, as the use of shadow prices would.

Section 4: Welfare constructs

In neoclassical economics, a standard concept of aggregate social welfare is total surplus in the economy as the sum of producer surplus (the area above the supply curve and below the realised price) and consumer surplus (CS) (the area below the demand curve and above the realised price, up to the Hicksian reservation price at which demand is zero). The change in CS is defined with reference to the standard Marshallian demand curve derived from the utility maximisation problem for a given budget constraint, and so income is held fixed but the implied consumer utility is not. There have been many empirical applications estimating the total CS arising due to specific products, although as these require estimation of a demand curve they are not suitable for statistical production.

Alternative consumer welfare measures hold utility constant and ask instead how much income at new prices the consumer needs to compensate for a price change (compensating variation (CV)) or how much income at old prices the consumer would forgo to avert a price change (equivalent variation (EV)). These measures are defined with reference to Hicksian (compensated) demand curves, which are the partial derivatives of the consumer's expenditure minimisation problem (the dual to their utility maximisation problem). These measures will differ. In general, for normal goods, for a price increase CV > ΔCS > EV, and for a price fall CV < ΔCS < EV (Figure 2). CV and EV can hence be thought of as analogous to the difference between Laspeyres and Paasche price indices, as the base prices vary between them in an analogous way (see Diewert and Mizobuchi, 2009). Nevertheless, change in CS is generally taken as a reasonable (and measurable) proxy for the Hicksian welfare concepts. All three are average (or income-like) constructs, in contrast to the marginal concepts involved in national income accounting.

Figure 2: CV, ΔCS*, and EV*



CV = w+v+z; EV = w; ΔCS = w+v. (Diagram assumes a normal good; for an inferior good the Marshallian curve is steeper than the Hicksian curve as income and substitution effects have opposite signs).

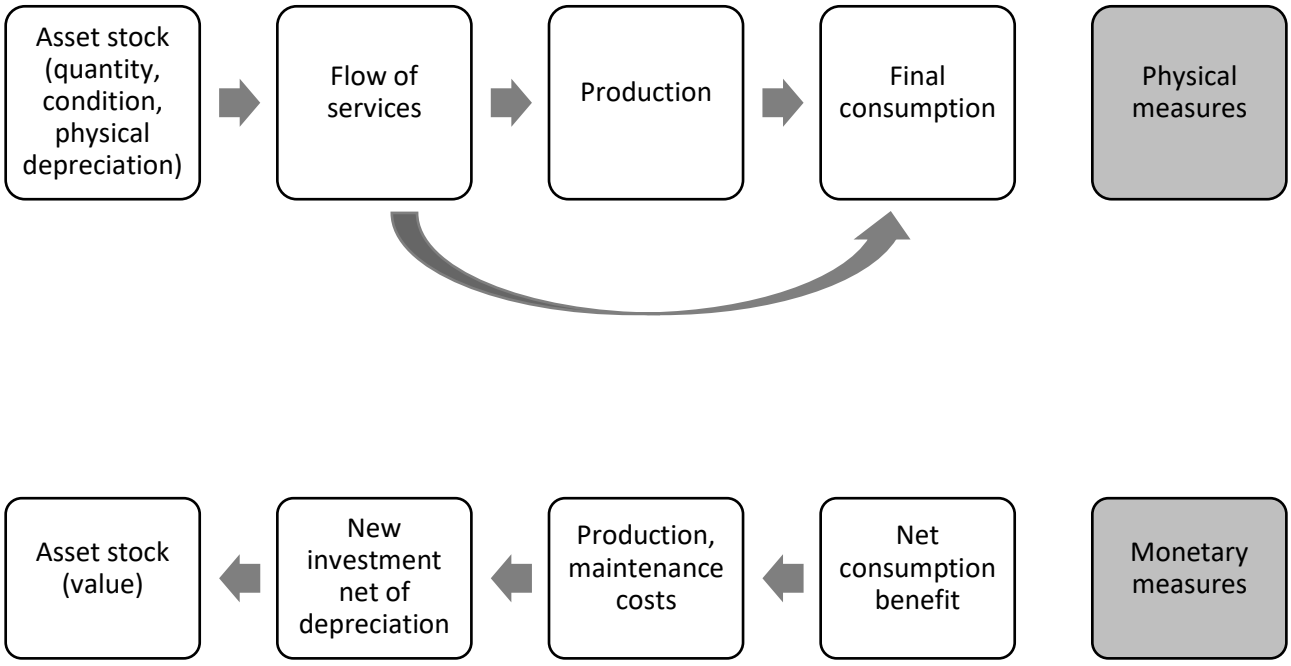
Stated preference methods aim to estimate compensating and equivalent variation, using willingness to accept (WTA) and willingness to pay (WTP) surveys. These surveys ask respondents to state monetary values corresponding to a change in quantities (not prices). Responses can be used to back out implied demand curves between quantities and shadow prices. These are, however, sometimes described in the literature as measures of CS, when they correspond to the CV and EV concepts. Some

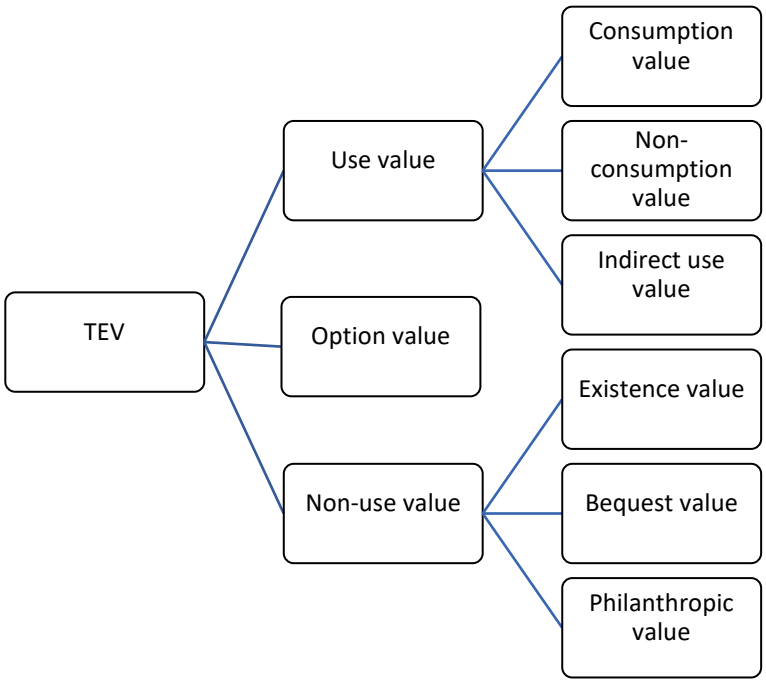
authors use these figures derived from stated preference (either WTP or more often WTA) surveys as estimates to add to an accounting aggregate like GDP. To complicate matters further, measures of the CS for particular goods using estimated (Marshallian, varying utility) demand functions from observed price and quantity data (rather than stated preference methods) describe (total) CS in terms of the difference between the realised price and a hypothetical reservation price at which demand is zero, which is appropriate for new goods whose quantity consumed was previously zero, but not necessarily for all contexts.

Importantly, the existing literature using stated preference methods to estimate consumer welfare omits the 'production' side for the missing components. EV and CV are alternative estimates reflecting consumers' marginal rate of substitution (at given relative shadow prices) between non-market and other goods. The role of the marginal rate of transformation in constraining attainable welfare is often omitted (although there are exceptions; for example, Hulten and Nakamura (2022) explicitly model the equality between MRS and MRT in their proposed digital welfare aggregate GDP-E).

Other conceptual social welfare frameworks are found in the literature. For natural capital (and cultural or heritage assets) the concept of total economic value (TEV) is widely used. Its origins are not clear but early examples referring to some of its components are Weisbrod (1964) and Krutilla (1967). Pearce and Turner (1990) synthesise earlier examples, and a recent explanation is Anderson et al (2022). Figure 3 illustrates the difference between the economic production function framework underpinning the input-output accounting matrix of the national accounts (and standard natural capital accounting) and the TEV approach. TEV provides a consumer welfare perspective, omitting the production side of the economy. It clearly borrows from utility theory but speaks to a broader philosophical conception of social (and individual) welfare, in an unspecified social choice framework. TEV approaches generally use the same array of estimation methods as the more standard neoclassical approach, raising the same questions.

Figure 3: (a) Production function and (b) TEV frameworks





Other alternative economic welfare measurement and assessment frameworks are constructed as a reaction to welfarism, understood as assessment of welfare in terms of individual utility alone and used for evaluating social aggregate welfare (Aitken, 2019; Basu and Lopez-Calva, 2011). Sen's (1980; 1985; 2009) capability approach (CA) argues that the metrics of individuals' capabilities and functionings, whilst generating individual utility, are not metrics of utility and are the closest approximations to a measure of 'standard of living' (Atkinson, 1999). For this reason, the CA is conventionally treated by statistical agencies as informing 'well-being' measures as opposed to economic welfare (Heys, Martin, Mkandawire, 2019). In terms of value categories, the framework of the CA recognises the broader value categories of the TEV framework, but adds further measurement of individual opportunity and agency to individual and social welfare analysis, as well as notions of intrinsic value (Wdowin, 2024). Its overall concern is with the centrality of the notion of freedom to individual and social welfare evaluation. The CA is also sensitive to heterogenous individual preferences and heterogenous individual needs in analysing distributional issues and, thus, to differences in the marginal value of resources to individuals' welfare (Wdowin, 2024).

The distinct welfare constructs draw different bounds around value concepts. Whilst a standard economic approach typically uses a use-based value system (therefore is necessarily anthropocentric), a TEV approach admits broader non-use based values, such as existence and bequest value, but is nevertheless anthropocentric in nature. A capabilities approach to welfare admits further types of value, including intrinsic and relational values. The use-based, anthropocentric value system underlies the SNA and SEEA.

Section 5: Average vs. marginal changes in social welfare

Estimates of shadow prices (or shadow values) can also differ according to whether *marginal* or *average* changes in social welfare from the change in the relevant capital asset are being measured. Both marginal and average changes are potentially valid approaches to estimating shadow prices, depending on context, and both can be found in the existing literature (UN et al, 2014; Scheufele and Pascoe, 2023, respectively). The use of either can depend on the purpose of the shadow price estimates. We cover in this section both marginal and average change approaches to shadow price (or value) estimates. The use of either a marginal or average change approach has implications for whether, and for what part of, consumer surplus is included in the shadow price estimate.

First, if shadow prices involve internalising externalities, when there are net positive externalities (or the difference between the shadow price and exchange price S_p-E_p is positive), for every quantity

demanded Q_0, the private demand for the good or service is less than the optimal social demand. This is shown in Figure 4a and Figure 4b[10], where in Figure 4a the exchange price is derived from interaction between supply and private demand, whilst in Figure 4b the shadow price is derived from the interaction between supply and social demand.

Figure 4a

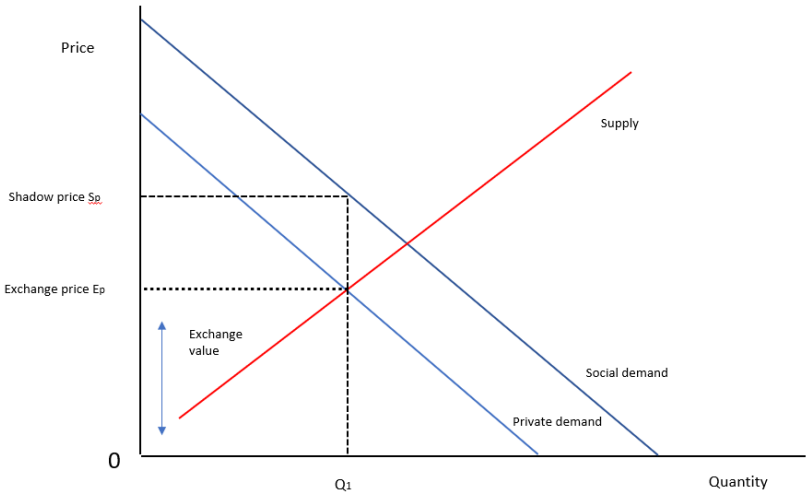
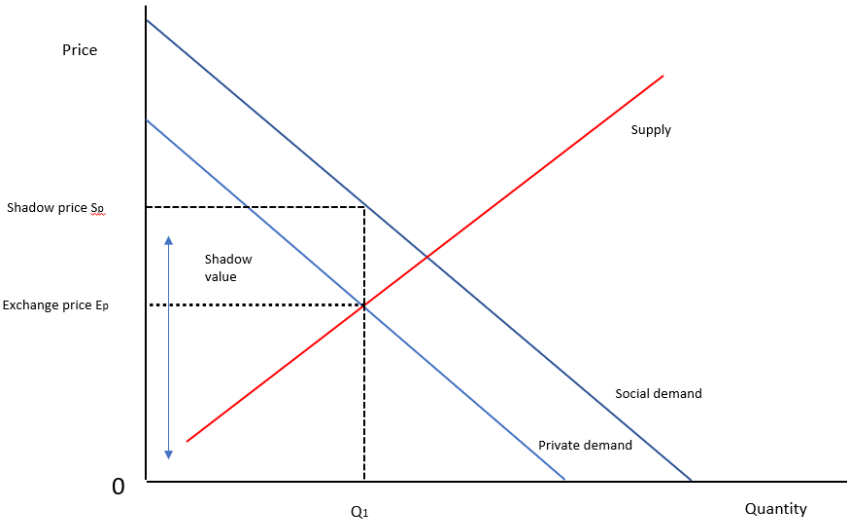


Figure 4b



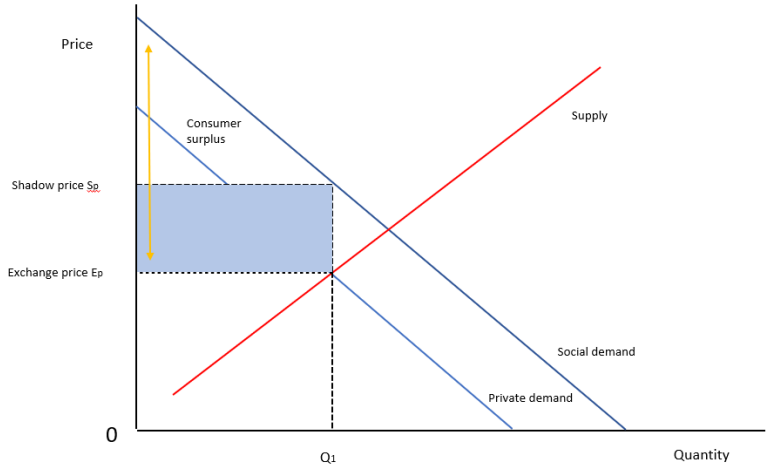
Further, if we take consumer surplus to be the area between the social demand curve and the shadow price, the exchange value does not include any consumer surplus. Nor does the shadow value. Thus,

[10] We thank Cliodhna Taylor for suggesting these figures.

when treating shadow prices as a marginal increase in social welfare, as in Figure 4b, and defining consumer surplus in this way, the shadow value will not include any consumer surplus.

In the case that consumer surplus is taken as the area between the exchange price and under the social demand curve, then some consumer surplus is captured in the shadow price, as in the blue area in Figure 4c. This is an average construct.

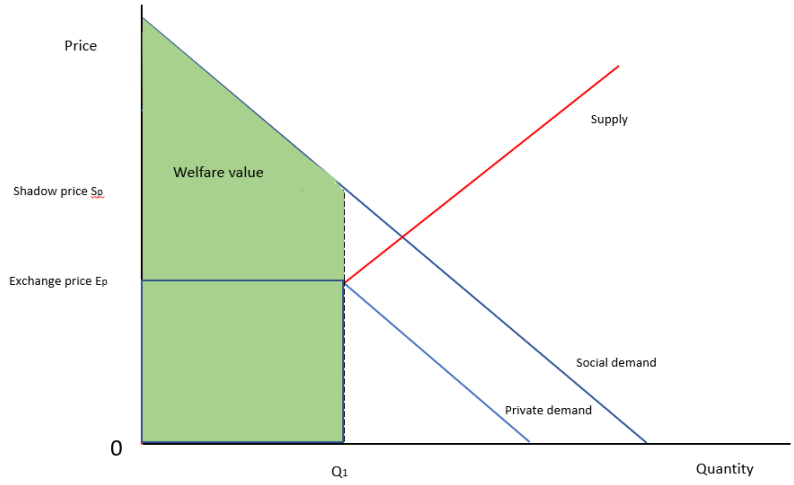
Figure 4c



Lastly, an alternative approach to shadow prices is to estimate the total change to welfare. In this case, the estimated shadow value would include all consumer surplus, however this is defined. The area of the welfare value in these cases is shown by the green area in Figure 4d.[11]

[11]In the case of a competitive market, we assume that MRT = MRS, such that the exchange price represents both the marginal cost of production and the marginal cost of consumption. Then the exchange price (as shown in figures 4a-d) represents the MRT. The welfare value depicted in Figure 4d is thus the part of the green area above the exchange price. The producer surplus is the area under the exchange price.

Figure 4d



Section 6: Natural capital

Significant advances have been made in the measurement and valuation of natural capital as a missing capital, especially since the adoption of the UN SEEA framework standardised guidelines across statistical agencies and organisations. Natural capital assets are considered currently in national accounting as an extension to the SNA, as measures in a separate thematic account, and in addition as accountable within inclusive wealth accounting frameworks (e.g. World Bank CWON, 2024). The SEEA framework potentially allows for extension of the production boundary to include some non-market goods and services that flow from environmental assets. Additional changes in SNA25 will include introducing the depletion of natural resources as a cost of production.

Broadly, according to the SEEA framework, the environment is an asset which provides goods and services, and is further split across individual environmental assets, such as water, timber and fish, and ecosystem assets such as forests and wetlands (UN et al, 2014). In turn, natural assets, understood in an SNA context, are stores of value representing a benefit or series of capital services accruing to the economic owner by holding or using the entity over a period of time (2008 SNA, para. 10.8). Environmental assets are “the naturally occurring living and non-living components of the Earth, together constituting the biophysical environment, which may provide benefits to humanity,” (UN et al, 2014b, 2.17), which encompass ecosystem assets (these latter exclude mineral and energy resources) defined as “spatial areas comprising a combination of biotic and abiotic components and other elements which function together” (UN et al, 2014b, 2.31).

Many environmental and ecosystem assets are not traded in markets, and therefore valuation requires exchange value alternatives, which use for example sum of costs or other valuation methods. The SEEA framework (UN et al., 2014) conceptually delineates two value theories behind the task of environmental and ecosystem asset valuation: the first is the exchange value approach, and the second a broader social welfare approach to economic value. Again, exchange values relate to values that would have been obtained if a market for such assets existed. Social welfare values, on the other hand, take broader overall costs and benefits of environmental and ecosystem assets into account. Both of these approaches are described across the literature as using 'shadow prices', either because the capital asset was previously 'missing' and its value has to be estimated, or because it incorporates social benefits in addition to private benefits. Exchange values described as shadow prices and applied to natural assets (or other missing capitals) do indeed go some way to introducing a wider social welfare calculus. But we prefer to keep the terms distinct, and reserve the term shadow prices for social welfare contexts.

This variation in terminology already hints towards the use of such estimates for varying purposes. The remainder of this section will elaborate this point conceptually and with examples, but it is worth highlighting again here that non-market valuation *methods* (such as stated preference methods) can be used to estimate either exchange values or a wider social welfare values. There is not a one-to-one match between method and value concepts.

6.1 Differences between the SNA and SEEA

Before turning to valuation methods, we begin by noting some differences between the SNA and SEEA frameworks, as well as the SEEA-CF and SEEA-EEA frameworks. This is because whilst the SNA and SEEA frameworks have developed in parallel, they are not exactly aligned (Wolf and Femia, 2022). Nor are all the components parts of SEEA[12] completely aligned. In particular, there are classification and methodological differences between the SEEA Central Framework (CF) (UN et al., 2014) and the SEEA Experimental Ecosystem Accounting (EEA) (UN et al., 2014). Extending the analysis in this paper to take account of the full set of differences in the various SEEA frameworks is an important future task. Throughout the rest of this paper it is specified which framework is referred to.

One area of difference concerns the asset boundaries of the SEEA-CF and SEEA-EEA. For example, the asset boundaries of the SEEA-CF and the SNA are the same in money-metric terms. That is, only assets

[12] There are several components to the SEEA: the SEEA Central Framework (UN et al., 2014b); the SEEA Experimental Ecosystem Accounting (UN et al., 2014); the SEEA Applications and Extensions (EC et al., 2014); and SEEA Water (UN, 2012) (Vardon et al, 2018).

that have an economic value according to the valuation principles of the SNA are included in the SEEA-CF (UN et al., 2014). However, in physical terms, the asset boundary of the SEEA-CF is broader, not limited only to assets with economic value according to the SNA.

In addition, there are some classification differences between the frameworks. As one example, in the SNA, land and soil resources are treated as one asset type, however in the SEEA-CF they are treated as two separate assets (UN et al., 2014). Another area of difference is methodological. For example, the SEEA-CF diverges from the SNA approach to how product flows are recorded (UN et al., 2014). Likewise, the way depletion is measured following the SNA and SEEA-CF differs.

There are differences also in the SEEA-CF and SEEA-EEA frameworks. Some differences are set out below but they are not exhaustively detailed here. Whilst the SEEA-CF includes *environmental* assets, the SEEA-EEA focuses on *ecosystem* assets: UN et al (2014) describe ecosystem assets as environmental assets viewed from a systems perspective.

The SEEA-EEA framework includes the flows of environmental assets that are natural inputs into the economy, such as flows of timber, and in this way align with the production boundaries of the SNA and SEEA-CF. However, SEEA-EEA also includes ESS from ecosystem processes, such as air filtration and flood protection, and ESS linked to human-environment interaction, such as recreational activity (UN et al., 2014). One important difference, then, is that the set of ESS flows in the SEEA-EEA framework contribute to both SNA and non-SNA benefits. Since the SEEA-CF deals with *environmental* assets, and SEEA-EEA with *ecosystem* assets, this means that the production boundary is broader in SEEA-EEA compared with the SEEA-CF and the SNA (SEEA, 2012, p.133). On the other hand, there are also some environmental assets monitored within the SEEA-CF that are not included as ecosystem assets in the SEEA-EEA, such as inputs from renewable energy sources (e.g. solar and wind) (UN et al., 2014).UN et al (2014) notes that, although the valuation principles for SEEA-EEA are consistent with those of SNA and SEEA-CF, care must be taken in identifying measures of value at exchange values and those including some consumer surplus, because of the range of valuation approaches used to value non-market ESS.[13]

6.2 Valuation

Since the SEEA, in line with the SNA, uses exchange values, we will turn our attention first to valuation methods linked to estimating exchange values of environmental and ecosystem assets. In the SEEA,

[13] Regarding SEEA CF and SEEA EEA, it has been observed that the valuation of assets is more aligned with classical marginal theory than with the basic principles of SNA (Wolf and Femia, 2022). Thus, certain valuation methods for environmental and ecosystem assets should not necessarily be attributed to the SNA, such as net present value techniques or replacement costs (Wolf and Femia, 2022).

the values accounted for are based on the assets' market prices or market equivalent prices (SNA 2008, 3.118). In some cases, market prices can be observed for the assets. When market prices are not observable market price equivalents are estimated. If no equivalent market exists, other approaches such as cost of production can be used (or other imputation or non-market valuation methods). In this case, the value of the non-monetary transaction is considered equal to the sum of the costs of producing the good or service (UN et al, 2014, 5.45). Cost-based approaches to ecosystem services (ESS) valuation, for instance, capture direct and indirect use value. This method depends on the existing ESS markets. Some examples include using expenditure information that is used to estimate the demand for the given ecosystem services (ESS), such as spending on defences for storm protection or sea wall construction, or spending on water filtration as an estimate of the value of water pollution damages.

For overall environmental asset valuation, where no market prices can be observed, two approaches are suggested: the written down replacement cost, and the discounted value of future returns (UN et al, 2014, 5.4.4).

For environmental and ecosystem services, an estimated market price may be gathered from payments for such services or trading schemes. Where these do not exist, valuation methods for market price equivalents consist in a unit resource rent approach, which represents an estimated price for the ESS (UN et al, 2014, 5.81), the replacement cost method which is based on costs that are associated with mitigating actions if the service was lost (excludes any consumer surplus), and the costs of treatment method which is based on the costs of repairing damages that would occur without the service (UN et al, 2014, p.119).

A simulated exchange price method is, furthermore, used to generate exchange values of environmental services whose prices cannot be observed in the market (Caparros et al, 2017). Different valuation techniques can be used here. In one recent study, the travel cost method has been used to generate simulated exchange prices in the context of recreation-related services (Scheufele and Pascoe, 2023). Alternatively, consumers' willingness to pay measures have been used to estimate a demand curve, from which exchange values are estimated (UN et al, 2014, 5.76). However, this is not equivalent to estimating consumer surplus (Fenichel, 2020), and, thus, care must be taken in delineating what is being estimated using the given non-market valuation method in question.

In particular, the valuation methods used for estimating SEEA-aligned exchange values could (although do not necessarily have to) differ from those used for shadow prices in that the former should be methods that necessarily exclude consumer surplus. That is, a key distinction in the use of valuation methods is whether consumer surplus is included in the estimate or not. At exchange values, valuation

methods excluding consumer surplus should be used. Whilst some categories of ESS may be more likely to already be included in the SNA production boundary, such as provisioning services,[14] all categories of ESS (provisioning, regulating and cultural services[15]) are within the scope of the SEEA and therefore valued at exchange values. The methods used must be those that exclude consumer surplus from the estimated exchange value. Thus, two separate questions need to be distinguished: (1) whether the ESS generates a consumer surplus, and (2) whether the valuation method adopted captures that consumer surplus. The latter question (2) also needs to be followed by a judgment on whether and in what cases it is desirable to capture the value of the consumer surplus.

This is where clarity is needed about the mapping of non-market valuation methods to concepts in estimating the value of SNA and non-SNA items. The literature covers examples of non-market valuation methods used to estimate an exchange value, or SNA-aligned benefits. For example, it is likely that some regulating services may generate a value which includes consumer surplus, such as through the positive health benefits linked to air filtration (UN et al, 2014, 5.67). They may also generate producer surplus, for example, in preventing damages to production (UN et al, 2014, 5.68). Thus, in SEEA accounting practice, where no market prices are available for regulating services, non-market valuation methods, such as consumer WTP are often used to capture the value.[16] In the cases that the valuation method does capture consumer surplus in the estimated value, it may be more fitting to consider the value estimates of some regulating services as social welfare values, which are consequently not directly comparable with exchange value estimates (used in SNA national accounting). A replacement cost approach to regulating services, for example, may, on the other hand, generate estimates considered suitable as market equivalent price estimates (UN et al, 2014, 5.70).

On the other hand, the value of some cultural services may only be determined in terms of social welfare. For example, it is a challenging, potentially impossible, task to estimate the exchange value of a symbolic or spiritual good. Other cultural services pose a different range of difficulties. For example, recreation and tourism economic activities are included within the SNA production boundary but at the same time can generate social welfare beyond that including both consumer or producer surplus (UN et al, 2014, 5.72).

[14] Provisioning services relate to goods extracted from an ecosystem. They often include SNA-type benefits, hence the value of production of some of these goods is included in the SNA production boundary (and in GDP) (UN et al, 2014, p.113).

[15] Cultural services are likely to include a larger number of services that relate to non-SNA benefits, and that generate consumer surplus, which can pose a particular challenge to estimating their exchange value.

[16] Apart from using different non-market valuation methods, another approach to accounting for the exchange value is to impute a price for some of these ESS based on what would be the market equivalent price. This is possible when there are existing markets that can be used as a proxy for a market of the given ESS.

Thus non-market valuation methods are used when no market prices or equivalents exist to estimate exchange values as well as broader social welfare estimates, which include consumer or producer surplus. These include a range of revealed and stated preference methods.

Existing non-market valuation methods applied to natural capital assets have been used to estimate both (1) changes in consumer surplus following a (potential) policy change, or (2) the aggregate level of consumer surplus associated with an environmental asset (UN et al, 2014, 5.96). At the same time, exchange value estimates are also generated through these non-market valuation methods, aligned with SNA accounting, because these revealed and stated preference methods rely on either a constructed demand curve or an existing market utility function.

In his Review, Dasgupta (2021) notes that revealed and stated preference methods do not reflect the production possibilities in an economy. Thus, Dasgupta rejects the use of revealed or stated preferences alone to estimate ESS shadow prices (p.306). Some ESS, such as fisheries as in Dasgupta's example (p.306), should, therefore, be viewed and valued as *production systems*. In these cases, insights from value estimates of ESS as production units are required. Given negative or positive externalities, however, market price equivalents of production systems could be over- or under-estimates of the shadow prices.

A broader category of social value, may also include values such as intrinsic or sacred value or broader types of existence value, as noted above. Dasgupta (2021) offers the example of sacred mangroves, which may be considered to have infinite or unquantifiable value. The example represents a different value category to the potentially infinite or unquantifiable value that might be attached to the last drops of drinking water or breaths of clean air. These non-economic considerations fall within the scope of some of the welfare frameworks mentioned above in Section 3, but fall outside the scope of this paper.

Finally, it is worth noting debates about the valuation of cultural and heritage capital. This category of asset bears a resemblance to natural capital. It is largely a non-SNA asset, in that much of it falls outside of the current production and asset boundaries, and faces some of the same issues of overlaps of valuation methods across estimating either exchange or social welfare values.

Cultural (and included in this category, heritage assets) are produced but can comprise both tangible and intangible assets, and can overlap in features with other types of capital such as natural capital or produced capital (Bakhshi, Coyle and Lawton, 2023). In general, cultural and heritage capital are considered difficult to measure and estimate their value because of their broad and qualitative nature. It is often argued that a large part of cultural value cannot be expressed in monetary terms or

understood in a quantitative or qualitative scale (Throsby, 2003). There have, however, been some recent attempts to measure and value cultural assets, see for example Bakhshi, Coyle and Lawton (2023) for a valuation study of a heritage asset. Significantly, the valuation of this intangible asset consists in valuing some non-SNA benefits. In addition, Wright and Eppink (2016) conduct a meta-analysis of a large number of valuation studies of heritage sites.

In a recent conceptual and empirical study of cultural and heritage capital, Bakhshi, Coyle and Lawton (2023) explore valuation approaches to the particular asset that is a state-owned manor house (Bleinheim Palace) as a heritage asset. Both market and non-market valuation methods are used in the overall analysis. In the conceptual side of the study, the authors (Bakhshi, Coyle and Lawton, 2023) identify a range of non-market asset valuation methods that are relevant more broadly to estimating the value of cultural and heritage capital assets.

Section 7: Human capital

Human capital has traditionally been taken as the accumulation of people's skills and knowledge (Becker, 1962), as well as competencies and attributes "embodied within people that facilitate the creation of personal, social and economic well-being," (OECD, 2001, p.18 cited by Mubarak et al, 2024). Dasgupta also proposes that "diversity of aspirations, talents and drives are features of human capital," (Dasgupta, 2021).

Whilst there is growing consensus around health as a fundamental asset class in human capital formation, research measuring health as human capital has been comparatively scarce, sometimes put down to the conceptual difference of health from other classes of human capital such as education or training (Becker, 2007). Some literature has presented health as not only an asset for individual well-being and welfare, but furthermore as an asset linked to returns on investment and economic productivity (Bloom and Canning, 2003). Arrow et al (2012) treat human capital and health capital as two separate capital stocks that contribute to estimates of levels of and changes to countries' total comprehensive wealth and sustainability over time. Work on measurement of health as human capital has followed, such as incorporating individual health status into human capital stock measures (O'Mahony and Samek, 2021).

While by certain criteria human capital overlaps with characteristics of a fixed asset in the SNA framework because "it raises the productive potential of the individuals concerned and is a source of

future economic benefit to them," (SNA, 2008), human capital is excluded from the SNA (2008) asset boundary because it is in part non-physical; non-appropriable; and difficult to measure.[17]

Three main approaches to measuring and valuing human capital are acknowledged in the economics literature: an income-based approach, a cost-based approach and an indicator-based approach. Commonly, a country's human capital stock is comprised of the aggregated sum of individuals' human capital, which can occur over all three of these approaches. An income-based and cost-based approach are both consistent with SNA national accounting principles, and, thus, with measures of other types of capital. The indicator-based approach stands apart from the other two methods in this regard.

The split of income and cost-based methods on the one hand, and indicator-based methods on the other, can broadly be mapped onto the two value concepts of exchange value and social welfare value, respectively. The first two align with SNA accounting principles, and are measures in terms of exchange values. Human capital is valued by its observable price in the market or by estimating a market equivalent price. The indicator-based approach can potentially capture broader welfare value, although whether this maps onto welfare value understood as consumer or producer surplus, as discussed in the case of natural capital above, should be explored.

Certain empirical valuation approaches are well-embedded in human capital stock measurement attempts and are consistently used across statistical agencies. For example, based on the above definition provided by Becker (1962), the UK's ONS take the human capital stock as "the value of the acquired skills and knowledge of the working age population living in the UK" (ONS, 2024). The value of labour services is observable from labour market transactions. Measuring lifetime earnings is a standard method for estimating this value. The ONS use people's projected present value lifetime earnings to value an individual's human capital, which are based on a person's highest qualification, their earnings and the assumption that they are active in the labour market until the age of 65 (Fender, 2013; Liu and Fraumeni, 2020). This is the standard international method provided by the United Nations Economic Commission for Europe (UNECE). Lifetime earnings can then be analysed both individually and as an aggregate capital stock measure. The lifetime earnings approach aligns with an income-based approach to human capital stock valuation.

A cost-based approach involves estimating the value of human capital stock based on the amount spent on investment in education and skills. Alternatively, an output-based approach to valuing

[17] Some aspects of human capital are well accounted for, such as accounting for investment in education and healthcare, but are nevertheless excluded from the SNA asset boundary by choice. In this sense, human capital is not 'missing' in the same way as the other 'missing capitals' discussed in this paper.

human capital looks to the total value of goods and services produced by the human capital stock. In certain professions the output is less tangible such as teaching which poses a challenge for this valuation method.

Less developed are methods for measuring and valuing the economic flows associated with the human capital stock that explain changes in the stock from one period to the next); on this, Mubarak et al (2024) develop a method for estimating the flows of human capital which identifies a range of factors that can affect the human capital stock from one period to another, and map these changes to broader SNA categories of economic flows.

Other standard approaches to valuing human capital relate to individuals' skills and education. Educational output indicators are used in this approach to estimate human capital. Within this method, the assumption is made that investment in education is related to the indicators (such as, for example, school enrolment rates or average years of schooling), and thus, an indication of human capital formation (Fender, ONS, 2013). Indicator-based human capital valuation methods in the domain of education have several limitations. For example, the schooling years measure does not discriminate between any possible variation of the costs and returns of education at different levels. Differences in quality of education are not well accounted for. Furthermore, education, as an example of an indicator to focus on, is not the only determinant of human capital.

Some of the more widely-used indicator-based measures come in the form of World Bank's Human Capital Index and the United Nation's Human Development Index (Liu and Fraumeni, 2020). They are built on two dimensions – health and education. As such, the indexes are constructed to generate insight on how investment in these two areas enhances productivity (Liu and Fraumeni, 2020). (The UN Human Development index also includes a variable on standard of living (GNI per capita)).

In a broader view, human capital enters Beyond GDP debates because of the view of non-economic benefits of investment in human capital as determinants of welfare and well-being (Liu and Fraumeni, 2020).

Considering the social welfare value of human capital assets is more challenging. What does it mean for human capital assets to have shadow prices in terms of social welfare values? Does the concept of consumer surplus make sense here (from a demand-side perspective)? Or producer surplus from a supply-side perspective?

In sum, the first question, then, regarding human capital valuation relates to identifying what are the non-SNA benefits of human capital assets excluded from the production boundary currently in conventional national accounting? Work on this is currently underway in the UK national accounts in

terms of exchange values. Secondly, however, in a broader welfare accounting context, we must ask the question of what would welfare value shadow prices of human capital assets consist in?

Moving to welfare value shadow prices could involve a move in valuation methods from cost-based and income-based approaches towards indicator-based approaches, especially if the purpose is for an appraisal context. These indicators may be more specific relating, for example, to education, or they may relate to broader social welfare impacts such as overall health, well-being, productivity or life satisfaction, where measures of these provide a shadow price of broader social welfare value to which human capital services add value. Thus, the human capital services are assessed as outcomes which are contributors to things such as health or well-being. In this case, 'life satisfaction' or 'well-being' are not assets but outcomes; rather the assets are being educated, healthy or socially skilled.

We raise a last exploratory point in the context of human capital. Within the inclusive wealth or Beyond GDP discussions, overlaps between capital assets are particularly challenging in the context of human, institutional and social capital stocks. Whilst social capital is beyond the scope of this paper, it raises challenging issues. Is it a standalone category of asset or should it be considered more as part of the shadow price of human capital? Dasgupta (2021) considers social, institutional and intangible capital as 'enabling' assets, which tallies with the latter approach.

Yamaguchi (2020) argues that there is a grey area involved in human capital stock valuation in terms of observable market prices. Whilst human capital is valued in this way, its total quantity also includes the unemployed. He recognises that accounting for unutilised capital may be a bigger problem in the context of inclusive wealth accounting than conventional national accounting based on market and market equivalent prices. However, there are further areas of overlap here. Unemployed human capital has value not only because the workers are ready once there is demand, but because these individuals contribute to social welfare through other household production (Yamaguchi, 2020). The overlaps between human capital and household production accounting, therefore, as well as other abovementioned missing capital assets, such as social and institutional capitals, are a vital point to consider in future research.

Section 8: Intangible capital

Intangible capital is a capital stock that is widely recognised in national and wealth accounting frameworks, as well as modern theories of economic growth, yet the term is used broadly and variably. One common definition of an intangible asset is that an intangible asset is "an identifiable non-monetary asset without physical substance" (UN, 2013). Examples of intangible assets include

databases, software and R+D as well as, less conventionally, heritage assets such as historic property. Broader approaches to intangible capital see it as encompassing assets associated with capital stocks as wide-ranging as digital, organisational and cultural capital, whilst narrower approaches deal with more specific delineations of intangible capital, such as digital goods and intellectual property alone. Intangible assets capitalised in the national accounts are computerised information (computer software and databases), innovative property (research and development; mineral exploration and evaluation; entertainment, literary or artistic originals) and other intellectual property products (SNA, 2008). There is indication that broader categories of data will be included in the 2025 SNA. Excluded from the ONS national accounts are design, financial product innovation, branding, organisational capital, and firm-specific training.

When it comes to valuation of intangible capital assets, they are generally considered in the context of firms and organisations. One rationale for this narrowing is the many conceptual overlaps such as between organisational intangible capital assets and human capital assets, or overlaps with household R+D and innovation.

The particular measurement purpose in question can range from internal business needs to national accounts statistics to investment decision-making, and determine the definition of intangible capital used (Van Criekingen et al, 2022). It is worth reflecting that a broader or narrower asset boundary, depending on the approach to intangible capital, has implications for what the accounts and statistics produced indicate. To take an example, in an SNA accounting context, for instance, the line of the asset boundary determines how investment growth patterns are reported (Nakamura, 2010).

Corrado, Hulten and Sichel (2005) identify three main categories of intangible assets: economic competencies; innovative property; and computerised information, based on business survey data, at the same time introducing a wide set of intangible assets. In the context of firm-level investments, intangible capital has been considered as types of knowledge-based, non-physical assets, which beyond the standard indicator of R+D investment, encompass also software tools, attributed designs, and strategies for improving brand awareness, business practices, services delivery, or managing after-sale services (Corrado et al, 2022).

A number of intangible capital assets are accounted for in the UK national accounts (with modest expansion due in SNA 2025). These capitalised intangible assets and currently included in GDP are measures for computer software, databases, R+D, mineral exploration and literary and artistic originals, following the changes made in the 2008 SNA (Mortensen, 2013; ONS, 2024). Since the 2008 SNA, these have been described collectively as Intellectual Property Products instead of ‘intangible fixed assets’ (van Criekingen et al, 2022; ONS, 2024).

Other intangible assets are not included in the UK national accounts, termed "uncapitalised intangible assets", including branding, financial product innovation, firm-specific training, and design (ONS, 2024). In terms of the Corrado, Hulten and Sichel (2005) categorisation, all assets under their heading of economic competencies are left out from the national accounts (i.e. market research and branding; operating models, platforms, supply chains, and distribution networks; employer-provided training), as well as attributed designs (industrial), and financial product development assets under the innovative property category (Corrado et al, 2022).

The capitalised intangible assets, included in the UK national accounts, are valued at exchange values. Conventional valuation methods for intangible assets in terms of market equivalent prices are: cost-based approaches; income-based approaches; and market-based approaches. In their review, van Criekingen et al (2022) report that three measurement methods are used to estimate the exchange values of intangible assets (the authors call these shadow price estimates, but use the methods to estimate exchange values of intangible assets). These are expenditure-based approaches; market valuation approach and an intellectual property right (IPR) based approach. The first, expenditure-based approach, estimates the value of intangible assets by applying a net present value approach, and project the past flow of expenses into a current stock of assets (van Criekingen et al, 2022). It is assumed that firms invest in the assets until the discounted present value of the expected income stream equals the cost of producing the marginal asset (van Criekingen et al, 2022). The market valuation approach assesses the value of intangibles based on the difference between the book and market value of the firm (van Criekingen et al, 2022). The IPR-based approach estimates the market value of legal rights being awarded.

In a large part of the empirical work carried out to estimate exchange values of intangible assets, the conventional valuation methods used rely heavily on business and organisation surveys. These valuation exercises subsequently link to intangible assets in the domain of firm or organisation-level investment. Martin (2019) proposes new methods for measuring the value of some uncapitalised intangible assets that currently fall beyond the ONS national accounting asset boundary through investment of firms in them: he focuses on in-house branding investments, employer-funded training investments, and in-house investments in organisational capital.

Intellectual property initially provides value to the creator for a given period. Once the given term expires, the value becomes entirely social. It is unclear from the literature how to understand the implications for value measurement of lasting monopoly rents arising from market power. Some authors argue that the market prices or exchange values of some categories of intangibles are largely

reflective of monopoly power (Kurz, 2023). One possibility would be to consider these exchange values as omitting a negative externality.

Overall, the above points summarise the advances made around valuing intangible assets at exchange values. Whilst one important strand of work on measuring the value of intangible assets relates to developing methods for including intangible assets currently outside the SNA asset boundary, but which are exchanged on the market, another strand has focused on the measurement issues around another group of intangible assets, also excluded from the national accounts, namely those intangible assets without a market price. The digital economy and digital goods are a prime example of the focus of this second strand.

Before we turn to digital assets valuation methods, a question that is accentuated in the case of digital assets with no market price is that of measuring a welfare-type shadow price. Many digital services are free, and hence, again as above, valuation methods can be unclear as to the relevant value concept, i.e. exchange or welfare values. The question is not limited to non-market assets, as we may also be interested in a welfare value of a market asset, but the particular valuation methods used for non-market assets means that these two questions ((1) valuing non-market assets and (2) valuing welfare values of intangibles) often become confused. Underlying the discussion of these next points is the question of what is involved in the move towards measuring welfare value shadow prices of intangible assets.

Digital goods and services generally fall into the broader category of benefits linked to intangible assets. There has been significant growth in the number and types of digital assets available in recent years (Jackson and Luu, 2023), and many of these have no market price. Developing techniques for their valuation, according to value concept, and contribution to economic welfare is thus an increasingly important endeavour.

When it comes to *digital* goods and services, there are three main approaches to valuing digital assets at exchange values: **market-based, income-based** and **cost-based** approaches. The ONS record two market-price equivalent measures of digital economy services in terms of (1) GVA where market prices are available and (2) gross output.

Regarding free digital goods, a number of valuation methods are being developed, although these are predominantly intended to be used within a national accounting context. It is in the context of these kinds of free digital goods that the 'value-type' shadow price question becomes relevant. That is, is an exchange value or consumer surplus/welfare value being measured? There are inconsistencies across

the literature in what is being measured across these valuation approaches: some measure a market-price equivalent value while others measure the consumer surplus or welfare value of the asset.

In studying valuation methods of free digital technology services, Bourgeois (2020) identifies three monetary valuation approaches: firstly, summing the advertising income for those services that are indirectly financed through advertising; secondly, assessing users' willingness-to-pay for the services or valuing the service by using standard methods used to value users' time spent on domestic tasks; thirdly, valuing the data generated by use of the services. Yet, these three approaches scaled do not all relate to the same concepts.

One specific area of digital capital valuation that has received recent attention is *data* valuation. Data is defined as a "produced asset consisting of stored digital records structured in such a way that they can be used to inform decisions" (Coyle and Manley, 2022). Coyle et al (2020) argue that having the ability to use and infer from data presents potential value to measures of aggregate economic welfare. Additionally, in the recently adopted 2025 SNA (United Nations Statistics Division, 2025), data, specifically for the purpose of measurement of data production, has been defined as, "information content that is produced by accessing and observing phenomena, and recording and storing information elements from these phenomena in a digital format and that provides an economic benefit when used in productive activities."

Data valuation presents a further example of a fuzzy mapping of valuation methods to exchange or broader welfare valuations of digital assets.

One recent overview of data valuation methods is provided in Coyle and Manley (2022). The methods identified there fall into three groups: cost-based; income-based and market-based methods. These partly coincide with the data valuation approaches delineated by Ker and Mazzini (2020) which are cost-based approaches, income-based approaches, approaches based on market capitalisation, and an approach based on the link between trade flows and data flows.

Market prices as a valuation method are scarce since there are not many examples of private markets for data (Coyle and Manley, 2022). Reviewing alternative valuation methods, Coyle and Manley (2022) find that valuation methods include and can be split across revealed and stated preference methods. Coyle and Diepeveen (2020) have advanced work on conceptualising a welfare value of data as an intangible asset. By identifying both economic and informational characteristics of data, the authors demonstrate how an expanded view of the characteristics of data can lead to accounting for a broader social welfare estimate.

Section 9: Estimation methods

Table 1: Estimation methods in existing literature

	Natural capital assets	Cultural and heritage capital assets	Human capital assets	Intangible capital assets
Market price and econometric methods	Methods capture the use value of ESS that are inputs to market products or businesses, such as raw materials. For example, they can estimate the value of the effects of water quality on agricultural or forestry output.	Production function approaches are used to measure the value of a cultural or heritage asset service as a contributing input to another market activity (Bakhshi, Coyle and Lawton, 2023).	Income (or output-based) approaches use outputs from human capital measured by labour market income to measure human capital asset values. Cost-based approaches rely on the value of the inputs that make up the production of human capital.	Market-based, income-based, and cost-based are used to value intangible capital assets at exchange values. For non-priced digital goods and services, measures of advertising income for services (Bourgeois, 2020), or the prices of premium internet goods as proxies have been used (Lourenze Poquiz, 2024).
Stated preferences				
Contingent valuation (CV)	Stated preference methods include WTP and WTA techniques which can be used to back out implied demand curves.	Individual and aggregate measures of WTP or WTA cultural and heritage assets are estimated through surveys (Bakhshi, Coyle and Lawton, 2023).	A number of studies has explored measures of WTP for quality-adjusted life years (e.g. Kouakou and Poder, 2022; Robinson et al, 2013).	Free digital goods are valued using survey-based CV methods (Coyle and Nguyen, 2020). CV methods are used for data valuation (Coyle and Manley, 2022).
Choice modelling and experiments	These methods are used to capture the use and non-use value of a range of ESS (UN et al, 2014).	Discrete choice experiments can generate cultural and heritage asset value estimates (Bakhshi, Coyle, Lawton, 2023).	Discrete choice experiments have been used to estimate WTP for quality-adjusted life years (e.g. van de Wetering et al, 2015; Yin et al, 2024).	Choice experiments are used for valuing free digital goods (Brynjolfsson, Collis and Eggers, 2019), and real options modelling is used for data valuation (Coyle and Manley, 2022).
Revealed preferences				
Hedonic valuation	Hedonic valuation methods capture both direct and indirect use value. They rely on	Studies use data to isolate effects of how heritage and cultural assets affect house prices	Hedonic valuation methods can be used to capture the quality and welfare value of schools (as inputs to	Hedonic pricing models are not applied widely in the case of intangible assets but methods

	estimating the value of ESS through monitoring how house prices, for example, are affected by specific ESS such as waterfront homes, homes near cliff edges or flood-prone areas. The value of other ESS such as air quality, visual aesthetics, tranquillity and landscapes are also estimated.	to make welfare value estimates of the assets (Bakhshi, Coyle and Lawton, 2023).	education and human capital) from house prices.	are developed for valuing intangible assets of firms (Cohen, 2009).
Travel-cost	These methods are widely employed to estimate the value of ESS, particularly those contributing to recreational activities (Scheufele and Pascoe, 2023). Expenditure across travel and other associated costs such as entry fees and accommodation can be used to estimate the demand for certain ESS in terms of aggregated travel costs.	For cultural and heritage assets, use visit numbers can be monitored or entry and ticket prices used to estimate asset values (Bakhshi, Coyle and Lawton, 2023).	Not applied to human capital valuation in the literature.	Not applied to intangible capital valuation in the literature.
Averting behaviour	These methods relate to the price paid (or stated WTP) to avoid incurring environmental costs. For example, the cost of water filtration may be used as a value proxy for water pollution damages (UN et al, 2014).	Not applied commonly to cultural or heritage capital valuation in the literature.	Averting behaviour methods could be used to value particular aspects of human capital, such as avoided health costs and expenditures.	Not applied commonly to intangible capital valuation in the literature.
Random utility	These models are used to estimate use and non-use value of ESS, mainly those associated with recreational	Not applied commonly to cultural or heritage capital valuation in the literature.	Not applied commonly to human capital valuation in the literature.	Not applied commonly to intangible capital valuation in the literature.

	activities (UN et al, 2014).			
Valuation of impacts	Valuation of natural capital assets through impacts are assessed using other methods included in this table, such as averting behaviour or well-being evaluations.	Valuation of cultural or heritage capital assets through impacts are assessed using other methods included in this table, such as hedonic valuation or well-being evaluations.	Valuation of human capital assets through impacts are assessed using other methods, such as indicator-based methods.	Valuation of data through impacts affected by data use (Coyle and Manley, 2022).
Productivity	Dasgupta (2021) advances a valuation approach to certain ESS based on ESS as production systems.	Not applied in work to date.	Productivity of workers is a commonly used measure contributing to standard valuations of human capital stocks e.g. in metrics such as output per worker etc.	Productivity of IP or other intangible assets is a commonly used measure.
Subjective well-being evaluation	Some studies evaluate subjective well-being from interactions with the natural environment (DEFRA, 2008).	Well-being evaluations are used to estimate welfare value (Bakhshi, Coyle and Lawton, 2023)	Method can capture some aspects of welfare value of human capital assets, such as self-assessed physical and mental health.	Not applied to intangible capital valuation in the literature.
Indicator-based	Physical accounts of environmental goods and services are compiled in the SEEA (UN et al, 2014).	Not applied commonly to cultural or heritage capital valuation in the literature.	These include, for example, education attainment or rates of education at different levels.	Not applied commonly to intangible capital valuation in the literature.
Broader value classes – valuation methods of expertise or democratic deliberation				
Existence value	Existence value is a category of the TEV framework, and studied in the context of natural capital assets.	Existence value is a category of the TEV framework, and relevant to cultural and heritage capital assets.	Human capital may be associated with existence value in certain contexts, for example, considering the existence value to individuals of farmers in the agricultural sector.	Intangible capital assets are not commonly associated with existence value in the literature.
Intrinsic or sacred value	Intrinsic or sacred value is a value type associated with natural capital	Intrinsic, historic or sacred value may be associated with	Some scholars argue for the intrinsic value of work (see Sandel, 2020).	This value type is not widely discussed in the literature in the

	assets which falls outside of the standard and TEV welfare value frameworks (Dasgupta, 2021).	cultural and heritage assets.		context of intangible assets.

(Green marks well- developed methods in the literature; yellow marks the conceptualisation/potential of use of methods in the applied domain; red marks no use or development of methods in the specified domain to our knowledge.)

Section 10: Classification and other issues

10.1 Classification - overlaps

Double counting poses conceptual issues in standard national accounting. There are naturally, therefore, conceptual issues around boundaries and double counting whatever prices are used – although it is especially pertinent with shadow prices, where missing capital asset definitions can be vague or ill-defined across the literature.

Accounting for multiple services belonging to different capital assets already poses a challenge when assets are valued at exchange values. There are several issues. One relates to the particular market conditions, for example, whether or not there is a market for the service such that externalities are internalised. For example, in imputing the price of an ESS based on an existing market acting as a proxy, such as the recreational and aesthetic services of a local park, one approach is to look to house prices. The house price represents a "bundle" of capital services, including some ESS. If there is a perfect market for the house, the exchange price does not include any consumer surplus, and thus, the value of the ESS can be separated from other capital goods and services in the overall product, and estimated at exchange value without including consumer surplus associated with the ESS. How should 'bundled' value of assets be classified when valued at shadow prices?

There is also debate around overlaps in terms of the value of benefits linked to an asset, but generated by several capital assets, and thus how to isolate how the value is allocated across different capital assets. This question arises, for example, when considering the value of social capital in relation to other categories of missing capitals. Does the value of an asset already reflect the value of benefits derived from social capital without these needing to be separately counted? That is, does the value of, say, a house in a given community, or a natural asset such as a park, already reflect the value of the social capital 'service' (as suggested in Dasgupta, 2021). Should attempts be made to isolate and

allocate the value of the social capital asset or associated service, separate from other estimated values? Similarly, social or institutional capital may affect expected value of flows of incomes for various capital assets, such as human capital assets, data or other intangible assets. Identifying such areas of overlap is important when it comes to the aim of constructing social welfare accounting aggregates.

A separate issue of overlaps pertinent to a social welfare approach is that missing capital assets have a range of benefits (and costs) associated to them, some of which are included within the SNA production boundary and some of which are not. There are overlaps in the beneficiaries of a particular missing capital asset (for example, households and firms benefitting from roads alongside the government as the agent that invests in them). Ecosystem assets valued at exchange values can extend the SNA asset boundary. However, the extension is problematic in that the values of many ecosystem assets are already partially incorporated in the value of other assets included within the SNA boundary (UN et al, 2014, p.139). Examples of this include, for instance, some provisioning (also regulating and cultural) ESS partially accounted for within the SNA boundary such as food items, timber and fish.

An enumeration of the main overlaps and underlaps would be desirable.

Finally, another question related to classification beyond our immediate scope here is the question of how to map the accounting of assets at exchange values or shadow prices onto a (1) period by period approach, or (2) long-term perspective approach. In theory, shadow prices should correspond to a long-term approach for comprehensive wealth evaluation as reflecting the net lifetime capital services provided.

10.2 Complementarities/interactions

A separate issue in the context of social welfare appraisal exercises is how to take account in shadow prices of the complementarities or interactions between different types of asset. This can perhaps be thought of in terms of the 'betas' in a 'portfolio' of assets. For example, investment in cleaner air may improve health and human capital, so the social return to the improved natural capital asset is higher as it includes healthier lungs, and more valuable human capital, as an ecosystem service. This seems to be an open research question in the inclusive/comprehensive wealth agenda.

A related issue (perhaps) is the distinction between enabling assets and others. Dasgupta (2021) considers produced, natural and human capital to be the main categories to be accounted for, while social, organisational and intangible capitals are enabling assets.

One way to conceptualise the distinction is in terms of the production function:

$$Y = A(K_{enable}) \,.\, F(K_{embodied,}\, L,E,M,S)$$

where the K terms represent the relevant capital services. Again, valuations could be at exchange values or shadow prices. As Dasgupta (2021) notes, it may be difficult to identify which capital service belongs in which part of the overall function, and ultimately this depends on the classification decisions.

There are two aspects of asset complementarity: the question of services linked to the same capital being complements to one another, and allocating the value generated from complementarities. For instance, we can consider a range of natural capital services or ecosystem services as complements to one another since they enhance the quality and value of the number of services interacting with one another (Dasgupta, 2021). In the case of some ecosystem services, they are perfect complements, in other cases imperfect but they are certainly not substitutes. There are many possible examples of interactions. We can imagine that as the demand for health increases, so too does the demand for clean air. We have also highlighted the potential value generated to comprehensive wealth of possible interaction effects between complements. Bridging these two notions raises the question of how to estimate and allocate the multiplicative value generated from the interaction effect within a given accounting framework. For example, a wind turbine without wind is a valueless asset. Equally, the value of wind cannot be harnessed without the existing produced asset of a wind turbine. In addition, more value may be generated the higher the wind speeds in the area or at higher altitudes. How can we measure the social welfare values of the assets?

There are correlations between the services linked to the same capital asset, but there are also correlations between the different categories of assets. We need to further consider different capital assets as complements to one another in generating value to overall social welfare e.g. the value generated from the interaction of clean air (natural capital good/asset) and health (as human capital asset).

Section 11: A framework for valuation methods

Table 2 summarises the range of valuation methods currently used or proposed for estimating (1) exchange values and (2) shadow prices, where exchange values are expected to be used in standard accounting contexts and shadow prices in contexts of broader welfare appraisal.

Regarding natural and cultural capital for SNA accounting purposes at exchange values, a range of non-market valuation methods are used including revealed and stated preference methods. These are methods used in the cases that no appropriate market prices or market price equivalents can be observed. Human capital assets, at exchange values, are valued using income-based or cost-based methods. At exchange values, market-based, income-based and cost-based methods are used for valuing intangible capital assets.

To estimate shadow prices for appraisal purposes, the following valuation approaches have been identified and mentioned above: for natural and cultural capital there are non-market valuation methods, or alternative subjective well-being or opportunity-based approaches to valuation. For human capital assets, health, indicator-based methods, or opportunity-based approaches to welfare assessment are used. For intangible capital assets, contingent valuation methods and the assessment of broader social impacts have been reviewed.

Table 2: Valuation methods for accounting vs. appraisal purposes

	Natural capital Cultural capital	Human capital	Intangible capital
Accounting	Exchange values		
	Non-market valuation methods: travel-cost method; contingent valuation (stated preference and choice modelling)	Income (output) based methods Cost-based methods	Market-based methods Income-based methods Cost-based methods
Appraisal	Shadow prices		
	Non-market valuation methods Opportunity criteria Subjective well-being estimation methods	Indicator-based methods Opportunity criteria Health	Impacts affected by data use Contingent valuation methods

Figure 5: Progression of non-market asset measures against purpose

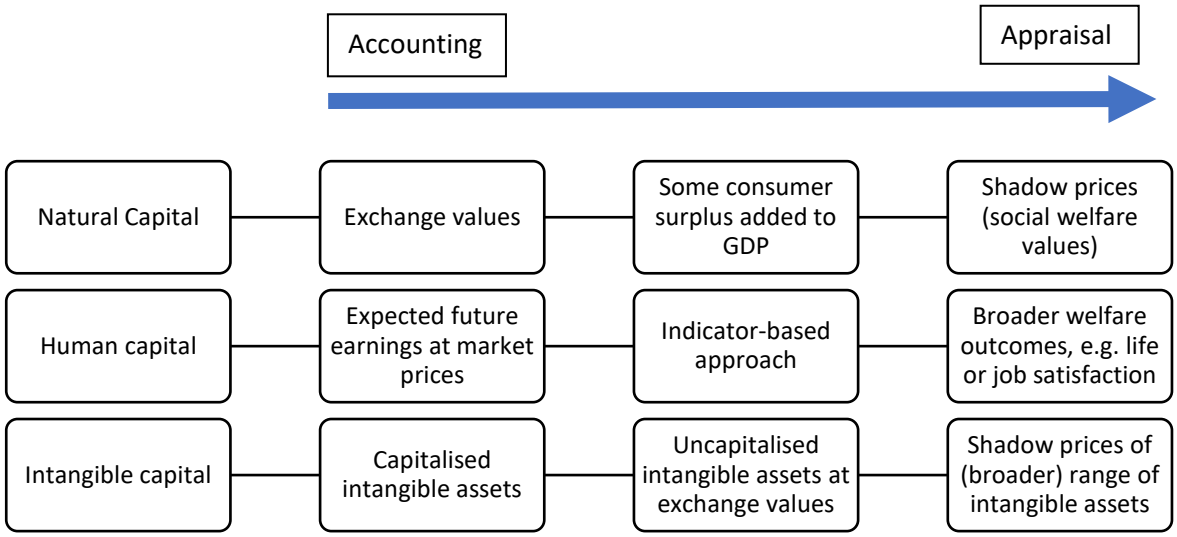


Figure 5 maps out the progression of measures used in shifting between the valuation purposes of frameworks. Here, we follow a shift from a framework for standard economic welfare accounting to a framework for welfare appraisal. Each step in the direction of appraisal purpose of estimates represents an extension to the production and asset boundaries for measures of inclusive wealth, in various ways depending on the asset category.

Conclusion

As the measurement of missing capitals becomes an increasingly demanded feature of economic welfare assessment, so too does the importance of systematising approaches to valuing them and estimating shadow prices. Recent revisions to the national accounts (SNA 2025) consist in expanding asset boundaries while valuing assets at exchange values. Alongside this, there is a growing body of work estimating the broader social value of missing capital assets, goods and services, valued at shadow prices. There is some lack of clarity in the relevant existing economic literature around the value constructs involved and the appropriate valuation methods for their estimation. Clarifying the relevant concepts forms the focus of this paper. The paper has reviewed conceptual and methodological issues in shifting from estimating exchange values to shadow prices of assets across four missing capitals: natural, cultural and heritage, human and intangible capital, and provides a consistent framework mapping asset category to valuation methods and the embedded value theory. To this end, the importance of being clear about the possible value concepts underlying shadow price estimates has been highlighted, as well as the importance of distinguishing between purposes of

valuation of missing capital assets. Finally, the paper has highlighted questions and areas for future research, especially regarding overlaps between asset categories as well as complementarities in generating value between them.

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