Centre for Efficiency and Productivity Analysis

Working Paper Series
No. WP172021

Framing Measurement Beyond GDP

Paul Schreyer

Date: November 2021

School of Economics
University of Queensland
St. Lucia, Qld. 4072
Australia

ISSN No. 1932 - 4398

Framing Measurement Beyond GDP *

Paul Schreyer OECD

November 29, 2021

Abstract

While the *Beyond GDP* agenda has been with us for some time, it has come centre stage in the Covid crisis. The idea of building back a greener, more inclusive, more resilient economy resonates well with measurement efforts beyond GDP. But the field of potential indicators is vast and measurement choices need some structure. We present a measurement framework that distinguishes between the production sphere, the well-being sphere and the asset sphere. GDP remains a cornerstone of the production sphere but is not suited to capture people's well-being, or sustainability of produced and natural assets. As one moves beyond GDP, however, ambitions for a single-valued aggregate have to be scaled down in favour of pragmatic choices for indicators.

Keywords: Beyond GDP, green accounting, national accounts, well-being.

1 Introduction

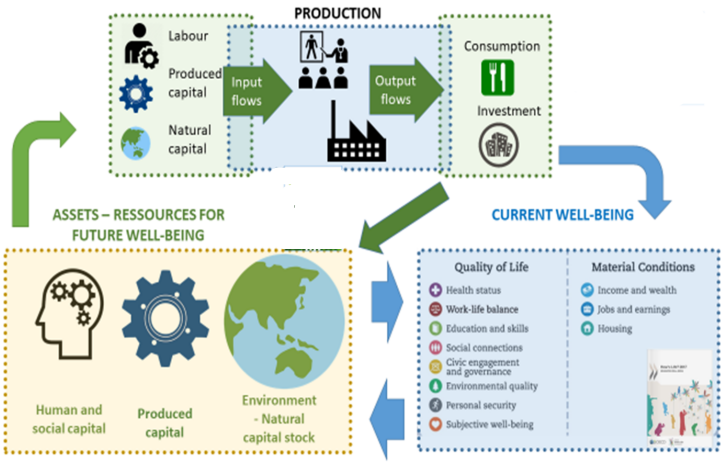
Sound economic, social and environmental measurement relies on sound conceptual frameworks that provide relevant evidence. New social, environmental and economic issues have surfaced over the last two decades or so. More recently, policy makers' desire to 'Build Back Better' from the pandemic has put additional weight on the need for measurement approaches *Beyond GDP* or rather *GDP and Beyond* [1].

*This paper draws on a document provided as input to the 2020 meeting of the OECD Council at Ministerial Level (see OECD[31])Opinions expressed are those of the author and do not necessarily reflect the views of the OECD or its Members.

[1]For a general discussion about GDP, its interpretation and uses, see for instance Stiglitz et al[44], Schreyer[39], Hoekstra[23], Heys et al[21] or Deaton and Schreyer[13].

At the risk of over-simplification, these issues can be addressed along three distinct but connected areas or spheres, each with its specific questions and corresponding measurement response (Figure (1)). They are the production (and market) sphere, the (*current*) well-being sphere, and the asset (or sustainability) sphere that provides the resources for *future* production and well-being. There is significant value in measuring each of these spheres, and the interactions between them. The three-tier framework is not new - its basic features can be found in Stiglitz, Sen and Fitoussi[44], in the OECDs approach towards measuring Green Growth and Well-Being, in a number of national statistical publications and at least in its very basic structure, in a large body of academic literature around the theory of environment-economic measurement[2].

Figure 1: Three spheres



Source: OECD[31]

The main purpose of what follows is sketching a measurement framework and drawing conclusions for the interpretation of well-known measures such as GDP or productivity growth. We also put forward some measurement proposals that are feasible and relevant. Not everything that can be captured conceptually can be measured in practice - at reasonable cost - and not everything that can

[2]Basic features can be found in Weitzmans[51] welfare interpretation of Net Domestic Product. Dasgupta [10], [11] are other examples. Fleurbaey and Blanchet[18] provide an in-depth theoretical treatment.

be aggregated in concept can be aggregated in practice. An example of the former is measuring societal shadow prices for all types of relevant assets, an example for the latter is coming up with a single measure that aggregates across all relevant dimensions of current well-being. A pragmatic approach is needed. The measurement agenda *can* be advanced and should be advanced to capture key aspects of the economy, society and the environment.

2 Production sphere: what gets in and what comes out of the "factory gates"

To characterise the production sphere, we consider a single-valued (for simplicity) non-negative aggregate measure of output, Q, volume GDP. And we consider the following (primary) inputs: L, to refer to labour input, measured as a single aggregate of hours worked; $S_K \equiv [S_{K1}, .., S_{K,m-1}]$ to refer to $m-1$ types of capital services flows from (mostly produced) capital stocks $K \equiv [K_1, .., K_{m-1}]$ within the asset boundary of the System of National Accounts (see European Commission et al.[16]). These comprise produced assets (such as machinery, equipment or intellectual property assets) and some non-produced assets, in particular land and subsoil assets (such as minerals or petrol in the ground). All of the above inputs are market inputs, with service flows acquired through market transactions or through ownership over assets.

Non-market ecosystem services. For the purpose at hand we extend the scope of factors that explicitly enter the production sphere and specify a flow of those ecosystem services $S_N \equiv [S_{N1}, .., S_{Nn}]$ that also shape the production sphere, but that are not subject to market transactions. The SEEA[46] defines ecosystem services as " [...]the multitude of resources and processes that are generated by ecosystem assets: collectively, these flows to people are referred to as ecosystem services. [...] Flows of ecosystem services may relate either to flows of natural inputs from the environment to the economy (e.g., from the logging of timber resources) or to flows of residuals to the environment (e.g., emissions and waste) due to economic and other human activity. Flows of both natural inputs and residuals can impact on ecosystem assets, including on their structure, composition, processes, functions and biodiversity." (SEEA 2012 [46], paragraph 2.14, p.16). Some of these ecosystem services are thus

the subject of market transactions (e.g. flows of timber resources) and would be captured as part of S_K whereas others would not be part of the standard national accounting system, such as emissions. Ecosystem services are rarely referred to in the measurement of production and productivity but correspond to what is generally meant in debates about 'the environment'. They will play a role for our conclusions on the measurement agenda and interpretation of sources of growth. Just like service flows from fixed assets (such as machinery) are related to a stock of assets, ecosystem services constitute flows from ecosystem assets such as forests, lakes or deep sea floors[3].

Ecosystem assets are defined spatially[4] and so are the associated ecosystem services, comprising provisioning services, regulating and maintenance services as well as cultural services. These go well beyond what enters directly as an input into producing units within the boundaries of the SNA. For instance, water filtration that helps crop yields provides direct input into the production of Q. Other ecosystem services such as cultural services (visual amenities or religious functions associated with nature) do not constitute input into production unless they are an enabling factor for example for the tourism industry. Provisioning services of timber from forests may fall under either S_N or S_K, depending whether economic ownership is exerted over the forest (in which case it is part of the SNA asset boundary) or not. Any particular type of ecosystem asset will provide a bundle of services to firms, households or government. But there is no unique mapping between flows of ecosystem services and particular ecosystem assets. As can already be gathered here, ecosystem services are complex, dynamic, spatially defined and potentially cross-border [5]. We shall re-

[3]See SEEA 2021[47] for a full description.

[4] "Each ecosystem asset has a range of ecosystem characteristics - such as land cover, biodiversity, soil type, altitude and slope, climate - which describe the operation and location of the ecosystem. Some of these characteristics may be considered relatively fixed (e.g., slope and altitude), while others may be more variable (e.g., rainfall, land cover and biodiversity)." (SEEA 2012 [46], paragraph 2.12, p.16).

[5]Globalised production in international value chains, coupled with digitalisation often entail cross-border flows of capital services from intangible assets such as intellectual property products. Several of the characteristics that apply to ecosystem services S_N are then equally valid for the measurement of inputs into subsidiaries of multi-national companies: for example, the free use of a design or patent by a subsidary has the form of a non-market transaction. In this context, Blanchet([3]) has argued that there is effectively no analytical way of capturing the contribution of individual factors of production from a domestic perspective and attention should be turned to measures of income, rather than GDP.

turn to these complexities later on and take it for the moment that production possibilities can be represented by a technology set ϕ^t such that:

$$\phi^t \equiv [(Q, L, S_K, S_N) : (L, S_K, S_N) \text{ can produce } Q \text{ in period } t]. \tag{1}$$

Measured productivity is conditional. For available flows of ecosystem services, for given wage rates w and user costs of economic assets, u_K, producers combine L and S_K in a cost-minising way to produce Q. To save on notation, we let $X \equiv [L, S_{K1}, ...S_{Km-1}]$ denote the m-valued vector of combined labour L and capital S_K inputs (other than ecosystem services), along with the m-valued vector of input prices $p_X \equiv [w, u_{K1}, ..., u_{Km-1}]$. Next, consider a conditional cost function[6] γ^t, defined as:

$$\gamma^t(Q, p_X, S_N) \equiv \min_X \left[p_X \cdot X \mid (Q, X, S_N) \in \phi^t\right] = p_X \cdot X. \tag{2}$$

γ^t thus reflects the minimum cost of producing Q, given a vector of input prices, and conditional on a level of entirely exogenous ecosystem services as well as autonomous technology available in period t. Minimum costs corresond to actual costs under the assumption of cost minisation. We use $p_X \cdot X$ to denote the inner product of prices and quantities: $p_X \cdot X \equiv \sum p_{Xi} X_i$.

To keep things simple (but without significant consequences for the points to follow) we assume constant returns to scale and homotheticity in ecosystem services so that γ^t can be written as $\gamma^t = Q^t \mu^t(p_X)/\xi(S_N)$ where $\mu^t(p_X)/\xi(S_N)$ are unit costs of producing Q, non-decreasing in p_X and non-increasing in S_N. Thus, rising input prices increase unit costs, and more ecosystem services reduce them. Productivity growth between two periods $t = 0, 1$ can now be expressed as the change in cost for given input prices and environmental variables. A family of (inverted) productivity indices is given by $\Pi(Q, p_X, S_N) \equiv \frac{\gamma^0(Q, p_X, S_N)}{\gamma^1(Q, p_X, S_N)}$. Given the simplifying assumptions above,

[6] This resembles a restricted cost function, as established by Lau[29] and McFadden[30]. However, restricted cost functions were put forward to address situations where some (market) inputs are fixed or can only be adjusted in the longer term. This does not apply in the case of ecosystem services or free intellectual property assets.

$$\Pi(Q, p_X, S_N) \equiv \frac{\gamma^0(Q, p_X, S_N)}{\gamma^1(Q, p_X, S_N)} = \frac{Q\mu^0(p_X)/\xi(S_N)}{Q\mu^1(p_X)/\xi(S_N)} = \frac{\mu^0(p_X)}{\mu^1(p_X)}. \tag{3}$$

Two natural choices to evaluate the productivity index in (3) are with prices p_X^1 and p_X^0. We choose a geometric average to obtain:

$$\Pi(p_X^1, p_X^0) = \left[\frac{\mu^0(p_X^1)}{\mu^1(p_X^1)}\frac{\mu^0(p_X^0)}{\mu^1(p_X^0)}\right]^{1/2} = \frac{\mu^0(p_X^0)}{\mu^1(p_X^1)}\left[\frac{\mu^1(p_X^1)}{\mu^1(p_X^0)}\frac{\mu^0(p_X^1)}{\mu^0(p_X^0)}\right]^{1/2}. \tag{4}$$

Assume that the unit cost function $\mu^t(p_X)$ has a translog form (introduced by Christensen et al.[9] and generalised by Diewert[12]). Diewert[14] has shown that this flexible functional form approximates an arbitrary cost function to the second degree and the input price index on the right hand side of (4) can be exactly represented by a Törnqvist index of the form $P_X^T \equiv \prod_{i=1}^m (p_{Xi}^1/p_{Xi}^0)^{0.5(v_i^1+v_i^0)}$ where $v_i^t \equiv \frac{p_{Xi}^t X_i^t}{p_X^t \cdot X^t}$ for $t = 0, 1$ is the cost share of each market input.

Next, expand (4) to arrive at a standard form of productivity measurement:

$$\begin{aligned}
\Pi(p_X^1, p_X^0) &= \frac{\mu^0(p_X^0)}{\mu^1(p_X^1)} P_X^T(p_X^1, p_X^0) \\
&= \frac{Q^0\mu^0(p_X^0)/\xi(S_N^0)}{Q^1\mu^1(p_X^1)/\xi(S_N^1)} P_X^T(p_X^1, p_X^0)\frac{Q^1/\xi(S_N^1)}{Q^0/\xi(S_N^0)} \\
&= \frac{p_X^0 \cdot X^0}{p_X^1 \cdot X^1} P_X^T(p_X^1, p_X^0)\frac{Q^1/\xi(S_N^1)}{Q^0/\xi(S_N^0)} \\
\Pi(p_X^1, p_X^0)\frac{\xi(S_N^1)}{\xi(S_N^0)} &= \frac{Q^1}{Q^0} \Big/ \left[\frac{p_X^1 \cdot X^1}{p_X^0 \cdot X^0} \Big/ P_X^T(p_X^1, p_X^0)\right].
\end{aligned} \tag{5}$$

The right hand side of (5) looks remarkably standard - productivity growth is the ratio between real output growth and 'real' (deflated) change in input values. But the left hand side shows the dependence of this growth accounting equation on the ecosystem variables via $\xi(S_N^1)/\xi(S_N^0)$. The point here is that even with the rather strong assumption of homothecity of costs in the environmental variables (which implies dependence of the input price index $P_X^T(p_X^1, p_X^0)$ and the theoretical productivity variable $\Pi(p_X^1, p_X^0)$ on input prices only), the standard way of computing multi-factor productivity - call it $MFP \equiv \frac{Q^1}{Q^0} \Big/ \left[\frac{p_X^1 \cdot X^1}{p_X^0 \cdot X^0} \Big/ P_X^T(p_X^1, p_X^0)\right] = \Pi(p_X^1, p_X^0)\frac{\xi(S_N^1)}{\xi(S_N^0)}$ - implies a conditionality on environmental variables[7]. Thus, if the production sphere benefits from

[7]If conditions are relaxed, e;g. to non-homotheticity of ecosystem services in costs, the

a rising flow of ecosystem services ($\frac{\xi(S_N^1)}{\xi(S_N^0)} \geq 1$), measured productivity growth MFP will be overstated: $MFP(p_X^1, p_X^0, S_N^1, S_N^0) \geq \Pi(p_X^1, p_X^0)$. Conversely, if production becomes less intensive in its use of ecosystem services, measured productivity growth is understated. Also, the production process might - as a by-product - enhance ecosystem assets, for instance when agricultural activity maintains or improves the landscape or enhances soil fertility through organic production techniques. Then S_N would take a negative sign and constitute a (non-remunerated) output. Whether measured productivity growth is over- or understated depends again on whether the flow of such by-products increases or decreases.

The link with ecosystem services here has been the simplest conceivable in the sense that their usage is free and there are no binding constraints or regulations. A richer framework would introduce constraints on the use of ecosystem services and recognise the fact that reducing the use of these services requires resources and implies foregoing market output. Pittman[34], Färe et al[17], Vanoli [49], Brandt et al[6], Cardenas Rodriguez et al[7] are examples of such work. For instance, the latter value the shadow prices of air emissions across a set of OECD countries. Such explicit adjustments or rather, decompositions of a potential GDP or MFP into observed (good) final outputs and the outputs devoted to abatement are possible and useful. Note, however, that by their very nature they embrace a *producer* viewpoint so that ecosystem services are valued from a private, not a social perspective.

To summarise, there is no suggestion here that price and productivity measures should systematically be adjusted for the entire set of ecosystem services. Indeed, the difficulties of measuring and valuing ecosystem services will settle the question. But explicit recognition of *selected* ecosystem services is possible and useful and can be pursued at reasonable statistical cost. And if no such adjustment is undertaken, it is important to remember that our standard productivity measurement tools will inevitably pick up such effects, and, in light of their rising importance, pull our MFP metrics further away from a traditional 'engineering' technology interpretation.

input price index the shift in unit costs would directly depend on S_N, reinforcing the point made here.

Non-market production of households. We have so far glossed over an important element in production, non-market activities carried out by households. With the exception of owner-occupied housing (where the System of National Accounts foresees an imputation for the value of housing services that house owners provide to themselves), other non-market services produced by households are not included in GDP. This includes, for instance, teaching services provided by parents to their children, nursing services provided to infirm relatives or friends, cooking or gardening on ones' own premises all of which are acts of production and yet outside GDP by convention.

There is a long tradition of estimating the value of the non-market production of households, starting in the 1930s (Reid[36]). A basic requirement is the availability of time use surveys, not necessary a matter of course. Valuation of hours of labour input at home entails other complications, with the replacement cost and the opportunity cost approaches as standard methods (for a recent application to OECD countries see for instance Van de Ven et al[50]). However, Schreyer and Diewert [40] have shown that the choice for valuing different types of household production depends on the socio-economic characteristics of the household - for example whether or not it is constrained in its supply of labour on the market. Thus, the valuation of unpaid household work is not a settled matter, and numbers are large. Regular evaluations in a standardised accounting framework without, however, an inclusion in GDP would seem the right way forward to recognise this important aspect of the production sphere. Indeed, as these activities clearly affect people's well-being outcome (health, education, social connections etc.) they also connect naturally to the well-being sphere.

Conclusion 1. GDP, production and productivity remain useful measures for governments' fiscal and monetary policies and macro-economic monitoring. But they need careful interpretation as ecosystem services increasingly interact with the production sphere and many of our standard measures are conditioned on these services. GDP is also oblivious to most production activity by private households outside the marketplace, it takes no account of how incomes are distributed and it is sometimes driven by income from intangible assets such as intellectual property that are moved between jurisdictions to minimise corporate tax burdens (Deaton and Schreyer[13]).

Accounting system. (1) and (2) constitute a simplified accounting system, with the production side reflected in (1) and the income side captured by (2). The national accounting system is complete by adding in the expenditure side where the current value of GDP ($Y^t \equiv P_Q^t Q^t$ with P_Q^t as the GDP deflator) equals private and government aggregate volume consumption C^t (with a corresponding deflator P_C^t) and a vector of volume investments $I^t \equiv [I_1^t, ...I_{m-1}^t]$. We ignore exports and imports and taxes for simplicity of exposition. Gross investment in market assets I^t corresponds to the change in the capital stock $\Delta K = K^t - K^{t-1}$ plus depreciation (or depletion) $D(K^{t-1})$, all valued at prices $p_I^t \equiv [p_{I,1}^t, ...p_{I,m-1}^t]$.

We pause here to underline that while measures of depreciation or consumption of fixed capital (the loss of value of *produced* assets as they are employed in production) are generally available, this is much less the case for depletion (or discoveries) of *non-produced* assets even if these are inside the SNA asset boundary, in particular sub-soil assets. A first and important task is measurement of such depletion and discoveries and the SEEA[46], [47] provides all the necessary guidance. Ecosystem services reduce or enhance ecosystem assets and so bear a resemblance to the notions of depreciation, depletion or discoveries. However, as pointed out above, they are complex to gauge and typically there are no meaningful market valuations to go by. We therefore just depict the stock-flow relationship in physical units and formulate it as a general, possibly non-linear, many-to-many mapping $f^t(\cdot)$ that also allows for other factors Ω to affect ecosystem assets.

$$\begin{aligned} &Y^t \equiv P_Q^t Q^t = P_C^t C^t + p_I^t \cdot I^t = p_X^t \cdot X^t = w^t L^t + u_K^t \cdot S_K^t \\ &\text{where } p_I^t \cdot \Delta K = p_I^t \cdot I^t - p_I^t \cdot D(K^{t-1}), \text{and} \\ &\Delta N = f^t(S_N^t, N^{t-1}, \Omega^t). \end{aligned} \tag{6}$$

Equation (6) constitutes the link between the production sphere and the asset sphere, further explored in Section 4. Equation (6) also constitutes a link to the well-being sphere in Section 3 because it gives immediate rise to net national income (NI), the flow of income adjusted for depreciation (and net income transfers from abroad - ignored here for simplicity). Relevance for economic well-being arises because, in a very simple setting, NI captures aspects of both current and future consumption in particular when expressed in real

terms after deflation with a consumption price index:

$$NI^t \equiv Y^t - p_I^t \cdot D(K^{t-1}) = P_C^t C^t + p_I^t \cdot \Delta K$$
$$NI^t/P_C^t = C^t + \frac{p_I^t}{P_C^t} \cdot \Delta K. \quad (7)$$

We also see that when capital is exactly kept intact ($\Delta K = 0$), the maximum possible consumption equals real net income which corresponds to the basic notion of Hicksian Income (Hicks [22] [8].). Weitzman[51] demonstrated how in a simple closed econonomy without technical progress real net income is proportional to the present discounted value of consumption that the economy is able to produce, thus also giving NI^t/P_C^t meaning as a dynamic measure of economic well-being - a proposal discussed in many places, starting with Usher[48]. Sefton and Weale[41] demonstrated that real savings (which equals real net investment in a closed economy), expressed in consumption equivalents, is the proper indicator of changes to inter-temporal well-being. All that said, the assumptions needed to confidently interpret real net income as a true measure of economic well-being are strong, and include reliance on intertemporal general equilibria, leaving aside aspects of substitutability between consumption and investment and the evolution of future productivity trends. Also, aggregate measures of income are oblivious to its distribution among individuals and households which will form a central theme as we turn to the well-being sphere in the next section.

With a more pragmatic, and less ambitious interpretation as maximum aggregate current consumption possibilities once allowance is made for replacement investment and depletion - but ignoring other non-market assets and therefore questions of sustainability - real net income remains a very useful concept, especially if:

- the set of SNA capital measures K is as complete as possible and includes in particular non-produced, non-financial assets such as subsoil assets and land. One notes that while the quantity of land is more or less fixed, its quality is not. Land degradation and land improvements are thus part of depreciation and capital formation, respectively;

[8] "However, if we do decide to include saving in our Welfare index, the appropriate concept of individual income can be nothing else but what the individual *thinks* he can consume without making himself worse off" (p. 123)

- deflation of NI is achieved with a consumption price index;
- national rather than domestic income forms the basis to correct for (actual and imputed) international transfers of income.

Conclusion 2. Real net national income is a measure that constitutes a first step towards capturing average current economic well-being. While available for most countries, its empirical basis needs improving through updated measures of depreciation, and full consideration of depletion, discoveries and quality change of those non-produced assets that are already part of the national accounts asset boundary, in particular subsoil assets and land.

3 Well-being sphere: what shapes people's lives?

The notion of well-being has gained increasing traction over the last twenty years as an agenda for research, measurement and policy. Particluar early impetus had come through the Human Development Index (UNDP[43]) and through the recommendations of the Stiglitz-Sen-Fitoussi Commission (Stiglitz et al [44]) but the body of related research is large (see Jorgenson[27] for an overview and Landefeld et al[28] for forthcoming work in the United States Bureau of Economic Analysis). The OECD's[32] empirical work with its *How's Life* indicator dashboard has also been on the forefront. It defines current well-being in terms of *Material Living Conditions* and *Quality of Life*, captured through eleven dimensions that shape peoples lives. These dimensions are income and wealth, jobs and earnings, housing, health, work-life balance, skills, social connections, civic engagement and governance, environmental quality, personal security and subjective well-being. A key feature of well-being measures is also that they go beyond averages and consider the distribution of outcomes across individuals and households. Inequalities are central to measuring well-being, both of the material and of the quality of life sort. We thus see that the aggregate income and (economic) wealth dimensions that link back to the production sphere are but a small part of the determinants of current well-being.

Distribution of well-being. To capture current well-being more formally, define a utility function for a household (or type of household) h such that

$U_h = U_h(C_h, S_{Nh}, Z_h)$ [9] where C_h is household's h current consumption of market products, $S_{Nh} \equiv [S_{Nh,1}, ...S_{Nh,n}]$ is its consumption of non-market ecosystem services and $Z_h \equiv [Z_{h,1}, ...Z_{h,l}]$ depicts the vector of other *Quality of Life* outcomes. Household h's minimum expenditure conditional on S_{Nh} and Z_h and a vector of consumer prices $p_C \equiv [p_{C,1}, ...p_{C,c}]$is then given by:

$$E_h(U_h, p_C, S_{Nh}, Z_h) \equiv \min_{C_h} [p_C \cdot C_h \mid U_h(C_h, S_{Nh}, Z_h) \geq U_h] = p_C \cdot C_h. \quad (8)$$

An important step in the task of measuring economic well-being is breaking down income, expenditure and consumption aggregates (6 and 7) by category of household, thus relaxing the assumption of a representative consumer. While there is a long tradition of measuring income and consumption by individual or by household through surveys (and tax records), these statistics are not normally sufficient to achieve a breakdown that is consistent with the national accounts and a series of adjustments are required (Jorgenson and Schreyer[26]). Recent research has already come forward with interesting results, including Zwijnenburg et al[54], Piketty et al[33], U.S. Bureau of Economic Analysis[2] and several national statistical offices). Figure 2 shows an example.

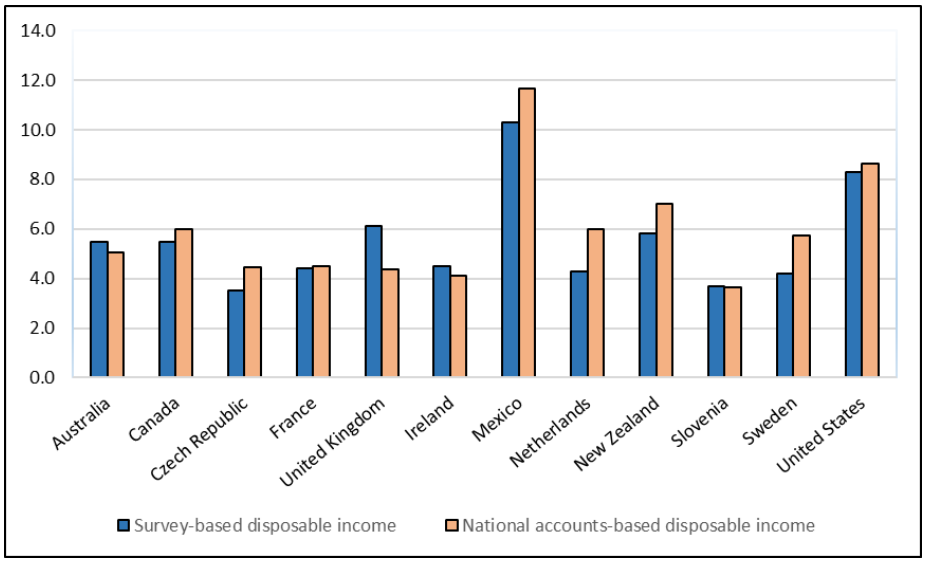
Measured living standards are conditional. There is no space here to discuss the many important practical questions that need to be resolved to achieve national accounts consistency and we refer to the above publications. But there is a conceptual point to be made here, namely that measures of the distribution of income or consumption, even when fully consistent with national accounts concepts remain approximations to living standards, including material living standards, because they are conditional on 'environmental variables' S_{Nh}, Z_h. This is readily seen by comparing consumption expenditures of two (groups of) households h and h' (for example the first and fifth quintile in the income distribution or households in two regions), using (8):

$$\frac{p_C \cdot C_h}{p_C \cdot C_{h'}} = \frac{E_h(U_h, p_C, S_{Nh}, Z_h)}{E_{h'}(U_{h'}, p_C, S_{Nh'}, Z_{h'})} \quad (9)$$

As can be seen from (9), consumption expenditures of the two households reflect both the levels of utility $U_h, U_{h'}$ - which is what we would like to capture

[9] It is assumed that U_h is continuous and increasing in the components of C_h, S_{Nh} and Z_h, and is concave in the components of C_h

Figure 2: Disposable income fifth over first quintile: survey-based and national accounts-based



Note: The graph shows disposable income per consumption unit for the fifth quintile relative to the adjusted disposable income for the first quintile.

Source: Zwijnenburg et al[55].

- *and* the household specific environmental variables. We have assumed here for simplicity that all consumers h and h' face the same prices p_C but household specific prices could be accommodated[10].

A true comparison of living standards based on consumption expenditure, call it $Q_{Uhh'}$, needs to be contingent on reference variables S_N, Z that are identical for the households under comparison. Thus, $E_h(U_h(C_h, S_{Nh}, Z_h), p_C, S_N, Z)$ is the amount which, if made available to the consumer when facing prices p_C and the reference quantities S_N, Z, would make the consumer just as well off as at $U_h(C_h, S_{Nh}, Z_h)$. This is of course nothing but Samuelson's[37] and Samuelson and Swamy's[38]) Money Metric Utility, extended to include environmental

[10]This is in particular needed for international comparisons because price levels differ between countries. Rao[35] provides an overview of comparisons of economic well-being in conjunction with purchasing power parities

variables as in Willig[52], Blundell et al[4] or Fleurbaey and Gaullier[19]. A living standard comparison $Q_{Uhh'}$ between two households is then given by

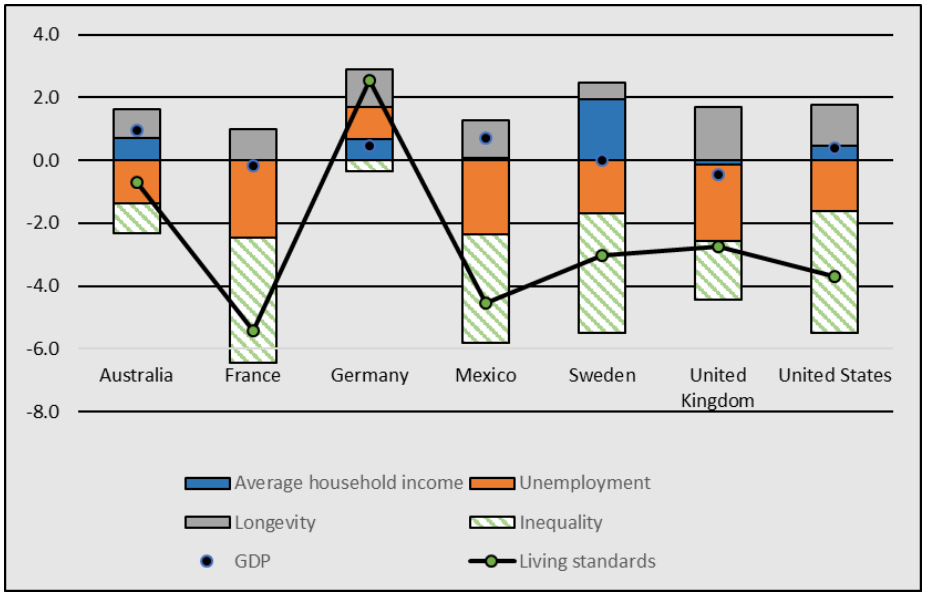
$$\begin{aligned} Q_{Uhh'} &\equiv \frac{E_h(U_h, p_C, S_N, Z)}{E_{h'}(U_{h'}, p_C, S_N, Z)} \\ &= \frac{E_h(U_h, p_C, S_{Nh}, Z_h)}{E_{h'}(U_{h'}, p_C, S_{Nh'}, Z_{h'})} \left[\frac{E_h(U_h, p_C, S_N, Z)}{E_h(U_h, p_C, S_{Nh}, Z_h)} \frac{E_{h'}(U_{h'}, p_C, S_{Nh'}, Z_{h'})}{E_{h'}(U_{h'}, p_C, S_N, Z)} \right] \\ &= \frac{p_C \cdot C_h}{p_C \cdot C_{h'}} \beta \qquad (10) \\ &\text{with } \beta \equiv \left[\frac{E_h(U_h, p_C, S_N, Z)}{E_h(U_h, p_C, S_{Nh}, Z_h)} \frac{E_{h'}(U_{h'}, p_C, S_{Nh'}, Z_{h'})}{E_{h'}(U_{h'}, p_C, S_N, Z)} \right]. \end{aligned}$$

For well-being comparisons, consumption expenditure (or income) comparisons between two households thus need to be adjusted by a factor β which corrects for the differences of each household's situation compared to reference conditions S_N and Z. More precisely β is an index of the expenditure that household h would have to be compensated for, given its distance to references conditions compared to the compensation of household h'. Each ratio in β constitutes an index of money metric utility or willingness to pay, reflective of household specific preferences and the household-specific situation with regard to the reference variables. We note that for β to equal unity so that the simple ratio of consumption expenditures is an accurate measure of relative well-being of the two households, preferences need to be identical and homothetic in the level of utility and the 'environmental' variables *and* each household needs to enjoy (or be subjected to) the same level of environmental variables.

Is it possible to measure expressions such as $E_h(U_h, p_C, S_N, Z)$? The answer is yes, although modelling is required and in general, the number of environmental variables that can be controlled for is limited. Examples include Fleurbaey and Gaulier[19], Jones and Klenow[24] or Boarini et al[5]. The latter estimate measures of equivalent income for health (life expectancy) and jobs for a group of countries (see Figure(3)), allowing for heterogenous preferences. In this case, the value of market consumption (or income) in a particular country is reduced by a monetary value that corresponds to the distance of a country's life expectancy from the world leader (Japan) times the (country-specific, revealed) willingness to pay for an extra year of life expectancy on average. Similarly, an equivalent income measure is constructed for the value of full employment

(above and beyond the remuneration for work which is already captured by market income/consumption).

Figure 3: Multi-dimensional living standards for bottom quintile of households
Average annual percentage change 2008-2013



Note: The graph shows the contributions of average household disposable income, unemployment and longevity to living standards and an adjustment for aversion to inequality. Elements are weighted with their shadow prices, i.e., the willingness to pay to avoid unemployment (capturing the value of jobs above and beyond the income generated by them) and the willingness-to-pay to reduce mortality risk to the best performining country.

Source: Boarini et al[5].

Conclusion 3. Constructing national accounts compatible measures of the distribution of consumption, income (and possibly wealth) by household is a key task ahead and a necessary input for a social welfare measure. Akin to GDP and productivity, such a welfare measure remains, however, conditional on the distribution of the outcome of other well-being dimensions across households. Integration of several - but likely not all - such dimensions into a broader, single measure of income or consumption is possible and worth pursuing when the theoretical basis for such a composite measure is solid. Other than that, the conditionality of income and consumption comparisons on environmental variables needs to be kept in mind and it is often helpful to show these in separate dashboards.

4 Asset sphere: the resources for future well-being

The notion of economic, environmental or social sustainability requires invoking assets in a broad sense. While there are many specific definitions of sustainability, they all take an inter-temporal view and preserving wealth is a natural way of thinking about this. The 1987 Brundtland Report's definition of sustainable development as " [...] development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations[45]). The OECDs work on well-being (OECD[32]) understands sustainability as acting in a way that assets are preserved for future generations' well-being. The World Banks *Changing Wealth of Nations* (World Bank[53]) is a concrete effort towards valuing the level and development of countries assets. And the 2015 UN Sustainable Development Goals and some of the associated indicators can also be understood as an effort to measure humanity's capacity to preserve economic, natural and social assets for future generations alongside measures of current well-being and its distribution.

Accounting prices - theoretically strong but very hard to implement. Indeed, the change in the value of comprehensive wealth is one way of defining and conceptualising sustainability, and a body of theoretical papers has explored this idea (for an overview see Dasgupta[10]). At the heart of the matter is an extension to all types of assets - market and non -market - of the ideas

around real savings or net investment as a measure of changes in intertemporal economic well-being (see Section 2). An inter-temporal social welfare function that augments the environment-economy accounting system as presented in (6) is formulated as the discounted value of future utilities of each of the $h = 1, ...H$ households:

$$V^0 = \sum_{t=0}^{\infty} W(U_1(C_1^t, S_{N1}^t), ...U_H(C_H^t, S_{NH}^t))(1+r)^{-t} \tag{11}$$

Taking account of the stock-flow relationships portrayed in (6), Dasgupta[10] and Arrow et al[1] introduce the notion of resource allocation mechanisms, i.e., future paths of the economic-environmental system, and demonstrate that it is possible, by recoursive reasoning, to map particular resource allocation mechanism onto today's capital stocks so that $V^0 = V^0(C_1^0, ..., C_H^0, K^0, N^0, \alpha)$ where α is a particular resource allocation mechanism[11]. No optimal behaviour is required to introduce this concept. 'Accounting prices' (i.e., marginal social valuations) of capital stocks are introduced, defined as $p_{AKi} \equiv \frac{\partial V^0(C_1^0,...,C_H^0,K^0,N^0,\alpha)}{\partial K_i}$, $p_{ANi} \equiv \frac{\partial V^0(C_1^0,...,C_H^0,K^0,N^0,\alpha)}{\partial N_i}$. The changes in stocks today (presented here in continuous time for simplicity), each valued at accounting prices, then gauge the change in intertemporal social welfare, depending on whether $dV^0 \gtreqless 0$ (Dasgupta[10]):

$$dV^0 = \sum_{i=1}^{m-1} p_{AKi} dK^0 + \sum_{i=1}^{n} p_{ANi} dN^0. \tag{12}$$

Tracking changes in the asset base with accounting prices would thus seem to be the most important effort to pursue. But it also turns out to be the most challenging venture, in concept and in practice. There are at least two difficulties here[12].

- Although 'only' present changes in assets need to be observed, their valuation with accounting prices requires projections of the future evolution of

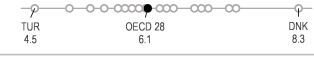
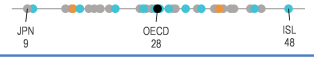
[11] Note that we have ignored quality of life variables Z here, for simplicity. With some stretch of imagination, each quality of life dimension (such as health, personal safety, etc.) could be conceived as either an additional type of capital (such as human capital or social capital) or as a service associated with such capital and integrated into the theoretical concept.

[12] See Fleurbaey and Blanchet[18] for a broader discussion of measurement and theoretical questions.

the socio-economic-environmental system, because the resource allocation mechanism α has to be described and evaluated. Conceptually, accounting prices reflect all the negative externalities associated with economic activities, missing markets, and increase when stocks of capital approach tipping points. Here we are in a different world from that normally inhabited by statistical offices - a world of scenario-building, horizon scanning and comprehensive modelling and forecasting. Ressource requirements apart, this raises some important institutional issues.

- An indicator of sustainability needs to be based on comprehensive wealth, encompassing a broad set of assets, from produced machinery to human capital, social capital and natural assets. But what is the exact scope and how should it be measured? There are many borderline cases, and measurement issues abound, including:
  - Whether or not **health** ought to be recognised as a separate asset, and in addition to human capital is a matter of debate and makes a tremendous difference to results[1].
  - **Human capital** measurement methods are well established, in particular those in the tradition of Jorgenson and Fraumeni [25] but one notes that they imply projections of future income. Another asset considered significant for the functioning of societies is **social capital**, i.e., the social norms, shared values and institutional arrangements that foster co-operation among population groups and the trust people have in others. For instance, OECD[32]'s headline indicators on the level and evolution of social capital are based on surveys on the level of trust between individuals and in institutions. It would appear very difficult to develop accounting prices for social capital.
  - Another key question is capturing and valuing **ecosystem assets**. Their deterioration or improvement represents a big part of what constitutes today's environmental concerns and it has been pointed out earlier that ecosystem assets are complex, dynamic, they do not observe national boundaries and there is no simple mapping to ecosystem service flows. Modelling accounting prices that attach to the change in ecosystem assets would appear to be a tall order.

Figure 4: Evolution of different types of capital in OECD countries

	Headline indicator	OECD average and range, 2018 or latest available year	OECD average change since 2010	No. of countries consistently improving	No. of countries consistently deteriorating
Economic Capital	**Produced fixed assets** (USD per capita at 2010 PPPs)		+11 percent points	23	3
	Financial net worth of general government (percentage of GDP)		-4 percent. points	5	13
	Household debt (as a share of household net disposable income)		-3 percent. points	12	13
Natural Capital	**Greenhouse gas emissions** (CO^2 equivalent, domestic production, tonnes per capita)		-1 tonne/ capita	22	2
	Material footprint (used raw material extracted to meet the economy's final demand, tonnes per capita)		+1.2 tonne/capita	3	16
	Red List Index of threatened species (0 = all species extinct; 1 = all species qualifying as least concern)		-0.01	13	2
Human Capital	**Educational attainment among young adults** (share of people aged 25-34 years with at least upper secondary education)		+2 percent. points	26	3
	Labour underutilization (share of unemployed, discouraged or underemployed workers in the labour force)		-4.8 percent. points	15	2
	Premature mortality (potential years of life lost due to medical conditions and fatal accidents per 100 000 inhabitants)		-620 years lost	29	2
Social Capital	**Trust in others** (mean score on a scale from 0 – 10)		No time series		
	Trust in government (share of the population responding positively)		+3 percent. points	9	6
	Gender parity in politics (share of women in national parliament)		+2.6 percent. points	11	2

Note: The snapshot depicts data for 2019, or the latest available year, for each indicator. The colour of the circle indicates the direction of change, relative to 2010, or the closest available year: consistent improvement is shown in blue, consistent deterioration in orange, no clear trend in grey, and insufficient time series to determine trends in white. For each indicator, the OECD country with the lowest (on the left) and highest (on the right) well-being level are labelled, along with the OECD average (in black, and unless all 37 members are included detailing the number of countries in the average).

Source: OECD[32].

Pragmatism is the word. Should we thus refrain from measuring and valuing assets and how they evolve over time? Definitely not. We do need relevant measures but pragmatism should reign and our ambitions to develop a robust single indicator of sustainability, or even non-sustainability need to be kept in check. The work by the World Bank[53] - motivated by the idea that we need to look at a broad set of assets to get a sense of where sustainability is heading - is a good example of a pragmatic approach. The *Dasgupta Review* [11] is a showcase for the many empirical and theoretical aspects that measurement of biodiversity and ecosystem services from biodiversity entail, even in physical terms. The OECD's *How's Life?* series (OECD[32]) organises and presents available cross-country evidence on assets, to paint a picture where things are heading with produced, human, social and natural capital - see Figure 4. No claim is made on comprehensiveness nor is there aggregation across assets.

Conclusion 4. *The comprehensive social* valuation of economic, environmental and social assets is an excellent reference framework to reason about sustainability. But its empirical implementation with an ambition of providing a comprehensive, single indicator of sustainability raises more questions than it may answer. A pragmatic approach is called for: starting with a fuller implementation of SNA assets, improved physical measures of natural assets, spatially-differentiated valuations of ecosystem services are good places to start. The latest version of the SEEA[46] provides excellent guidance here. The measurement of human capital is also well-established and worth pursuing periodically.

References

[1] Arrow, K. J., P. Dasgupta, K-G. Mler, "Evaluating projects and assessing sustainable development in imperfect economies", Environmental and Resource Economics 26(4):647685, 2003.

[2] Bureau of Economic Analysis, *Distribution of Personal Income*, Prototype statics; U.S. BEA, 2020. https://www.bea.gov/data/special-topics/distribution-of-personal-income

[3] Blanchet, D., What Should the Concept of Domestic Production Mean in Globalized Economies? *Economie et Statistique / Economics and Statistics*, 517518519, 205214, 2020, https://doi.org/10.24187/ecostat.2020.517t.2019.

[4] Blundell, R., I. Preston and I. Walker, An Introduction to Applied Welfare Analysis, in R. Blundell, I. Preston and I. Walker (eds) The Measurement of Household Welfare, 1-50, Cambridge, Cambridge University Press.

[5] Boarini, R., M. Fleurbaey, F. Murtin and P. Schreyer, "Well-being during the Great Recession: New Evidence from a Measure of Multi-dimensional Living Standards with Heterogenous Preferences", *Scandinavian Journal of Economics*, forthcoming.

[6] Brandt, N., P. Schreyer and V. Zipperer (2014), "Productivity Measurement with Natural Capital and Bad Outputs", OECD Economics Department Working Papers, No. 1154, OECD Publishing, Paris, 2014; https://doi.org/10.1787/5jz0wh5t0ztd-en

[7] Crdenas Rodrguez M., Hai I. and Souchier M. , "Environmentally Adjusted Multifactor Productivity: Methodology and Empirical Results for OECD and G20 Countries", OECD Green Growth Papers, No. 2018/02, OECD Publishing, Paris, 2018.

[8] Caves, D.W., L.R. Christensen and W.E. Diewert, The Economic Theory of Index Numbers and the Measurement of Input, Output and Productivity, Econometrica 50, 1393-1414, 1982.

[9] Christensen, L.R., Jorgenson, D.W., Lau, L.J., Conjugate duality and the transcendental logarithmic production function, *Econometrica* 39, 255256, 1971.

[10] Dasgupta, P. The Welfare Economic Theory of Green National Accounts, Environmental and Resource Economics, Vol. 42(1), pp. 3-38, 2009.

[11] Dasgupta, P. , The Economics of Biodiversity: The Dasgupta Review. (London: HM Treasury), 2021; `https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/962785/The_Economics_of_Biodiversity_The_Dasgupta_Review_Full_Report.pdf`

[12] Diewert, W. E., Applications of duality theory. In: Intrilligator, M.D., Kendrick, D.A. (Eds.), Frontiers of Quantitative Economics, vol. II. North-Holland Publishing Co., Amsterdam, pp. 106171, 1974.

[13] Deaton, A. and P. Schreyer, "GDP, wellbeing, and health: thoughts on the 2017 round of the International Comparison Program", Review of Income and Wealth, forthcoming 2021.

[14] Diewert, W. E., Exact and Superlative Index Numbers; *Journal of Econometrics* 4, 115-145, 1976.

[15] Diewert, E. W., "The measurement of productivity in the nonmarket sector June", *Journal of Productivity Analysis* 37(3), 2011.

[16] European Commission, IMF, OECD, World Bank, United Nations, *2008 System of National Accounts*, New York, United Nations; `http://unstats.un.org/unsd/nationalaccount/sna2008.asp`, 2009.

[17] Fre, R., S. Grosskopf, C. A. Knox Lovell and S. Yaisawarng, Derivation of Shadow Prices for Undesirable Outputs: A Distance Function Approach, The Review of Economics and Statistics, Vol.75(2), 374-380, 1993.

[18] Fleurbaey, M. and D. Blanchet, Beyond GDP: Measuring Welfare and Assessing Sustainability, Oxford University Press, 2013.

[19] Fleurbaey, M. and G. Gaulier, International Comparisons of Living Standards by Equivalent Incomes, Scandinavian Journal of Economics, Vol. 111, Issue 3, 529-624, 2009.

[20] Haskel, J. and S. Westlake, Capitalism Without Capital: The Rise of the Intangible Economy, Princeton University Press, 2017.

[21] Heys, R., J. Martin and W. Mkandawire, "GDP and Welfare: A Spectrum of Opportunity" ESCoE DP 2019-16; 2019. https://www.escoe.ac.uk/publications/gdp-and-welfare-a-spectrum-of-opportunity/

[22] Hicks J. R., "The Valuation of the Social Income", Economica , New Series, Vol. 7, No. 26 (May), 105-124, 1940.

[23] Hoekstra, R. , Replacing GDP by 2030: Towards a Common Language for the Well-being and Sustainability Community, Cambridge University Press, 2019.

[24] Jones, C.I. and P.J. Klenow, Beyond GDP: Welfare across Countries and Time, American Economic Review, vol. 106, no. 9, 2426-2457, 2016.

[25] Jorgenson, D. and B. M. Fraumeni, "The Accumulation of Human and Nonhuman Capital, 1948-84", in The Measurement of Saving, Investment, and Wealth, National Bureau of Economic Research, 227-286, 1989, https://EconPapers.repec.org/RePEc:nbr:nberch:8121.

[26] Jorgenson, D.W. and P. Schreyer, Measuring Individual Economic Well-Being and Social Welfare within the Framework of the System of National Accounts, The Review of Income and Wealth, Vol. 63, pp. S2, S460-S-477, 2017.

[27] Jorgenson, D. W., "Production and Welfare: Progress in Economic Measurement." Journal of Economic Literature, 56 (3): 867-919, 2018.

[28] Landefeld, S., S. Villones and A. Holdren, GDP and Beyond: Priorities and Plans, Survey of Current Business Vol. 100 (6), 2020, https://apps.bea.gov/scb/2020/06-june/0620-beyond-gdp-landefeld.htm

[29] Lau, L. J., "A Characterization of the Normalized, Restricted Profit Function," *Journal of Economic Theory*, Feb., 12, 131-63, 1976.

[30] McFadden, D., Cost, Revenue and Profit Functions in *Production Economics: A Dual Approach to Theory and Applications*, Vol. 1, ed. by M. Fuss and D. McFadden (Amsterdam: North-Holland), 3109, 1978.

[31] OECD, Framing the Measurement of Production, Well-being and Sustainability; SDD/CSSP(2020)2/REV1; https://one.oecd.org/document/SDD/CSSP(2020)2/REV1/en/pdf

[32] OECD, Hows Life?, OECD Publishing, Paris, 2011, 2013, 2015, 2017, 2020, http://www.oecd.org/statistics/how-s-life-23089679.htm .

[33] Piketty T., E. Saez, G. Zucman, "Distributional National Accounts: Methods and Estimates for the United States", The Quarterly Journal of Economics, Volume 133, Issue 2, May, 553609, 2018.

[34] Pittman, R. W., Multilateral Productivity Comparisons with Undesirable Outputs, The Economic Journal, Vol. 93, No. 372, 883-891, 1983.

[35] Rao, P., "Welfare Comparisons With Heterogenous Prices, Consumption, and Preferences", in Adler, M. and M. Fleurbaey (eds.) The Oxford Handbook of Well-being and Public Policy, Oxford University Press, Oxford, 2016.

[36] Reid, M., The Economics of Household Production, N.Y. Wiley, 1934.

[37] Samuelson P. A., "Complementarity: An essay on the 40th anniversary of the Hicks-Allen revolution in demand theory", Journal of Economic Literature 12; 1255-1289, 1974.

[38] Samuelson, P. A. and S. Swamy, "Invariant economic index numbers and canonical duality: survey and synthesis", American Economic Review 64, 566-593, 1974.

[39] Schreyer, P. , GDP, in Adler, M. and M. Fleurbaey (eds.), The Oxford Handbook of Well-being and Public Policy, Oxford University Press, Oxford, 2016.

[40] Schreyer, P. and W. E. Diewert; Household Production, Leisure and Living Standards; in: D.W. Jorgenson, J.S. Landefeld and P. Schreyer (eds.) Measuring Economic Sustainability and Progress; NBER Book Series Studies in Income and Wealth http://www.nber.org/chapters/c12826, 2014.

[41] Sefton J . A. and M. R. Weale, "The Concept of Income in a General Equilibrium", Review of Eonomic Studies 73, 219-49, 2006.

[42] Shephard, R.W. , Cost and Production Functions, Princeton: Princeton University Press, 1953.

[43] UNDP, Human Development Index, 2020; http://hdr.undp.org/en/content/human-development-index-hdi

[44] Stiglitz, J. E., A. Sen, and J-P. Fitoussi, Report by the Commission on Measurement of Economic Performance and Social Progress, 2009, https://ec.europa.eu/eurostat/documents/118025/118123/Fitoussi+Commission+report.

[45] United Nations, Our Common Future, Report of the World Commission on Environment and Development, 1987; file:///C:/Users/Schreyer_P/Downloads/our_common_futurebrundtlandreport1987.pdf

[46] United Nations, European Union, Food and Agriculture Organization of the United Nations, Organisation for Economic Co-operation and Development, World Bank Group, *System of Environmental-Economic Accounting 2012 - Experimental Ecosystem Accounting*, New York, 2014; https://seea.un.org/sites/seea.un.org/files/seea_eea_final_en_1.pdf

[47] United Nations Statistical Commission 2021, System of Environmental-Economic AccountingEcosystem Accounting: Final Draft Prepared by the Committee of Experts on Environmental-Economic Accounting; 2021. https://unstats.un.org/unsd/statcom/52nd-session/documents/BG-3f-SEEA-EA_Final_draft-E.pdf

[48] Usher, D., The Measurement of Real Income, The Review of Income and Wealth, 22(4), 305-3029, 1976.

[49] Vanoli, A., Reflections on Environmental Accounting Issues, Review of Income and Wealth, Series 41, Number 2, June, 113-137, 1995.

[50] Van de Ven, P., J. Zwijnenburg, and M. De Queljoe, Including unpaid household activities: An estimate of its impact on macro-economic indicators in the G7 economies and the way forward, OECD Statistics Working Papers, 2018/04, OECD Publishing, Paris, 2018. http://dx.doi.org/10.1787/bc9d30dc-en

[51] Weitzman, M. L., On the Welfare Significance of National Product in a Dynamic Economy, *The Quarterly Journal of Economics*, 1976, Vol. 90, pp. 156-162.

[52] Willig, R, Social Welfare Dominance, Vol. 71, No. 2, Papers and Proceedings of the Ninety-Third Annual Meeting of the American Economic Association, May, 200-204, 1981.

[53] World Bank, The Changing Wealth of Nations 2018, The World Bank Publising, Washington D.C., 2018. `https://openknowledge.worldbank.org/handle/10986/29001`

[54] Zwijnenburg, J., S. Bournot and F. Giovannelli, Expert group on disparities in a national accounts framework: Results from the 2015 exercise, OECD Statistics Working Papers, No. 2016/10, OECD Publishing, Paris, 2017. `https://doi.org/10.1787/2daa921e-en`.

[55] Zwijnenburg, J., S. Bournot, D. Grahn and E. Guidetti, "Distribution of Household Income, Consumption and Saving in line with National Accounts: Methodology and results from the 2020 collection round", OECD Statistics Working Papers, forthcoming 2021.