Guidance Note on Valuation of mineral and energy resources (WS.10),
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Summary of main recommendations

The new SNA should:

- Include further clarifications on the delineation of mineral and energy resources, by relying on the same three resource classes as in SEEA 2012 (i.e., "commercially recoverable resources", "potentially commercially recoverable resources" and "non-commercial and other known deposits"). In the case that reliable information on their value exists, these three classes should be included in the national accounts, provided that separate estimates can be compiled for the different classes.
- Underline that the aim of the SNA (and the SEEA) is to compile market(-equivalent) values, not social values (e.g., consumer surplus/welfare based measures).
- Add clarifications on the calculation of net present values (NPVs) for (specific types of) mineral and energy resources, by explicitly referring to Chapter 5 in the SEEA-CF. This includes, amongst others, the recommendation (i) to use a constant rate of extraction or the most recent quantity of extraction as forecasts of future production; and (ii) to assume that the output price of the extracted resource follows a long-run historical trend.
- Explain that different types of mineral and energy resources may require slightly different NPV treatments, underlining the relevance of properly distinguishing different types, e.g., renewable from non-renewable resources.
- Explain that compilers should try to compile the value of mineral and energy deposits at a disaggregated level, ideally at the deposit level, and then sum the obtained values up to the national level.
- Emphasise specific compilation issues, i.e. (i) the sensitivity of results to the choice of the discount rate; (ii) heterogeneity of extraction costs across space; (iii) constraints imposed on mineral production at the micro level by initial investments in physical capital; and (iv) volatility in the value of mineral assets introduced by short-run price fluctuations of commodity prices.

Topics

> Measuring natural resource asset values and wealth highly depends on NPV calculations which require a range of assumptions and projections. This note addresses the following three questions:
> (1) Is further guidance needed to improve and harmonise the measurement of resource rents and NPV calculations?
> (2) Are alternative valuation techniques, currently being developed in the context of ecosystem accounting, relevant for the SEEA-CF and SNA?
> (3) Are there specific natural resources for which valuation methods have recently evolved, and therefore should be translated into additional accounting guidance?

In general, it should be noted that the use of NPV is a broad topic that incorporates features of natural resources that are being addressed in other papers. The attention to the specific questions is to put a boundary on the discussion.

Question 1

Paragraphs 29.103 and 29.105 of the 2008 SNA address the issue of extending the SNA to incorporate aspects of SEEA. Chapter 5 of the System of Environmental Economic Accounts—Central framework, SEEA-CF, contains a comprehensive discussion of the valuation of natural resources. Additionally, there are two AEG documents (attached) that have examined the valuation of natural resources from the perspective of combining the SEEA-CF approach with the SNA. The AEG documents refer to the work of the OECD Task Force on implementation of the SEEA CF. More information on the latter can be found in Pionnier and Yamaguchi (2018)[1]. All this work informs the points made below.

Classification

The AEG documents firstly addressed the issue of the classifying mineral and energy assets, recommending further clarifications are added to the SNA for delineating mineral and energy resources, by explicitly referring to the SEEA-CF and relying on the same three resource classes, based on the UNFC-2009 Classification, i.e., Class A ("commercially recoverable resources"), Class B ("potentially commercially recoverable resources"), and Class C ("non-commercial and other known deposits"). This would increase the consistency between both accounting manuals and make the SNA definition of economic assets more precise in the case of mineral and energy

[1] Pionnier, P. and S. Yamaguchi (2018), "Compiling mineral and energy resource accounts according to the System of Environmental-Economic Accounting (SEEA) 2012: A contribution to the calculation of Green Growth Indicators", OECD Green Growth Papers, No. 2018/03, OECD Publishing, Paris, https://doi.org/10.1787/3fcfcd7f-en.

resources. Furthermore, the papers explain that the inclusion of these three classes should be allowed in national accounts' balance sheets in the case that reliable information on their value exists, with the additional requirement that separate accounts for the different classes, similarly to the SEEA-CF, should be distinguished. This would be flexible enough for countries to decide what type of assets they prefer to value depending on local specificities and priorities, while also adding clarity and allowing more meaningful international comparisons of balance sheets.

Valuation

More pertinent to the discussion of NPV, the 2014 AEG document (attached) raised the issue of the volatility of commodity prices and how modelling the distribution of these prices as well as investment and extraction costs might be useful to accurately portray the value of mineral and energy resources. However, the 2016 AEG document (also attached) re-examined these issues and concluded that "trying to implement such valuation techniques is not being considered as a priority for national statistical offices, because it would require high quality data on how mining revenues, investments and extraction costs are determined at the micro level". Instead, the 2016 AEG document recommended in paragraph 18, "that clarifications are added to the 2008 SNA, by explicitly referring to Chapter 5 in the SEEA-CF when it comes to the computation of NPVs of mineral and energy deposits, thereby underlining that the aim of the SNA (and the SEEA) is to compute market(-equivalent) values, not social values, of mineral and energy deposits, and emphasising issues to which national accountants should pay particular attention: sensitivity of final results to the choice of the discount rate; heterogeneity of extraction costs across space; constraints imposed on mineral production at the micro level by initial investments in physical capital; and volatility in the value of mineral assets introduced by short-run price fluctuations of commodity prices." Some of these issues are further explained below.

For reference, consider the following NPV formula for a subsoil asset

$$V_t = \sum_{s=0}^{S} \frac{p_{t+s} \cdot q_{t+s} - C(q_{t+s})}{(1+r)^{t+s}}$$

where p is the output price of the extracted resource in period t, q the quantity of the extracted resource, and C the extraction cost for the quantity, the dimensions of which are explained below, S is the asset life, and r is the discount rate.

- *Resource rent*

The discussions in the appendix of Chapter 5 in the SEEA-CF deal with the computation of the pq term in the numerator as this is the revenue component of the resource rent. When s=0 the price of the output and the amount extracted are observable—it is the evolution of the price and quantity over time that needs to be modelled. The appendix to chapter 5 in the SEEA CF (A5.12 and A5.13) suggests (i) using a constant rate of extraction or the most recent quantity of extraction as estimates of future production; and (ii) assume that p follows a long-run historical trend or follows the general rate of inflation. Though these assumptions may not be realistic when resource prices are volatile, as in the recent volatility in per barrel oil prices, it would be impractical to provide standard guidance on how forecasting models should be used. The 2015 AEG document presents a model that incorporates the dynamic aspect of resource prices. However, for statistical offices to implement such a model would be a formidable task and there would be the risk of undercutting credibility of statistical offices with inaccurate forecasts. Accordingly, the SEEA-CF approach as described above seems much more reasonable to incorporate into the SNA guidance. Pionnier and Yamaguchi (2018) also conclude that "in order to mitigate the issue related to the volatility of resource prices for the valuation of mineral and energy deposits, it is recommended to focus on underlying price trends, using moving averages for instance". They also refer to the possible extraction of price information from future contracts and analysts' forecasts but leave that for future research.

- *Extraction costs*

The extraction costs, C, should include the costs of extracting in the period and the opportunity cost of doing so. Though the actual costs of extraction is obtainable from companies, measuring the opportunity cost of extraction can be approached by different methods. The opportunity cost concerns the rate of return on the stock (reserve) in the ground (abstracting from the consideration that this may change as the price of the resource changes).

  - Depletion

For subsoil assets, depletion is the draw down from a stock that is determined at some point in time. In terms of the above equation, one would set s=0 to compute the stock. From a geological point of view, what is identified as the stock in the initial time period is the reserve that is deemed economically viable. As the resource price increases, more of the resource may become viable—there is a difference between proven reserves and exploitable reserves. In addition, there can be additions to the initial amount of proven reserves through discovery, which would force a change in the entire sequence of computations. As stated in a study:

> "Current reserves represent only a small portion of the mineral resources remaining in the earth's crust. Exploration and development lead to the discovery and proving up of previously unknown mineral deposits and—perhaps just as important—additional reserves at existing mines and known deposits" (emphasis added). Page 7 in MINERAL RESOURCES AND SUSTAINABILITY: CHALLENGES FOR EARTH SCIENTISTS Committee on Earth Resources Board on Earth Sciences and Resources Commission on Geosciences, Environment, and Resources, National Research Council. NATIONAL ACADEMY PRESS Washington, D.C. 1996

This is relevant because the last line in Table 5.5 of the SEEA-CF indicates that resource rent is the sum of depletion and net return on environmental assets. Suppose discoveries keep pace with extraction so that there is no decrease in reserves—what does depletion mean in such a situation? Relatedly, the determination of the asset life S entails assumptions about reserves and how they may grow with increases in resource prices. In fact, equation (7) in paragraph A5.23 of Annex A5.1 of the SEEA-CF specifically accounts for discoveries, though they are offset by the physical amount of catastrophic losses. It is beyond the scope of this note to address the computation of the value of depletion. This is discussed in guidance note WS.6 on ownership and depletion of natural resources. However, for this guidance note, it is important to stress the relevance of clearly distinguishing between upward reappraisals and discoveries in the flow accounts for sustainability analyses, as this would indicate whether a value is arising at the expense of another resource category or via true discoveries (see Pionnier and Yamaguchi (2018)).

- Opportunity costs

Regarding the rate of return on the asset needed for the computation of the opportunity cost, it is usually taken to be the rate of return on produced capital and the SNA and the OECD capital measurement manual provide discussion on how estimates might be obtained. Note that using a rate of return that derives from all produced capital assets carries with it the implicit assumption that all produced capital in a sense is similar or economically substitutable. Though this may be a reasonable assumption for plant and equipment, it is not clear that it is a reasonable assumption for natural resources. In determining rates of return on assets, capital heterogeneity and vintage play an important role and it is also not clear how these apply in the case of natural resources. One could look at average returns to produced assets in specific industries to capture the differences in natural resources: oil companies likely have rates of return different from those from coal mining firms. Such an approach need not be restricted to subsoil assets—timber industries and fisheries also share this complication with an additional complication that they are renewable. Table 5.5 in chapter 5 of the SEEA-CF provides the general framework of obtaining resource rent and subsequent sections of Chapter 5 give the details for various natural resource assets. These could be applied to a revision of the SNA that seeks to address valuation for specific natural resource assets.

- *Level of aggregation*

Another important issue that needs to be taken into account in measuring the value of mineral and energy resources is the heterogeneity of extraction costs across deposits. In this regard, paragraph 5.194 of the SEEA-CF notes that the calculation of NPV estimates for stocks of mineral and energy resources "should be undertaken at the level of an individual resource type, ideally for specific deposits of a resource, and then summed over the range of different resources in order to obtain a total value of mineral and energy resources". Pionnier and Yamaguchi (2018) explain that "neglecting this hetereogeneity is a problem if the lowest-cost and highest-value reserves are extracted first, implying that current extraction costs are poor predictors of future extraction costs". In that case, one would expect increasing average extraction costs over time.

- Discount rate

The selection of the discount rate is clearly a decisive determinant of the NPV. Annex A5.2 in the SEEA-CF discusses various issues about the discount rate. Because of an absence of data, it is not likely that discount rates could be tailored to specific natural resources. Accordingly, the recommendation to use an exogenous rate is appropriate and akin to the SNA recommendations for using an exogenous reference rate in the computation of FISIM. Even so, there is still the problem of selecting a specific rate. A combination of risk-free rates, which are or could be government bond rates can be used and one way of combining them would be by maturity with longer maturities having greater weight for long-lived assets. Whether there should be a different exogenous rate for each natural resource is a question that should be explored. In addition, as stated in the SEEA-CF, a variety of estimates using different discount rates should be provided. Interestingly, the US Securities and Exchange Commission requires a 10% discount rate in its filings by oil companies.

To be clear, the above reference to government bond rates is to their market determined yields and not to the stated rate or coupon rate of the bond. This is an important distinction. The stated interest rate is a fixed interest rate, while the yield is a market rate that results from the interaction of government demand for funds and the supply of funds. Thus, the market yield on long-term government securities allows for the interaction of private and public views of long-term risk and the use of capital. In contrast, sometimes governments use social rates of discount in their computations of the net present value of environmental investments because of the desire to capture societal dimensions of the investment. The use of such rates, however, necessitate assumptions about differences in risk between public and market rates. As Deborah Lucas states: "Considerations of transparency, consistency and auditability suggest limiting the discretion of policymakers and government analysts in the selection of discount rates (Deborah Lucas (2014) Rebutting Arrow and Lind: why governments should use market rates for discounting, Journal of Natural Resources Policy Research, 6:1, 85-91). Accordingly, it is inappropriate for the SNA to adopt a "social" discount rate because that invariably entails subjective judgments that are beyond the scope of the SNA. The above citation of paragraph 18 from 2016 AEG document states a similar position.

Question 2

There have been many discussions within the context of the SEEA-CF and the SEEA Ecosystem Accounting (SEEA-EA) about alternative methods of valuation. Simply put, these alternative methods are geared toward estimating asset or service values in the absence of market prices. The 2008 SNA is clear that valuations should be based on market prices but allows for the imputation of market prices when they are not available. The imputation methods largely use market prices—mostly for similar goods. Hedonic methods based on product characteristics are sometimes used to impute prices as well. Some of the alternative methods employed in the SEEA manuals could be classified as these types of imputation. However, others, such as simulated exchange values or willingness-to-pay methods, clearly cannot be so classified. These methods rely on too many subjective judgments for national accounting standards and their measurement objective is not a price per se. Instead, it is often a welfare measure that includes consumer surplus, which is beyond the scope of the SNA. In addition, there is considerable debate about the usefulness and quality of the estimates using simulated exchange rates and related methods. Accordingly, such estimates should not be incorporated into the core SNA. The numerous subjective (even arbitrary) choices that would need to be made by the national statistical office to employ these methods has the potential to undercut the integrity and public trust in an agency expected to provide objective statistics and would erode the comparability of monetary values across accounts.[2] It should be

[2] Such estimates may have a place in a supplementary account but only if they are accompanied by complete transparency of computational methods and assumptions; even this should be approached with caution.

noted here that a separate group on valuation will provide more guidance on the principles and methodologies for valuing transactions and positions in the system of national accounts.

Question 3

The discussion above has focused on non-renewable resources. Renewable resources require some adjustments as also discussed in chapter 5 of the SEEA-CF. Another classification that bears on the accounting treatment is the distinction between cultivated and natural resources. In short, asset specific NPV treatments are going to rely on decisions made about classification. This is touched on in WS.12as well as WS.8 and WS.11.

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Agenda item: 7.1

Methodology for the valuation of natural resources

Introduction

The valuation of natural resources is primarily intended to compare different assets using a common denominator, a comparison that cannot be made using purely physical data. Nevertheless, the measurement of remaining stocks in physical units is also essential, not only because it is the one which is most relevant when analysing the depletion of natural resources, but also because it is a necessary intermediary step for the valuation of natural resources.

The international comparability of natural resource stocks in physical units still needs further improvement. The main issue is the coexistence of different classifications to measure remaining stocks. Moving to the classification advocated by the System of Environmental- Economic Accounting 2012 Central Framework (SEEA 2012) may be difficult in practice due the level of aggregation or the focus on specific types of resources in the original classification system chosen by countries or international organisations. Efforts need to be made to convince them to choose the SEEA-CF classification as a reporting standard or to make sure that an easy conversion to the preferred classification is feasible. This point will be discussed in the first section of this paper.

Once data on physical stocks are available in an internationally comparable classification system, valuation can start. The valuation methodology will be discussed in the second section of this paper. Given that there is usually little direct information on prices of the assets underground, the SEEA 2012 suggests valuing stocks of natural resources using the net present value (NPV) method. This method relies on the assumption that the asset market is in equilibrium, implying that the market value of the asset is equal to the sum of discounted future income associated with the exploitation of the asset. As commodity prices show large swings, there is significant uncertainty about their future development. Given this volatility of commodity prices, it does not seem reasonable to assume that extracting firms take their decisions looking only at the current price or an average of recent developments in prices. From an accounting perspective, only focusing on current or recent prices can also lead to volatile stock of assets in monetary units, thus reducing the usefulness of these accounts. Here, it will be suggested to rely more heavily on dynamic optimisation models in order to compute the NPV, thus ensuring that production and price forecasts are consistent and that the ability of producers to react to changing economic conditions in the future is taken into account. In this way, at least part of the uncertainty regarding future price developments will be embedded in the NPV computations.

Guidance on documentation provided

Not relevant.

Main issues to be discussed

- *Does the AEG agree that the volatility of commodity prices is a key issue for the valuation of natural assets?*
- *Does the AEG agree that relying more heavily on modelling (dynamic optimisation) maybe a reasonable way forward for the valuation of natural resources (and possibly other assets)?*

Methodology for the valuation of natural resources

I. International comparability of natural asset accounts in physical units

1. Four main classifications are currently available to report stock volumes of natural resources (see Table 1). They result from a convergence process in reporting standards that started at the beginning of the 1990s. While CRIRSCO and SPE-PRMS focus on different types of resources, the UNFC-2009 and SEEA-2012 classifications apply to all types of resources. None of these classifications only takes geological criteria into account. Economic and technological criteria are also considered. This implies that resource stocks have to be regularly re-assessed in the light of new geological knowledge, progress in extraction technology and shifts in economic and political conditions.

Table 1: Overview of existing classifications

Abbreviation	Full Name	Subject Resource	Latest edition (first edition)
CRIRSCO,	Committee For Mineral Reserves International Reporting Standards	Minerals	2013 (2006)
SPE-PRMS	Society of Petroleum Engineers – Petroleum Resources Management System	Fossil Energy (crude oil and natural gas)	2007
UNFC-2009,	United Nations Framework Classification for Fossil Energy and Mineral Resources	Minerals and Fossil Energy	2009 (1997)
SEEA-2012	System of Environmental-Economic Accounting – Central Framework	Renewable and non-renewable natural resources and land	2012 (2003)

2. The UNFC-2009 classification system, on which the SEEA 2012 classification is built (see Table 2), is thought as an umbrella, relevant for both fossil energy and minerals. It is based on three dimensions: the economic and social viability of the project (dimension E), the field project status and its feasibility (F), and the geological knowledge about the available quantities (G). Quantifying reserves means attributing a triplet (E,F,G) to these reserves. As an example, a mineral resource described by the triplet (1,1,1) should be understood as a resource for which extraction and sale have been confirmed to be economically viable (first1), extraction is technically feasible (second 1) and the quantities associated to this resourcecan be estimated with a high level of confidence (third 1).

3. Even though correspondence tables have been developed, moving to the classification advocated by the SEEA 2012 may be difficult in practice due the level of aggregation or the focus on specific types of resources in the original classification system chosen by countries or international

Table 2: Australia's subsoil assets as measured by the ABS, BP, the EIA, the USGS and how these definitions relate to SEEA-2012 classes

Fundamental Characterization	Solid Mineral Classes	*PRMS Classes*	Mineral Project Development Stage	*PRMS Sub-Class*	UNFC E axis	UNFC F axis	UNFC G axis: Proved Measured	UNFC G axis: Probable Indicated	UNFC G axis: Possible Inferred
							1P/1C Low Estimate		
							2P/2C Best Estimate		
							3P/3C High Estimate		
Discovered and Commercially Recoverable	Mineral Reserves	*Reserves*	On Production	*On Production*	1	1.1	1	2	3
			Project Implementation	*Approved for Development*	1	1.2	1	2	3
			Feasibility Study	*Justified for Development*	1	1.3	1	2	3
Discovered and Not Commercially Recoverable	Mineral Resources	*Contingent Resources*	Pre-Feasibility Study	*Development Pending*	1	2.1	1	2	3
					2.1	2.1	1	2	3
			Order of Magnitude Studies	*Development Unclarified or on Hold*	2.1	2.2	1	2	3
					3.2	2.2	1	2	3
	Discovered Not Economic			*Development not Viable*	2.2	2.3	1	2	3
	Unrecoverable				3.3	4.1	1	2	3
Undiscovered	Exploration Results	*Prospective Resources*	Conceptual Studies	*Prospect*	3.2	3.1	4.1	4.2	4.3
				Lead	3.2	3.2	4.1	4.2	4.3
				Play	3.2	3.3	4.1	4.2	4.3
	Unrecoverable				3.3	4.2	4.1	4.2	4.3

Australia's Natural Resource System	Reported Categories	E axis	F axis	G axis
Economically Demonstrated Resources (EDRs)	JORC Reserves and JORC Resources (measured and indicated) Development Pending			

BP and EIA

USGS

SEEA-2012 Class A

SEEA-2012 Class B

SEEA-2012 Class C

organisations. As an example, Table 2 shows how Australia's subsoil assets are reported by the Australian Bureau of Statistics (ABS), British Petroleum (BP), the U.S. Energy Information Administration (EIA) and the U.S. Geological Survey (USGS). Obviously, none of the definitions chosen by these agencies matches the classification into three classes (A, B and C), as advocated in SEEA 2012. Moreover, there is no immediate way to move this SEEA 2012 classification given the currently available data. This example, coming from a country that is already well advanced in the implementation of environmental- economic accounting, shows that efforts need to be done in order to convince countries and international organisations to choose the SEEA 2012 classification as a reporting standard or to make sure that an easy conversion to it is feasible.

II. Valuation of remaining stocks of natural resources

4. The SNA and the SEEA 2012 stipulate that the valuation of natural resources should be consistent with the valuation of produced assets. For produced assets, the most common approach in the absence of observed market prices is to use the replacement value of the assets using data on investment expenditure and assumptions regarding asset lives and depreciation rates. Also in the case of natural resources other than land, there is usually little direct information on prices of the assets in the ground[1]. In this case, prices that would be observed if these natural assets were exchanged on the market need to be estimated using an alternative methodology. Consequently, the SEEA 2012 suggests valuing stocks of natural resources using the net present value (NPV) method. This method rests on the assumption that the asset market is in equilibrium, implying that the market value of the asset is equal to the sum of discounted future income associated with the exploitation of the asset. In the case of natural resources, expected income corresponds to the flow of discounted expected resource rents.

5. NPV computations in the field of national accounts usually make a direct application of the NPV formula expressing the value of a natural resource as the discounted value of future flows of profits that can be derived from it. This requires making price and production forecasts and choosing a discount rate. We call these computations direct NPV computations. The standard NPV formula is as follows:

$$V_t = \sum_{s=0}^{+\infty} \frac{\pi_{t+s}}{(1+r)^s} = \sum_{s=0}^{+\infty} \frac{p_{t+s} \cdot q_{t+s} - C(q_{t+s})}{(1+r)^s} \qquad (1)$$

where π_{t+s}, p_{t+s} and q_{t+s} are, respectively, the nominal value of the resource rent, the output price and the extracted quantity at date *(t+s)*. $C(q_{t+s})$ corresponds to extraction costs at date *(t+s)* and r is the discount rate that is applied to all future income streams. For reasons of simplicity, here we assume that the discount rate remains constant over time.

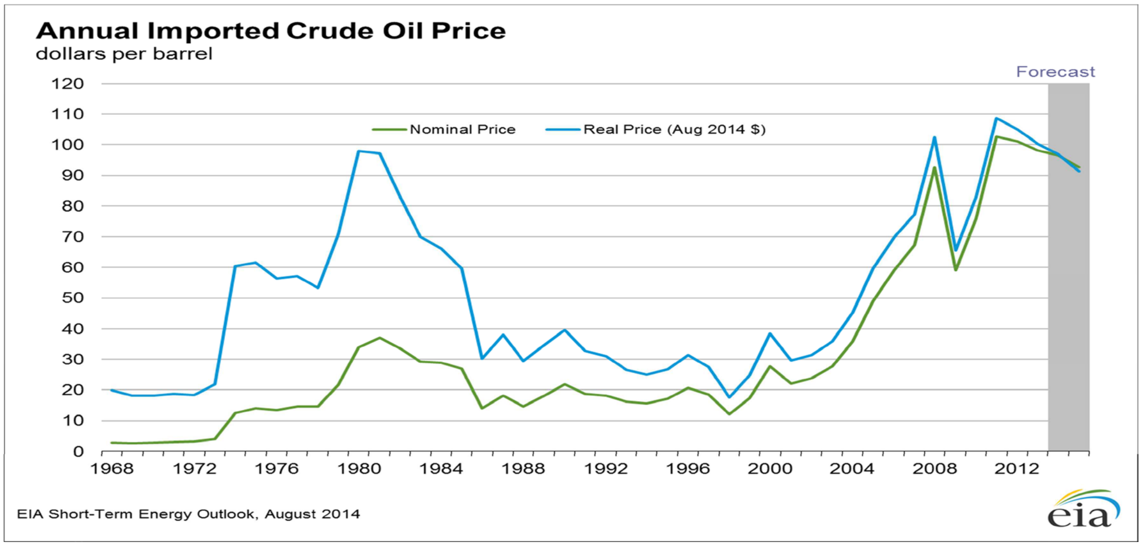
6. Considering the problem in this way, the risk is either to make inconsistent price and production forecasts, or to neglect the fact that commodity prices are uncertain in the future and that producers may be able to adapt to changing economic conditions in real time. As a simplifying assumption, the SEEA 2012 (§A5.12 and A5.13) suggests (1) using a constant rate of extraction or the most recent quantity of extraction as estimates of future production;and (2) assuming that unit resource rents follow a long-run historical trend or evolve in line with an expected general rate of inflation. However, in a world where commodity prices are highly volatile, it does not seem reasonable to assume that

[1] The price of the asset *in the ground* has to be distinguished from the current output price charged by the extraction industry. Indeed, it is probably not feasible nor optimal to extract all the resource at one point in time. Hence, profits from extraction occurring at different points in time have to be discounted and summed up in order to derive the price of the asset in the ground.

mining firms take their decisions looking only at the current price or its expected value in the future. Take the example of oil prices. They have been characterised by large swings in the 2000s, but also in the 1970s and 1980s (see Figure 1).

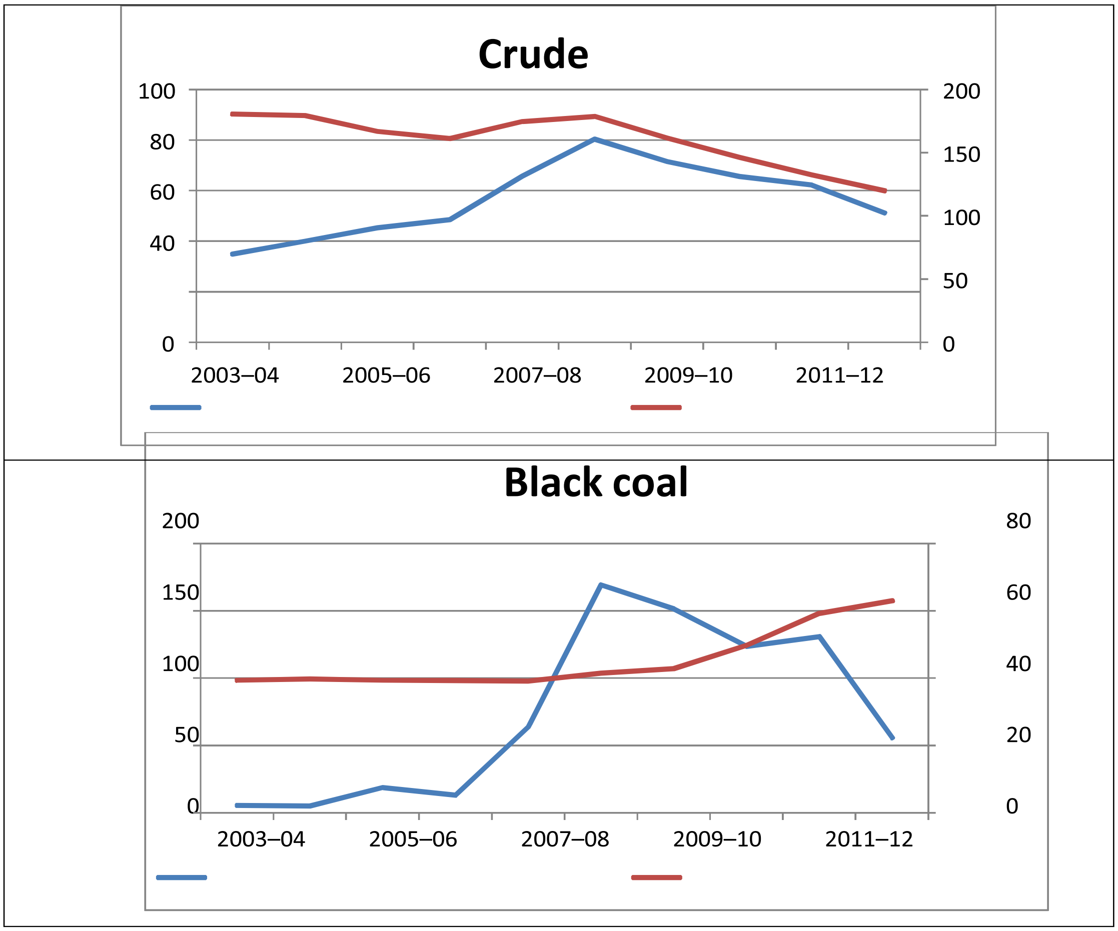
7. From an accounting perspective, a valuation method relying exclusively on current commodity prices or their expected value in the future will lead to volatile results. One can notice, for instance in the environmental asset accounts published by the Australian Bureau of Statistics, that revaluation may be the main driver of asset accounts in monetary units (see Figure 2). This, of course, reduces the usefulness of these accounts.

Figure 1: Nominal and real oil prices (U.S. dollars per barrel)



Source: U.S. Energy Information Administration, August 2014 Short-Term Energy Outlook
http://www.eia.gov/forecasts/aeo/index.cfm

Figure 2: Australian crude oil and black coal reserves, physical and monetary units



Source: Australian Bureau of Statistics, 2014 Australian Environmental-Economic Accounts http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/4655.02014?OpenDocument

8. It seems more logical to take the uncertainty about future prices, i.e. the whole price distribution, into account when computing the NPV. Let us take an example assuming that production and price forecasts are not made independently from each other. In other words, when they choose their output level, producers are assumed to maximize their intertemporal profit subject to specific costs and production constraints and given an exogenous commodity price process. Furthermore, assume that current prices are below extraction costs and that expected prices at future dates are equal to current prices[2]. Does it imply that the net present value of the resource is equal to zero? If the price developments are highly volatile, this is probably not the case. Indeed, high volatility means that in some events, with a strictly positive probability, future prices will be higher than extraction costs, in which case it will be profitable to extract the resource[3]. Note that considering the full distribution of prices can only increase the NPV because production is bounded from below by zero. Due to this

[2] Computing the expectation of future prices in such a way is fully legitimate if (log-) commodity prices follow a random walk without drift, which is sometimes believed to be the case for natural resources.

[3] Another concrete example, taken from economic history and quoted by Pindyck (Irreversibility, Uncertainty and Investment, *Journal of Economic Literature, Vol. XXIX, pp. 1110-1148*, 1991), further justifies the interest in price volatility. Pindyck recalls that oil prices fell during the mid-1980s but that the perceived uncertainty over future oil prices rose at the same time. “In response, oil companies paid more than ever for offshore leases and other oil-bearing lands, even though their development expenditures fell and they produced less.”

non-linearity, the expected NPV is different from the NPV computed at the expected price level.

9. Here, we come back to the standard NPV formula (1) in order to introduce additional ingredients to take uncertainty into account. It will be more convenient to consider the continuous-time analogue of formula (1) in the following:

$$V_t = \int_0^{+\infty} \pi_{t+s} e^{-rs} ds = \int_0^{+\infty} \pi_s e^{-r(s-t)} ds \qquad (2)$$

Leibniz' differentiation rule implies that:

$$\frac{dV_t}{dt} = -\pi_t + rV_t \qquad (3)$$

Formula (3) shows that the net present value V_t can be obtained, in any case, as the solution of a differential equation. This equation simply says that, in equilibrium, the normal return to the (natural) asset (rV_t) is equal to the sum of the resource rent (π_t) and the increase in the value of the asset between date t and date $(t+dt)$, which is a standard result in capital theory (see OECD 2009). The particular solution of this equation depends on the shape of the resource rent (profit) function π_t.

10. Now we introduce uncertainty in the model. In order to keep things simple, we consider that uncertainty is only related to future resource prices and that the model is stationary. In this case, the resource rent function may be written more explicitly as $\pi(p_t)$. This is justified when, for instance, extracted quantities are given or chosen, so that the resource rent is maximised at each date given observed prices at that date. Given the presence of uncertainty, we now focus on the expected NPV and we condition on resource prices observed at date t. Hence, V_t becomes $V(p_t)$ and it is defined by the following equation:

$$V(p_t) = E\left[\int_t^{+\infty} \pi(p_s) e^{-r(s-t)} ds | p_t\right] \qquad (4)$$

It is now possible to show that $V(p_t)$ is the solution of the following differential equation, which is similar to (3):

$$\frac{E[dV(p_t)]}{dt} = -\pi(p_t) + rV(p_t) \qquad (5)$$

Specifying a stochastic process for resource prices, i.e. making explicit how they depend on time, allows going further. We now assume that the evolution of resource prices is partly deterministic (i.e. predictable) and partly stochastic (i.e. unpredictable). This is the case, for instance, when the evolution of resource prices is specified in the following way[4]:

$$dp_t = \mu \cdot dt + \sigma\sqrt{dt} \cdot dz_t \qquad (6)$$

where dz_t are independently distributed Gaussian increments with mean 0 and variance 1. With this specification, resource prices p_t have a variance equal to $\sigma^2 t$ around a linear deterministic

[4] In technical terms, this is called a Brownian motion with drift. Of course, more general price processes could be considered, for instance a geometric Brownian motion where $\frac{dp_t}{p_t}$ and not dp_t is equal to $\mu \cdot dt + \sigma\sqrt{dt} \cdot dz$, thus ensuring that prices never become negative. Parameters μ and σ could also depend on time or on p_t. The reasoning would be the same but the eventual (partial) differential equation characterising $V(p_t)$ would be more complicated to solve.

trend μt. Making use of the differentiation rule for functions of stochastic variables (Itô's lemma):

$$\frac{E[dV(p_t)}{dt} = V'(p_t)\mu + \frac{1}{2}V''(p_t)\sigma^2 \qquad (7)$$

the differential equation (5) in $V(p_t)$ can be rewritten more explicitly as:

$$\frac{1}{2}V''(p_t)\sigma^2 + V'(p_t)\mu - rV(p_t) = -\pi(p_t) \qquad (8)$$

Notice that when prices are assumed to remain constant over time $(\mu = \sigma = 0)$, this equationsimply says that the NPV of the resource can be computed as $\frac{\pi(p_t)}{r}$, a result that can also be derived using equation (1) in the simple case of constant prices over time. More generally, the solution of equation (8) depends on the shape of the resource rent (profit) function $\pi(p_t)$.

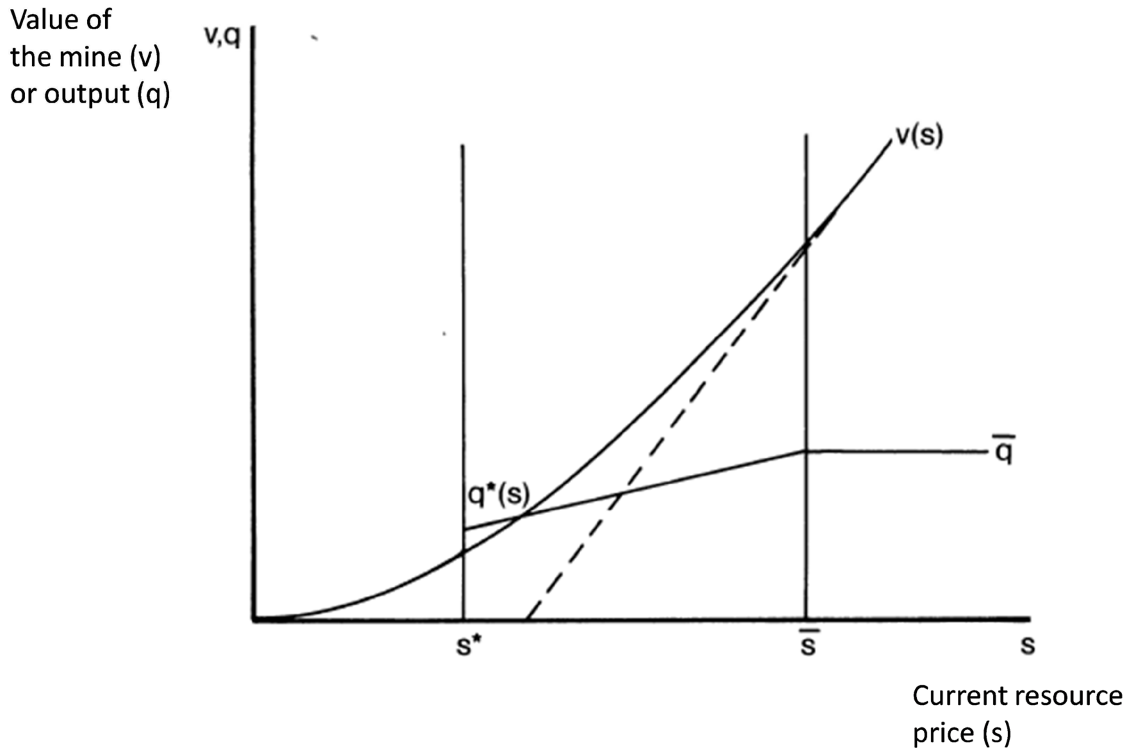
11. Brennan and Schwartz (1985)[5] offer an interesting example of how these techniques may be used to value stocks of natural resources. In their model, a mining firm chooses output given quadratic extraction costs and an exogenous stochastic price process. Current output (q) is constrained to lie between 0 and $\bar{q}$. The resource stock is assumed to be infinite. This assumption allows linking the mine value (v) to the current commodity price (s) analytically[6]. Two price levels have a particular importance in this model: s^* is the price below which current production is chosen to be 0 and $\bar{s}$ is the price above which the mine produces at full capacity. The result may be shown graphically (see Figure 3). One can already notice that the mine value is strictly positive even when the current resource price falls below s^*, i.e. when current production is equal to zero because prices are too low to ensure a positive profit. This would not be the case if the mining firm were required to perpetually produce at full capacity, in which case the value function of the mine would correspond to the dotted line. This would not be the case, either, for any valuation assumingthat current rents remain constant in the future[7].

[5] Evaluating Natural Resource Investments, *Journal of Business, Vol. 58, No. 2, pp. 135-157*. We are referring to the model developed in the appendix of their paper.

[6] Without this assumption, the mine value could still be computed. But with an additional state variable in the model (e.g. the remaining resource stock), we would have to solve partial rather than ordinary differential equations and this would require numerical techniques.

[7] This model can be further refined in order to explain other economic historical facts. Indeed, Brennan and Schwartz (1985) show how sunk costs of opening and closing a mine can explain the hysteresis often observed in extractive resourceindustries. During periods of low prices, firms may continue to operate unprofitable mines that had been opened when prices were high. This is exactly what happened to many copper mines built during the 1970s when copper prices were high: they were kept open during the mid-1980s when copper prices had fallen to their lowest levels in real terms since the Great Depression. Conversely at other times, firms may fail to reopen seemingly profitable mines that have been closed when prices were low.

Figure 3: NPV of a mine as a function of the current resource price (Brennan andSchwartz 1985)



12. Admittedly, relying on a dynamic optimisation framework in order to compute NPVs involves critical modelling assumptions. But it is a necessary step if one wants to consider that mining firms do not only consider expected future prices and are able to adapt to changing economic conditions in the future. Note that these assumptions also need to be made, even implicitly, when one relies on direct NPV computations. Two of these modelling assumptions can be mentioned:

- Specifying the right stochastic process for commodity prices. It is a hotly debated issue in the finance literature and choices made at this stage can partly drive final results.
- Specifying how extraction costs depend on current production or remaining reserves. It is a difficult task given the current scarcity of data on extraction costs. An econometric analysis on the subject would require reliable and informative data. But this is one more reason, if needed, justifying why statisticians working in the field of environmental accounting, and national accounts alike, should consider the improvement of data qualityon extraction costs as a priority.

In any case, this methodology should not be discarded for its mathematical complexity. Providing convincing unit rent and production forecasts and choosing a relevant discount rate is also problematic when one wants to directly compute the NPV of a natural resource stock without explicitly relying on dynamic optimisation. In this context, results from dynamic optimisation can certainly be considered as a useful comparison, not only for valuing natural resources but also for other assets whose valuation relies on NPV-estimates.

III. Main issues for discussion within the AEG

13. The AEG is invited to discuss the following topics:

- Does the AEG agree that the volatility of commodity prices is a key issue for the valuation of natural assets?

- Does it agree that relying more heavily on modelling (dynamic optimisation) may bea reasonable way forward for the valuation of natural resources (and possibly other assets)?

10th Meeting of the Advisory Expert Group on National Accounts, 13-15 April 2016, Paris, France

Agenda item: 13

Classification and valuation of natural resources

Introduction

The inclusion of mineral and energy resources in national accounts' balance sheets is currently limited to "mineral and energy reserves located on or below the earth's surface that are economically exploitable, given current technology and relative prices" (2008 SNA, § 10.179). This definition could be made less ambiguous by referring to an internationally-agreed classification such as the United Nations Framework Classification 2009 (UNFC-2009), being applicable to both mineral and energy resources and alreadyused in the SEEA-Central Framework. It should also be examined whether the SNA is right in excluding some known deposits that have a positive economic value, only because they are not currently profitable. Finally, giving additional guidance for the valuation of mineral and energy deposits is key to ensure international comparability. All these classification and valuation issues will be addressed in a forthcoming working paper summarising the work done under the auspices of the OECD Task Force on the implementation of the SEEA. The AEG is asked to consider clarifications that could be added to the 2008 SNA.

Documentation

Classification and delineation of mineral and energy resources in national accounts' balance sheets

Main issues to be discussed

Does the AEG agree that further clarifications of the 2008 SNA should be added by:

- explicitly referring to the SEEA 2012 and relying on the same three resource classes, based on the UNFC-2009 classification, in order to delineate mineral and energy resources;
- allowing the inclusion of the three classes of mineral and energy resources in national accounts' balance sheets in the case that reliable information on their value exists, with the additional requirement that separate accounts for the different classes, similarly to the SEEA 2012, should be distinguished;
- explicitly referring to Chapter 5 in the SEEA 2012 when it comes to the computation of net present values of mineral and energy deposits, thereby underlining that the aim of the SNA (and the SEEA) is to compute market values, not social values, of mineral and energy deposits, and emphasising issues to which national accountants should pay particular attention: sensitivity of final results to the choice of the discount rate; heterogeneity of extraction costs across space; constraints imposed on mineral production at the micro level by initial investments in physical capital; and volatility in the value of mineral assets introduced by short-run price fluctuations of commodity prices.

I. Classification and delineation of mineral and energy resources in national accounts' balance sheets

1. Now that the System of Environmental Economic Accounting 2012 (SEEA 2012) has been adopted as an international statistical standard by the UN Statistical Commission (UNSC), it is crucial to ensure that the 2008 System of National Accounts (2008 SNA) and the SEEA 2012 give fully consistent guidelines when it comes to environmental economic accounting. The purpose of this note is to indicate how both manuals could be perfectly aligned for the accounting of mineral and energy resources.

2. Two necessary conditions are used to define economic assets in the 2008 SNA. An economic asset needs (i) to be owned by an institutional unit, and (ii) to provide economic benefits to its owner. Key references in the 2008 SNA are §3.18 to §3.49[3]. In this respect, it should be noted that the 2008 SNA explicitly acknowledges that future economic benefits involve risks for the owner of the asset because not only economic and technical conditions but also assumed interest rates for discounting future benefits mayevolve over time[4].

3. The conditions required for mineral and energy resources to be included in national accounts' balance sheets are more stringent than for other economic assets. Indeed, an exception for these assets is made in Chapters 10 and 12 of the 2008 SNA, where it is stated that only mineral and energy resources that are "economically exploitable, given current technology and relative prices" are to be included in national accounts' balance sheets[5]. This condition is more restrictive than requiring that these assets have an economic value on the market (see below).

4. In the following, we argue that the 2008 SNA criteria for delineating mineral and energy resources in national accounts' balance sheets (i) are imprecise and prone to diverging interpretations by countries, (ii) are not fully consistent with SEEA 2012, and (iii) lack economic justification.

5. The definition of the asset boundary for mineral and energy resources in the 2008 SNA is imprecise, because it does not make reference to any internationally-agreed classification system. It is truethat different classification systems relevant for mineral and energy resources co-exist around the world. Some of them are only relevant for specific resources such as minerals (e.g. CRIRSCO classification) or oil and gas resources (e.g. SPE-PRMS classification). Nevertheless, the convergence and mapping between the different classification systems is now well advanced. An overarching classification relevant for all types of mineral and energy resources, known as the United Nations Framework Classification- 2009 (UNFC-2009), has recently been developed under the auspices of the

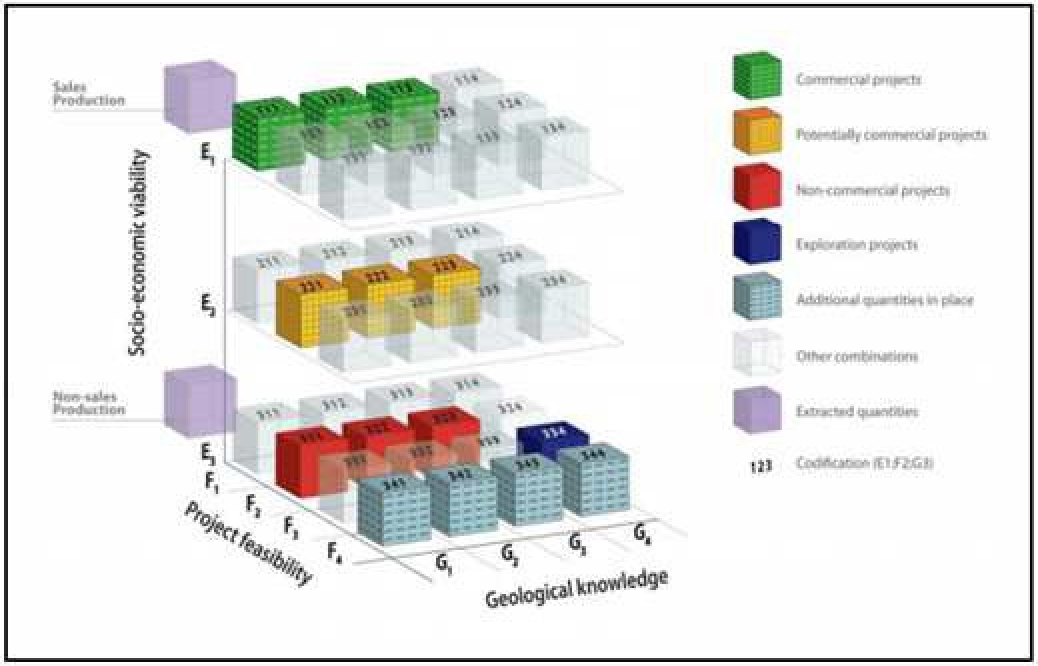
[3] See in particular 2008 SNA, **§3.18**: "In order to discuss stocks, it is necessary to define assets and liabilities and these definitions depend crucially on the concepts of benefit and ownership."; **§3.21**: "The legal owner of entities such as goods and services, natural resources, financial assets and liabilities is the institutional unit entitled in lawand sustainable in law to claim the benefits associated with the entities."; and **§3.22**: "No entity that does not have a legal owner, either on an individual or collective basis, is recognized in the SNA.".

[4] See 2008 SNA, **§3.23**: "The acts of production, consumption and accumulation involve varying degrees of risk. Two main forms of risk can be identified. The first sort refers to production. These arise because of such uncertainties as the demand for goods and services once produced, developments in the economy in general and technical innovation that affects the benefits to be earned from capital and natural resources. The consequence is that benefits from capital, natural resources and labour in the form of operating surplus and income from employment arenot wholly predictable in advance, but embody a degree of risk."; and **§3.24**: "The second type of risk refers to the process of transferring benefits between time periods. It arises because of uncertainty over interest rates in future periods, which in turn affects the comparative performance of different types of benefits."

[5] See 2008 SNA, **§10.179**: "Mineral and energy resources consist of mineral and energy reserves located on or belowthe earth's surface that are economically exploitable, given current technology and relative prices."; and **§12.17**: "In the SNA, subsoil assets are defined as those proven subsoil resources of coal, oil and natural gas, of metallic minerals or of non-metallic minerals that are economically exploitable, given current technology and relative prices.".

UNECE and its Expert Group on Resource Classification (EGRC)[6]. It can be mapped with the main other classification systems. The UNFC-2009 distinguishes three dimensions for classifying mineral and energy resources: socio-economic viability, project feasibility and geological knowledge of the available underground stock and relies on an unambiguous codification of deposits (see Figure 1).

Figure 1: UNFC-2009 classification system



6. The SEEA 2012 already makes reference to the UNFC-2009 classification in order to delineate mineral and energy resources. It distinguishes three classes of resources, namely Class A ("commercially recoverable resources"), Class B ("potentially commercially recoverable resources"), and Class C ("non-commercial and other known deposits"). Note that these three classes of resources cover all known resources in a country.

7. The current definition of the mineral and energy asset boundaries in the 2008 SNA is ambiguous and prone to diverging interpretations by countries. For instance, Tables 1 and 2 at the end this paper showhow it is currently interpreted by Australia and Canada, which are among the few countries in the world toaccount for mineral and energy resources in their national accounts' balance sheets. Note that both countries refer to specific terminologies in their balance sheets, namely "Economic Demonstrated Resources" (EDRs) for Australia and established reserves / recoverable reserves for Canada. In the tables, these national definitions have been mapped with the UNFC-2009 classification and the SEEA-2012 Classes[7].

8. Our first recommendation is that further clarifications are added to the 2008 SNA, by explicitly

[6] See http://www.unece.org/energy/se/reserves.html and UNECE (2013): United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 incorporating Specifications for its Applications. *Energy Series N°42* http://www.unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/pub/UNFC2009_Spec_ES42.pdf

[7] This mapping has been carried out with the OECD Task Force on the Implementation of the SEEA-Central Framework (OECD SEEA Task Force) and validated by countries.

referring to the SEEA 2012 and relying on the same three resource classes, based on the UNFC-2009 classification, in order to delineate mineral and energy resources. This would increase the consistency between both accounting manuals and make the SNA definition of economic asset more precise in the case of mineral and energy resources.

9. A related point to clarify is which SEEA-2012 classes of mineral and energy resources are to be included in the national accounts' balance sheets. Here, both theoretical and practical considerations have to be taken into account.

10. From an economic point of view, it makes perfect sense to attribute a non-zero value to deposits that are not economically viable under current resource prices, if price volatility is high enough to make future extraction profitable with a positive probability. As also advocated in *Nature's Numbers*, a reporton environmental-economic accounting published in 1999 by the US National Research Council[8], "Petroleum companies, for example, pay millions of dollars for offshore leases to explore for oil deposits that are not yet proved reserves. […] The option of developing such deposits in the future has a positive value because the price may rise, or some other development may make the deposits economic. Thus, afull accounting of subsoil assets should consider not only reserves, but also other mineral resources with a positive market value."

11. From a practical point of view, it is admittedly more difficult to value deposits that are currently non-profitable. Nevertheless, that should not be a reason for the SNA to exclude them as a matter of principle from the national accounts' balance sheets. On the contrary, realising that deposits may have a significant value on the market even if they are not currently profitable should provide an incentive to improve valuation techniques (see below). At a minimum, the same position could apply for these depositsas for goodwill and marketing assets in the 2008 SNA, i.e. to give the possibility to include them in the national accounts' balance sheets as soon as reliable information on their value exists by the evidence of sales/purchases[9].

12. Actually, the SEEA 2012 already allows to include all three classes of mineral and energy resources, i.e. all known resources, in the monetary asset accounts, contrary to the 2008 SNA. The SEEA 2012 only recommends keeping separate accounts for these three classes[10], because valuation is more uncertain for Classes B and C and because Classes B and C are not available for immediate extraction, which looks like a reasonable answer to a practical measurement problem.

13. Our second recommendation is that further clarifications are added to the 2008 SNA, by allowing the inclusion of the three classes of mineral and energy resources in national accounts' balance sheets in the case that reliable information on their value exists, with the additional requirement that separate accounts for the different classes, similarly to the SEEA 2012, should be distinguished. This proposal is flexible enough for countries to decide what type of assets they prefer to value depending on local specificities and priorities. On the other hand, it adds clarity and allows more meaningful international comparisons of balance sheets. Coming back to the previous examples for Australia and Canada, it can

[8] See Chapter 3 on subsoil assets: http://www.bea.gov/scb/pdf/national/niparel/2000/0200srm.pdf

[9] See 2008 SNA, **§10.199**: "The value of goodwill and marketing assets is defined as the difference between the value paid for an enterprise as a going concern and the sum of its assets less the sum of its liabilities, each item of which has been separately identified and valued. Although goodwill is likely to be present in most corporations, for reasons of reliability of measurement it is only recorded in the SNA when its value is evidenced by a market transaction, usually the sale of the whole corporation. Exceptionally, identified marketing assets may be sold individually and separately from the whole corporation in which case their sale should also be recorded under this item."

[10] See **SEEA 2012 §5.193**: "While the measurement boundary extends to all known deposits in physical terms, it maynot be possible to value all of these deposits in monetary terms owing to degrees of uncertainty regarding expected extraction profiles and incomes. Consequently, the resource rents for deposits in classes B and C cannot be determined with confidence. It is therefore recommended that valuation be undertaken only for deposits in class A: Commercially recoverable resources. If valuation of deposits in classes B and C is undertaken, the values for each class should be clearly distinguished."

be noted that this recommendation is consistent with current practice in Canada, and only implies that Australia disentangles resource Classes A and B in its national accounts' balance sheets.

II. Valuation of mineral and energy resources in national accounts' balance sheets

14. When it comes to the valuation of mineral and energy deposits in practice, it can be noticed that the 2008 SNA only gives limited guidance, even for deposits that are profitable under current conditions[11]. Similar to the 2008 SNA, Chapter 5 on asset accounts in the SEEA 2012 recommends to rely on net present value (NPV) computations, but the SEEA clearly gives much more guidance on how the monetary accounts relate to the physical accounts, how to compute resource rents based on national accounts' aggregates, and how to choose discount rates for the computation of NPVs.

15. The OECD Task Force on the Implementation of SEEA also worked recently on the valuation of stocks of mineral and energy resources based on net present values. The starting point for the work of the Task Force were the research priorities identified in Nature's Numbers (1999). These research prioritiesare as follows: (i) the valuation of mineral resources that are not reserves (i.e. valuation of currently non- profitable deposits); (ii) the impact of ore-reserve and extraction cost heterogeneity on valuation calculations; (iii) the distortions resulting from the constraints imposed on mineral production by associated capital; (iv) the volatility in the value of mineral assets introduced by short-run price fluctuations; and (v) the difference between the market and social values of subsoil mineral assets.

16. The OECD Task Force mainly worked on the first four topics. As one of the results, the heterogeneity of extraction costs across space has been identified as one of the most important issues for valuation. As working at the mine (i.e. establishment) level is the best way to take this heterogeneity into consideration, the possibility to do so in practice is currently being explored with national statistical offices. According to the mining engineering literature, output at the mine level remains broadly constant due to constraints imposed by initial investments in fixed capital, thus simplifying NPV computations[12].

17. In respect of the impact of the volatility of commodity prices on the stock values of reserves, the OECD Task Force explored the financial literature where assets are commonly valued taking into account not only the expectation of future revenues, but also their statistical distribution, leading to asset valuesthat may be less sensitive to volatility in current revenues and thus resource rents[13]. However, trying to implement such valuation techniques is not being considered as a priority for national statistical offices, because it would require high quality data on how mining revenues, investments and extraction costs are determined at the micro level. In the short run, using long-term averages of resource prices seems to be theeasiest way forward to tackle the volatility issue. Nevertheless, the work of the Task Force shows that more sophisticated tools already exist and are currently used, including by mining companies to valuetheir own projects.

18. Our third recommendation is that clarifications are added to the 2008 SNA, by explicitly referring to Chapter 5 in the SEEA 2012 when it comes to the computation of net present values of mineral and energy deposits, thereby underlining that the aim of the SNA (and the SEEA) is to compute market values, not social values, of mineral and energy deposits, and emphasising issues to which

[11] See 2008 SNA. **§13.49**: "The value of subsoil mineral and energy resources is usually determined by the present value of the expected net returns resulting from the commercial exploitation of those resources […]."

[12] The intuition here is that given convex investment costs, mining companies have an incentive to make all necessary investments in physical capital (infrastructure, machinery) before extraction starts. The initial level of investment then constraints output at the mine level.

[13] See document prepared for the 9th meeting of the Advisory Expert Group on National Accounts (8-10 September 2014, Agenda Item 7.1: http://unstats.un.org/unsd/nationalaccount/aeg/2014/M9-71.pdf). In theory, these techniques could be applied for the valuation of currently non-profitable deposits. Valuing these assets would eliminate the part of the volatility in balance sheets related to the fact that assets can switch from currently non-profitable to currently profitable, and vice-versa, depending on market conditions.

national accountants should pay particular attention: sensitivity of final results to the choice of the discount rate; heterogeneity of extraction costs across space; constraints imposed on mineral production at the micro level by initial investments in physical capital; and volatility in the value of mineral assets introduced by short-run price fluctuations of commodity prices.

Table 1: Coverage of mineral and energy resources in the Australian balance sheets

Fundamental Characterization	CRIRSCO Template for Solid Mineral Classes	*SPE-PRMS Classes*	*SPE-PRMS Sub-Classes*	UNFC Class	UNFC Sub-class	UNFC E axis	UNFC F axis	UNFC G axis: Proved / Measured (*1P/1C Low Estimate*)	UNFC G axis: Probable / Indicated (*2P/2C Best Estimate*)	UNFC G axis: Possible / Inferred (*3P/3C High Estimate*)	SEEA-2012
Discovered and Commercially Recoverable	Mineral Reserves	*Reserves*	*On Production*	Commercial Projects	On Production	1	1.1	1	2	3	SEEA-2012 Class A
			Approved for Development		Approved for Development	1	1.2	1	2	3	
			Justified for Development		Justified for Development	1	1.3	1	2	3	
Discovered and Not Commercially Recoverable	Mineral Resources	*Contingent Resources*	*Development Pending*	Potentially Commercial Projects	Development Pending	1.1	2.1	1	2	3	SEEA-2012 Class B
						2	1.3	1	2	3	
						2	2.1	1	2	3	
			Development Unclarified or on Hold: *On Hold*		Development On Hold	2	2.2	1	2	3	
	Inventory (not defined in template)		*Development Unclarified or on Hold*: *Unclarified*	Non-Commercial Projects	Development Unclarified	3.2	1.3	1	2	3	SEEA-2012 Class C
						3.2	2.1	1	2	3	
						3.2	2.2	1	2	3	
			Development not Viable		Development Not Viable	3.3	1.3	1	2	3	
						3.3	2.1	1	2	3	
						3.3	2.2	1	2	3	
						3.3	2.3	1	2	3	
		Unrecoverable	*Unrecoverable*	Additional Quantities in Place		3.3	4	1	2	3	
Undiscovered	Exploration Results	*Prospective Resources*	*Prospect*	Exploration Projects	(No sub-classes defined)	3.2	3.1	4.1	4.2	4.3	
			Lead			3.2	3.2	4.1	4.2	4.3	
			Play			3.2	3.3	4.1	4.2	4.3	
	Unrecoverable					3.3	4	4.1	4.2	4.3	

Australia's Natural Resource System	Reported Categories	E axis	F axis	G axis
Economically Demonstrated Resources (EDRs)	JORC Reserves and JORC Resources (measured and indicated) Development			

Table 2: Coverage of mineral and energy resources in the Canadian balance sheet

Fundamental Characterization	CRIRSCO Template for Solid Mineral Classes	*SPE-PRMS Classes*	*SPE-PRMS Sub-Classes*	UNFC Class	UNFC Sub-class	UNFC E axis	UNFC F axis	UNFC G axis: Proved / Measured (*1P/1C Low Estimate*)	UNFC G axis: Probable / Indicated (*2P/2C Best Estimate*)	UNFC G axis: Possible / Inferred (*3P/3C High Estimate*)	SEEA-2012
Discovered and Commercially Recoverable	Mineral Reserves	*Reserves*	*On Production*	Commercial Projects	On Production	1	1.1	1	2	3	SEEA-2012 Class A
			Approved for Development		Approved for Development	1	1.2	1	2	3	
			Justified for Development		Justified for Development	1	1.3	1	2	3	
Discovered and Not Commercially Recoverable	Mineral Resources	*Contingent Resources*	*Development Pending*	Potentially Commercial Projects	Development Pending	1.1	2.1	1	2	3	SEEA-2012 Class B
						2	1.3	1	2	3	
						2	2.1	1	2	3	
			Development Unclarified or on Hold: *On Hold*		Development On Hold	2	2.2	1	2	3	
	Inventory (not defined in template)		*Development Unclarified or on Hold*: *Unclarified*	Non-Commercial Projects	Development Unclarified	3.2	1.3	1	2	3	SEEA-2012 Class C
						3.2	2.1	1	2	3	
						3.2	2.2	1	2	3	
			Development not Viable		Development Not Viable	3.3	1.3	1	2	3	
						3.3	2.1	1	2	3	
						3.3	2.2	1	2	3	
						3.3	2.3	1	2	3	
		Unrecoverable	*Unrecoverable*	Additional Quantities in Place		3.3	4	1	2	3	
Undiscovered	Exploration Results	*Prospective Resources*	*Prospect*	Exploration Projects	(No sub-classes defined)	3.2	3.1	4.1	4.2	4.3	
			Lead			3.2	3.2	4.1	4.2	4.3	
			Play			3.2	3.3	4.1	4.2	4.3	
	Unrecoverable					3.3	4	4.1	4.2	4.3	

Canada's Natural Resource System | E axis | F axis | G axis

Economically Recoverable Reserves: Established Reserves (crude oil, natural gas), Proven and Probable Reserves (metals & potash)

or

Recoverable Reserves in active mines (coal), Remaining established reserves under active development (bitumen)