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Analysis

Available capital, utilized capital, and shadow prices in inclusive wealth accounting

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ABSTRACT

Previously, accounting for comprehensive or inclusive wealth has focused on the supply side of capital assets. However, human well-being created by capital assets inherently depends on the demand side as well. In particular, if capital is not utilized at its full capacity, then realized or actual human well-being may be less affected by available capital than by effective or utilized capital. In principle, this notion is embodied in a shadow price, which is defined as the marginal contribution of capital assets to social well-being. The shadow price becomes higher if the underlying resource allocation mechanism improves. In practice, one can account for such underutilization by adjusting shadow prices to reflect only the utilized quantity of the capital in question. Furthermore, capital utilization has different, nuanced implications for produced, human, and natural capital, and its implications even vary across some classes of natural capital. Within this line of theoretical thought, we provide empirical estimates of the changes in inclusive wealth and sustainability of selected developing countries in recent years by comparing available and utilized capital assets. We find that sustainability assessments may be revised based on utilized capital, due to, among others, human capital underemployment and non-renewable natural capital accessibility.

Wealth is not his that has it, but his that enjoys it.

—Benjamin Franklin

1. Introduction

1.1. Motivation

Bruntland Commission's (1987) well-known definition of sustainable development is almost classic and has been investigated in numerous ways. The commission defines development as sustainable if it meets present needs without compromising the ability of future generations to meet their own needs. This notion is similar to that of maximizing consumption without destroying wealth, and economists have appealed to the concept of capital being intact since the studies of Fisher (1906), Lindahl (1932), and Hicks (1946). In particular, they refer to "sustainable development" as "non-declining wealth," which is the aggregate value of produced, human, and natural capital as well as other immeasurable capital assets and exogenous factors that affect well-being. This concept was put into practice by economists from the World Bank (Hamilton and Clemens, 1999) using models of perfect economies and by Dasgupta and Mäler (2000), Arrow et al. (2003, 2012), and Fenichel and Abbott (2014) based on models of imperfect economies. Practical measurement at the unit of nations has also been here to stay (World Bank, 2006, 2011; UNU-IHDP and UNEP, 2012, 2014).

As is evident from this line of argument, the underlying assumption behind the recent shift toward (inclusive) wealth accounting is that the capital assets being accounted for should represent the abilities of future generations to meet their own needs. To better reflect this correspondence, Dasgupta (2009) developed the idea of a *productive base* that consists of both capital assets and institutions. This notion is laudable, as a non-deteriorating productive base assures the minimum infrastructure on which future generations can thrive. Although the qualifier "productive" is used, the term implies a broad set of capital assets and institutions that work to enhance the value of capital assets in terms of social well-being rather than just the conventional production of goods and services. However, this concept still focuses on the provisioning side of capital assets, as is clear from the claim of Arrow et al. (2003, 648) that what matters is "whether the economy's production possibility set is growing."

This focus does not imply that these authors are oblivious of the demand side of capital assets, of course. The missing link lies in shadow

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prices, which are defined as the marginal contributions of capital assets to social well-being. The whole theoretical framework is constructed elegantly so that the two sides are tied via shadow prices. Much like market prices, shadow prices are at least partially determined by the intersection of supply and demand, as they embody information on scarcity and substitutability with other relevant goods (Dasgupta, 2009). Moreover, shadow prices represent the practical uses of these assets, which include not only contributions to production and consumption but also the direct enjoyment of the stock itself by individuals (Arrow et al., 2012).

The supply and demand sides should coincide in efficient economies, equalizing the marginal rates of substitution and marginal rates of technical substitution (Solow, 2012). In practice, however, economies are imperfect, and this principle does not hold. Thus, information on both supply and demand should be employed to determine shadow prices. In their response, Arrow et al. (2013) argue that the shadow prices used in inclusive wealth accounting is a step in the right direction of reflecting more the demand side.

In practice, however, inclusive wealth accounting mainly records stock prices and available quantities on the supply side to varying degrees, as we will see. For example, the value of produced capital does not reflect how much it is utilized for production or consumption activities. Furthermore, human capital is valued by its observable price in the market, but its total quantity also includes the unemployed. In a somewhat different example, non-renewable natural capital also covers resources that are not clearly usable given carbon budget constraints and shifts to renewable energy under climate targets. Renewable natural capital accounting is relatively free from this problem in practice, as access to non-timber forest benefits is already taken into account and only permanent croplands or pasturelands are quantified (FAO, 2013). The current accounting practices therefore could lead to systematic over- or under-estimation of changes in human well-being.

In short, inclusive wealth accounting measures produced, human, and natural capital stock in the spirit of broadly accounting for capital assets that are often ignored. As such, it currently focuses on measuring the available capital stock, with the exception of renewable natural capital. This focus on available capital is useful for tracking changes in the economy's production possibility set to achieve *potential* well-being (Arrow et al., 2012). However, if a non-negligible share of the available capital stock is expected to be left unused, a problem arises if the index is intended to serve as a proxy for realized social well-being. In sum, the change in the available capital stock could overestimate the change in realized social well-being. To fill the gap between available and effective or utilized capital, we propose adjusting the shadow prices of the capital assets. As we will show, nations' sustainability assessments can drastically differ from current assessments when we use the non-declining effective or utilized capital stock.

In particular, the same set of capital assets would have higher shadow prices under a more efficient resource allocation mechanism (RAM) (Dasgupta, 2014). A RAM is defined as a mapping from the state of the economy to an economic program (Dasgupta and Mäler, 2000; Arrow et al., 2003; Fenichel and Abbott, 2014; Hanley et al., 2015). The notion of RAM signifies the infrastructure of the economy on which capital assets work well. Thus, assumptions about institutions, cultures, information availability, and behavioral feedbacks are embedded in RAM (Arrow et al., 2003; Dasgupta, 2009; Fenichel and Abbott, 2014). In our context, a more efficient RAM would employ or deploy a larger portion of available capital, and thus yield higher social well-being. In theory and empirical examples, we will see how the shadow price can be adjusted to reflect how much of available capital is actually employed or deployed.[1]

RAM is defined as a mapping, but it can be manifested in the form of enabling assets, which consist of knowledge, institutions, social capital, time, among others (UNU-IHDP and UNEP, 2012; Dasgupta, 2014). As they are distinct from capital assets, it is difficult if not impossible to value enabling assets by their shadow price and quantity. When RAM or enabling assets change, so does the way capital assets are converted into well-being. This corresponds to the change in total factor productivity (TFP). Being measured as a residual in national accounting, TFP indicates the degree to which factors of production are efficiently employed. Likewise, in wealth accounting theory, residuals in observed social well-being also remain that cannot be explained by changes in wealth. To fill this gap, UNU-IHDP and UNEP (2012, 2014) account for oil capital gains, carbon damage, and TFP. In wealth accounting, TFP is meant to represent the overall efficiency of an economy that transforms wealth into well-being. Thus, the TFP of capital assets may partially disappear if the degree of capital employment is properly accounted for. For example, an increase in capital utilization is likely to translate into more output and utility even if the capital in question does not change.

1.2. Arguments for available capital

Importantly, the conventional national accounting for income and product may be free from the problem of including unutilized capital. This is partly because income and product from unutilized capital is reduced if income is based on the market exchange in conventional national accounting (Obst et al., 2016). Essentially, the shadow price should be the net present value of future income from capital, which makes our suggestion even more relevant.

It is as well to clarify that we are not arguing that accounting only for utilized capital assets should replace the current form of accounting, under which the maximum available capital assets are recorded. In fact, both types of information are relevant, as in the case of potential versus actual output. The gap between these two accounting types can be narrowed by improving the prevailing RAM that gives rise to underutilization or unemployment.[2]

Furthermore, the failure to account for unutilized capital assets may even be defendable in some contexts. Unemployed human capital has value per se, not only because such workers are ready to work when the demand for labor is sufficient but also because they contribute to social well-being via domestic work. Although it is not explicitly stated, inclusive wealth (UNU-IHDP and UNEP, 2012, 2014) accounts for available human capital, possibly because of the shadow work that is still largely performed by women in many countries. Although we focus on the value of human capital only via the labor market, we again argue that both pieces of information are meaningful.

Another rationale for accounting for available capital is that the definition of sustainable development resonates well with the concept of maintaining capital intact (Pigou, 1941). According to this notion, the current development path is deemed sustainable as long as the

[1] Heterogenous shadow prices do not cause problems for conventional national accounting, in which the law of one price holds. Similarly, this issue does not arise for pricing in the System of Environmental Economic Accounting, in (*footnote continued*) which exchange values are adopted. In inclusive wealth accounting, shadow prices are defined as capital's marginal contribution to social well-being, which is greater than or equal to exchange values in imperfect markets.

[2] In the context of labor, it is sometimes stressed that unemployment is different from underemployment. In particular, in low-income agricultural economies, peasants are at least involved in some production processes, but the marginal values of their products are not on par with those in competitive sectors (Dasgupta et al., 1972). Such underemployment can be considered distinct from unemployment, which is used to refer to joblessness. In this context, however, we use the term “unemployment” broadly in terms of both width (i.e., the spectrum of capital assets) and depth (i.e., the spectrum of imperfect employment) because applying this notion to non-human capital is useful and because distinguishing unemployment and underemployment is conceptually and empirically difficult for some forms of capital (e.g., produced and renewable natural capital).

current generation does not consume capital but rather passes it on to the next generation. However, this definition does not highlight how the capital is used by future generations.

Unused or redundant capital assets can hold value for other reasons. Some studies treat networks of firms or individuals as a type of capital[3] that can be relied upon when necessary, although that necessary moment may not occur. Social capital, which often incorporates the idea of networks, may also be partially redundant but still beneficial.[4] Likewise, in uncertain environments, resilience may also be valuable as a form of capital in the case of exogenous shocks (Mäler and Li, 2010). From its very definition, this class of capital is also not used regularly. Produced, human, and natural capital can all potentially have such option values. However, even if option values are to be included in shadow prices, as we believe to be relevant, the heterogeneity of capital assets in terms of the extent of their utilization is pertinent. Overall, we stress that available and utilized capital assets are equally important pieces of information for understanding sustainable social well-being.[5]

The rest of this paper proceeds as follows. In the next section, we review the related literature. In particular, we touch on the unemployment of human capital and the capabilities approach. Section 3 lays out a basic framework for dealing with capital utilization in wealth accounting by adjusting shadow prices under a resource allocation mechanism. Section 4 discusses the in-depth implications of capital utilization for produced, human, non-renewable, and renewable natural capital. In Section 5, we demonstrate applications to wealth accounting and sustainability assessments for selected countries. Section 6 concludes.

2. Related literature: primary goods, capabilities, and functionings

Although the demand-side utilization of capital is still rarely reflected in the mainstream literature, let alone in wealth accounting, focus on the demand side of capital assets is not entirely new. In a classic study on cost-benefit analysis, Dasgupta et al. (1972) demonstrated that shadow prices, rather than market prices, for the labor force should be used in imperfect poor economies with underemployment or unemployment, unlike in the case of full employment. The net social profit raised by a marginal project in such a situation thus includes the difference between the gross profit and the sum of the direct opportunity cost of labor, the cost that arises from the change in the balance of consumption and investment, and the redistribution effects.

Only a few studies, if any, address the issue of unemployment in the context of wealth accounting and sustainability assessments. Aronsson (2010) focused on the changing marginal utility of consumption in a heterogenous-agent setting. In particular, when unemployment exists, the marginal utility of consumption differs for the employed and unemployed. He showed that the current-value Hamiltonian should be adjusted to account for the forward-looking terms that correspond to this difference in marginal utility to determine the indicator of non-declining well-being. These studies identified the shadow prices in economies in which human capital is partially unemployed. Their focus was on the increased marginal utility of consumption as a result of unemployment rather than on the more direct effect on potential future utility.

In the broader development context, the literature distinguishes between availability and entitlement (Sen, 1981). On the supply side, inclusive wealth captures economic facilities, which "refer to the opportunities that individuals respectively enjoy to utilize economic resources for the purpose of consumption, or production, or exchange" (Sen, 1999). In a similar vein, in laying out a conceptual framework for analyzing agriculture and food systems, Bebbington (1999) and Ericksen (2008) distinguished between availability, access, and utilization. A critique of the inclusive wealth index also pointed out that people's access to capital assets can be computed, although doing so would require a considerable amount of information (Roman and Thiry, 2016).

In response to Rawls' (1971) concept of primary goods,[6] Sen (1985) suggested the idea of capabilities, as is well known, because the actual use of a primary good depend on an individual's status. A famous example is the use of a bicycle to a disabled person. Indeed, the Bruntland Committee stressed not compromising the *abilities* of future generations to meet their own needs, which may suggest that studying individuals' *capabilities* to utilize inclusive wealth may be appropriate. Formally, a vector of primary goods or commodities, $x \in X$, is converted into a vector of those characteristics, $y = y(x)$. A utilization function, $f \in F$, converts the characteristics of these commodities into the functionings that individuals can achieve. Thus, the achieved functionings are given by the vector

$$d = f(y(x)).$$

If one considers functionings, d, as representing "well-being" and commodities, x, as representing the set of capital assets that collectively forms "inclusive wealth," our current motivation is essentially determining d.

However, this capabilities approach has also been criticized because of its focus on individuals' abilities to use resources instead of their actual uses in practice (Skidelsky and Skidelsky, 2012). A criticism on the other end of the spectrum is that capabilities still comprise an opportunity set that requires far too many comparisons (Dasgupta, 2019).

In sum, the capability of utilizing inclusive wealth as a primary good is relevant to the original definition of sustainable development. However, when this notion is translated into the form of non-declining social well-being, the focus shifts to the actual achievement of this well-being. Thus, within the capabilities framework, the idea of functionings is the closest concept that we aim to study. To ensure that wealth moves in the same direction as actual social well-being instead of that of potential social well-being, simply accounting for utilized capital assets looks most promising. Doing so does not necessarily require a detour via capabilities. Thus, in this study, we do not directly appeal to the framework of capabilities any further, although we acknowledge its relevance.

3. Conceptual framework

The framework of wealth accounting for sustainability assessment is constructed so that shadow prices measure the marginal contribution of capital assets to social well-being. However, under current wealth accounting practice, capital assets are broadly measured in principle regardless of whether they are utilized in full capacity. For example, in

[3] Ito and Howe (2016), for example, discuss a paradigm shift toward *pulling* human or financial resources from networks only when necessary rather than *pushing* them to be always on call.

[4] Some, however, suggest that social capital is like a muscle, whose value tends to be reduced if it is not used frequently. In this way, the unemployment of social capital may also translate to devaluation.

[5] One may object to the idea of reflecting the demand side of capital assets by appealing to the analogy of produced and financial capital in corporate balance sheets, which include both available and utilized capital assets. However, faced with market competition, firms should employ their capital assets efficiently, at least in the long run. Otherwise, they would simply go under. Thus, the focus on the unemployment of capital assets in corporate accounting, although interesting in the short run, is not relevant in the long run.

[6] Dasgupta (2019) noted that inclusive wealth corresponds to Rawls' (1971) idea of primary goods. His point is surprising at first but is convincing upon reflection, as primary goods are means to an end. However, means to an end are slightly different from determinants of the constituents of well-being, as the determinants of well-being already include the use of the goods to achieve the end.

recent reports by both the World Bank (2006, 2011, 2018) and UNEP (2012, 2014), produced capital is measured by the accumulation of investment series over its service life with depreciation. Although economic depreciation is taken into account, the accounting is based on supply-side investment, which does not reflect the extent to which capital is utilized. In both the World Bank and UNEP reports, human capital is accounted for as the discounted lifetime incomes of those who have finished schooling. In principle, this measurement is equivalent to measuring the value of educated knowledge embodied in the available labor force, although the latest World Bank report makes progress in taking the probabilities of being either employed or self-employed into account. Non-renewable natural capital, such as fossil fuels and mineral resources, is measured as the value of recoverable stock assuming it is depleted until total exhaustion, whereas renewable natural capital, such as forests and agricultural land, is an exception rather than the rule in that only the available stock is accounted for. To summarize, the wealth accounting reports by the World Bank and UNEP are both based on measurements of the available capital stock irrespective of whether the capital is utilized.

The current accounting practice can be rationalized as accounting for available capital assets, which can be readily available for future use. However, if a certain share of capital assets is chronically unutilized under the current resource allocation mechanism (RAM) of the economy under study (Arrow et al., 2003),[7] and if this RAM is of a business-as-usual type, then theory suggests that only the portion of capital assets that is actually expected to contribute to well-being should be included in the value of capital assets.

Essentially, a given set of capital assets may not translate into the same social well-being if the RAM is different. "[I]f an economy's institutions are weak or simply bad, the shadow prices of those same assets would be small" (Dasgupta, 2014, 20).[8] For example, even for the same set of fishery resources (natural capital), fishing vessels (produced capital), and fishers (human capital), the dividend from the resource could differ depending on the employment of the vessels and labor in combination (Fenichel et al., 2018). As long as capital utilization can be embedded in RAM, it can be represented by shadow prices.

We operationalize the idea of shadow prices dependent on the underlying RAM. In particular, the RAM determines how a given capital asset is allocated into utilized and unutilized capital, that is,

$$\alpha\colon Q_{it} \rightarrow [(Q^{e}_{i\tau}, Q^{u}_{i\tau})]^{\infty}_{\tau=t},$$

where $Q_{i\tau} = Q_{i\tau}{}^{e} + Q_{i\tau}{}^{u}$ denotes the available capital of type i, which is the sum of utilized and unutilized capital at each time $\tau \geq$ t. Shadow prices can be adjusted to account for underutilization if heterogenous prices can be measured and attached to $Q_i{}^{e}$ and $Q_i{}^{u}$. For example, suppose that human capital is chronically unemployed in an economy under study. The jobless workforce on the margin cannot participate in the production process. Assume also that the current RAM implies that chronic unemployment is expected to prevail in the future. The employed workforce is associated with the price that prevails in the current labor market with unemployment. Thus, differentiated shadow prices are attached to different groups of human capital.

In consumption terms, social well-being is defined as

$$V(t) = \int_{t}^{\infty} C(s)e^{-\rho(s-t)}ds,$$

where $\rho > 0$ is the consumption discount rate. In the work of Arrow et al. (2003, 2012), the shadow prices of capital assets are defined as their marginal contributions to social well-being if they are increased. We bypass this definition by allowing for non-marginal shadow prices. In particular, the shadow price of the capital asset in question, whether it is utilized or unutilized, is defined as the net present value of its expected future income flows in the consumption numeraire, B_i:

$$p_i^{j}(t) = \int_{t}^{\infty} B^{j}{}_{i}(s)e^{-\rho(s-t)}ds,$$

where $j \in (e,u)$ denotes the current status of utilization. In addition, utilized capital assets are assumed to be homogenous.

Note that our formulation is general, allowing for the possibility that currently unutilized capital may be expected to become utilized in the future. For example, infrastructure, such as roads, airports, telecommunications links, and so on, is typically constructed with an intentional provision of redundant capital early in its lifetime to accommodate future growth. Formally, $p_i^{j}(t)$ can be positive even if $B_i^{j}(t)$ is non-positive, especially if $B_i^{j}(s)$ for $s > t$ is expected to be positive. Likewise, currently unemployed human capital can become employed when the economy picks up in the future.

In this study, we assume certain income when we compute capital income, $B_i^{j}(t)$. However, just because capital is unutilized and continues to be unutilized does not necessarily mean that the investment decision was inefficient. In the microeconomic setting of a firm, irreversible investments are made to accommodate future changes in the business environment in many cases, even if the probability of full capacity utilization is very small. The individual decision to extend one's education also depends on education's value as insurance, aside from an apparent non-use value. It is also well-known since Krutilla's (1967) study that the non-use, or quasi-option, value is an important class of the value of nature. Although this value is not observable by behavior, it can constitute income from natural capital (Fenichel et al., 2018). In this study, however, with no sound methodology to identify the intentional idleness of produced and human capital or the use and non-use values of natural capital, we must exclude this aspect of the analysis for now and consider it for future studies.

The shadow price for the utilized or employed capital (p^{e}) is associated with the capital quantity in use, and the shadow price for the underutilized or unemployed capital (p^{u}) is associated with unused capital.[9] Their weighted average shadow price is

$$\overline{p} = \frac{(p^{e}Q^{e} + p^{u}Q^{u})}{Q},$$

which can be multiplied by total available capital, which is the sum of utilized and unutilized capital to arrive at the total value.[10] This weighted average shadow price can be rewritten as

$$\overline{p} = p^{e}\frac{Q - Q^{u}}{Q} + p^{u}\frac{Q^{u}}{Q} = p^{e}(1 - \phi) + p^{u}\phi \leq p^{e},$$

where $\phi \equiv Q^{u}/Q$ denotes the underutilization or unemployment rate, which is another way of saying that $(1 - \phi)$ is the capacity utilization rate. In the above inequality, we have assumed $p^{e} \geq p^{u}$, because the capital in question should contribute to well-being. In the special case of p^{u} equal to zero, as in the case of the wage in the human capital market, this expression simplifies to

$$\overline{p} = \frac{p^{e}Q^{e}}{Q} = p^{e}(1 - \phi).$$

[7] A RAM defines the institutions that govern the political economy. It can be viewed as only being changeable by an external force or a revolution. As a referee points out, it is convenient to consider it as a mechanism that limits a feasible policy set to a specific policy.

[8] Thus, institutions can be better placed as enabling assets, rather than capital assets with their own shadow prices. Arrow et al. (2012) and UNU-IHDP and UNEP (2012, 2014) crystalized the value of institutions by way of total factor productivity (TFP). In the current study, we take a different tack to see the change in shadow prices, more in line with the original idea of RAM as enabling assets expounded in Dasgupta (2014).

[9] In the remainder of this section, we omit the capital type suffix i to save on notation.

[10] Of course, the simple sum $p^{e}Q^{e} + p^{u}Q^{u}$ can be used directly as the total value. The weighted average price $\overline{p}$ is useful because this shadow price contains all the relevant information on the RAM. In particular, it includes the extent to which capital assets are utilized.

A project or policy reform to improve the utilization or employment of capital can be considered as a change in the RAM. Suppose that the current policy marginally changes the RAM to trim down the under-utilization. Its effect on the weighted shadow price would be

$$-\frac{\partial \overline{p}}{\partial \phi} = p^e - p^u \geq 0,$$

which is the difference between utilized and unutilized shadow prices. If the project under study is large, the shadow prices should change so that both partial and general equilibrium effects should be taken into account.[11]

Some caveats are in order. The analysis described in this study can be connected to the measure of Hicksian income, that is, the green net national product (NNP). In consumption terms, the NNP can be written as

$$\text{NNP} = \text{C} + \sum_{\text{i}} \sum_{\text{j}} p_i^j \dot{Q}_i^j.$$

Note that the added portion of capital stock is not necessarily utilized in non-optimal settings. Sustainability in wealth and well-being is satisfied at t, if genuine savings

$$\text{NNP} - \text{C} = \sum_{\text{i}} \sum_{\text{j}} p_i^j \dot{Q}_i^j$$

is non-negative at t.

Although the utilization of capital is measured by aggregate figures at the macroeconomic level, the choice of utilization can also be founded upon microeconomic reasoning. In principle, aggregating microeconomic results amount to macroeconomic accounting. However, there may be some wedges between these figures. Cairns (2009) finds that a microeconomic analysis of the oil industry leads to a significant departure from macro-founded green accounting of the Hotelling type.

4. Application to specific capital assets

4.1. Produced capital

In practice, it is customary that private manufactured capital is not always fully utilized. Thus, the concept of capital utilization or capacity utilization has been used at times in applied work (Nadiri and Rosen, 1969). For example, Shapiro (1986) developed a model in which a firm chooses its capital accumulation and capital utilization (as well as labor). Indeed, capital utilization is often defined as the proportion of time that capital is working productively (Betancourt and Clague, 2012). Similarly, Cette et al. (2015) used French firm-level data to show that accounting for capacity utilization along with working time and capital operating time eliminates short-term increasing returns.

The capacity utilization rate also has macroeconomic significance. For example, the Business Tendency Surveys for Manufacturing (OECD, 2018) show that the United States has experienced a consistently lower utilization rate than its German counterpart has, and this gap has widened further in recent years. Thus, the supply-side constraint holds in Germany, but not in the Unites States. Since 2000, Brazil, Germany, the U.K., and the U.S. have seen capacity utilization within the range of 73–90%, except during the Great Recession in the late 2000's, when all countries seem to have experienced sharp declines in capacity utilization (Santacreu and Zhu, 2018).

The capacity utilization index is also crucial in terms of the efficient management of firms' resources, especially in the short run, when firms cannot change their capital levels. It is critical for a firm to meet market demand with less capacity and a higher load factor, which represents the amount of capital that has been used to its full capacity. In the U.S. airline industry, for instance, the load factor has increased from 62% in 1993 to 80% in 2007, and this increase has been found to correlate with internet use (Dana Jr. and Orlov, 2014). This example implies that the utilization of produced capital can be boosted by narrowing the supply-demand gap, in particular with the use of information technology. Although this example comes from the private sector, the lesson applies to a wide variety of infrastructure and housing stock, which comprise a large share of produced capital in wealth accounting.

These studies show that capital or capacity utilization are critical for explaining variations in realized output. In the context of this study, the realization of social well-being determined by produced capital income depends on the utilization of produced capital regardless of whether it is privately or publicly installed.

Under both national and wealth accounting, the prices and quantities of produced capital are inseparably accounted for by accumulating past investments net of depreciation (i.e., perpetual inventory method) (World Bank, 2011; UNU-IHDP and UNEP, 2012, 2014).[12] Thus, to account for deployment of capital requires we use $\overline{p}$ as the adjusted shadow price, assuming that idle capital has no value.

In this application, we use capital utilization data collated by the World Bank Group's (2018) Enterprise Surveys. The employed produced capital works out to be simply the product of produced capital and the capital utilization rate in the current year.

4.2. Human capital

Unemployment of human capital has been the center of economic debate since at least the 1930s, following the Great Depression. Since then, creating effective demand has been suggested as a way to reduce unemployment, which remains a primary indicator of economic performance. Of course, the interpretation of the unemployment rate requires caution. As is well known, the official unemployment rate assumes availability to work and search for a job, and, thus, does not include “discouraged workers” who have given up seeking a job for various socioeconomic or personal reasons. World Bank (2018) further notes that “[i]n countries without unemployment or welfare benefits people eke out a living in vulnerable employment. In countries with well-developed safety nets workers can afford to wait for suitable or desirable jobs. But high and sustained unemployment indicates serious inefficiencies in resource allocation.” This resource allocation problem seems to be especially prevalent in developing countries. For example, in India, the number of working-age women has doubled, but ten million fewer women have jobs, incurring an immense opportunity cost of investing in unemployed human capital (The Economist, 2018).[13]

The lifetime income approach to measuring human capital was suggested by Jorgenson and Fraumeni (1989, 1992). Inclusive wealth accounting also considers the capital income that human capital is expected to yield, following Klenow and Rodríguez-Clare (1997). They assume that the labor market is competitive so that the marginal productivity of labor equals the real wage. To simplify the current inclusive wealth accounting methods (Arrow et al., 2012; UNU-IHDP and UNEP, 2012, 2014), the total value of human capital is computed by[14]

[11] In particular, the shadow price of utilized capital generally differs from the price that would be observed under full employment. The latter counterfactual price depends on the slope of the supply curve. In what follows, we assume that the perturbation is small.

[12] Yamaguchi and Managi (2019) showed that accounting for produced capital using the perpetual inventory method with proper depreciation is theoretically equivalent to using its backward-looking shadow price, which can be further equated to the forward-looking shadow price under no uncertainty.

[13] In addition, the recent happiness literature emphasizes that unemployment, along with ill health and divorce, is a key factor that reduces subjective well-being (e.g., Oswald, 1997). However, insofar as social well-being in the context of inclusive wealth accounting has not (yet) assumed a direct channel from capital to subjective well-being, this aspect is also removed from the current analysis.

[14] In a recent interesting OECD initiative toward a more complete account of human capital, actual rather than available human capital is used (Liu, 2011).

$$p^e \times (Q^e + Q^u) = \int_t^T \frac{wL}{Le^{rA}} e^{-\delta(\tau - t)} d\tau \times Pe^{rA} = wP\left[\frac{1 - e^{-\delta(T-t)}}{\delta}\right], \quad (1)$$

where *w*, *L*, *r*, *A*, *P*, and *(T-t)* denote the wage rate, employed labor, the rate of return on education, educational attainment, the educated population of five-year-old individuals plus the average years of educational attainment (both employed and unemployed), and the remaining working years, respectively. $\delta > 0$ denotes the social discount rate. This equation means that the wage rate of human capital in the presence of unemployment (imperfect RAM) is multiplied by the maximum available quantity under full employment (perfect RAM). Preserving the notations in the previous section, this expression is equivalent to measuring

$$p^e Q^e + p^e Q^u,$$

whereas, in the case of an imperfect RAM, the quantity that should be measured is

$$p^e Q^e + p^u Q^u.$$

Consequently, the Eq. (1) overestimates the real value of human capital that corresponds to actual social well-being. Our revision thus involves adjusting the shadow price to reflect the imperfect RAM that we observe in the real world, in which a meaningful amount of human capital continues to be unemployed.

For our purpose of considering employed human capital and actual well-being, given the available human capital Q_H, the weighted average shadow price in the case of an imperfect RAM

$$\overline{p_H} = \frac{(p_H^e Q_H^e + p_H^u Q_H^u)}{Q_H}$$

can be applied (after adding the suffix *H* to notify human capital). If we assume that the shadow price of unemployed capital, $p_H{}^u$, is null for simplicity, this expression is equivalent to adjusting the quantity of capital from Q_H to $Q_H{}^e$ while preserving the shadow price of employed capital $p_H{}^e$.

In the application to human capital, we use the unemployment rate (as a percent of the total labor force) as well as the labor force participation rate (as a percent of the total population ages 15–64) retrieved from ILO (2017). The adjusted shadow price can be computed as

$$\overline{p_H} = \frac{p_H^e Q_H^e}{Q_H} = p_H^e (1 - \phi_H) = p_H^e \, \pi \, (1 - m),$$

where π and *m* are the labor force participation rate and the unemployment rate, respectively.

4.3. Non-renewable natural capital

Non-renewable natural capital, such as oil, natural gas, coal, and mineral resources, has some exceptional characteristics in terms of its utilization. For starters, it would not be efficient or optimal to utilize all of these resources at present even if doing so were possible. Because the final service that arises can be obtained only through joint production with produced and human capital, efficient utilization depends on the utilization of the other invested capital in place that is essential for exploiting the resource. Clearly, non-utilization cannot be the criterion for our adjustment of the change in wealth as an indicator of well-being enhancement.[15]

Moreover, some utilitarian capital value is realized by *not* using these resources, or postponing their utilization, partly because of the sheer externalities created through their use and partly because they can be in the future. If we can predict the portion of natural capital that will not be used, this portion may not be included in valuable capital. The recent Paris agreement and the consequent carbon budget approach made this fact explicit (Barbier and Burgess, 2017; Aengenheyster et al., 2018; van der Ploeg, 2018).[16] Assuming a certain relationship between emissions and temperature changes based on climate sensitivity, the carbon budget is determined by the temperature target. Admittedly, this budget is currently not binding in practice; it is possible that the whole world will burn fossil fuels and overshoot a predetermined carbon budget.[17] Thus, a carbon budget that complies with the Paris agreement may not reflect the reality of imperfect economies in the spirit of Arrow et al. (2003).[18] However, for lack of a more plausible cutoff point, we regard the fraction of fossil fuel that may not be accessible under the Paris constraint as unutilized capital.[19]

In other words, the current method of regarding the untapped capital under the two-degree target as unemployed is equivalent to assuming that the RAM will be in line with the Paris Agreement. This assumption is different from using the optimal RAM (Hamilton and Clemens, 1999; Nordhaus, 2008) or a RAM with constant resource revenue (Arrow et al., 2003) or constant proportion of resource use (Hamilton, 2016). In yet other words, the notion of underutilization of fossil fuels differs from that of other capital assets. Our assumption is not inconsistent with utilization of other capital assets, in that we (conservatively) exclude capital that does not contribute to well-being. Assuming that the unusable capital has no value, the shadow price $\overline{p} = p^e(1 - \phi)$ can be applied.

In application, we use the values for ϕ from McGlade and Ekins (2015), who report regional disaggregation of fossil fuel capital that cannot be used when a two-degree target is imposed. Each permissible capital is valued using its average rental price, which is interpreted as p^e.[20]

4.4. Renewable natural capital

The now abundant literature on the valuation of ecosystem services has explicitly argued that only the portion of such services relevant to economic welfare should be taken into account (Boyd and Banzhaf, 2007; Tallis et al., 2012; Sutton et al., 2016). Likewise, the forward-looking shadow price of renewable natural capital, which is essentially the net present value of ecosystem services (Fenichel and Abbott, 2014), should only explain accessible capital assets. In the context of the management of commons, some scholars have also pointed out the negative effect of underuse on maintaining the value of such goods for the next generation (Heller, 1998; Buchanan and Yoon, 2000; Takeuchi et al., 2016; Miyanaga and Shimada, 2018).

When studying accessibility to ecosystem services from renewable

(footnote continued)
The latest wealth accounting by the World Bank seems to take a different tack in that only utilized capital is accounted for (Lange et al., 2018).

[15] A reviewer pointed out that, more generally, this principle holds for "fund" resources (e.g., Daly and Farley, 2011).

[16] Aengenheyster et al. (2018) reported that, under the two-degree target, cumulative CO_2 emissions from 2015 onwards may not exceed 424 GtC.

[17] Note that, as we have mentioned, even if a certain portion of natural capital is never used under a given RAM, it still has an option or quasi-option value. Lacking a plausible methodology to compute this value, however, we do not address this value in our analysis.

[18] This issue is somewhat reminiscent of the decision to use carbon emissions or the resultant carbon damage to define each country's loss of well-being due to carbon. Our study revolves around future emissions.

[19] Earlier exhaustible resource economists used the capacity utilization of natural resources as the current extraction rate (Stiglitz, 1974). Our concept of the adjusted quantity is broader than this concept of capacity utilization.

[20] Note also that the user (scarcity) cost is expected to be higher and accelerating when faced with a carbon budget than it is otherwise (Barbier and Burgess, 2017). However, this user cost under the carbon budget cannot be used directly for the valuation of total capital, as it overestimates the corresponding social well-being. In particular, endogenous capital gains should be deducted from the difference in the total value of wealth (Arrow et al., 2012).

natural capital, we should bear in mind that it embodies multiple functions.[21] The literature on environmental valuation defines the instrumental and intrinsic values of the environment (Turner et al., 2003; Bateman et al., 2011). In the specific context of ecosystem services, MEA (2005) has drawn the line among provisioning, regulating, cultural, and supporting services using instrumental values. The notion of utilization differs across services. In particular, the discussion of non-renewable natural capital also applies to provisioning services from renewable natural capital, and the portions of this capital to be used under a specific RAM should be treated as utilized capital. Cultural services are limited to those that can be physically and economically accessed by people under the prevalent RAM. In contrast, regulating and supporting services are generally similar to public goods (e.g., clean air or flood prevention) and, thus, do not have to be divided into available and utilized capital.

The shadow price of forest capital is comprised of the present-looking timber rental price and the forward-looking non-timber benefit. The latter value is the net present value of various non-provisioning ecosystem services, such as climate regulation, flood control, soil erosion control, pollination, and amenities, among others. This value is empirically based on the capitalized value of ecosystem services reported by the TEEB study (van der Ploeg and de Groot, 2010). For the timber value, only commercial forests are taken into account, and, for the non-timber forest benefit, only the portion of forests that can be accessed by local communities is considered (UNU-IHDP and UNEP, 2014).

Regarding agricultural land, UNU-IHDP and UNEP (2014) account for permanent cropland and pastureland areas from FAO (2013). This is a conventional estimate, excluding arable land with temporary cropland, meadows and pastureland. The FAOSTAT Land Use classification upon which FAO (2013) builds considers land use, not land cover.[22] The demand side of agricultural land is already reflected in the dataset.

In a nutshell, both forest and agricultural land accounting already carefully employ their usable quantity, so that effectively the shadow price $\bar{p}$ is already applied. For example, in the case of non-timber forest benefit, ϕ is assumed to be 0.9 to obtain $\bar{p}$ (UNU-IHDP and UNEP, 2012).

5. Case studies: the change in available and utilized wealth in selected countries

In this section, we apply the conceptual framework outlined in previous sections to selected countries. Limited data availability, especially for capacity utilization (World Bank Group, 2018), prevents us from performing a thorough cross-sectional analysis. In particular, the capacity utilization dataset covers a few years, or frequently only one year, for the variable of a given country, and developed countries are not covered. However, in principle, extending our analysis to a fuller set of countries is straightforward. We have chosen Nigeria, Botswana, Senegal, and India as case studies, as these countries are witnessing interesting substitutions from natural to produced and human capital as their populations change. Moreover, South Asia and sub-Saharan Africa are often pointed out as the two most serious regions in terms of declining wealth per capita (Dasgupta, 2007; Yamaguchi, 2018).

The largest country in west Africa, Nigeria offers an interesting case study, as it is facing a textbook challenge of converting subsoil assets into other forms of capital (Table 1). Not only does Nigeria sit on a gigantic natural resource base, but it also faces policy challenge of job creation for an increasing younger generation. Both produced and human capital increased from 2007 to 2014, but the population also increased from 146 M to 176 M (20.5%) (UNDESA, 2017), so produced and human capital per capita increased and decreased, respectively. Natural capital of almost all types, from oil and gas to forests and fisheries has declined over the studied period.

Table 1
Available and utilized capital *per capita* in Nigeria, 2007 and 2014.

Unit: constant 2005 US$		2007	2014	Change rate
Produced capital	Available	1266	1504	2.5%
	Utilized	845	1113	4.0%
Human capital	Available	5992	5718	−0.7%
	Utilized	3146	3006	−0.6%
Non-renewable natural capital	Available	3745	2678	−4.7%
	Utilized	2944	2014	−5.3%
Renewable natural capital	Utilized	1596	1251	−3.4%
Inclusive wealth	Available	12,598	11,152	−3.4%
	Utilized	8532	7384	−1.7%

Note: Calculated from the population given by UNDESA (2017); produced, human, and natural capital taken from Inclusive Wealth Report 2018 (see Yamaguchi et al., 2019 for a summary); the capacity utilization given by the World Bank Group (2018), unemployment and total labor force (modeled ILO estimate) in ILO (2017); and the unburnable fossil fuel rate of McGlade and Ekins (2015). The computation of utilized inclusive wealth already uses renewable natural capital in utilization. The change rate is annualized.

On the demand side, produced capital utilization increased from 66.8% in 2007 to 74% in 2014, boosting the rate of change of utilized produced capital. Unemployment and the labor participation of human capital hardly changed (ILO, 2017). Unburnable fossil fuels in Africa are reported to be 21% of oil, 33% of gas, and 85% of coal (McGlade and Ekins, 2015). As a result, the inclusive wealth per capita decline is worse when utilization is taken into account.

Often hailed as a resource-rich country that has successfully kept the resource curse at bay by converting mineral resources into other forms of capital (Lange, 2004), Botswana is another interesting example in Africa (Table 2). Available produced and human capital increased from 2007 to 2010. Moreover, produced capital utilization improved from 66% to 76% from 2007 to 2010. However, unemployment and labor force participation slightly worsened from 17% to 18% and 65% to 62%, respectively, implying that activated human capital actually decreased by 0.3%. This dent in employed human capital was more than compensated by the improvement in produced capital utilization, however, and the resulting inclusive wealth increased slightly.

Not every African country has lost human capital in recent years. In Table 3, we show similar statistics for Senegal. As a result of improvements in both unemployment (from 10% to 6%) and labor force participation (from 54% to 59%) from 2007 to 2014, employed human capital increased at a higher rate than available human capital did. This likely changed the country's sustainability assessment from negative (−0.1%) to positive (0.3%).

Finally, India is also one of the mostly debated countries regarding wealth per capita under a huge and increasing population (Arrow et al., 2012). Its neglect of female education (Dasgupta, 2007; Sen, 2016), and more recently, unemployment of female human capital (The Economist, 2018), are well-known issues. In terms of available capital, both produced and human capital have improved from 2006 to 2014 (Table 4). Produced capital utilization significantly improved from 71% to 82% from 2006 to 2014. Combined with its provision, utilized produced capital almost doubled. On the human capital front, however, although unemployment slightly improved from 4% to 3%, labor force participation worsened from 62% to 56% during the same period, resulting in the decline in employed human capital. Regarding natural capital, India is home to vast unburnable subsoil assets, and, thus, its figures worsen when going from a total to an accessible capital viewpoint.

[21] Although natural capital is not the only class of capital that possess multiple functions, the value of human capital is frequently limited to the return on education in wealth accounting.

[22] FAO (2013) noted that this definition is also compliant with that of the System of Environmental-Economic Accounting for Agriculture Forestry and Fisheries.

Table 2
Available and utilized capital *per capita* in Botswana, 2007 and 2010.

Unit: constant 2005 US$		2007	2010	Change rate
Produced capital	Available	15,124	17,583	2.2%
	Utilized	9936	13,433	4.4%
Human capital	Available	20,569	21,282	0.5%
	Utilized	11,052	10,826	−0.3%
Non-renewable natural capital	Available	485	435	−1.5%
	Utilized	73	44	−7.0%
Renewable natural capital	Utilized	29,311	27,109	−1.1%
Inclusive wealth	Available	65,489	66,408	0.2%
	Utilized	50,373	51,412	0.3%

Note: See note for Table 1.

Table 3
Available and utilized capital *per capita* in Senegal, 2007 and 2014.

Unit: constant 2005 US$		2007	2014	Change rate
Produced capital	Available	2219	2635	2.5%
	Utilized	1691	2105	3.2%
Human capital	Available	7991	8455	0.8%
	Utilized	3868	4642	2.6%
Non-renewable natural capital	Available	0	0	–
	Utilized	0	0	–
Renewable natural capital	Utilized	4654	3690	−3.3%
Inclusive wealth	Available	14,865	14,780	−0.1%
	Utilized	10,214	10,438	0.3%

Note: See note for Table 1.

Table 4
Available and utilized capital *per capita* in India, 2006 and 2014.

Unit: constant 2005 US$		2006	2014	Change rate
Produced capital	Available	2119	3902	9.1%
	Utilized	1502	3192	11.4%
Human capital	Available	9487	10,214	1.1%
	Utilized	5624	5550	−0.2%
Non-renewable natural capital	Available	1742	1459	−2.5%
	Utilized	627	458	−4.4%
Renewable natural capital	Utilized	1009	896	−1.7%
Inclusive wealth	Available	14,356	16,470	2.0%
	Utilized	8762	10,096	2.0%

Note: See note for Table 1.

In sum, for all the selected countries in South Asia and sub-Saharan Africa in recent years, utilized produced capital went up hand in hand with available produced capital. When it comes to human capital, however, employed capital decreased in Nigeria, Botswana, and India, in contrast to a rise in available capital in Botswana and India. More importantly, this decline in employed human capital is glossed over in the bottom-line improvement in inclusive wealth. The sample countries show better performance judging from utilized capital than from available capital, mainly because of large investment in and utilization of produced capital.

It is also interesting to observe the order of the magnitude of the proportion of utilized capital in the studied countries. In particular, only slightly more than half of the available human capital is employed in the sample countries. The proportion of available capital, or accessible capital in the RAM we assume, is even less for fossil fuels. Produced capital relatively has a high and increasing utilization rate, which more than compensates the loss in utilized human and natural capital.

6. Discussion and conclusion

Based on the idea that achieved social well-being depends on utilized capital assets, this study has investigated the adjustment of shadow prices to determine utilized inclusive wealth. Institutions, formalized as a resource allocation mechanism (RAM), can determine how capital assets are actually used, and thus determine their shadow prices. The utilization of capital assets has very different implications depending on the class of capital. Underutilization of produced capital can be easily imagined as idle facilities, creating the output gap. It is well known that raising the capacity utilization of produced capital can increase output without incurring significant production costs (Santacreu and Zhu, 2018). It is straightforward to extend this argument from output to social well-being on the one hand and from produced to human and natural capital on the other hand. In principle, social well-being can be increased by improving the RAM to utilize capital assets without incurring considerable social costs. Although this notion may sound straightforward, the literature on genuine savings and wealth accounting has stressed that investing in capital is the only solution for countries plagued with declining capital assets. Of course, as we have emphasized, the actual methods for raising capacity utilization differ from one form of capital to another. Human capital unemployment signifies deeply-rooted social and cultural constraints, as well as economic performances, as they create missed opportunities and development. Regarding non-renewable natural capital, the notion of underutilization we have adopted is more of inaccessibility under a RAM with a climate target. In contrast, access to ecosystem services have been frequently discussed in their relation to human well-being, so that utilization of renewable natural capital is already incorporated into the current accounting.

The numerical examples in the last section, although still patchy, demonstrate that produced capital in utilization is increasing in India and the studied sub-Saharan African countries, whereas the same does not hold for human capital. In recent years, some countries accumulate human capital while lowering their employment, which can be glossed over by improvement in available capital assets. In addition, the accessible fossil fuel capital suggested by climate targets is declining at an alarming rate.

It is relatively straightforward to tease out policy implications from these results. On its face, available human capital has accumulated in most countries around the world, with the exception of those plagued by civil war or political turmoil (UNU-IHDP and UNEP, 2014; Lange et al., 2018). Part of the reason that this accumulation may have not led to a proportional increase in well-being could simply be due to the unemployment of human capital, where unemployment is not limited to job seekers but also encompassing discouraged workers and domestic shadow workers. Lange et al. (2018) showed a counterfactual in which employing the same proportions of female and male workers would raise current global human capital by 18%. By the same token, the Economist (2018) argues that equal employment of women would yield extra 235 m workers and 27% output in India. The underlying theory suggests that, even if available capital assets do not change, the RAM can be perturbed to raise the utilization of capital assets to improve actual social well-being. Prescriptions for the underlying RAM to raise employed human capital vary from country to country, but along with countercyclical policy to increase and stabilize human capital employment, utilizing potential human capital can ultimately improve social well-being. Although this notion is obvious, its degree is demonstrated by the differences in available and utilized capital in our examples.

Regarding natural capital, only a small fraction of potential non-renewable natural capital is accessible, as crucial debates have started on the fossil fuels for which extraction would not be permitted under climate targets. Replacement of fossil fuels by produced and human capital in resource-rich nations is more acute and vital than is considered.

Moreover, we could use the framework for policy evaluation (Collins et al., 2017). Suppose we would like to conduct a social cost-benefit analysis of an expansive fiscal policy to increase public expenditure on infrastructure, which is expected to increase the

utilization of both produced and human capital, perhaps at the cost of natural capital. All else equal, this project would increase utilized capital assets, and the net increase can be interpreted as the policy's contribution to well-being. Clearly, this channel should also be included in the social cost-benefit analysis, along with the output of investment. However, our analysis also suggests that even if capital assets are superficially increasing, the failure to utilize them might translate into less utilized capital, resulting in a possible decline in actual social well-being. In fact, projection of actual demand for produced capital is notoriously so difficult that publicly invested infrastructure sometimes ends up with white elephants.

We also note that a relevant discussion can be found in the celebrated capabilities approach to the object of social justice (see Section 2). Inclusive wealth on the supply side corresponds to primary goods, whereas actual well-being corresponds to functionings. This study does not directly use such an approach because our focus is not on numerous sets of capabilities but on proxies for resource allocation mechanism and actual social well-being. That said, a formal analytical framework that revises the capabilities framework to fit wealth accounting could be largely promising.

As we have observed, wealth accounting already excludes untapped portions in forest and agricultural land. This treatment is in stark contrast with that of produced and human capital, for which non-utilization is rarely addressed in the wealth accounting literature. It is interesting to ponder why these treatments differ. For one thing, natural capital is provided by nature. In contrast, produced and human capital are the results of investment activities, which may suggest that capital that ends up being unused cannot be created. Besides, ecosystem services yielded from natural capital stocks have been closely investigated in the context of their relevance to human well-being (e.g., Tallis et al., 2012), whereas produced and human capital have been discussed chiefly as factors of production.

Our specific methodology of accounting for shadow prices and quantities is not detailed enough to encompass access to capital assets and human capabilities. However, the framework laid out in this study can be expanded to cover these ideas in theory to move toward a more full-fledged depiction of improvements in realized well-being over time, with more applications to national figures that are released in the future.

Declaration of competing interest

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

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