Sustainable Development: Proposal for a New Indicator

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Prepared at the request of

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by

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Contents

Objective

Develop a new globally useful metric and indicator for sustainable development that combines sustainability with human development.

Summary of Proposed Metric

More important than the details of the metric proposed are the guiding principles and building blocks of the metric, which are explained below:

1) The metric will necessarily be composite given the multiple dimensions that need to be capture, but that does not imply that it would be a single number. In fact, a multi-dimensional measure may provide greater value than a single number or score.

2) Human Development is a key goal, and sustainability is a part of *how* that is to be achieved. One could discount or correct "development" for lack of sustainability, or treat development as development per se (e.g., HDI) and correct for unsustainable practices in the sustainability analysis. We propose a hybrid approach, in the manner detailed subsequently.

3) There should be targets for selected sub-components of the metric, especially on the sustainability dimension. While for many components more (or less, depending on the metric) is better, without proper targets it becomes meaningless to just show large gaps between developed vs. developing countries. Different targets can reflect not only the state of development and legacy issues but differences in geography, climate, etc.

4) What the targets should be is likely to be a rather contentious issue. We propose the development of cohorts (similar countries) to help set targets instead of creating individual targets per country. This is for both simplicity reasons and because of a proposed computational (machine learning) based mechanism for setting targets.

5) One mechanism for dealing with the targets is the concept of gaps. This is a mechanism for estimating the value of not meeting the targets, and applies to both development and sustainability.

The net output for this metric aims to be an understandable, actionable, and comparison-friendly metric.

Introduction

Metrics are a useful mechanism to both judge where one is and also establish targets. Here, one has to be very careful of the "Fallacy of Misplaced Concreteness",[1] whereby one associates different meanings or relevance to an indirect (if not different) measure. For example, while GDP (Gross Domestic Product) is universally acceptable as one metric, it is also recognised that

[1] "For the Common Good: Redirecting the Economy toward Community, the Environment, and a Sustainable Future", Daly and Cobb (1994), 2nd Edition, Beacon Press.

it shouldn't be the sole measure, and it certainly shouldn't make claims of well-being. The Human Development Index (HDI) was created[2] precisely to measure development above and beyond economics, that too a narrow slice of economics (viz., GDP = consumption + (capital) investment + exports − imports [final goods and services only]).

HDI itself has many limitations well articulated in the discussion paper "Alternative Indicators of sustainable development and well-being: A discussion paper for the High-level Panel on Global Sustainability" (author unknown), and this note begins the process of additional or alternative metrics for sustainable development. Like all metrics, there are challenges and trade-offs, ranging from data availability, complexity, etc. to subjectivity of selected parameters.

The twin concepts of sustainability and human development each have a history of metrics and indicators, many of which are in widespread use. However, there are few metrics that combine both of these concepts. A part of this is due to the difficult nature of measuring sustainability in a transparent, neutral, and globally accepted manner.

Considering the two dimensions of sustainable development (sustainability and human development), human development has received more focus, perhaps because the metrics have been easier. It is also possible that development has received a greater policy focus since some believe sustainability can be "added on" subsequently (ala Kuznets).[3]

Human Development Index (HDI) is a composite measure that goes beyond economic development (typically measured by Gross Domestic Product, GDP) to add in dimensions such as education and health (in its current iteration). In addition, there are developing country-centric metrics such as the Millennium Development Goals, which have targets along various dimensions of development, mostly quantitative, but some less rigorously defined.

Sustainability on the other hand has found far less widespread acceptance, rather uptake, despite several metrics in literature such as Green GDP/NNP (net national product), which factors in depletion of resources, ecological footprint, etc. A very detailed set of metrics is available via the briefing papers for the "Beyond GDP" efforts by the EU.

As there is no single measure that will suffice for the complex needs of capturing sustainable development, any indicator chosen will likely be a composite measure. In addition, the proposed indicator should be easy to operationalise (gather data for) and thus be amenable to periodic updates. It should also allow for meaningful comparisons, both cross-geographically and cross-temporally. Any indicator should also, ideally, limit its use of subjective measures since these can both be contentious and hard to gather data for.

It will never be easy to come up with a universally acceptable (rather, desirable) measure, especially not without extensive multi-stakeholder discussions. Nonetheless, this note is an attempt at capturing both existing literature and ideas as well as proposing something slightly

[2] Pakistani economist Mahboob Al Haq developed HDI for UNDP.

[3] If one follows Kuznet's model for development, now vs. sustainability, this would lead to the model where lesser developed countries first become less sustainable as the develop, and only after they reach a fair level of development does sustainability grow faster than development. Of course, his analysis was not prescriptive, and, in fact, didn't factor in time series data for measures of development.

different. All attempts have been made to be transparent with the reasoning and implications, e.g., how a particular formulation impacts selected nations or citizens.

Desired qualities of a new metric

Before we discuss the proposed metric, we begin with some observations (more descriptive than prescriptive) about current metrics and issues that would be worth considering in the new metric. Please note that this is not an exhaustive list, nor in any particular order.

1. Capturing variance and comparison: One should capture variance to compare across or within countries. Eg: Gini Coefficient. In addition, the indicator should allow for cross-temporal comparisons within a country or across countries. If we consider equity to be a component of sustainability (with environment and economics) then variance is a justifiable component of a proposed indicator.
2. Granularity of data: One should pick indicators that are simple to measure and compare, which has a bearing on the granularity of data considered. For instance, are we measuring at a household-level versus neighbourhood-level versus regional versus national-level?
3. Rate of change of the metric: For measures like GDP, the rate of change is a useful and often prized metric. It is unlikely a composite measure would display meaningful variations on an annual basis, in which case sub-components may be required to help guide and recognize short and medium term policies that are societally beneficial.
4. What isn't measured: What isn't measured has to be clarified. For instance, leisure time, unpaid work, etc is not captured in the GDP. There are updates or corrections to GDP such as Genuine Progress that reflect some of these.
5. Limiting what is "desirable": Realistically, you have to limit sustainability instead of attempting to capture everything that is "desirable", such as the notion of happiness. Examples of other desirable qualities that may be difficult to measure, subjective, or even very contentious include openness of the society, level of democracy and rights, and the ability for an individual to be successful independent of their parents or family (social mobility).
6. Absolute versus relative indicator: A country that has already invested heavily in infrastructure creation, even though it consumed resources, should be reflected differently than a country where certain infrastructure is missing. Above and beyond indicators like with the millennium development goals, this has implications for expected or future expenditures/effort. Externalities and depletion/consumption of resources should be properly accounted for in flows and transactions. Hence, the indicator has to accommodate where a country is in the path of development.
7. Choosing weights in a composite measure: How do we choose the weights in a composite measure? Is it meant to be descriptive or prescriptive? A dynamic descriptive process would almost be something fed heavily by data.
8. Timescales: What are the timescales considered? For instance, local air pollution impacts the population acutely. Taking the long-term view, you may consider carbon or climate change. What would then be the balance between these?
9. Targets: Can there be targets for sustainable development like the MDGs? If one does not develop sustainably, one faces a penalty.
10. Kuznet's curve: Do we accept Kuznet's curve as inevitable for development? If so, this has implications for what different countries should be doing. In particular, this would

place greater burden on the developed world to be more sustainable. The flip side of this is to lose the opportunity to "do it right the first time" in developing regions, who are yet to undergo much of the energy and economic growth expected in the coming decades. A practical problem (unlikely to be captured into a metric) deals with the who (where) sustainability should expand the most first, is a challenge of NIMBY (Not In My Back Yard), where people are willing to embrace a development goal or target in principle but not for themselves.

11. Separating production and consumption: This is a known challenge for economic measures, whereby consumption could be a better indicator of welfare and also externalities than production, especially given cross-border transfers. For instance, given the shift of manufacturing to China, its environmental impacts and carbon footprint appear very bad. But the overwhelming majority of that production may be slated for, say, US consumption. Extending that, one can consider a number of developing countries who exploit an available natural resource and export it. Ecological footprint attempts to capture some of these issues.
12. Can/should we distinguish between types of production/expenses? This can be called input versus output side metrics. Just because a country spends more money, if they are not getting more bang for buck then that should not be counted as positively. For example, when the US spends 1/6 of its GDP on healthcare, it has infant mortality rankings somewhere close to 40 or 50th in the world, can that be reflected? Or, is this sufficiently captured in infant mortality and GDP corrections?
13. Accounting for varied and moving targets: For instance, if one takes minimum earnings levels to provide for a certain number of calories, it would depend on the culturally acceptable and available diet. What should be the mode for and level of updates?

The main focus areas for any proposed Sustainable Development Indicator (SDI) would ideally address many of the challenges listed above:

First, sustainability has different dimensions: economic, environmental, and equitable. This is also known as the triple bottom line: profits, people, and planet. These need to be expounded individually and the tradeoffs have to be detailed too.

Second, there is a need to capture variance instead of just a single average or a total number. This is often articulated as a Gini Index, but even that concept has its limitations.

The last area would be a serious examination of a mechanism to capture both absolute and relative sustainable development that factors in where a country is on the path to development. This is important since one cannot expect a one-size-fits all solution to sustainable development. In addition, to what extent is utilisation of resources or even growth a zero-sum game, i.e., one country (or sub-group therein) is more advanced precisely because others are less so?

Proposed metric: Sustainable Development Indicator (SDI)

Introduction

One could always be more sustainable by reducing consumption, but this would, in today's economy, affect human development, and is unlikely to find societal acceptance. An oft-quoted statement providing an analogy is that the only truly secure computer is one that is not on the Internet. The next best alternative is to undertake the effort to make it secure, by design and by operations. Similarly, consumption could be encouraged if it were sustainable. This impacts not only the quantum of resources but also their type (with factors like choice of product, their "localness", etc.). Countries (rather individuals) should be free to choose how they achieve the balance.

In the proposed measure, there is a desire to minimize the non-sustainable aspect of consumption of energy of materials. Here, we should remove the penalty for consumption of fully sustainable energy (ideally, factoring life-cycle costs and externalities, e.g., the production of a solar panel), and also reward not only the use of sustainable materials (natural, replenishable materials) but also recycling and re-use.

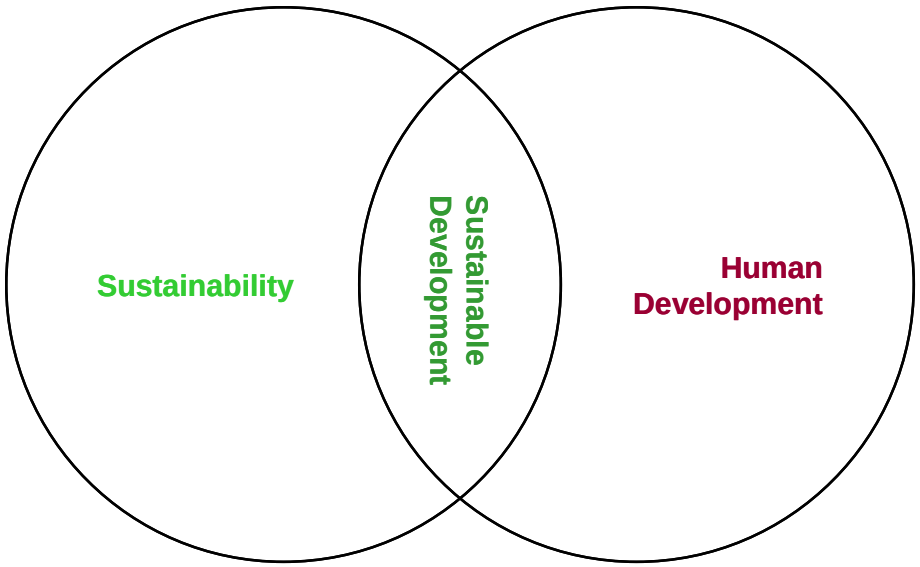

Figure: Sustainable Development

Composition of the metric:

The primary starting point for the SDI metric is that each dimension (sustainability) and human development has sub-metrics and even targets. Their composite (with additions detailed below) leads to the SDI.

Drilling down, the targets themselves have absolute components, and failure to reach said targets or levels indicates room for improvement. For instance, 100 per cent literacy for youth between ages of 8-14.

Another aspect of the SDI is that the targets, where possible, are output side. This means that expenditure on healthcare isn't the goal, healthcare outcomes is the goal. This implies poverty

is measured not as the dollars needed for calories, but actual calories consumed per capita. In addition, there is a factor for variance, which implies that there is a minimum target, and a penalty for falling below the target.[4]

Categories of the composite development metric

The details of the components can be debated (based on data, availability, its impact, etc.). One can even start with MDGs as part of the target, or one can develop updated targets such as below. The below table is a *tentative* list of the categories which will be part of the composite development metric (details under preparation).

While most measures are normalized, the details of normalization vary with each sub-category. For development, the measures are absolute, in that the goals are not cohort based. Thus, something like life expectancy normalizes similar to HDI (2010 version) as below:

(Value – lowest value) / (highest value – lowest value).

This yields a range between 0 and 1.

Variance adds a factor captured by the Gini Coefficient, which is also between 0 and 1 (but needs to be inverted as [1- Gini] since a Gini of 1 is not the ideal but the worst condition, absolute inequality.

The development components, all normalized between 0 – 1, are then combined via a geometric mean (n^{th} root of the product of n variables).

Metric	**Sub-Metrics**	**Details**	**Discussion**
Economic	Genuine Savings (as per World Bank Definition)	PPP adjusted	Normalized as above
	Variance	Per capita Income Gini coefficient	[1-Gini] is a multiplier to income; given a Gini of 0 is nearly impossible, this is also normalized
Food	Calories	Fraction malnourished	[1-% malnourished]
	Other nutrition	Protein, micro-nutrients	Iodine is a good micronutrient as a proxy; others can be used

[4] Experts indicate that calories alone are not an appropriate measure, since raw calories have improved in some countries, but *nutrition* is poor. Nutrition factors in quality of calories as well (protein, vitamins, micronutrients (e.g., iodine), etc. The proposed calorie indicator could be enhanced with a composite metric for nutrition.

Water/Sanitation	Clean drinking water	% of population with home/immediately nearby access	
	Improved Sanitation	% of population with modern sanitation available	
Health	Longevity	Years	Normalized as above
	Infant mortality	Per 1,000	Either U1 or U5 mortality; again normalized as above
	Polluting (inefficient) biomass cooking stoves	Fraction using polluting stoves	[1-% of homes using polluting stoves]
Education	8-14 age-group literacy	%	
	Total literacy	%	
	Variance (8-14 age group)	Gender gap; percentage difference divided by girls' literacy	[1 – gender gap]
Energy	Households lacking electricity	%	[1 - %]

Notes: *Infant mortality was removed from HDI, but we suggest it has enormous value since it ties closely to short/medium-term policies.*

Biomass cookstoves per se are not penalized; only inefficient cookstoves using non-sustainable biomass are penalized.

Categories of the composite sustainability metric:

When we consider sustainability, the components of a composite measure are more challenging.

Metric	**Sub-Metrics**	**Details/Discussion**
Energy	Fraction Renewable	This is based on consumption, not generation This is normalized at a cohort level
	Energy intensity (energy per GDP)	[1-normalized value at a cohort level]
Materials	Total material consumption by sub-categories corrected by	Cement, steel, and petrochemicals. The impacts of the materials are

	environmental factors (see below)	normalized by their environmental impact during production, but the accounting is for the consuming nation. Thus, "green cement" (e.g., which utilizes some recycled components, like fly ash) would have a lower value. This is net (post recycling). [1- normalized at a cohort level]
Environment	CO2 per capita	[1-normalized at a cohort level]
	SO2, NOx, etc.	Local and regional pollutants Use healthcare driven models to set targets[5]

It is important to capture emissions and other environmental impacts on a consumption basis only. Thus, a country extracting raw material shouldn't be the "loser" in the metric, rather the consuming nation.

Consumption is a useful measure since this ends the challenge of national accounting norms and borders. E.g., many nations in Europe have an interconnected grid. Thus, they may themselves avoid any coal plants but may import coal (or nuclear, or another locally absent) power. As an example, let us consider a Country A consuming 1,000,000 tonnes of cement. Some fraction is domestic, while the remainder comes from countries B and C. Each country producing cement has a total (weighted average) metric for its environmental impact, which is based mainly on technology and operating performance. Thus, Country A's account for the cement would be normalised based on the environmental impact of the respective cement(s) used.[6] Operationalizing this, one would first start with average numbers only.

When we extend this to ecological footprint (embedded in the sustainability components), it is consumption and not production that is of value. Else, nations like Australia would be free to do almost anything they want, but a nation like Singapore (where exports and imports are greater than the GDP) would be rather limited. In fact, accounting for transportation hubs like Singapore should be done at the consumer side, since if we chose to dismantle a hub like Singapore on the grounds of local carrying capacity, that economic and environmental activity would simply shift elsewhere. If this were more dispersed, it might have employment implications for developing regions, but the efficiency gains from hubs like Singapore, Rotterdam, etc. likely compensate on a materials and energy point of view.

[5] If one applies risk-based targets, one could justifiably argue for a cohort model. Using cost-benefit style calculations, $/life saved from environmental factors indicates what the cost is for any particular regulation or policy. One tool has been to use "value of life" estimates to set the guidelines. But from a developing region, opportunity costs may be more appropriate, since there are lower hanging fruit still remaining to be done, e.g., fire and earthquake codes, before worrying about particulates at sizes of 2.5 microns versus 10 versus 50, i.e., PM 2.5 vs PM 10 vs PM 50. Note that only the most developed of regions even measure particulates at the smallest size today.

[6] In theory, one could do plant level accounting, but this becomes intractable. Even this formulation may require some simplification as it entails pair-wise accounting of supplier nations (for the factors) and consumer nations (to whose account the impact is booked).

Ideally, one would want an accurate lifecycle, supply-chain based metric of consumption and its sustainability implications, e.g., an input-output matrix based measure. However, input output tables, above and beyond being very data intensive, have limitations of granularity (in practice) and dynamics. Thus, we have chosen to limit measures of consumption from a development perspective.

Is it worth looking at direct linkages between development and sustainability or should those be let at an aggregate level? If we consider something like agriculture, a critical component of the global economy from an employment perspective though less and less so from a GDP perspective, then development can easily be measured by yield (productivity). The highest yields are often from Western Europe, by almost an order of magnitude more than in some of the lesser developed regions. But, on the sustainability side, such productivity is highly energy and fertilizer intensive, and thus would lose points for its energy and other inputs. From a metrics point of view, aggregate is likely superior, since how much (and what type) of agriculture a country pursues is a decision driven by local needs, culture, etc. It is only when we are examining sector-specific policies would the more disaggregated data like above be appropriate. In an ideal world, the macro could be built up from a sum of all the micro, but that appears to be a long term goal.

If we come back to the issue of sustainability within development or sustainability as a separate dimension, examining the current methodologies we find there is value to keeping them separate at the least (though it can be embedded as well – a "hybrid" approach so to speak). GDP, even with corrections, tends to drown out many other factors. E.g., Genuine Savings, as reported by the World Bank, including corrections for depletion of resources, environmental impact (though right now measured as Carbon only), etc. indicates that developing regions are worse off than developed from a "weak sustainability" measure. Similarly, energy intensity (energy required per GDP) is misleading since almost all developed regions have better energy intensity than developing, despite consuming far more energy, simply because the GDP is disproportionately high (a combination of productivity, structural issues, i.e., more services, and what is captured in GDP).

Are we considering weak Sustainability vs. strong Sustainability? The former allows for innovated or engineering (manufactured) substitutes for a natural resource. The latter does not, in part because the true value of a natural resource (e.g., a forest, the ozone layer, etc.) is hard to quantify. While the indirect resource value may be difficult, there are cases where substitution of resources through innovation is not only equivalent, but perhaps superior. E.g., the primary fuel for lighting during parts of the 1800s was blubber (whale oil). This was gradually replaced by kerosene and then electric lighting. Similarly, innovation and materials substitution can be a net positive, but here the change is not because of depletion of the earlier natural resource but because of the superiority of the substitute. It may be appropriate to consider strong sustainability only at a global level but weak sustainability only at a national level.

Sustainability Targets and Cohorts:

It is unreasonable to believe that developing countries will approach the level of development as highly developed nations in the near term. Is the same naturally true for sustainability? What does sustainability mean when the environmental impact is low precisely because of low

development? And, ala Kuznets, as they develop, they become less and less sustainable (at least under today's Business As Usual models).

This issue comes up when we consider targets – should they be absolute or relative? We propose development targets be absolute but sustainability be relative, but periodically updated. The reason for this is because there are likely few highly sustainable nations that are not highly developed (the data remains to be put through the model). Thus, developing regions are given a temporarily slightly lower target for sustainability as they strive to develop.

Extending this, the target for sustainability is modified based not only on the level of development of a nation but also other factors such as climate (which impacts heating/cooling needs, etc., geography, population density, etc.) The idea is to use Machine Learning (computational) tools to determine the most "similar" countries to form a handful or two of cohort nations. Appendix 2 has details on such tools. While the details of this are to be worked out, the fundamental (and new) idea is that instead of a priori knowing the targets, cohort nations are chosen, and then the best performances within the cohort are used to set the target. In essence, the data speaks to the model, instead of vice versa.

Does such a model diminish the pressure on developing regions? I.e., since they start lower, they only need to target "a certain amount" higher? E.g., carbon emissions from developing regions. The use of Machine Learning (ML) for determining cohorts and targets removes political values from the targets. It is possible that the targets may still not be aggressive enough, but it is premature to say so. Also, from a highly practical point of view, a cohort based target (which can still be aspirationally high) is much more meaningful than an obvious gap in sustainability. It is infeasible to imagine a developing city like Dhaka can become developed AND environmentally clean like, say, Zurich, in a short period of time (and one can extend the analogy to nations, where developing countries fare even worse because of rural/urban divides along many dimensions).

Sustainable Development and gaps:

Once targets are created as above, is there a meaningful manner to create comparisons? This extends to both sustainability and development. One mechanism for this is to apply the concept of *gaps.* This examines where a country is in meeting the targets, and then adds an economic penalty based on the cost required to develop or clean up.

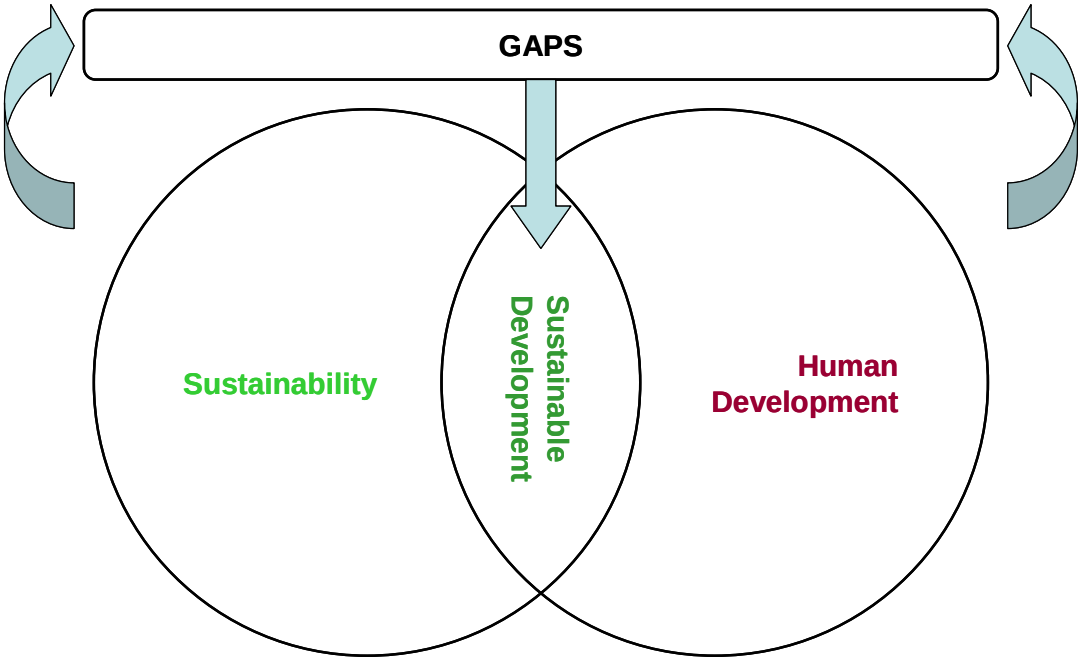

Figure: Sustainability gaps

One of the thoughts behind the "gap" mechanism is the Kaldor-Hicks criteria for dealing with social efficiency via welfare transfers. To simplify, something is worthwhile if it leaves society better off, even with winners and losers, since the winners could always pay off the losers for their losses. This says nothing about how or whether this is actually done, and isn't a prescriptive policy, but one that is in contrast to a Pareto Optimal solution where the equilibrium cannot be disturbed as some may disagree (Pareto Optimal solutions have no further improvements possible without someone being worse off).

One useful analogy for this is to consider a coal-fired power plant. It is estimated that some 25-30 per cent of the costs of a coal-based power in the US are for meeting environmental standards.[7] Thus, if one were to remove environmental constraints (which, today, don't factor in carbon emissions), then one could theoretically obtain cheaper power. Thus, a nation without commensurate emissions either has paid the costs of removing such emissions or it simply doesn't have such a power plant. The latter ranges from fuel substitution (which, ultimately, could move to renewables) all the way to simply not having such any equivalent power plant in the first place. Ignoring importing energy, this could be because of energy efficiency or because of lower demand stemming from lower development. In the proposed SDI, development that has inappropriate emissions is penalized.

As we consider development and sustainability, there are links, and either one or both parts of the SDI capture any positive or negative development. In fact, the creation of goals for development reduces the burden of accuracy of input side measures. E.g., if we consider cooking, many developing regions use biomass for cooking. In theory, biomass could be a good fuel for cooking compared to non-renewable fossil fuels, but it has several major drawbacks.

[7] Integrated Environmental Control Model (IECM) analysis, Carnegie Mellon University (http://www.cmu.edu/epp/iecm/)

First, it is often not replenished, i.e., citizens cut down any available biomass, without replanting. Second, the health impacts on citizens (indoor air pollution) are very high, combined with the very low efficiency of traditional cooking stoves. If a country is using "modern" cooking stoves, it benefits from lower penalties for inefficient cooking stoves but has a negative for sustainability due to use of fossil fuels. If it uses replenishable biomass in efficient cooking stoves, its SDI would reflect that positively (since replenishment would help forest cover whose loss would otherwise show up in the Genuine Savings metric).

Let's examine one example of gaps in some detail, sanitation. As per MDG literature, this is a more expensive proposition (and harder target) than drinking water. Primary surveys in rural India at CSTEP indicate a very low proportion of rural homes have individual (household level) sanitation (toilets). The cost to build one in a rural setting is estimated to be Rs. 15,000. This includes a septic tank – a lower figure sometimes quoted excludes waste disposal/management. If we estimate 130 million homes requiring such infrastructure, the total capital costs come to an estimated $50 billion only.[8] Assuming this is built out over 5 years (to be aggressive), that still comes to only about 1% of the GDP of India. Personal conversations with development scholars indicate that the benefits (e.g., healthcare, productivity, etc.) would be far greater than 1% of the GDP annually.

The exact modalities of gaps are under development. The two choices are to use relative measures or absolute measures. Relative measures (e.g., across countries) become a moving target, and thus comparisons over time become challenging. An absolute target is proposed, but the absolute target itself becomes updateable periodically. E.g., the fraction of energy that is renewable. In the short or even medium run, 100 per cent renewables are unlikely, except for the rare nation blessed with high hydropower potential. In fact, most present power grids finds themselves struggling to incorporate more than, perhaps, 20 per cent intermittent renewables such as wind and solar. Thus, the target is set at a reasonable best feasible, independent of what the global average is, but over time, the target should be updated, perhaps every 10 years. However, once we do have a target, using an estimated premium or incremental cost for, say, making "x" percent of energy carbon neutral (leaving the details to the country of how it is to be done), this helps compare gaps across countries using a common framework. In fact, one potential off-shoot of this may be the concept of gaps as a percent of nominal GDP.

Comparing SDIs

A single number is easy and makes it easy to compare nations, but the value and insights (and predictive power for policy linkages) becomes inaccessible. We believe listing separate Development, Sustainability, and Gaps will be useful. If any nation does wish to have simplified comparators, Gaps can be useful. Given the non-absolute nature of these (cohort driven), a

[8] This estimate excludes urban toilet needs, which are lower in absolute number, and where, other than unauthorized developments (slums), is part of cost of building a house. One alternative discussed is community toilets. While cheaper, institutional challenges make this untenable, in contrast to community handpumps where the maintenance needs are far lower. The Andhra Pradesh State Government in India has a reimbursement scheme, "Indiramma" for rural/poorer households building a toilet, and this provides an estimated Rs. 5,000-8,000 depending on criteria, but there are not many takers. The Rs. 15,000 estimate for true costs is based on CSTEP primary survey data. [Note the scheme focuses on housing and not sanitation per se].

single number is problematic. A qualified Gap score may be more insightful, similar to how a golf score is based on a handicap. Thus, the Gap could be cohort linked.

If we consider energy per GDP (energy intensity), it is a useful measure that tells us about sustainability more than development since two nations with similar energy intensity could have very different development based on the overall energy (or GDP). Similarly, while SDI is chosen as a composite measure, a visualization of both the development and the sustainability of a nation, along two axes in a graph, would be a useful comparator. The numeric calculation of SDI is where the concepts of gaps would come in.

The hypothetical graph of the dimensions of sustainable development shows how different countries could be placed. The size of the circle represents the total population of the country, signifying scale, while shading (light to dark) could help visualize the Gaps. Intuitively, especially given a Kuznet type of model of development, one would expect more countries to the lower right than the upper left of the diagonal.

While we currently have not applied this new indicator to the countries across the world, we find there are four quadrants amongst which countries could find themselves, considering the dual dimensions of sustainability and human development. High vs. low development; high vs. low sustainability. Ideally, a country should aspire to high sustainability with high development. Given a large number of countries have low development, the main challenge would be to find pathways for increasing development while simultaneously maintaining, rather, improving sustainability.

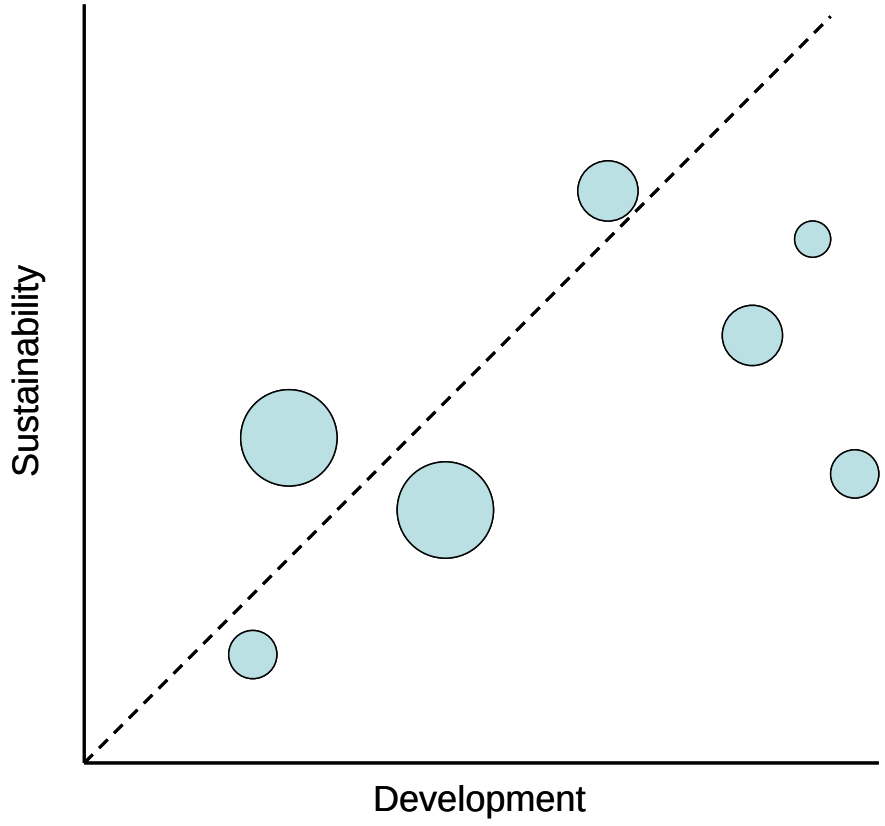

Figure: A hypothetical graph with sustainability and development as dimensions illustrating how different countries could be placed in it. Shading (light-to-dark) could also signify the Gaps (as defined previously).

Limitations:

One major drawback of this methodology, with targets revised every 10 years, and different targets for different nations by cohort is that comparisons become difficult. Temporal comparison limitations are easier to justify since so many things are a moving target. 10 years is considered a medium-term, which allows for policy efforts to take shape and bear fruit, and revisions become justified as technologies, structural set-ups (e.g., financial flows via globalization in a highly service economy), aspirations, household patterns, etc. can all change substantively in 10 years. Instantaneous comparisons with such an indicator are harder, but the underlying data should allow further comparisons on a case by case basis. As stated before, can two countries with, say, identical carbon emissions per capita be compared if their GDPs are more than an order of magnitude apart?

There are other limitations we recognize up front, but those are ones that can be corrected for with refinements (and checking whether appropriate data are readily available). First, it does not handle population growth explicitly. It is an embedded characteristic. Same goes for innovation, but the use of cohorts and of 10 year resets should help that. Lastly, it doesn't handle temporal issues explicitly, especially inter-generational. Only in the sustainability metrics could strong sustainability be potentially applied for global non-replenishable natural resources.

Further discussion:

The attempt in this note is to come up with a useful metric that corrects for several of the drawbacks of existing or popular metrics. No claim is made that this resolves all the issues, but it might offer new insights and guidance. In that sense, it may not be a replacement, but another indicator. E.g., many consumer goods now list "carbon footprint", even though carbon is not the only indicator of sustainability. But it remains one that is nonetheless useful, and one welcomed by many consumers and decision-makers.

This framework is still under development, and ready for stakeholder discussion before discussing specifics and values, and CSTEP welcomes comments on the overall concept and outline note (tongia@cstep.in).

Appendix 1: Discussion on Existing Metrics

Below are a few general framings for sustainability and economics.

- GDP = consumption + (capital) investment + exports − imports [final goods and services only]
- GNP = includes net income from abroad
- NNP = GNP - Depreciation of Capital
- Green NNP = GNP - Depreciation of Produced Assets - Depletion of Natural Resources
- Genuine Savings = Production - Consumption + value of education [knowledge capital]- Depreciation of Produced Assets - Depletion of Natural Assets

  (Also takes out net borrowings)

Genuine Savings is already a well-recognized (but not necessarily perfect[9]) metric, and statistics on this are published by the World Bank.

[9] One of the major criticisms of this indicator ("The World Bank's "genuine savings" measure and sustainability", J. Ram Pillarisetti, *Ecological Economics* 55 (2005) 599– 609) is its lack of additional predictive power compared to direct use of underlying components. In addition, GDP dominates many factors, e.g., CO2 emissions. The absolute emissions of the US may be ~25% of global emissions but the penalty is relatively small.

Appendix 2: Machine Learning and Computation tools for Development

A traditional approach to modeling and analysis has been what can be considered an engineer's (or economist's) approach. One has a model, and then examines the data to see the fit, including values for parameters or coefficients. As an example, a common tool is a regression analysis.

Recently, the growth of "machine learning" (ML)—which is sometimes considered a variant of artificial intelligence)—and advanced computational tools have offered a new alternative, whereby the data itself is used to come up with the best (most predictive) model, including relationship and weightage between variables. What this allows for could be far greater predictive power, as well as new insights that might have been hidden using conventional means. It also offers the advantage of being relatively neutral, and is now being applied for human development. The latter has matured as can be evidenced by the presentations at the AAAI Artificial Intelligence for Development Spring Symposium in 2010.

In attempting to produce cohorts and their targets, ML can help us identify the best groupings in terms of similar countries, and then we can set targets as the best practices within that cohort. Now, similar need not just be "large", Latin American, or natural-resource rich, etc. It can be the appropriate groupings of these. Whether we end up with 5 or 10 or however many cohorts can also be driven by the data. Just like a greater fit in regression analysis (R-squared) is possible with more independent variables, the adjusted R-squared may not always improve (which penalizes for complexity based on adding variables). Similarly, 20 or 30 groupings may be feasible in theory, but an adjusted fit may help us identify the balance between number of and predictive power of the groupings.

As an example, such techniques have been applied to healthcare in developing regions in the paper "Determinants of National Diarrheal, Disease Burden" by S. T. Green and colleagues.[10] To simplify the value of the mechanisms, above and beyond the analytic value of the findings, using such techniques, we can better group countries together instead of traditional measures like geography, HDI position, GDP, etc. Thus, Brazil may have more in common with S. Africa than its neighbors. For the SDI, this lets one add atypical but likely important factors like land-locked vs. not land-locked, annual rainfall, etc. Classification and Regression Tree, or CARTmay be a useful tool for the analysis, which is one of several candidates within ML techniques.

[10] "Determinants of National Diarrheal Disease Burden" S. T. Green., M. Small, E Casman, *Environmental Science and Technology*, Vol 43, No. 4 (2009).

Appendix 3: About CSTEP

The Center for Study of Science, Technology, and Policy (CSTEP) is a private, not-for-profit research institution with a vision to undertake research in engineering, science, and technology where it is relevant to Indian (and global) economic and human development. Work at CSTEP is interdisciplinary, and spans subjects such as energy, infrastructure, materials science, information and communications technologies, and security.

CSTEP Research

Energy
India faces tremendous challenges generating sufficient energy to propel its growth in an environmentally and economically sustainable manner. CSTEP is working on projects related to climate change, solar thermal energy, electricity market reform, smart grids, and energy games.

Information & Communications Technology
Information and communication technologies present great opportunities for countries such as India that are in the process of rapid economic development to create the groundwork for shared growth. CSTEP has worked on both general and specific issues related to ICT for development in an Indian and international context.

Infrastructure
CSTEP operates a Next Generation Infrastructure Laboratory (NGIL) to study design and policy-related infrastructure questions with both innovative and conventional tools. One major project is to create simulation-based games for policy analysis.

Security
India faces security challenges of all types: internal, external, economic, political, social, environmental and CSTEP performs evidence-based analysis, some classified, of these challenges.

New Materials
New materials are key to improvements in human welfare. CSTEP's focus is on new material development in the energy area, with an emphasis on batteries. This has implications for energy conservation and efficiency, disposal of waste and environmental sustainability, and innovations for new methods of energy use and storage.