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Sustainable development goal deficits and the Covid 19 pandemic

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ABSTRACT

In publications spanning the last 20 years, the present author has discussed the ranking of entire nations by their social and economic performance. Here the sustainable development goals (SDGs) achievements of all OECD member nations for 2020 are investigated, using a set of nine indicators of “Human Well-being” published by the OECD office in Paris, and also using Covid-19 data published by the World Health Organization (WHO). We show that the pandemic struck more severely those nations that already before Jan.1, 2020 harbored unrecognized and unattended well-being deficits in terms of indicators such as care for the elderly, personal safety, and hygiene. The calculations support views argued forcefully by J.E. Stiglitz, J.- P. Fitoussi and M. Durand (2019): markets are not in equilibrium all the time, and economics needs a new paradigm recognizing the possibility of Pareto inefficiency.

1. Introduction

The ranking methods to be employed here were originally demonstrated by Cooper et al. (2010) and involve the calculation for each nation of a policy efficiency index, determined by a model of fractional programming. In the recent volume Thore & Tarverdyan (2021) the present author reported on some early calculations ranking the sustainable developments goals (SDGs) achievements of all OECD member nations for 2020, using a selection of SDG indicators published by the OECD office in Paris. This work is continued here, using a set of nine indicators of “Human Well-being”, now also including an index of income equality (defined as 100 minus the Gini index). The data on Covid-19, downloaded from the World Health Organization (WHO) data base, refer to September 1, 2020 and thus include the arrival of the “second wave” of the virus.

The present text extends my earlier work to the case of variable returns to scale (the mathematical analysis thus being a case of the so-called BCC model of data envelopment analysis.) The earlier tentative conclusions are reinforced. The pandemic struck more severely those nations that already before Jan.1, 2020 harbored unrecognized and unattended Human Well-being deficits in terms of indicators such as care for the elderly, personal safety, and hygiene. With income equality now added to the list, the calculations provide strong empirical support to views forcefully argued by Stiglitz et al. (2019): markets are not in equilibrium all the time, and economics needs a new paradigm recognizing the possibility of Pareto inefficiency.

In brief, in the pages to follow we shall discuss one of the most burning social and economic issues of the day – how nations meet or fail to meet the sustainability goals set by the UN, drawing on developments in data collection, economic theory and operations research.

1.1. Background: what exactly is “Human well-being”?

Receiving in 2001 a shared Nobel prize for his analysis of markets with asymmetric information, Joseph Stiglitz stated:

"The construction of a macroeconomic model which embraces the ... imperfections of information ... in markets has become one of my major preoccupations ... “ (quoted from the official Stiglitz, 2001 Nobel lecture, the Nobel Foundation, Stockholm p.508).

In his further comments, Stiglitz argued that a "new paradigm" of the science of economics must allow for the possibility of markets not clearing and the absence of Pareto efficiency.

What precisely is the nature of the asymmetric information that markets fail to transmit? In 2001 the International Labor Organization in Geneva had started an ambitious program of estimating the “decent work deficit” of each member nation, to be calculated as the difference between actual employment data and data on “decent work”, encompassing information about the character of the workplace, the conditions of work etc. The market information about the deficit is asymmetric: it is known to the workers but not fully recognized by the employers. One of the expressed goals of decent work is to promote the opportunities for women and men to obtain employment -in conditions of freedom, equity, security and human dignity" (ILO, 2001). There exist no markets for these goals, and the individual worker cannot buy insurance against any such deficit.
In a number of resolutions, the UN General Assembly has similarly promoted the recognition of a wide range of social and economic policy aims, including a set of “Millenium Goals” (UN 2000, 2012) eventually leading to the UN, 2015 adoption of seventeen “Sustainable Development Goals” (SDGs). The UN resolution The 2030 Agenda for Sustainable Development instructs each member country to submit annual reports on its performance, identifying several targets for each goal. A further step was taken by the UN statistical office, listing a set of 230 statistical indicators of the SDGs. International organizations (like the UN, the OECD and EU) now maintain regularly updated databases on these indicators.

The abundance of new data throws new light on the asymmetries of information that economic markets fail to pick up, raising the possibility that undetected pockets of well-being deficits can exist in many nations. Can these pockets, if they do exist, be measured?

In the midst of a severe global financial crisis, French President N. Sarkozy in 2008 created a high level Commission on the Measurement of Economic Performance and Social Progress headed by J. Stiglitz, fellow Nobelist A. Sen and French economist J.P. Fitoussie. In their final report, their main recommendation was to “shift emphasis from measuring economic production to measuring peoples’ wellbeing” (Stiglitz et al., 2009, p.12).

The idea of using peoples’ wellbeing as a metric of economic and societal progress had already been around for some time, see Nordhaus and Tobin, (1972).

Under the leadership of M. Durand, its chief statistician, the OECD office in Paris subsequently published several reports on measuring human well-being and progress. Two reports dated 2013 list possible statistical indicators, and also discuss the problem of forming an overall index, the main stumbling-block of course being the task of finding appropriate weights to the individual indicators. For a detailed review see McGregor et al., 2015, Measuring what Matters, Overseas Development Institute, June 2015.

How should the concept of Human Well-being be understood in relation to the UN SDG indicators? Actually, every single dimension of the proposed definitions of well-being can be found as an official indicator of a SDG. They include factors such as health, sanitation, and care of the elderly. Responding to the detailed discussions in the publication J.E. Stiglitz, J.-P. Fitoussi and M. Durand, Measuring What Counts, The Global Movement for Well-Being, 2019, we shall also include low income inequality (measured by the conventional Gini index) as one of the dimensions of human well-being. For the purpose of the present investigation of human well-being we select nine indicators:

- **OBSERVITY** an indicator of SDG II (End hunger, achieve food security and improved nutrition), defined as individuals having a body mass index of 30 or more; in percent of the adult population, latest data for 2016.
- **SANITATION** sanitation, an indicator of SDG VI (Ensure availability and sustainable management of water and sanitation for all), percent of population using at least basic sanitation services, latest data for 2017.
- **UNEMPLOYMENT** unemployment, an indicator of SDG VIII (Promote …economic growth, full and productive employment and decent work for all), percent of total labor force, latest data for 2019.
- **MOBILE** use of mobile phones, an indicator of SDG IX (Build resilient infrastructure), measured as the number of mobile broadband subscriptions per 100 inhabitants, latest data for 2018.
- **ELDERLY** an indicator of SDG X (Reduce inequality within and among countries), elderly poverty rate, calculated as% of population aged 65 or over, latest data for 2016.
- **UNEQUALITY** an indicator of SDG X (Reduce inequality within and among countries), the Gini index adjusted for top income, latest data for 2018. The Gini coefficient reflects the degree of inequality of the vertical income distribution in a country.
- **WASTE** an indicator of SDG XII (Ensure sustainable consumption and production patterns), amount of municipal solid waste in kg/day/capita, latest data n.a.
- **SAFE** an indicator of SDG XVI (Promote peaceful and inclusive societies….) measured as the percentage of population feeling safe walking alone at night, latest data for 2019.

Data on Covid-19 are brought from the WHO data base, yielding the variable

- **SURVIVE** the Covid-19 percentage survival rate, an indicator of SDG III (Ensure healthy lives and promote well-being for all at all ages), calculated as 100 minus percentage accumulated death rate up to September 1, 2020.

Most individuals surviving the pandemic recuperate at home, some being assisted by a strong physique, many drawing on the care of family or others. The survival rate is a shorthand indicator of many factors of well-being. (Low absolute numbers of deaths are not necessarily a good indicator, in some countries rather signaling low levels of travel and tourism.)

For the data on the nine indicators listed above, see the table in the Appendix. Some of the goals are desirable, others are unwanted. For the programming purposes to be described in a moment, it is necessary to convert OBSERVITY, UNEMPLOYMENT, ELDERLY, UNEQUALITY and WASTE into something wanted rather than something unwanted. Such conversion is easy when the indicator is a simple percentage. For WASTE we pick the number 10 kg/day/capita as an arbitrary upper limit on the amount of discharge of municipal waste. Denoting the vector of desirable outputs by Y, one then has

\[ Y = (100 - \text{OBSERVITY, SANITATION, MOBILE, \ldots, ELDERLY, \ldots, WASTE, SAFE, SURVIVE}) \]

The function of Human Well-being can then be written \( V = V(Y) \).

Several alternative subsets of indicators of the full set \( Y \) will be used in the computations to be reported in the subsequent. Results omitting the indicator SURVIVE describe conditions in 2019 (before the Covid-19 virus had left China); results including SURVIVE provide a picture of the onslaught of the «second wave» of the virus.

2. Tinbergen’s theory of economic policy redivivus

At this point it is helpful briefly to review the received theory of economic and social policy as codified in two standard tracts by Jan Tinbergen (North Holland, Amsterdam 1952 and 1956). This takes us back to the heydays of the classical model of market equilibrium, at that time embraced by the entire economic profession.

Following in the steps of Marshall and Walras, consumers and firms alike were supposed to be guided in their economic decisions by maximizing behavior; consumers maximizing their utility and firms their profits. Similarly, in his 1956 work, Tinbergen introduces a «welfare function» \( V(Y, Z) \) for a policymaker or an entire nation, with the variable \( Y \) denoting a vector of policy targets and \( Z \) a vector of instruments controlled by the policymaker. The problem at hand is one of maximizing \( V(Y, Z) \) subject to side conditions involving available data and non-target economic variables. The format is illustrated by a great number of examples, ranging from monetary and currency policy to tax policy. Widening the scope of his investigation even further, Tinbergen also considered social security schemes, guarantees of minimum income or minimum employment, equalization of opportunities, monetary reforms, centralization production decisions, industrial democracy and nationalization. In brief, Tinbergen pioneered the idea of determining optimal social and economic policy by a model of mathematical programming.

Following up on these early notions, we shall here consider the United Nation SDGs as viable arguments of a « SDG welfare function» or
«SDG welfare index» \( V(Y) \), with \( Y \) being our set of desirable SDG goals. We shall avoid, however, the idea of a simple linear index and instead prefer the weaker assumption that \( V \) is concave. Already Irving Fisher in his book *The Making of Index Numbers* (1922) had stated «the simple arithmetic average produces one of the very worst of index numbers.» In the present case it would implicitly assume that the SDGs are all perfect substitutes, which of course they are not.\(^1\)

The curvature of the function \( V(Y) \) would measure how a country can compensate for some lack of attainment of one goal by providing more of some other goal. Unlike the earlier, authoritarian Millennium Development Goals, the SDGs were derived from multi-constituent dialog. The UN does not prioritize any of the SDGs. Yet some nations have adopted a favorite SDG to pursue disproportionately, such as their national carbon footprint. In Covid-19 policy almost any increase in the national survival rate achieved at the cost of lower conventional well-being seems to be socially acceptable.

An easy way to account for the possibility of marginal substitution between the SDGs (still staying with the mathematical toolkit of Tinbergen’s days, see Tinbergen *Econométrie*, 1941) would be to assume that the SDG welfare function is linear in its logarithms, say

\[
V(Y) = \mu_1 \log(100 - OBESITY) + \mu_2 \log SANITA + \ldots + \mu_9 \log SURVIVE
\]

(1)

with \( \mu_1, \mu_2, \ldots, \mu_9 \) being weights to be determined. In his 1969 Nobel lecture Tinbergen (1969) returned to the need to determine an overarching utility function reflecting the preferences of the policy-maker, including educational variables, the income distribution and even economic and social institutions:

«It is better first to specify the social welfare function as precisely as possible… and then … use it for finding the socioeconomic optimum.»

To find such a wide-ranging socioeconomic optimum certainly a great number of «side conditions» have to be spelled out. A modern representation of Tinbergen’s thoughts in this respect might well include constraints set by the available GDP, total expenditure on R&D, and government expenditure on education. Altogether, we shall here use the following three determinants of economic and social policy:

- \( X_1 \) gross domestic product per capita, in 2017 US dollar equivalents (purchasing power parity).
- \( X_2 \) investments in research & development, in pro mille of GDP (several OECD countries report R&D less than 1 percent of GDP which would make the logarithm negative; hence we opted for pro mille instead), latest data for 2017.
- \( X_3 \) government spending on health and education, latest data for 2016.

These factors can be seen as key levers of economic policy that each nation have available to improve the well-being of its citizens. Investments in research & development and government spending on health and education both constitute links to the future, hopefully a future with improved individual well-being. \( X_2 \) is of course a standard economic variable measuring the increase of «human capital». \( X_3 \) is included in our list with some misgivings: government involvement in hospital care and schools varies considerably from one other country to another.

Returning to the modern problem of assessing the SDG results of countries, it is natural to compare the considerations of personal well-being to the idea of the corresponding *imputed costs*. In the common manner, the imputed cost of a particular input is seen as the welfare foregone by withdrawing one unit of the input in question. Just as we can form the SDG welfare of a country by weighting together (the logarithms of) the SDG data in the Appendix, we might then also form the corresponding imputed cost \( U(X) \) by weighting together (the logarithms of) the economic input data, like this:

\[
U(X) = b + \nu_1 \log X_1 + \nu_2 \log X_2 + \nu_3 \log X_3
\]

(2)

At this point the weights \( \mu, \nu \) and the constant \( b \) appearing in (1) and (2) are all unknowns, to be determined.\(^2\)

Serving after World War II as director of the newly established Central Planning Bureau for the Netherlands, Tinbergen naturally was concerned with the economic and social policy of one single country: the Netherlands. Here, however, we need to take one step further, considering the policy tasks of an entire assembly of different countries, like the OECD.

The concept of «relative efficiency» is routinely used in the engineering literature to compare the performance of productive units. It is defined as the ratio of output obtained per use of inputs. It is straightforward enough when each project has only a single input and a single output. In the multidimensional case one needs first to form some kind of aggregate of the outputs, and another aggregate of the inputs. To form those aggregates, it is necessary to attach individual weights - virtual weights - to each output and each input. If those weights were known, the values of the aggregates could be calculated, and the ratio between aggregate output and aggregate input would serve as the desired efficiency measure. Furthermore, if the ratio for a particular project equals 1, the project is said to be efficient. Projects scoring an efficiency ratio less than 1 are called sub-efficient.

Dealing with situations of social and economic planning, Cooper et al. (2010) determined the relative efficiency of policy achievements of a set of 52 countries from all parts of the world. An aggregate of the outputs of a country was formed: the social welfare \( V(Y) \) of the goals. Similarly, an aggregate of inputs: the imputed costs \( U(X) \) of the policy parameters. The calculations aimed at maximizing the policy efficiency ratio \( \Theta = V(Y)/U(X) \) of each country.

In a chapter in the volume Thore & Tarverdyan (2021 2021), the present author calculated the policy efficiency ratio of each of the 36 member states of the OECD as the ratio between its total SDG welfare achieved and its imputed economic and social policy cost. Extending this earlier work,\(^3\) using the inputs \( X_j = (X_{1j}, r = 1,2,3) \) and several combinations of the goals \( Y_j = (Y_{ij}, i = 1,2,3) \) for each OECD member, we shall here calculate

\[
\Theta_j = \mu_j \log Y_j / (b_j + \nu_j \log X_j), j = 1,2, \ldots, 36
\]

(3)

The aim of economic and environmental policy presumably is to make the ratio \( \Theta \) as large as possible – to maximize the SDG welfare function for any given level of social costs. The general idea here is that the ratio \( \Theta \) signals the relative success of policy: it is equal to 100 percent if all goals are being achieved, and less than 1 if one or several of these goal posts remain unfulfilled. A ratio greater than 1 would somehow indicate that the SDG welfare exceeded its imputed cost so that welfare could be obtained for free - which does not make sense:

\[
\Theta_j \leq 1, j = 1,2, \ldots, 36
\]

(4)

The optimizing principle now to be spelled out will be used to determine the virtual weights \( \mu_j, b_j \) and \( \nu_j \) of each member state endogenously, rather than assuming them to be given *a priori*. While those virtual weights reflect the individual priorities of each state, they are also being watched by the international community at large. The very idea of the UN sustainability goals is *team work*, that all nations face similar

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1 W.A. Barnett, creator of the modern Divisia monetary index, approvingly cites Fisher’s uncompromising views, see Barnett, 2017.

2 The presence of the constant term \( b \) in (2) is significant, permitting variable returns to scale. See the discussion of the BCC model of DEA in section 4 below.

3 The deadline for my work reported in the Elsevier volume was mid-December 2020. The present calculations were carried out in April 2021.
challenges, and that international cooperation is needed to face those challenges.

Condition (4) states, in the sense already explained, that the virtual weights of each member state yield policy decisions that are «meaningful». Additionally, we now require that those same weights also be meaningful to every single other member state. Priorities are certainly permitted to vary between states. The priority of coal mining in Poland is greater than in other places in Europe. But the overall goal priorities of Poland must not be so extreme that another OECD member state in its own home context would consider them non-meaningful. A minimum of team consensus is required to uphold optimal harmony. The very idea of an index requires the presence of some degree of commensurable affinity.

Let \( j = 0 \) be the country currently considered. The programming problem for this country then reads:

\[
\max \mu_0 \log Y_0 / (b_0 + \nu_0 \log X_0)
\]
subject to

\[
\mu_j \log Y_j / (b_j + \nu_j \log X_j) \leq 1, \quad j = 1, 2, \ldots, 36
\]
\[
\mu, \nu \geq 0
\]

Program (5) is a case of fractional programming, both the maximand and the constraints featuring fractions. To solve it, the virtual weights of the goals are normalized to produce a SDG index equal to unity:

\[
\mu_0 \log Y_0 = 1
\]

A linear programming equivalent of (5) and (6) is immediately obtained as

\[
\min b_0 + \nu_0 \log X_0
\]
subject to

\[
-\mu_j \log Y_j + b_j + \nu_j \log X_j \geq 0, j = 1, 2, \ldots, 36
\]
\[
\mu_j \log Y_j = 1.
\]
\[
\mu, \nu \geq 0.
\]

Additionally we also require all virtual weights \( \mu \) and \( \nu \) to be positive, say

\[
\mu, \nu \geq \varepsilon
\]

where \( \varepsilon \) is an infinitesimally small positive number. No zero index weights are permitted. The rationale behind this condition will later become evident.

For some countries, the solution to (7) will generate virtual index weights that produce a ratio of policy efficiency rating (3) equal to 100 percent. Ranking all countries in terms of their policy performance, no single winner emerges but instead a team of «best» performers. Countries with a policy efficiency less than 1 are sub-efficient.

### 3. A first look at the programming results

The calculations of Human Well-Being, using the three economic resource inputs listed in Section 2 and all nine sustainability development goals (SDGs) listed in Section 1.1 (see the data appendix), resulted in 31 of the 36 OECD member states recording maximal efficiency results. They are

- Australia, Austria, Belgium, Chile, Czechia, Denmark, Estonia, Finland, France, Greece, Hungary, Iceland, Ireland, Israel, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovenia, Slovakia, Spain, Sweden, Switzerland, Turkey

These nations all reached a policy efficiency rating of \( \Theta^* = 1 \). Their actual goal results coincide with those of the optimal solution. The optimization solves for an entire team of countries, not for individual world winners. It solves for a group of «model» countries that collectively define a performance frontier. In that sense, their achievements are all equally good.

At this point, some words about modeling strategy might be helpful. The list (8) is not set in stone and depends to some extent upon the choice of SDG indicators. Quite generally, when you add more output dimensions to model (7), the number of observations scoring an efficiency ratio equal to one tends to increase. For instance, omitting the output dimension 100 - UNEQUAL, Sweden drops out of the list (8). Sweden reports an outstanding income distribution record. (Norway, Slovenia and Sweden all reported a Gini coefficient of 27, the lowest number among all OECD members.) Include income equality as an indicator and Sweden scores an efficiency rating equal to 1. Omit it and Sweden’s ranking drops to 0.962.4

Omitting even more SDG indicators, more nations drop out. For instance, removing the two indicators MOBILE and 10 - WASTE, the policy efficiency rating of Belgium falls below 1 and also has to leave the list (8).

Obviously, the selection of indicators is crucial. The concept of Human Well-being can be defined in many different ways. Examining again the list of indicators chosen here, they may be classified under two headings: generalities and specifics. 100 - UNEMPL and 100 - UNEQUAL are macro-economic variables providing indirect information about the country-wide nature of peoples’ social and economic satisfaction. The other indicators tell specific stories about one narrowly defined dimension of Well-being, like 100 - OBESITY. Both categories of indicators are needed for a reasonably complete account of peoples’ sentiments.

Countries like Ireland, Mexico, Poland and Portugal still dependent on small-hold family farming are doing well. SDG indicators like 100 - OBESITY, 10 - WASTE and SAFE no doubt favor conservative farm communities with stable demographic structures.

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4 See Thore, Tarverdyan 2021, Chapter 3.6.
and

Table 2
Key Covid-19 statistics for five non-Pareto OECD nations. See the website Table 2.

|                | Canada | Germany | Italy | UK  | US   |
|----------------|--------|---------|-------|-----|------|
| Survival rate % | 98.8   | 98.9    | 88.3  | 92.6| 98.2 |
| April 1, 2020   | 92.8   | 96.18   | 86.81 | 87.62| 96.91|
| Sept. 1, 2020   | 97.69  | 97.33   | 96.97 | 97.09| 98.18|
| Cumulative deaths | 89    | 732     | 12,400| 2500| 2900 |
| April 1, 2020   | 9100   | 9300    | 35,500| 41,500| 182,200|
| Sept. 1, 2020   | 23,002 | 76,963  | 110,704 | 126,824 | 550,539 |
| Cumulative confirmed cases | 7700 | 67,400 | 105,800 | 34,000 | 163,200 |
| April 1, 2020   | 127,900| 243,600 | 269,200| 335,300| 5900,000 |
| Sept. 1, 2020   | 994,836| 2885,386| 3650,247| 4351,759| 30,304,462 |

Several paragraphs of Western technology and life-style, on the other hand, are absent from the list (8). Where are the US, Canada, the UK? As we shall argue more fully in a moment, technology and modernity do not by itself create Human Well-being.

Form a linear combination of the 31 efficient states with the combined SDG goal result \( \sum_j (logY_j) \lambda_j \) and the combined resource use \( \sum_j (logX_j) \lambda_j \) where \( \lambda_j \) is a vector of non-negative weights adding to 1 (one weight for each efficient OECD member state). Any such linear combination represents a hypothetical composite member state that would also be rated as SDG policy efficient. It is the efficiency frontier of the 36 OECD member states, representing «best practice». Their policy efficiency ratios of all these composite countries are equal to 1.

4. Data envelopment analysis

Data envelopment analysis (DEA) is an operations research technique proposed in Charnes et al. (1978) and Banker, Charnes & Cooper (1985). Employing DEA, Golany & Thore (1997a,1997b) demonstrated how it can be used to evaluate the socioeconomic performance of a large number of nations drawn from all continents.

DEA determines two geometrical constructs in the input-output space: the envelope and the efficiency frontier. Analyzing the SDG achievements of OECD member states, we shall follow Banker, Charnes & Cooper (the «BCC model») in drawing the upper convex envelope enclosing the given observations as tightly as possible. Not all points on the envelope may be efficient, thus being located beneath the efficiency frontier.

Consider now the linear programming problem (7) and its dual

\[
\begin{align*}
\text{Max } & \Phi + \epsilon(s + t) \\
\text{subject to } & \Phi logY_s - \sum_j (logY_j) \lambda_j + s = 0 \\
& \sum_j (logX_j) \lambda_j + t = logX_0 \\
& \sum_j \lambda_j = 1, \\
& \lambda, s, t \geq 0, \Phi \text{ unconstrained}
\end{align*}
\]

Program (9) describes a hypothetical projection of an OECD member state onto the SDG policy efficiency frontier by expanding its SDG achievements equi-proportionally. The dual variable \( \Phi \) obtained as the dual to the normalizing constraint (7b) represents the factor of expansion and \( \Phi logY_0 \) the expanded SDG achievements.

The variables \( s \) and \( t \) are the duals to the positivity conditions \( \mu_j \geq \epsilon \) and \( \nu \geq \epsilon \). Eq. (9a) defines the goal slack \( s \) as the difference between the best practice SDG achievement \( \sum_j (logY_j) \lambda_j \) and the expanded achievement \( \Phi logY_0 \). Eq. (9b) defines resource slack \( t \) as the difference between actual resources use \( logX_0 \) and best practice use \( \sum_j (logX_j) \lambda_j \). Finally, the small positive constant \( \epsilon \) is a so-called non-Archimedean ordinal number, allowing the maximization over \( \Phi \) to preempt the optimization involving the slacks.

If the policy efficiency rating of an OECD nation equals 1 and both slack variables \( s^* \) and \( t^* \) vanish, then (9a) reduces to \( logY_0 - \sum_j (logY_j) \lambda_j = 0 \) and (9b) reduces to \( \sum_j (logX_j) \lambda_j = logX_0 \) that is, the OECD observation is located on the efficiency frontier. Such countries display Pareto efficiency, a state of classical equilibrium named after the Italian economist Vilfredo Pareto (1848–1923). In the present case, it refers to a situation where a country reaches a maximal rate of policy efficiency equal to 1 and no SDG well-being observation falls short of the maximally possible. No goal slack and no resource use slack is permitted.

Notice how we have been able to tie the ideas of efficiency as used in the engineering literature to one of the central concepts of classical economic equilibrium.

Countries for which it is not possible to drive down all slack variables to zero are non-Pareto. Vilfredo Pareto himself would of course have shuddered at the thought of non-efficiency, being incompatible with the dogmas of «economic man» and the «invisible hand». DEA has led to a revolutionary insight in economics: the discovery of sub-optimal or even irrational behavior. Furthermore, the matter of efficiency or sub-efficiency in any given case is an empirical one, to be determined by numerical calculation.5

5. Non-Pareto OECD member states

Five OECD member states fail to reach Pareto efficiency. They fall below the efficiency frontier. They are (with their \( \theta^*_j \) efficiency ratios, all falling short of 1):

- Canada (0.99891), Germany (0.99922), Italy (0.99929), UK (0.99996), US (0.99993).

These nations still solve the programming problem (7) and its accompanying dual (9). They are located on the envelope, but dip down below the efficiency frontier. They exhibit positive SDG slacks and/or excessive use of resources. They are non-Pareto.

It should not surprise us that a limited number of countries fall below the efficiency frontier. Of course there will be a list spelling out the names of some less successful OECD members exhibiting human well-being deficits. But the identity of these underachievers is certainly a great surprise: they are some of the most modern, advanced and richest nations in the Western world. Remember that the explanatory factors \( X_0, X_2 \) and \( X_3 \) stand for GDP, R&D, and government spending on health and education - factors certainly being in ample supply in these nations and yet going together with well-being poverty in terms of basic sanitation, care of the elderly, waste disposal and personal safety.

The possible presence of such undocumented pockets of poverty in rich countries has been pointed out by trailblazers like J.E. Stiglitz and his team but has eluded most professional economists. Several reasons may be proposed to explain this lack of perception. One is the counterintuitive perception that «isolation» is poverty. Even the Stiglitz et al. volume cited a moment ago deals mainly with poverty in terms of income inequality. It is only with the recognition and measurement of the UN sustainability development goals that economists finally have the opportunity to assess the full dimensionality of well-being poverty.
Table 1 compares the actually recorded SDG well-being values of each country (the top entry in each cell) with its projection onto the efficiency frontier ('best practice', the bottom entry). For each of these countries, the actual performance falls short of the possible. There is a deficit in terms of every one of our nine SDG indicators. For Canada and Germany, the deficits are considerable in terms of human contacts (MOBILE) and personal safety (SAFE). Italy faces a huge deficit in personal safety. The UK is not faring well in terms of personal mobile contacts. And the results for the US are overall disappointing.

The poor performance in terms of these indicators have certainly been discussed nationally, even if the overall shortcomings compared with other countries have not been documented. For instance, the US Centers for Disease Control and Prevention on its website (cdc.gov) declares obesity to be a ‘common, serious, and costly disease’ with obesity prevalence in the entire population having increased from 30.5% at the turn of the century to 42.4% in 2017–2018.

Similarly, in January 2018, the UK’s Office for National Statistics said “the number of violent crimes and sex offenses recorded by police in England and Wales has risen sharply over the past year,” and that “recorded sexual offenses and violent crimes have more than doubled in England and Wales since the turn of the century.”

In a widely circulated work Piketty (2012) argues that economic inequality in modern nations tends to increase as a consequence of the accumulation of productive capital. The results in Table 1 confirm that a few developed Western nations do indeed face serious income equality deficits. Have these deficits been around for a long time? Are they the results of economic and cultural upheavals in the new millennium? We do not know.

It is worth noting that our calculations imply nothing about causality. There is no assumption (nor any demonstration) that modernity and technological change somehow would cause the creation of pockets of unrecognized deficits of well-being.

Finally, let us examine the contribution of each individual Pareto nation to the linear composite

\[\sum (\log X_j) / \rho\] is best practice. Some Pareto nations participate more often in forming this composite than others, see the list below (each Pareto nation is listed with its relative weight \(\rho\)).

Canada : Slovenia (0.45), Norway (0.31), New Zealand (0.15), Chile (0.09);
Germany : Chechua (0.44), Austria (0.36), Japan (0.20);
Italy : Spain (0.47), Slovakia (0.30) Japan (0.18), Chile (0.02), Greece (0.2);
UK : Greece (0.57), Estonia (0.27), New Zealand (0.10), Norway (0.03),
Chile (0.02), Slovenia (0.02);
US : Japan (0.85), New Zealand (0.15).

Policy-makers keen on improving the SDG well-being record of their own country will no doubt look at this list of peers with some interest, in particular at those with some geographical affinity (Norway setting an example for Canada, Austria for Germany, etc.).

6. Covid-19 results

In order to establish a basis for evaluating the programming results for the coronavirus, we first solve model (7) omitting entirely CORONA as a well-being indicator. This simulates actual conditions as of January 1, 2020, before the virus had spread beyond China.

Remarkably, the solution turns out to be identical to the one obtained when CORONA is included. The list of Pareto optimal countries is the same, and so is the list of sub-optimal countries. The calculated best practice for each suboptimal country also stays the same. This does not mean that the virus does not impact the SDGs; those effects will no doubt for many countries be disastrous (but will not be known statistically until each country in due course submits its SDG reports to the UN agency). What it does mean is that those pockets of SDG well-being deficits that we have identified existed already before the advent of the virus. The identity of the well-being deficit countries was known before the virus struck. It includes some of the richest countries in the Western world, who could easily have afforded to improve their SDG record. Apparently, the problem is not a lack of money, not even a lack of R&D, government health or educational expenses.

Nobody knows for how long these deficit pocket have existed, but the possibility arises that we have here encountered deep-going structural problems in the Western world associated with considerable political and social turmoil during the first decades of the 21st century. Accelerating migration (from the country-side to large cities, and from poor to rich countries), pervasive warfare directed by warlords and by drug kingpins, religious extremism, the failures of the capitalist system to check inherent corruption and the widening power of global monopolists may all be cited as factors obverse to the noble ideals of the SDGs.

The pre-existence of pockets of well-being deficits makes government Covid-19 policy so much more difficult. Time is of essence in fighting this or any pandemic, to delay the spread of the infection and to gain time scaling up the nation’s available health facilities. And yet valuable time had already been lost. A weak personal well-being record increases the vulnerability of the population. OBESITY and low recorded values of SANITA increase the probability both of catching the virus and of poor recuperation. UNEQUAL is positively correlated with factors like poor health and crowded living conditions that make individuals vulnerable to the virus. MOBILE tells us something about the frequency of people’s social contacts; few contacts can signal personal loneliness and depression, delaying the recovery of Covid-19 patients. Data on the goal ELDERLY signify the presence of lacking care of the elderly, one of the most vulnerable cohorts of a nation’s population. An increasing UNEQUAL typically goes together with growing numbers of low-skilled labor employed in clinics and hospitals directly exposed to the Covid-19 virus. WASTE tells us something about the general state of hygiene around the home, the accumulation of waste creating conditions for the virus to thrive. A good record of the indicator SAFE, finally, gives us a picture of trust; communities ridden by crime and gang warfare are hotbeds of the pandemic. None of all these unfortunate conditions of vulnerability can be reversed in a hurry. The price of sins of past social and health policy inaction has to be paid.

Detailed data on the incidence of the virus in the five deficit countries are listed in Table 2 below.

Table 3 above converts the survival deficits displayed in Table 1 into numbers of Covid-19 cases surviving. For instance, Canada registered an accumulated number of 127,900 confirmed cases and 92.89% x

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6 In a recent paper in this journal, Antonelli and Gehringer (2017) investigated the causal relation between technological change and increasing levels of income inequality. See also Sinha et al. (2020).
127,900 = 118,806 survivals by Sept 1, 2020. In a hypothetical world of Pareto equilibrium, best practice survivals would have amounted to 96.76% x 127,900 = 123,756 survivals. That is, 4950 more cases surviving. This is a huge number, considering that the total accumulated number of deaths at the same date amounted to 9100 cases. Pareto optimum would have more than halved the total number of deaths.

The results for the remaining non Paretoans are similar. The hypothetical state of Pareto efficiency would have seen dramatically lower numbers of death. In Germany with 9300 deaths, 4190 of them would have survived; in Italy with 35,500 deaths, 25,527 would have survived; in the UK with 41,500 deaths, 38,963 would have survived; and in the US with 182,200 deaths, 72,570 would have survived.

What do these huge numbers tell us? Figures never lie but they have to be interpreted correctly. First and foremost they tell us that for some of the most advanced and modern Western nations the idea of Pareto optimum is a chimera and a lie. A few economists under the leadership of J. Stiglitz and his Paris associates have been telling us so. Blinded by optimum is a chimera and a lie. A few economists under the leadership of the most advanced and modern Western nations the idea of Pareto to be interpreted correctly. First and foremost they tell us that for some US with 182,200 deaths, 72,570 would have survived.

Pareto equilibrium, best practice survivals would have amounted to (2019) points the finger at increasing income inequality in the modern performance of each nation is measured by its concepts of Jan Tinbergen (2015, 2016) demonstrated how a model of fractional pro

vide the necessary mathematical and statistical machinery to measure (Tinbergen 1952, 1956), forming an aggregate social utility function to be maximized subject to resource conditions. Adopting the same approach, we have here ranked all OECD member nations by their attainment of the UN Social Development Goals (the SDGs). The performance of each nation is measured by its «SDG policy efficacy ratio», defined as its SDG welfare divided by virtual resource costs. Optimal performance and Pareto efficiency is achieved for countries scoring an efficiency ratio equal to 1; suboptimal performance is associated with an efficiency ratio less than 1, thus recognizing the possibility of disequilibrium.

In publications spanning more than two decades, J. Stiglitz and associates have analyzed the presence of information asymmetries in markets, arguing that the mainstream equilibrium model of economists needs to be replaced by a new paradigm allowing for the possibility of uncovered needs and structural poverty. The recent volume Stiglitz et al. (2019) points the finger at increasing income inequality in the modern world creating structural SDG deficits. Our own work is meant to provide the necessary mathematical and statistical machinery to measure these deficits, if they exist.

In the present paper we have demonstrated how the maximization of the SDG policy efficiency ratio actually is identical to determining the upper convex envelope enclosing the observations in the multidimensional space of the SDGs and all resources used, thus being a case of the so-called BCC model (Baker, Charnes, Cooper 1984) of data envelopment analysis. The similar result for the conical hull and the CCR model (Charnes et al., 1978) had been established earlier, by Cooper, Thore and Tarverdyan (2011).

The computer runs carried out for the present paper rank all OECD nations in terms of their attained «Human Well-being», defined by a list of nine SDGs featuring indicators of nutrition, hygiene, care of the elderly and more. Crucially, the indicators also include the Gini index measuring the lack of income equality, and the Covid-19 virus. The computer runs thus aim at providing statistical verification of the arguments by Stiglitz, Fitoussie and Durand.

The present calculations show that five OECD countries are falling short of Pareto efficiency, harboring pockets of human well-being deficits: Canada, Germany, Italy, UK and the US. These results confirm that some modern and advanced Western nations have failed to protect vulnerable segments of their population. Furthermore, the list of underachieving nations was known even before the Covid-19 virus had appeared. In a strange manner, it was already too late: the breeding grounds had already been plowed and tilled, sown with dragon’s teeth.

There seems to be a lesson to be drawn from our results. How can the world prepare itself for the next pandemic? Creating more hospital beds, storing protection equipment and ventilators is certainly helpful but do not go to the root of the problem. Underlying human well-being deficits in society somehow have to be attacked. Street violence and gangs need to be controlled, crowded living quarters sheltering undernourished and unintegrated transients need to be rebuilt, waste dumps need to be removed, — all for the simple reason of saving lives when the virus strikes again.

The agenda for the future should include both social management and the direction of new technology (see Betz et al 2019). The operations research techniques described in the present paper can be helpful on both accounts.

Author statement

In the recent volume Thore & Tarverdyan (2021) the present author reported on some early calculations ranking the sustainable development goals (SDGs) achievements of the OECD member nations for 2020, using a selection SDG indicators published by the OECD office in Paris, and also using Covid-19 data published by the World Health Organization (WHO). This work is continued here, using a set of nine indicators of "Human Well-being", now also including the Gini index of income equality (defined as 100 minus the Gini index).

Appendix. Nine indicators of Human Well-being, all OECD countries

The data listed below were extracted from J. Sachs et al. (2020), as recorded by the author in December 2020. For the dating of each variable, see Section 1.

| Country | OBESITY | SANITA | UNEMPL | MOBILE | ELDERLY | UNEQUAL | WASTE | SAFE | SURVIVE |
|---------|---------|--------|--------|--------|---------|---------|-------|------|--------|
| Australia | 29.00 | 100.00 | 5.47 | 134.88 | 23.20 | 35.68 | 2.23 | 64.92 | 97.46 |
| Austria | 20.10 | 99.97 | 5.39 | 88.12 | 8.70 | 31.97 | 2.40 | 83.64 | 97.32 |
| Belgium | 22.10 | 99.49 | 6.46 | 75.15 | 8.20 | 29.84 | 1.33 | 64.77 | 80.23 |
| Canada | 29.40 | 98.60 | 5.87 | 72.17 | 10.50 | 35.01 | 2.33 | 82.14 | 92.89 |
| Chile | 28.00 | 99.89 | 7.01 | 88.25 | 16.30 | 53.30 | 1.08 | 47.39 | 97.26 |
| Chechia | 26.00 | 99.14 | 2.07 | 81.99 | 4.50 | 30.24 | 1.10 | 72.39 | 98.28 |
| Denmark | 19.70 | 99.60 | 5.36 | 129.01 | 8.10 | 28.75 | 2.34 | 87.06 | 96.33 |
| Estonia | 21.20 | 99.61 | 5.59 | 131.35 | 35.70 | 37.35 | 1.47 | 74.89 | 97.33 |

(continued on next page)
References

Antonelli, C., Ghringer, A., 2017. «Technological change, rent and income inequalities: a Schumpeterian approach». Technol. Forecasting Social Change 115, 85–98.

Barker, R.D., Charnes, A., Cooper, W.W., 1984. «Some models for estimating technical and scale inefficiencies in data envelopment analysis». Mgmt Sci. 30, 1078–1092.

Barnett, W.A., 2017. Center For Financial Stability. interviewed by A Serletis, New York.

Betz, U.A.K., Betz, F., Kim, R., Monks, B., Phillips, F., 2019. The early study B. Honoring George Koza, published by the

Thore, S., Tarverdyan, R., 2021. Measuring The Sustainable Development Goals Performance Of Nations Battling The Corona Pandemic. Elsevier Publishers, in press.

Thore, S., Tarverdyan, R., 2015. Diagnostics For a Globalized World. World Scientific, Singapore and Now publishers, Hanover, Mass.

Thore, S., Tarverdyan, R., 2016. «The sustainable competitiveness of nations»– J. Technol. Dev. Social Change 106, 108–114.

Thore, S., Tarverdyan, R., 2021. Measuring The Sustainable Development Goals Performance Of Nations Battling The Corona Pandemic. Elsevier Publishers, in press.

Thore, S., Tarverdyan, R. 2010. A utility function approach for evaluating country performances with DEA - the twin goals of decent work and a fair globalization. In: Hockley, L.R. (Ed.), Global Operations Management. Nova Science Publishers, New York, pp. 49–72.

International Labor Office, 2001. Reducing the decent work deficit: a global challenge. UN, 2012. Major books published. In operations research:

Economic Logistics: The Optimization of Spatial and Sectoral Resource, Production and Distribution Systems, Quorum, Westport 1991. On high tech capitalism:
The early study B. Honoring George Koza, published by the

Thore, S., Tarverdyan, R., 2021. Measuring The Sustainable Development Goals Performance Of Nations Battling The Corona Pandemic. Elsevier Publishers, in press.

Thore, S., Tarverdyan, R. 2010. A utility function approach for evaluating country performances with DEA - the twin goals of decent work and a fair globalization. In: Hockley, L.R. (Ed.), Global Operations Management. Nova Science Publishers, New York, pp. 49–72.

International Labor Office, 2001. Reducing the decent work deficit: a global challenge. UN, 2012. Major books published. In operations research:

Economic Logistics: The Optimization of Spatial and Sectoral Resource, Production and Distribution Systems, Quorum, Westport 1991. On high tech capitalism:
The early study B. Honoring George Koza, published by the

Thore, S., Tarverdyan, R. 2021. Measuring The Sustainable Development Goals Performance Of Nations Battling The Corona Pandemic. Elsevier Publishers, in press.