

From economic productivity to productive
well-being*

PRELIMINARY DRAFT

Please, do not cite without authors' permission.

Charles-Henri DiMaria[†], Chiara Peroni[‡] and Francesco Sarracino[§]

October 29, 2021

*The authors gratefully acknowledge the financial support of the Observatoire de la Compétitivité, Ministère de l'Economie, DG Compétitivité, Luxembourg, and STATEC. This article reflects the views of the authors and does not engage in any way STATEC, STATEC Research or funding partners. The authors wish to thank the colleagues from STATEC (the National Statistical Institute of Luxembourg), and STATEC Research for helpful comments and suggestions.

[†]Institut national de la statistique et des études économiques du Grand-Duché du Luxembourg (STATEC Research), 14, rue Erasme, L-2013, Luxembourg. Tel.: +352 247-74248; e-mail: charles-henri.dimaria@statec.etat.lu

[‡]Institut national de la statistique et des études économiques du Grand-Duché du Luxembourg (STATEC Research), Luxembourg.

[§]Institut national de la statistique et des études économiques du Grand-Duché du Luxembourg (STATEC Research), Luxembourg.

Abstract

Productivity - a driver of economic growth – does not imply societal well-being, nor environmental sustainability. Various authors contributed frameworks to incorporate environmental issues in the computation of productivity. Similarly, many authors focused on the role of well-being for productivity, but studies proposing ways to account for both well-being and sustainability in productivity measurement are scarce. We check whether and to what extent it is possible to include subjective well-being and sustainability measures among the inputs and/or outputs of a traditional productivity framework. Differently from previous literature, we adopt a data-driven approach to test whether subjective well-being and adjusted net savings meaningfully contribute to computing a productivity-like indicator. We apply Data Envelopment Analysis to European data from 2005 to 2018. We find that including subjective well-being among the inputs and the outputs of productivity contributes to a measure of economic performance that accounts for quality of growth.

Keywords: DEA, life satisfaction, adjusted net savings, productivity, Europe.

JEL Codes: I31, O47, C43.

1 Introduction

Economic productivity, i.e. the ratio of goods and services produced (outputs) divided by resources used in the production process (inputs), is usually considered a core indicator of economic performance, and a proxy of improving living conditions. Productivity provides a measure of how efficiently a production process uses scarce resources. Enhancing productivity means making better use of available resources, and creating new technological abilities to provide more or better goods and services to the society. Hence, productivity is often regarded as the ultimate engine of growth, and a proxy for technical progress. In fact, it is usually held that expanding the set of goods and services available for consumption allows people to satisfy a growing number of needs, thus improving their living conditions (Solow, 1956). However, the efficient mobilization of resources for economic output does not imply societal well-being, nor environmental sustainability. These aspects are important and, in case of sustainability, urgent for modern societies.

Numerous authors warned that growing productivity does not necessarily translate into improved living conditions or environmental quality. For instance, waste and pollution are two negative sides of production processes.

Many authors proposed frameworks for efficiency/productivity indicators to account, for instance, for pollution as an undesirable by-product of production (an early attempt in this regard is Pittman (1983)). Zhou et al. (2018) provide a survey of some frameworks used to introduce sustainability in productivity measurement. A recent example is DiMaria (2019), who introduced adjusted net savings (ANS), an indicator of weak sustainability and welfare, in the set of desirable outputs. Conversely, studies proposing ways to account for both subjective well-being and sustainability in productivity measurement are scarce.

In recent years, the subjective well-being literature shed new light on the ability of economic growth to deliver better lives (Easterlin, 2017; Helliwell and Aknin, 2018; Sarracino and O’Connor, 2021a). Empirical evidence provided a nuanced view about the role of economic growth for subjective well-being, and suggested that quality of economic growth matters (Helliwell, 2016): if economic growth is compatible with a cohesive and inclusive society, it is reasonable to expect that well-being will improve (Easterlin, 2013; Oishi and Kesebir, 2015; Mikucka et al., 2017). In contrast, if economic growth leads to loneliness and inequality, well-being may arguably decline.

Subjective well-being is the result of the presence of positive emotions, the absence of negative ones and satisfaction with life as a whole (Diener et al., 1999). In practice, however, subjective well-being is frequently monitored through one of its components: life satisfaction, which is regarded as an evaluative and cognitive measure of subjective well-being. This individual level information is usually collected in the course of surveys, when respondents are asked questions such as: “All things considered, how satisfied are you with your life as a whole these days?” (Van Praag et al., 2003). Answers usually range on a scale where low/high scores indicate total dis/satisfaction. Various tests, from different disciplines, provided evidence supporting the validity and reliability of life satisfaction as a measure of how people fare with their lives (Blanchflower and Oswald, 2004; Van Reekum et al., 2007; Schimmack et al., 2010; Kahneman and Krueger, 2006; Layard, 2005).

The relationship between productivity and subjective well-being received particular attention in the economic literature. Available evidence seems to support the view that subjective well-being, often measured with life satisfaction, increases labor productivity (Edmans, 2011; Böckerman and Ilmakunnas, 2012; Bryson et al., 2017). In particular, Oswald et al. (2015) show that happiness increases productivity in an experimental setting. According to the authors, productivity gains are due to the fact that satisfied workers are more committed to their work than others. However, few studies have tried to merge productivity and subjective well-being in one composite indicator of

economic performance. For instance, DiMaria et al. (2020) evaluated whether life satisfaction (as an input or an output) contributed to efficiency following a procedure proposed by Pastor et al. (2002), and four waves of the European Social Survey (2004, 2006, 2008, and 2010). Results indicate that for some countries, mainly Western European economies, life satisfaction should be regarded as an input, and therefore it belongs to the denominator of productivity computations. For Eastern European countries life satisfaction is more likely to be an output, and therefore it belongs to the numerator of productivity indexes.

We contribute to this literature by exploring whether and to what extent it is possible to extend the inputs and outputs of a traditional productivity framework to include subjective well-being and sustainability measures. Specifically, we use a data-driven approach to check the feasibility of computing productivity-like indicators accounting for life satisfaction and adjusted net savings. We posit that it is important to evaluate how well economies deliver goods and services given the resources they use. At the same time, we seek to go “beyond GDP”, and to include measures of subjective well-being and environmental quality among economic indices of performance for “inclusive growth”. In the framework of productivity measurement this means classifying life satisfaction either as an input, an output or both; it also implies checking whether sustainability is a desirable by-product of economic production. This research is relevant because, if confirmed, it would suggest the existence of a virtuous circle where investing in life satisfaction, by prioritizing social relations and environmental quality, would contribute to economic productivity (Sarracino, 2019). However, the resulting economic growth would be *qualitatively* different from the traditional one, and arguably more socially and environmentally sustainable (Sarracino and O’Connor, 2021b).

Our starting point is the usual definition of productivity indicators as outputs divided by inputs, where outputs are GDP (to account for economic performance), life satisfaction and adjusted net saving (as an indicator of sustainability) and inputs are labour, physical capital and life satisfaction. We use data envelopment analysis, a linear programming technique, to compute optimal weights to aggregate inputs and outputs to derive productivity indicators. Since the seminal paper by Charnes et al. (1978), the number of publications using DEA to assess efficiency/productivity has been on the rise (Emrouznejad and Liang Yang (2018) counted more than 10,000 publications using DEA between 1978 and 2016).

The evolution of the DEA framework can be divided in two periods (Liu et al., 2013). The first one, up to 1999, is mainly driven by methodological development. A notable example in this regard is the research on returns to scale

(RTS) to better characterize the production process (see, for instance, Seiford and Zhu (1999)). A second example is the decomposition and interpretation of DEA-productivity indicators in terms of efficiency change and technical change (see, for instance, Arcelus and Arozena (1999)). Another important contribution belonging to the early period of DEA, and related to the present work, is the introduction of undesirable output (Färe et al., 1989), such as pollution, and the possibility for outputs/inputs to take negative values (see for example Cooper et al. (1999a)).

The second period, starting after 1999, is mainly about the investigation of productivity in specific industries, such as banks, health care, agriculture and farm, transportation, and education. Particularly relevant for our work is the use of DEA in sustainability studies. This line of research started to grow after 2008 thanks to methodological improvements of the early 2000s, namely the introduction of concepts such as bad output, and the possibility to deal with negative values (Zhou et al., 2018). We emphasize that the introduction of sustainability issues in DEA empirical analysis marks an important theoretical development, as it seeks to include qualitative aspects in the computation of productivity. It is also noteworthy the fact that – independently from the framework, hypotheses, decomposition of productivity indicators, and topics under scrutiny – these studies have a point in common: the preliminary selection of inputs and outputs. In fact, the vast majority of studies adopts an a-priori sets of inputs and outputs based on heuristic decision-making or expert judgement. However, some authors introduced data-driven methods exploiting DEA models to select the set of relevant inputs and outputs based on optimality criteria (see, for instance, the recent works by Peyrache et al. (2020) and Toloo et al. (2021)).

Our contribution sits at the cross-road of these developments. From a qualitative point of view, we investigate the suitability of accounting for life satisfaction and sustainability in the assessment of the performance of economies. From a technical point of view, we build on the possibility to consider negative values, and optimal selection methods to select relevant inputs and outputs. In particular, we use a test procedure developed by Toloo et al. (2021). Intuitively, our idea is to determine if optimal weights used in the aggregation of outputs and inputs are zero for life satisfaction and adjusted net savings. Weights equal to zero would indicate that the latter two variables can not be considered as relevant in the new productivity indicator.

We find that life satisfaction should be regarded as an input for some countries, and as an output for others, whereas adjusted net savings do not appear to be a relevant output to benchmark countries. These results suggest that including life satisfaction among the inputs and the outputs of productivity

could meaningfully contribute to the definition of a measure of economic performance that accounts for the quality of growth.

The paper is structured as follows. The next section describes the method and data used in our analysis. Section 3 reports our findings: we first present the result of our optimal selection model; we then offer a classification of the considered countries based on classification tree; we finally use our results to compute a well-being adjusted Malmquist index of productivity. The last section summarizes our findings and discusses limits and advantages of the proposed measure of productivity.

2 Method and data

2.1 The variable selection method

Economic productivity is commonly defined as the ratio of goods and services produced (output volume) by the quantity of resources used in the production processes (volume of inputs). Then,

$$\text{Productivity} = \frac{\text{output volume}}{\text{volume of inputs}} = \frac{\sum_i r_i y_i}{\sum_j w_j x_j}. \quad (1)$$

The $y_i, i = 1, \dots, s$ are the outputs, in cross country analysis it is usually total GDP in constant terms, and the $x_j, j = 1, \dots, m$ are inputs – at minimum physical capital K (machinery and equipments), and labour L (people or hours worked). Productivity measures how efficiently inputs are used in the production process. The ratio increases when output volume increases for a given value of inputs. Similarly, the ratio increases if the volume of inputs reduces for a given value of output volume. In our case, we add life satisfaction (WBO), and/or adjusted net savings (ANS) to the set of outputs; and life satisfaction (WBI) to the list of inputs. Our starting point is:

$$\text{Productivity} = \frac{r_{GDP}GDP + r_{WBO}WBO + r_{ANS}ANS}{w_K K + w_L L + w_{WBI}WBI}. \quad (2)$$

The problem with equation (2) is the computation of weights ($r_{GDP}, r_{WBO}, r_{ANS}, w_K, w_L, w_{WBI}$). One could use prices or income shares as weights (e.g. OECD (2001)), but prices/income shares for life satisfaction and adjusted net saving do not exist. Data Envelopment Analysis is a convenient framework to find optimal values for the weights without additional information. The idea is to compute optimal weights so that the ratio of equation (2), for a country labelled 0, is as large as possible, and the same ratios for all other countries

are positive and below 1. As a consequence, countries with the highest ratios will have an optimal value of 1, and the closest to zero the ratio is, the lowest the efficiency is. This method allows to benchmark countries with respect to the most efficient ones. Formally, we have the following fractional program:

$$\max_{(r_{GDP}, r_{WBO}, r_{ANS}, w_K, w_L, w_{WBI})} \frac{r_{GDP}GDP_0 + r_{WBO}WBO_0 + r_{ANS}ANS_0}{w_K K_0 + w_L L_0 + w_{WBI}WBI_0} \quad (3)$$

$$s.t. \frac{r_{GDP}GDP_j + r_{WBO}WBO_j + r_{ANS}ANS_j}{w_K K_j + w_L L_j + w_{WBI}WBI_j} \leq 1, j = 1, \dots, N \quad (4)$$

$$r_{GDP}, r_{WBO}, r_{ANS}, w_K, w_L, w_{WBI} \geq 0 \quad (5)$$

This model can be converted into a linear program model, as follows: let $t = 1/(w_K K_j + w_L L_j + w_{WBI}WBI_j)$, then the previous fractional program becomes:

$$\max_{(r_{GDP}, r_{WBO}, r_{ANS}, w_K, w_L, w_{WBI})} t(r_{GDP}GDP_0 + r_{WBO}WBO_0 + r_{ANS}ANS_0) \quad (6)$$

$$t(w_K K_0 + w_L L_0 + w_{WBI}WBI_0) = 1 \quad (7)$$

$$s.t. \quad (8)$$

$$t(r_{GDP}GDP_j + r_{WBO}WBO_j + r_{ANS}ANS_j) \quad (9)$$

$$- t(w_K K_j + w_L L_j + w_{WBI}WBI_j) \leq 0, j = 1, \dots, N$$

$$r_{GDP}, r_{WBO}, r_{ANS}, w_K, w_L, w_{WBI} \geq 0 \quad (10)$$

$$t \geq 0 \quad (11)$$

Changing notation, $tr_y = u_y$ and $tw_x = v_x$ ($y \in \{GDP, WBO, ANS\}, x \in \{K, L, WBI\}$), then:

$$\max_{(u_{GDP}, u_{WBO}, u_{ANS}, v_K, v_L, v_{WBI})} u_{GDP}GDP_0 + u_{WBO}WBO_0 + u_{ANS}ANS_0 \quad (12)$$

$$v_K K_0 + v_L L_0 + v_{WBI}WBI_0 = 1 \quad (13)$$

$$s.t. \quad (14)$$

$$(u_{GDP}GDP_j + u_{WBO}WBO_j + u_{ANS}ANS_j) \quad (15)$$

$$- (v_K K_j + v_L L_j + v_{WBI}WBI_j) \leq 0, j = 1, \dots, N$$

$$u_{GDP}, u_{WBO}, u_{ANS}, v_K, v_L, v_{WBI} \geq 0 \quad (16)$$

Last, this linear program has a dual representation:

$$\min_{\lambda_j} \theta_0 \tag{17}$$

$$\sum_j \lambda_j K_j \leq \theta_0 K_0 \tag{18}$$

$$\sum_j \lambda_j L_j \leq \theta_0 L_0 \tag{19}$$

$$\sum_j \lambda_j WBI_j \leq \theta_0 WBI_0 \tag{20}$$

$$\sum_j \lambda_j GDP_j \geq GDP_0 \tag{21}$$

$$\sum_j \lambda_j WBO_j \geq WBO_0 \tag{22}$$

$$\sum_j \lambda_j ANS_j \geq ANS_0 \tag{23}$$

$$\lambda_j \geq 0 \tag{24}$$

In this model any improvement in productivity can only be obtained by decreasing the use of inputs. In this case, we speak of an input orientated model. Alternatively, one may be interested in assessing to what extent outputs can be increased given the use of inputs. In this case, we refer to the output orientated model:

$$\max_{\lambda_j} \phi_0 \quad (25)$$

$$\sum_j \lambda_j K_j \leq K_0 \quad (26)$$

$$\sum_j \lambda_j L_j \leq L_0 \quad (27)$$

$$\sum_j \lambda_j WBI_j \leq WBI_0 \quad (28)$$

$$\sum_j \lambda_j GDP_j \geq \phi_0 GDP_0 \quad (29)$$

$$\sum_j \lambda_j WBO_j \geq \phi_0 WBO_0 \quad (30)$$

$$\sum_j \lambda_j ANS_j \geq \phi_0 ANS_0 \quad (31)$$

$$\lambda_j \geq 0 \quad (32)$$

This representation is useful to illustrate how we proceed to check whether life satisfaction is an input, output or both, and adjusted net savings belong to the set of outputs production. We adopt the procedure by Toloo et al. (2021) (Peyrache et al. (2020) propose a related approach). We re-write the model

defined by equations (25) to (32) as follows:

$$\max_{\lambda_j} \phi_0 \quad (33)$$

$$\sum_j \lambda_j K_j \leq K_0 \quad (34)$$

$$\sum_j \lambda_j L_j \leq L_0 \quad (35)$$

$$\sum_j \lambda_j WBI_j \leq WBI_0 + M(1 - d_{WBI}) \quad (36)$$

$$\sum_j \lambda_j GDP_j \geq \phi_0 GDP_0 \quad (37)$$

$$\sum_j \lambda_j WBO_j \geq \phi_0 WBO_0 - M(1 - d_{WBO}) \quad (38)$$

$$\sum_j \lambda_j ANS_j \geq \phi_0 ANS_0 - M(1 - d_{ANS}) \quad (39)$$

$$d_{WBI} + d_{WBO} + d_{ANS} \leq k^{sup} \quad (40)$$

$$d_{WBI} + d_{WBO} + d_{ANS} \geq k_{inf} \quad (41)$$

$$\lambda_j \geq 0, \sum_j \lambda_j = 1, (d_{WBI}, d_{WBO}, d_{ANS}) \in \{0, 1\}^3. \quad (42)$$

In this model, M is a large positive number. Assume, for example, that $d_{WBO} = 1$ then constraint (38) becomes $\sum_j \lambda_j WBO_j \geq \phi_0 WBO_0$, WBO contributes to the computation of productivity, and life satisfaction is an output. Conversely, if $d_{WBO} = 0$ the constraint becomes $\sum_j \lambda_j WBO_j \geq \phi_0 WBO_0 - M$. As M is large, then the constraint is never binding ($\phi_0 WBO_0 - M < 0, \forall \phi_0, M$ large enough) and life satisfaction does not contribute to productivity assessment. The same reasoning holds for other variables.

Another important aspect of the model is the introduction of constraints (40) and (41). If $k_{inf} = 1$ then we impose to select at least one of the extra variables (WBI, WBO or ANS). If $k_{inf} = 1$ and $k^{sup} = 1$ then we want to have only one extra variable selected. If $k_{inf} = 1$ and $k^{sup} = 3$ then we can have from one to three extra variables in the computation of productivity.

In this framework, the status of life satisfaction and adjusted net savings as inputs and/or outputs is country and time specific. In principle, we could impose the set of inputs and/or outputs to be the same for all countries. It would suffice to stack the model across countries and/or time. However, we chose to have no a priori, and to use a specification that allows the status of life satisfaction and adjusted net savings to change over time and across

countries. In other words, our model allows life satisfaction to be an input (output) for all countries at the same time, and/or for all years. The same holds for adjusted net savings.

As explained by Toloo et al. (2021), the input and output orientated models can lead to select different variables. Toloo et al. (2021) propose a model that integrates both orientations in a single model. For the sake of present work, we follow the output orientated model. The reason is that we are interested in assessing productivity as the ability to increase outputs *given* the level of inputs used. In other words, we do not consider the hypothesis that a country is willing to decrease the use of inputs, in particular of life satisfaction, for a given level of outputs (as it is assumed in input orientated models). This amounts to assume that countries seek to increase sustainability and life satisfaction. However, we recall that, by definition, inputs are resources which are under the management’s control. Inputs can be increased or decreased at will: if it is easy to envisage that countries seek to increase life satisfaction, it is not as obvious to imagine a country that deliberately chooses to decrease it. In some circumstances, however, this may be the case. Think, for instance, of the famous quote by Winston Churchill during the Second World War: “I have nothing to offer but blood, toil, tears and sweat”. This is an example of a country asking sacrifices to the population during adversities or economic downturns. Arguably, however, this is not often the case. Therefore, we choose the output orientated approach and we assume that decreasing the use of inputs is not a favored policy option.

A second important assumption concerns returns to scale. The model above assumes variable returns to scale, as clarified by the constraint $\sum_j \lambda_j = 1$. However, Toloo et al. (2021) documented that the same procedure holds also under the assumption of constant returns to scale (CRS). For our purposes, we assume CRS as it is a good benchmark to assess productivity for countries. In addition, in the case of CRS, productivity measurements yield similar results under the input and the output orientated models. A final important point for our work relates to the computation of Malmquist productivity index. Some authors (e.g. Kerstens and Van de Woestyne (2014)) claim that the Malmquist productivity index has no total factor productivity (TFP) interpretation in general, and argue in favor of the HicksMoorsteen index. An advantage of choosing CRS is that the HicksMoorsteen index collapses to the usual Malmquist index, thus overcoming the disputes over the most appropriate measure of TFP. At worst, CRS model is conventionally regarded as the best discriminating DEA model then a relevant benchmark (Podinovski et al. (2014)).

2.2 Variables used to assess productivity

We retrieve measures of output (GDP) and inputs (capital and labor) from the Penn World Tables, version 10 (Feenstra et al., 2015). The sample includes 23 European countries (Austria, Belgium, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Lithuania, Luxembourg, Netherlands, Poland, Slovakia, Slovenia, Spain, Sweden, Turkey, United Kingdom).

Adjusted net savings is computed by the World Bank. Adjusted Net Saving is the national saving minus fixed capital consumption plus education expenditure minus depletion of natural resources and minus damages from CO2 emissions and particulate emissions. Adjusted net savings is a standard indicator of (weak) sustainability¹. Our data cover the period from 2005 to 2018 because of data availability about life satisfaction. Moreover, for the sake of simplicity, we select countries for which adjusted net saving is positive.²

We draw data on life satisfaction from the Eurobarometer (2005 - 2018). Eurobarometer is the polling instrument of the European Union, and it is used to regularly monitor the state of public opinion in Europe. It covers issues related to the European Union, as well as attitudes on subjects of political or social nature³. For instance, during the interview, people are asked to reply to the following question: “On the whole, are you very satisfied, fairly satisfied, not very satisfied, or not at all satisfied with the life you lead?”. This is a typical wording used to monitor respondent’s satisfaction with life. For the purposes of present study, we use the share of people, by country and year, declaring to be very satisfied with the life they lead.

A characteristic feature of our work is the simultaneous introduction of life satisfaction in the set of inputs (WBI) and in the set of outputs (WBO) of production. If WBI is measured as WBO then we would have a conflict between constraint (36) and (38). We overcome this difficulty thanks to a feature of the Eurobarometer. The survey is usually administered twice per year. For each year, we have two measurements of life satisfaction: one around August, and one in January. This gives us access to two temporally distinct measurements of life satisfaction. Specifically, we measure WBI as the share of people that are very satisfied with their life (as observed in the August surveys) multiplied

¹https://www.un.org/esa/sustdev/natlinfo/indicators/methodology_sheets/econ_development/adjusted_net_saving.pdf presents the indicator.

²As a remark, adjusted net savings can be negative, in this case a specific DEA model has to be used, for example Cooper et al. (1999b). However, the main idea behind the variable selection procedure remains the same. In this document we restrict ourselves to the case of positive adjusted net savings.

³(<https://europa.eu/eurobarometer/about>)

by hours worked. Thus, WBI is the number of hours worked by the share of very satisfied people. Formally:

$$WBI = (\text{share of people very satisfied with their life}) \cdot \text{hours worked}_t \quad (43)$$

This amounts to treating life satisfaction as a multiplier on work force: the higher the share of people satisfied with their lives, the larger the positive effect on labor. This modelling approach is similar to the one adopted by Barro and Lee (1994) regarding educational attainment, or by Botev et al. (2019) for human capital. Let δ_j be the share of people very satisfied with their life in country j , then the *total employment* input is $(1 + \delta_j)\dot{hours}_j = \Omega_j \dot{hours}_j$. The effect of life satisfaction is reflected in the effective labour input as in the model by Lucas (1988).

As for WBO, we assume that Governments, to a certain extent, act as social benevolent planners who foster the production of more goods and services to satisfy a growing set of needs thus, ultimately, improving people's lives. In present work, this amounts to assume that countries seek to maximise the share of the population that is very satisfied with their life. From this point of view we are consistent with the idea of the benevolent social planner in theories of optimal growth model. WBO is based on life satisfaction measured in the month of January of each year, and it is defined as follows:

$$WBO = (\text{share of people very satisfied with their life}) \cdot \text{population}_t \quad (44)$$

we emphasize that WBI and WBO are observed at two different time periods: WBI relates to life satisfaction declared in the month of August at time t and it is multiplied by hours worked; WBO is based on the life satisfaction reported in January at time $t + 1$, and it is multiplied by population.

Our hypotheses are:

1. Life satisfaction in productivity measurement is
 - (a) an input only: $d_{WBI} = 1$ and $d_{WBO} = 0$ and:
 - i. Adjusted net saving is an output $d_{ANS} = 1$ or,
 - ii. Adjusted net saving is not an output $d_{ANS} = 0$.
 - (b) an output only: $d_{WBI} = 0$ and $d_{WBO} = 1$ and:
 - i. Adjusted net saving is an output $d_{ANS} = 1$ or,
 - ii. Adjusted net saving is not an output $d_{ANS} = 0$.
 - (c) an input and an output: $d_{WBI} = 1$ and $d_{WBO} = 1$ and:

- i. Adjusted net saving is an output $d_{ANS} = 1$ or,
 - ii. Adjusted net saving is not an output $d_{ANS} = 0$.
- (d) not an input and not an output: $d_{WBI} = 0$ and $d_{WBO} = 0$ and:
- i. Adjusted net saving is an output $d_{ANS} = 1$ or,
 - ii. Adjusted net saving is not an output $d_{ANS} = 0$.

3 Results

The results of the optimal selection method indicate that life satisfaction appears either as an input or as an output for almost all countries and all years considered (see table 1). The countries where life satisfaction is almost always an input are: Denmark, Ireland, Netherlands, Poland, Sweden, United Kingdom, Finland, Cyprus, Luxembourg and Turkey. Those where life satisfaction is always an output are: Estonia, Hungary and Italy followed by France (93%), Czech Republic and Lithuania (86%), and Spain (71%). Belgium and Slovenia are the only countries where adjusted net savings appear most of the time an output (79% and 71% respectively). Interestingly, life satisfaction is never at the same time an input and an output of the production process, nor adjusted net savings and life satisfaction are concurrently outputs. Each year only one extra variable is selected.

In sum, the method for optimal selection of variables indicates that it is meaningful to correct traditional measures of productivity including life satisfaction among the inputs and outputs of production.

What makes life satisfaction an input or an output of the production process? To answer this question, we use classification tree, a data exploration tool that allows us to group similar observations. This technique is particularly useful to investigate the features of countries-years (number of observations = 23 countries * 14 years = 322) when life satisfaction is an input or life satisfaction and adjusted net savings are outputs. The classification tree selects countries into groups based on the optimal values of the dichotomous variables d_{WBI} , d_{WBO} , d_{ANS} .

Figure 1 shows some of the partitions generated by the algorithm. We find that a significant number of country/years for which life satisfaction is an input are characterized by a large share of their population being very satisfied with their life (over 36%). This group includes countries such as: Denmark, Luxembourg, Netherlands, Sweden, United Kingdom and Poland. The latter is rather an exception: differently from the other countries, Poland exhibits a lower share of very satisfied people (between 11% and 36%), and a low level

Table 1: Share of times (in percentage) that WBI, WBO and ANS meaningfully contribute to the estimates of productivity. The share is computed over the pooled sample of countries-years.

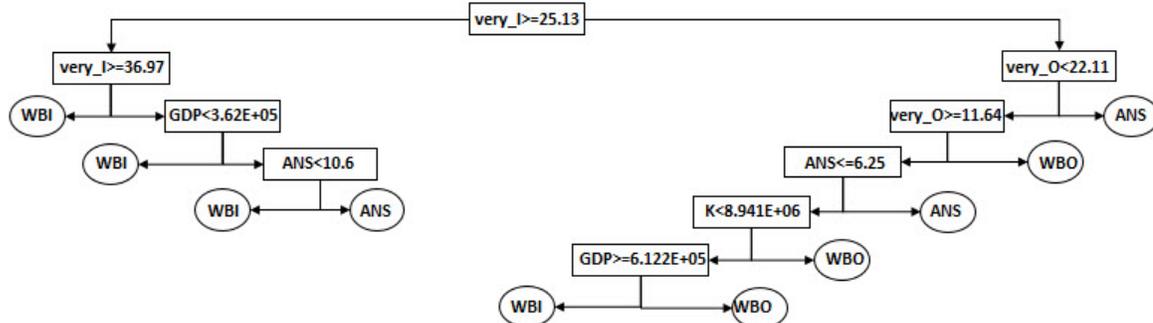
country	WBI	WBO	ANS
Austria	0	64	36
Belgium	14	7	79
Croatia	21	36	43
Cyprus	71	7	21
Czech Republic	0	86	14
Denmark	100	0	0
Estonia	0	100	0
Finland	79	0	21
France	0	93	7
Germany	21	43	36
Hungary	0	100	0
Ireland	100	0	0
Italy	0	100	0
Lithuania	14	86	0
Luxembourg	71	29	0
Netherlands	100	0	0
Poland	100	0	0
Slovakia	0	64	36
Slovenia	21	7	71
Spain	0	71	29
Sweden	100	0	0
Turkey	57	7	36
United Kingdom	86	0	14

Note: authors' own computations on PWT v.10, and Eurobarometer data.

of physical capital compared to its GDP.

Countries listing adjusted net savings as outputs are divided into two main groups: the first one is characterized by countries with a relatively large share of people very satisfied with their life, large GDP and high adjusted net savings (this is the case of Belgium, for instance). The second group includes countries with an average share of people very satisfied with their life, or with a relatively high value of adjusted net savings. Slovenia and Turkey are examples of countries belonging to this group. For the remaining countries, mainly characterised by low shares of people very satisfied with their life, life satisfaction appears mainly an output of the production process.

Figure 1: Segment of a classification tree to group countries based on life satisfaction (input and output) and adjusted net savings.



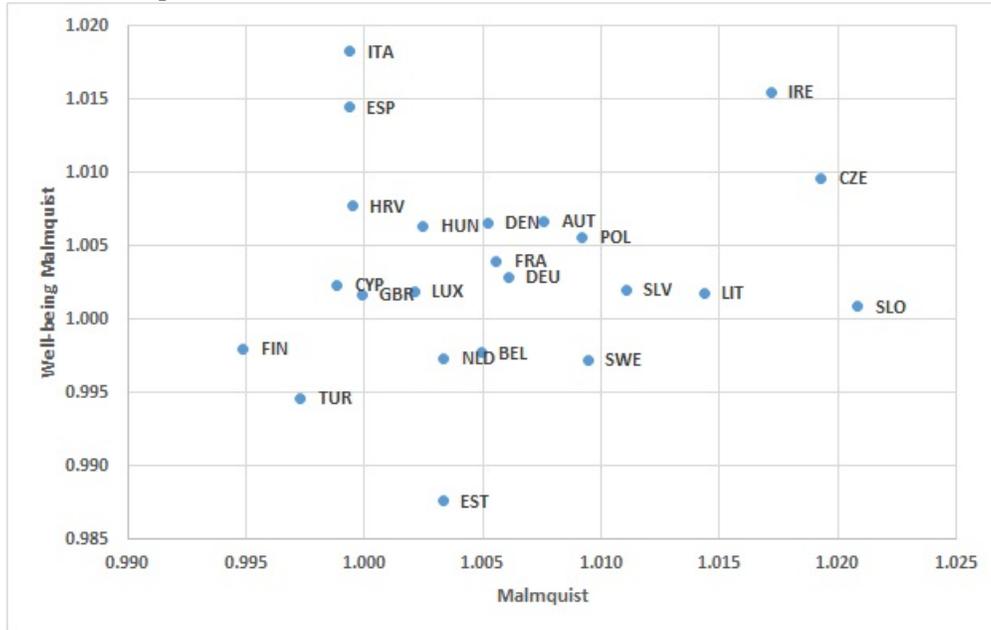
Note: authors' own computations on PWT v.10, and Eurobarometer data. very_I: share of people very satisfied with their life (mid-year - input) very_O: share of people very satisfied with their life (beginning of year - output) K: capital, ANS: adjusted Net Saving, WBI well-being input, WBO well-being output. Left branch: condition is true. Right branch: condition is false.

If it is meaningful to add life satisfaction among the inputs and outputs of production, how would such well-being adjusted productivity look like? This is the last step of our analysis: we compute well-being adjusted Malmquist productivity (see the vertical axis of figure 2, and we contrast it with traditional Malmquist productivity index (see the horizontal axis of figure 2). We recall that well-being adjusted productivity includes life satisfaction as an input and as an output, assumes constant returns to scale, and it is based on an output orientated method (see Grifell-Tatj and Lovell (1995) for a presentation of Malmquist TFP indexes).

Figure 2 indicates that, in general, if a country has a positive growth

rate for TFP (Malmquist over unity) it has also a positive growth rate for well-being adjusted productivity. The two measures correlate quite well for some countries, such as Luxembourg. However, the association between the two measures is not statistically significant: some countries have a significantly lower well-being Malmquist than TFP Malmquist (Slovakia is a good example), whereas other countries, such as Italy or Spain, report almost no TFP growth, but large well-being adjusted Malmquist values. In other words, when we account for life satisfaction among the inputs and outputs of production, we find that some countries appear more efficient in transforming inputs into outputs than they usually are using Malmquist index. The Spearman's rho of similarity of rankings is 0.10, not statistically significant ($Prob > |t| = 0.6472$). Thus, we conclude that the two indexes provide significantly different information from each other. The top five countries in the well-being adjusted Malmquist ranking are Italy, Ireland, Spain Czech Republic and Croatia. The bottom five are: Belgium, Netherlands, Sweden, Turkey and Estonia.

Figure 2: Correlation between average Malmquist (TFP) and well-being adjusted Malmquist indeces

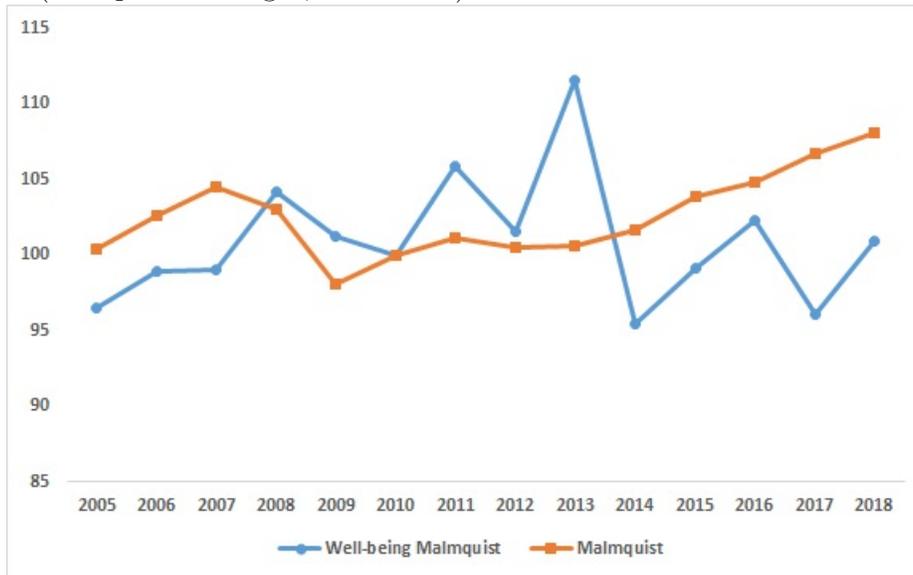


Note: Each indicator minus 1 is a growth rate. A value of 1 means a growth rate of 0.

The comparison of European averages of the two indexes over time re-

veals that Malmquist TFP is less volatile than well-being adjusted Malmquist. Moreover, the trend of well-being adjusted Malmquist seems at odd with the trend of Malmquist index. We can distinguish two periods: the first one, from 2005 to 2009, is characterized by a positive trend for well-being adjusted Malmquist index, and a negative one for Malmquist index. The second period, from 2009 on-ward, is characterized by an un-interrupted growth of the Malmquist index, and flat (if not declining) well-being adjusted Malmquist index. The break in the trend of well-being adjusted Malmquist index between 2013 and 2014 appears as particularly striking.

Figure 3: Changes over time of Malmquist index and of the well-being adjusted index. (European averages, 2010=100).



Note: authors' own computations on PWT v.10, and Eurobarometer data.

4 Conclusion

Is it desirable and possible to build measures of productivity that account for people's well-being? Our answer, based on data from 23 European countries monitored over 14 years, is affirmative. It is desirable to build improved measures of productivity that keep into account the fact that productivity, per se, is not strictly good or bad for quality of life and for the environment. From

this point of view, much of previous elaboration focused on providing frameworks to integrate (mainly) environmental variables in traditional productivity measurements. It is also desirable because recent studies provided convincing evidence that people’s well-being contributes to productivity, and that subjective well-being is not necessarily an outcome of production process. In 1968, Kennedy notoriously stated that GDP “measures everything in short, except that which makes life worthwhile”. We also show that it is possible to integrate subjective well-being measures in traditional productivity computations, thus trying to go beyond the usual economic variables. In this regard, we ground our answer on a data-driven approach for optimal selection of variables (Toloo et al., 2021).

Specifically, we check whether life satisfaction – a widely used, valid and reliable measure of subjective well-being – contributes meaningfully to productivity measures as an input and/or as an output, and that at the same time adjusted net savings – a proxy for sustainability – is an output of production. Results indicate that life satisfaction should be considered among the inputs and the outputs of production. Moreover, we found that life satisfaction is likely an input in countries where the share of people satisfied with their lives is high (above 36%). Conversely, life satisfaction is likely an output in countries where the share of people satisfied with their lives is low.

We used the results of our analysis to compute well-being adjusted Malmquist productivity indexes, and we contrasted the new variable with usual Malmquist indexes. Evidence indicates that the ranking of countries based on well-being adjusted Malmquist indexes is significantly different from the one derived from the usual Malmquist index. The correlation coefficient of the Spearman’s rank test is 0.10, not statistically different from zero. Finally, the changes over time of the European averages of the two indexes indicate that well-being adjusted Malmquist indexes are more volatile than the usual indexes, and follow different trajectories. The first period, between 2005 and 2008, shows a positive trend which continues until 2013 when it reverts. The well-being adjusted Malmquist index indicates a remarkable break in the series between 2013 and 2014. The Malmquist index, on the contrary, follows a positive trend from 2009 on-ward.

Our work is not free from limitations and caveats. As we do not detect life satisfaction as an output and simultaneously as an input, we do not definitely solve the issue about what is the best indicator to compare countries. However, our results suggests that life satisfaction should be taken on board. We do so by including it among the inputs and the outputs of production. Furthermore, productivity indicators based on DEA are usually decomposed into efficiency and technical change. In our case, it is challenging to conceptualize

the meaning of technical change for well-being adjusted productivity indicators. Perhaps, new wordings, such as societal progress, should be introduced to speak about technical change in relation to well-being. We should also keep in mind that high productivity growth rates can coexist with deteriorating conditions. As the efficient frontier is a relative benchmark, an inefficient country may experience productivity growth if best performers lose efficiency. Under these circumstances, productivity growth does not signal improved conditions.

It is also important to clarify some caveats related to the application of efficiency to subjective well-being. First, we stress that the underlying idea of efficiency indicators is that improvements can be attained when less inputs are used to produce at least the same level of output. In other words, from the efficiency point of view, if subjective well-being is an input, it may be optimal to reduce it. This option may not be socially desirable or acceptable. Thus, our productivity measure implicitly assumes that Governments are benevolent and interested in expanding well-being. Another caveat has to do with the substitutability of outputs. Assume that the computation of productivity indexes uses subjective well-being, adjusted net saving, and GDP as outputs. In this circumstances, the level of productivity could remain the same if the combination of outputs (aggregate value) remains unchanged. This amounts to saying that GDP, sustainability, and subjective well-being may be substitutable. This is the same critic that is often addressed to indicators of sustainability drawing a distinction between weak and strong sustainability. In this case, our well-being adjusted measure of productivity is a weak-productive-well-being indicator.

With these limits and caveats in mind, we believe that our contribution provides a sensible framework to include direct measures of utility (subjective well-being) in traditional productivity computations. This framework is in its infancy and could be refined in various ways. For instance, it would be interesting to check the robustness of our findings in presence of longer time-series and a larger sample of countries, not just European ones. It would also be interesting to check to what extent our results are robust to the use of alternative measures of subjective well-being, such as objective measures. Unfortunately, to the best of our knowledge, objective measures of well-being are not widely available or comparable across countries and over time. Another interesting approach would be to consider the creation of well-being as a several step process using network DEA. In a first step, GDP and adjusted net savings result from the use of economic resources such as labour and capital. Then, as a second step, GDP and adjusted net savings generate well-being.

References

- Arcelus, F. and Arozena, P. (1999). Measuring sectoral productivity across time and across countries. *European Journal of Operational Research*, 119(2):254–266.
- Barro, R. J. and Lee, J.-W. (1994). Sources of economic growth. In *Carnegie-Rochester conference series on public policy*, volume 40, pages 1–46. Elsevier.
- Blanchflower, D. G. and Oswald, A. J. (2004). Money, sex and happiness: An empirical study. *Scandinavian Journal of Economics*, 106(3):393–415.
- Böckerman, P. and Ilmakunnas, P. (2012). The job satisfaction-productivity nexus: A study using matched survey and register data. *ILR Review*, 65(2):244–262.
- Botev, J., Egert, B., Smidova, Z., and Turner, D. (2019). A new macroeconomic measure of human capital with strong empirical links to productivity. OECD Economic Department Working Paper 1575, OECD.
- Bryson, A., Forth, J., and Stokes, L. (2017). Does employees subjective well-being affect workplace performance? *Human relations*, 70(8):1017–1037.
- Charnes, A., Cooper, W. W., and Rhodes, E. (1978). Measuring the efficiency of decision making units. *European journal of operational research*, 2(6):429–444.
- Cooper, W. W., Kyung Sam, P., and Pastor, J. T. (1999a). Ram: A range adjusted measure of inefficiency for use with additive models, and relations to other models and measures in dea. *Journal of Productivity Analysis*, 11(1):5 – 42.
- Cooper, W. W., Park, K. S., and Pastor, J. T. (1999b). Ram: A range adjusted measure of inefficiency for use with additive models, and relations to other models and measures in dea. *Journal of Productivity Analysis*, 11(1):5–42.
- Diener, E., Suh, E. M., Lucas, R. E., and Smith, H. L. (1999). Subjective well-being: Three decades of progress. *Psychological bulletin*, 125(2):276.
- DiMaria, C.-H. (2019). Sustainability, welfare and efficiency of nations. *Quality & Quantity*, 53(3):1141–1163.

- DiMaria, C. H., Peroni, C., and Sarracino, F. (2020). Happiness matters: Productivity gains from subjective well-being. *Journal of Happiness Studies*, 21(1):139–160.
- Easterlin, R. (2017). Paradox lost? *Review of Behavioral Economics*, 4(4):311–39.
- Easterlin, R. A. (2013). Happiness, growth, and public policy. *Economic Inquiry*, 51(1):1–15.
- Edmans, A. (2011). Does the stock market fully value intangibles? Employee satisfaction and equity prices. *Journal of Financial economics*, 101(3):621–640.
- Emrouznejad, A. and liang Yang, G. (2018). A survey and analysis of the first 40 years of scholarly literature in DEA: 1978–2016. *Socio-Economic Planning Sciences*, 61:4–8. Recent developments on the use of DEA in the public sector.
- Färe, R., Grosskopf, S., Lovell, C. K., and Pasurka, C. (1989). Multilateral productivity comparisons when some outputs are undesirable: a nonparametric approach. *The review of economics and statistics*, 71(1):90–98.
- Feenstra, R. C., Inklaar, R., and Timmer, M. P. (2015). The next generation of the Penn World Table. *American economic review*, 105(10):3150–82.
- Griffell-Tatj, E. and Lovell, C. (1995). A note on the malmquist productivity index. *Economics Letters*, 47(2):169–175.
- Helliwell, J. (2016). Life satisfaction and quality of development. In Bartolini, S., Bilancini, E., Bruni, L., and Porta, P., editors, *Policies for Happiness*, chapter 7, page 149. Oxford University Press.
- Helliwell, J. F. and Akin, L. B. (2018). Expanding the social science of happiness. *Nature human behaviour*, 2(4):248–252.
- Kahneman, D. and Krueger, A. B. (2006). Developments in the measurement of subjective well-being. *Journal of Economic perspectives*, 20(1):3–24.
- Kerstens, K. and Van de Woestyne, I. (2014). Comparing malmquist and hicksmoorsteen productivity indices: Exploring the impact of unbalanced vs. balanced panel data. *European Journal of Operational Research*, 233(3):749–758.

- Layard, R. (2005). *Happiness: Lessons from a New Science*. Penguin, New York.
- Liu, J. S., Lu, L. Y., Lu, W.-M., and Lin, B. J. (2013). A survey of DEA applications. *Omega*, 41(5):893–902.
- Lucas, R. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, 22(1):3–42.
- Mikucka, M., Sarracino, F., and Dubrow, J. K. (2017). When does economic growth improve life satisfaction? Multilevel analysis of the roles of social trust and income inequality in 46 countries, 1981–2012. *World Development*, 93:447–459.
- OECD (2001). *Measuring Productivity, Measurement Of Aggregate And Industry-Level Productivity Growth*. OECD Manual. OECD.
- Oishi, S. and Kesebir, S. (2015). Income inequality explains why economic growth does not always translate to an increase in happiness. *Psychological science*, 26(10):1630–1638.
- Oswald, A. J., Proto, E., and Sgroi, D. (2015). Happiness and productivity. *Journal of labor economics*, 33(4):789–822.
- Pastor, J. T., Ruiz, J. L., and Sirvent, I. (2002). A statistical test for nested radial dea models. *Operations Research*, 50(4):728–735.
- Peyrache, A., Rose, C., and Sicilia, G. (2020). Variable selection in data envelopment analysis. *European Journal of Operational Research*, 282(2):644–659.
- Pittman, R. W. (1983). Multilateral productivity comparisons with undesirable outputs. *The Economic Journal*, 93(372):883–891.
- Podinovski, V. V., Ismail, I., Bouzdine-Chameeva, T., and Zhang, W. (2014). Combining the assumptions of variable and constant returns to scale in the efficiency evaluation of secondary schools. *European Journal of Operational Research*, 239(2):504–513.
- Sarracino, F. (2019). When does economic growth improve well-being? In Rojas, M., editor, *The Economics of Happiness*, pages 355–370. Springer.

- Sarracino, F. and O'Connor, K. J. (2021a). Economic growth and well-being beyond the Easterlin paradox. In Bruni, L., Smerigli, A., and DeRosa, D., editors, *A Modern Guide to the Economics of Happiness*. Edward Elgar Publishing.
- Sarracino, F. and O'Connor, K. J. (2021b). Neo-humanism and COVID-19: Opportunities for a socially and environmentally sustainable world. arXiv preprint 2105.00556, arXiv.
- Schimmack, U., Krause, P., Wagner, G. G., and Schupp, J. (2010). Stability and change of well being: An experimentally enhanced latent state-trait-error analysis. *Social Indicators Research*, 95(1):19.
- Seiford, L. M. and Zhu, J. (1999). An investigation of returns to scale in data envelopment analysis. *Omega*, 27(1):1–11.
- Solow, R. M. (1956). A contribution to the theory of economic growth. *The quarterly journal of economics*, 70(1):65–94.
- Toloo, M., Keshavarz, E., and Hatami-Marbini, A. (2021). Selecting data envelopment analysis models: A data-driven application to EU countries. *Omega*, 101:102248.
- Van Praag, B. M., Frijters, P., and Ferrer-i Carbonell, A. (2003). The anatomy of subjective well-being. *Journal of Economic Behavior & Organization*, 51(1):29–49.
- Van Reekum, C. M., Urry, H. L., Johnstone, T., Thurow, M. E., Frye, C. J., Jackson, C. A., Schaefer, H. S., Alexander, A. L., and Davidson, R. J. (2007). Individual differences in amygdala and ventromedial prefrontal cortex activity are associated with evaluation speed and psychological well-being. *Journal of Cognitive Neuroscience*, 19(2):237–248.
- Zhou, H., Yang, Y., Chen, Y., and Zhu, J. (2018). Data envelopment analysis application in sustainability: The origins, development and future directions. *European Journal of Operational Research*, 264(1):1–16.