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RESEARCH PAPER

Happiness Matters: Productivity Gains from Subjective Well-Being

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Abstract
This article studies the link between subjective well-being and productivity at the aggregate level, using a matched dataset from surveys and official statistics. Well-being and productivity are measured, respectively, by life satisfaction and total factor productivity. The analysis, which applies non-parametric frontier techniques in a production framework, finds that life satisfaction generates significant productivity gains in a sample of 20 European countries. These results confirm the evidence of a positive association between the variables of interest found at the individual and firm level, and support the view that promoting subjective well-being is not only desirable per se, but it is conducive to higher productivity and improved countries' economic performances.

Keywords Productivity · Subjective well-being · Total factor productivity · Efficiency · Life satisfaction · Economic growth · DEA · Combined data

JEL Classification E23 · I31 · O47

1 Introduction

Despite the popularity of well-being measures in the academic and policy debate, the economic consequences of well-being are still largely unexplored. We contribute to this literature by studying the link between well-being and productivity at country-level, using a nationally representative combined dataset. This is relevant for two reasons: first, the empirical literature has never tested the relationship between well-being and productivity at aggregate level; second, economic policy institutions, which focus on industry-level and

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aggregate-level relations, need evidence to support their decisions, especially as low productivity growth is at the forefront of the policy debate and alternative sources of productivity growth are being investigated.

Previous studies have investigated the link between workers' well-being, labour productivity and firm performance, finding an overall positive association among these variables. Several studies focus on job satisfaction and workers' engagement, aspects related to workers' overall well-being. For instance, GALLUP (2017) shows that companies in which employees are more engaged experience less absenteeism, less turnover, less thefts; firms also benefit from higher customers' satisfaction. These aspects contribute to firms' productivity and profitability. Using data on stock returns of firms listed in the "100 Best Companies to Work For in America", Edmans (2012) shows that job satisfaction is beneficial to firms' market value. Bryson et al. (2017) report a positive significant correlation between job satisfaction and productivity using a nationally representative employer-employees matched dataset for the United Kingdom. Among studies focusing on the broader concept of well-being, Harter and Schmidt (2000) and Harter et al. (2003) report significant positive correlations between employees' average well-being levels and companies' returns. Oswald et al. (2014) provide experimental evidence showing that positive shocks to happiness result in significant productivity gains. Such gains stem from increased effort rather than from higher precision in executing standardised tasks. In a related article, Proto et al. (2010) observe that productivity is affected by short-run and artificially-induced increases in happiness, as well as by long-lasting shocks such as family bereavement, parental divorce and health problems. Furthermore, empirical studies in the field of psychology and organisational behaviour relate happiness to traits associated to enhanced individuals' job performances. Some of these studies show that happier workers are more pragmatic, less absent, more cooperative and friendly (Bateman and Organ 1983; Judge et al. 2001), change their job less often and they are more accurate and willing to help others (Spector 1997). There is also evidence that happier people are more engaged in their work, earn more money, and have better relationships with colleagues and customers (George and Brief 1992; Pavot and Diener 1993a; Spector 1997; Wright and Cropanzano 2000). Arguably, all these aspects are linked to labour productivity and overall job performance.

The studies we report above suggest pathways through which well-being affects productivity at the individual level. This evidence, however, is often based on small number of firms or, in the case of experimental data, individuals; studies on firms' performances suffer a similar drawback, as they focus on few firms or a restricted number of industries. In our view this raises two issues. Firstly, the evidence is hardly generalizable to the whole economy. Secondly, it is unclear whether it holds at the aggregate level. On the one hand, the existence of a relationship between productivity and well-being at the micro level suggests that such relationship could also hold at the aggregate level. On the other hand, it is also possible that the relationship would cancel out at aggregate level due to variations across industries and occupations. Our analysis of the relationship between subjective well-being and productivity at country level provides three main contributions: first, it checks whether the positive link between productivity and well-being operates also at the aggregate level; second, it establishes whether the results hold for the overall economy using nationally representative data issued from a matched survey-registry dataset; third, it provides evidence relevant to policy-makers, who often rely on macro-economic figures to inform decision making.

Throughout the article, productivity and well-being are measured, respectively, by total factor productivity and life satisfaction. Total factor productivity, a key indicator of economic performance used by economic policy institutions and academics alike, is an overall measure of efficiency in the use of resources (OECD 2001). Life satisfaction, i.e. people's self-assessment of their life as a whole, is a widely used proxy for subjective well-being. An extensive literature, involving various disciplines and scientific domains, supports the reliability of subjective well-being measures, such as life satisfaction. These measures correlate with objective measures of well-being such as the heart rate, blood pressure, frequency of Duchenne smiles and neurological tests of brain activity (Blanchflower and Oswald 2004; van Reekum et al. 2007). Moreover, various proxies of subjective well-being correlate strongly with each other (Schwarz and Strack 1999; Wanous and Hudy 2001; Schimmack et al. 2010) and with the judgements about the respondent's well-being provided by friends, relatives or clinical experts (Schneider and Schimmack 2009; Kahneman and Krueger 2006; Layard 2005).

The analysis uses macro-economic data sourced from the Macroeconomic Database of the European Commission and national level data on life satisfaction—our measure of subjective well-being—from the European Social Survey. These datasets provide consistent, comparable and repeated information over time about the overall economy and life satisfaction for a set of countries with homogeneous technology. As a result, the analysis focuses on 20 European countries. We use Data Envelopment Analysis (DEA)—a non-parametric frontier technique to model production from the field of operational research (Charnes et al. 1978) particularly suited to analyse small datasets—to compute measures of countries productive efficiency and total factor productivity.

The results indicate that well-being generates significant productivity gains. However, we can not exclude the possibility of reverse causation, that is, higher productivity could generate higher well-being. To address this issue, we test whether well-being is an output (outcome) of the production process along with standard production of goods and services. Our results are robust to this alternative specification: well-being should be regarded as a productive resource, rather than an outcome of a production process. Results also hold when life satisfaction is replaced by a measure of job satisfaction.

The paper is structured as follows: Sect. 2 describes the empirical strategy adopted in the paper. Section 3 gives an overview of the data used in this study. Section 4 presents our findings, and Sect. 5 provides some final remarks.

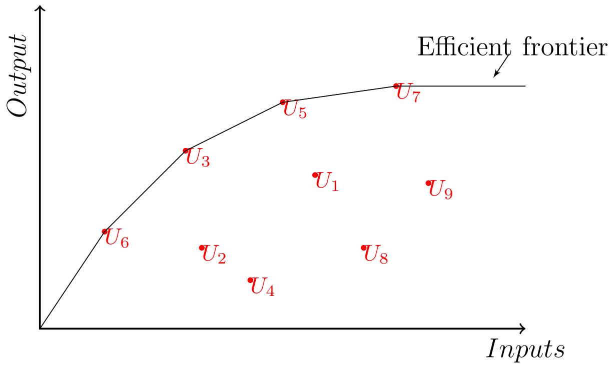
2 Empirical Strategy

Among productivity indicators, total factor productivity (hereafter TFP) compares outputs to all inputs used in producing those outputs.[1] Hence, TFP is an overall measure of how well producing units use their resources, and its increases reflect the ability to expand output by using inputs more efficiently and/or adopting new technologies. For these reasons, TFP is regarded as a key indicator of the economic performance of firms and industries and, at the national level, as a source of economic growth and improvements in living standards.

To compute TFP at country-level we use DEA, a deterministic technique widely applied in management and economic studies to analyse production processes—the act of transforming inputs to production into outputs—at the firm and industry level. It is also applied to study productivity at the country level (see, for example Färe et al. 1994b; Lafuente et al.

[1] Note that a basic measure of productivity is a ratio of output to inputs (OECD 2001).

Fig. 1 Diagram illustrating the efficient frontier and production set. *Note*: Producing units are denoted by *U*. Each unit's position is determined by the observed combination of inputs and output. The efficient frontier is given by the observed highest levels of output given input



2016; Kumar and Russell 2002). Compared to alternative methods, such as stochastic frontiers and standard econometric techniques, DEA permits to compute productivity measures from small datasets (Del Gatto et al. 2011). In addition, DEA allows to model production activities without the need of specifying functional forms of production functions. The idea is that production units employ similar technologies described by production possibility sets (collection of inputs–output). As a result, variations in productivity performances are due to variations in efficiency in production, which are captured by "distances" from a best-practice frontier (or efficient frontier). Such distances are also termed as efficiency scores. Note that in a DEA framework, the concept of productivity is closely linked to that of efficiency. Thus, in what follows, the terms productivity, productive efficiency, and TFP are used interchangeably.

Empirically, DEA applies linear programming techniques to available data on outputs and inputs to construct the best-practice frontier and compute efficiency scores (the scores take values between zero and one). This is done by maximising a ration of weighted outputs to inputs under a set of constraints. Typically, scores are computed for all producing units for a given period of time.[2] TFP indices, which show the evolution of TFP over time, are computed by linking the scores of adjacent periods. "Appendix 1" to this article provides further technical details on the method.

Figure 1 represents graphically the production possibility set and the frontier. Each producing unit (U_i) corresponds to a point and is described by a combination of output and input. The frontier depicts the highest observed levels of output *per* given levels of input. The closer the unit to the frontier, the higher its efficiency.

We compute efficiency scores and TFP indices for 20 European countries using macroeconomic and life satisfaction data. In our case, producing units are countries. Inputs to production are physical inputs, namely capital and labour, and subjective well-being. The output is Gross Domestic Product (GDP), an overall measure of economic activity, or, the value of the production of goods and services. Thus, in this framework life satisfaction enters the analysis as a variable in the production set. Broadly speaking, our analysis relies on comparing two types of productivity scores: those from production models that include life satisfaction as an input (or output) to production, and those from standard models,

[2] DEA solves sets of cross-sectional linear programmes with optimisation techniques. This delivers distance measures which are interpreted as TFP indicators.

which compare outputs to physical inputs (without life satisfaction). In this study, the use of DEA allows us to overcome the problem of the small sample size encountered when working at the aggregate level, which limits the reliability of inference based on traditional econometric techniques.[3] Our empirical strategy comprises two stages:

- First, we establish whether productivity indices that account for life satisfaction are valid (the indices have been constructed by including life satisfaction in the input/output set). We do so by checking the significance of the correlation between well-being-adjusted productivity measures and standard productivity measures—those computed by comparing value added to physical inputs, typically capital and labour (Färe et al. 1994b).
- Second, we analyse the contribution of life satisfaction to productive efficiency using a variable-selection test for DEA models. In other words, we test whether life satisfaction should be modelled as an input or an output to production. This allows us to establish whether life satisfaction has a statistically significant effect on productivity, i.e. it generates efficiency gains. This also serves as a test of reverse causality for the relationship between life satisfaction and productivity.

A crucial assumption of this study is that life satisfaction can be treated as a conventional factor to production, i.e. it is a variable under the control of policy-makers (at aggregate level) or managers (at firm level). This assumption is supported by a growing body of evidence from several disciplines showing that it is possible to undertake actions to improve people's well-being in organisations and countries (for a review, see: Bartolini 2014). Several studies document various strategies to improve people's satisfaction on the workplace (Silva and Caetano 2007; Nakamura and Otsuka 2007; Bartolini and Sarracino 2007). Urban planners study spaces' restructuring in order to improve people's quality of life (Crawford and Holder 2007; Haybron 2011; Rogers et al. 2011). Additionally, at the aggregate level, a number of economic studies showed that well-being trends differ significantly across countries and that changes in well-being are recorded also over short periods of time (Easterlin and Angelescu 2009; Sacks et al. 2012). Moreover, well-being can be viewed as an intangible input to production. Finally, productivity studies have started looking at the role of intangible factors in production, and have examined the role of human capital and organisational capital (management and HR practises) in productivity performances (Syverson 2011).

3 Data

This analysis uses a combined dataset of economic and subjective well-being variables from different sources, namely the "annual macro-economic database of the European Commission" (AMECO) and the European Social Survey (ESS). Variables are observed at country level and measure countries' inputs and output to production, namely GDP, employment and capital stock, and aggregate life satisfaction.

[3] At the same time, DEA requires the observational units (countries) to be comparable and to have access to the same technology. We regard the set of countries in the sample as sufficiently homogeneous to obtain meaningful results.

Data on GDP, aggregate employment and capital stock are available at yearly frequency and are sourced from AMECO, a database of the European Commission which aims to provide internationally comparable series on key macroeconomic variables.[4] GDP and capital stock are in billion of euros and are converted using purchasing power parities (PPP); employment is measured in thousands of full-time equivalent workers.

The measure of aggregate life satisfaction is constructed from individual observations from the ESS. The survey is conducted every two years and, as a result, observations are available for four time periods, namely 2004, 2006, 2008 and 2010.[5] Life satisfaction is measured using answers to the following question: "All things considered, how satisfied are you with your life as a whole nowadays? Please answer using this card, where 0 means extremely dissatisfied and 10 means extremely satisfied"; answers are coded on a 0 to 10 scale.[6] The ESS includes also another proxy of well-being, namely people's happiness; this is monitored through the following question: "Taking all things together, how happy would you say you are?", whose answers are also coded on a 0 to 10 scale. Despite being often used as synonyms, happiness and life satisfaction are different concepts: happiness is regarded as an emotional measure of subjective well-being, whereas life satisfaction is a cognitive evaluation and it is thus considered a more reliable measure of subjective well-being than happiness (Diener 2006). This is why we adopt life satisfaction as the preferred proxy of subjective well-being.

Aggregate life satisfaction is constructed as a weighted average of individuals' life satisfaction. To retain all observations and use the sample weights provided in the original database, we replaced missing values using the mode of the observations within a strata. In other words, for a given country, missing values are replaced by the most frequently observed value among the individuals having the same weight.[7] Missing data for Greece and the Czech Republic in 2004 were replaced by the average of values recorded for 2002 and 2006. After imputation, we computed average levels of life satisfaction for each country in the sample and for each available wave of the survey.[8]

The resulting dataset is a panel of aggregate-level variables, ranging from 2004 to 2010, and observed at biennial frequency. The sample covers the 20 countries listed in Table 1, which also reports the sample means for the variables in the dataset. Table 2 reports detailed descriptives for life satisfaction data. We observe that life satisfaction varies widely across countries and over time. The countries with the highest level of life satisfaction are Denmark and Switzerland. Nordic countries such as Finland, Norway and Sweden have averages close to 8. In contrast, Portugal and Hungary are the countries where people are least satisfied, with averages below 6. The majority of countries exhibits an increase in life satisfaction over the period, whereas the trend

4 The primary source of AMECO data is countries' national accounts.

5 The year 2002 is not included as some of the countries in our sample were not surveyed. ESS survey documentation is available at http://ess.nsd.uib.no/ess/.

6 Various studies document that the 0 to 10 scale is a standard and reliable scale for measuring well-being (see Pavot and Diener 1993b; Krueger and Schkade 2008).

7 Various imputation techniques are available. We opted for mode replacement because this technique does not alter the distribution of the variable of interest and, therefore, this allows us to use the given sample weights. Alternative methods, such as the imputation using the predicted values from a happiness regression, may alter the original distribution of the variable. In this case it is necessary to re-compute the sample weights, which is not trivial.

8 Note that, while life satisfaction is an integer variable, average life satisfaction is measured on a continuous scale. Thus, we do not need to adopt DEA frameworks designed to deal with integer values.

Table 1 Descriptive statistics. *Data source*: AMECO, ESS

Country	Codes	GDP	Labour	Capital	LS
Belgium	BE	313.93	6802.75	809.70	7.40
Switzerland	CH	348.23	7243.75	995.34	8.02
Czech Republic	CZ	123.60	9083.82	345.10	6.44
Germany	DE	2325.83	56,585.50	6904.09	6.84
Denmark	DK	210.05	4383.03	476.76	8.45
Estonia	EE	11.63	1189.31	30.59	6.24
Spain	ES	940.05	32,810.57	3336.86	7.29
Finland	FI	163.77	4171.95	410.43	7.97
France	FR	1754.61	39,633.90	5369.06	6.29
United Kingdom	GB	1644.47	47,830.28	4589.72	7.07
Greece	GR	199.16	9544.37	719.72	6.05
Hungary	HU	85.53	8205.18	180.53	5.53
Ireland	IE	167.41	3670.54	471.99	7.19
Netherlands	NL	536.34	11,812.95	1452.38	7.57
Norway	NO	236.76	3538.00	641.63	7.81
Poland	PL	274.68	31,010.17	524.37	6.69
Portugal	PT	157.08	9807.30	440.80	5.65
Sweden	SE	306.18	7192.63	919.29	7.86
Slovenia	SI	30.75	1621.47	69.46	6.94
Slovakia	SK	56.01	3829.14	86.18	6.11

Figures are country averages over the period. Units: GDP and capital stock are in billion Euros and have been converted using purchasing power parities (PPP); employment (labour) is measured in thousand workers (FTE). Life satisfaction (LS) is measured on a scale between 0 and 10. Here, life satisfaction values are country averages on individual observations, so values are non-integers

is flat in France, Denmark and Finland. Greece and Ireland, on the contrary, experienced the largest fall in life satisfaction over the considered period. Overall, data show a sustained growth in life satisfaction in new EU member states, in contrast to weaker dynamics in the other countries, possibly suggesting that some convergence mechanism is at play.

Table 3 reports countries' average TFP growth, computed using DEA under various assumptions on the role of life satisfaction in production. The assumptions are as follows: one that excludes life satisfaction (TFP_W); one that include life satisfaction as an input (TFP_I); one that include life satisfaction as an output (TFP_O) of production. Including life satisfaction as an input leads to slightly higher productivity growth in many countries.

Figure 2 plots TFP growth rates versus average levels of life satisfaction. The superimposed OLS regression line suggests a mildly positive correlation between average TFP and life satisfaction across countries.

The dataset, however, is small and these preliminary results do not allow us to draw conclusions on the nature of the relation between the two variables, which motivates the analysis in this paper.

Table 2 Life satisfaction data. *Data source*: ESS, 2004–2010

Country	2004	2006	2008	2010	Average	% Growth
BE	7.43	7.41	7.27	7.51	7.40	0.36
CH	8.01	8.03	7.91	8.14	8.02	0.56
CZ	6.41	6.49	6.57	6.30	6.44	– 0.53
DE	6.70	6.71	6.84	7.11	6.84	2.03
DK	8.47	8.48	8.52	8.35	8.45	– 0.46
EE	5.89	6.37	6.20	6.52	6.24	3.56
ES	7.12	7.45	7.26	7.32	7.29	0.93
FI	8.00	7.99	7.94	7.94	7.97	– 0.24
FR	6.37	6.32	6.26	6.21	6.29	– 0.87
GB	7.03	7.13	7.02	7.10	7.07	0.31
GR	6.39	6.19	5.98	5.65	6.05	– 4.01
HU	5.65	5.33	5.31	5.84	5.53	1.32
IE	7.69	7.48	7.14	6.46	7.19	– 5.64
NL	7.48	7.48	7.62	7.69	7.57	0.93
NO	7.66	7.76	7.89	7.93	7.81	1.18
PL	6.22	6.67	6.87	7.01	6.69	4.04
PT	5.62	5.47	5.62	5.87	5.65	1.53
SE	7.84	7.83	7.86	7.91	7.86	0.28
SI	6.90	6.97	6.93	6.97	6.94	0.36
SK	5.59	6.08	6.37	6.41	6.11	4.73

Numbers in the table are average life satisfaction levels per country; % growth is the average of life satisfaction yearly rates of growth

4 Results

This section explores the role of life satisfaction in the production process, by testing whether life satisfaction should be regarded as an input to production (a resource) or rather an output of the production process (an outcome).

4.1 Reliability of TFP

Before testing the impact of life satisfaction on countries' productivity performance, we need to establish whether productivity measures computed including life satisfaction in the inputs and output sets are valid. We refer to these measures of productivity as to "LS-adjusted" productivity scores. To do so, we exploit the fact that DEA efficiency scores permit to rank countries according to their productivity performance.[9] We proceed as follows. We compute DEA scores for each country and year, and link them to obtain TFP growth indices computed under different assumptions on the role of life satisfaction in production: namely, life satisfaction as an input, output, or none of the two. Then, we rank countries from the highest to the lowest productivity growth; we compare the ranks using the

[9] This is because countries' positions are established by comparing their output to the "optimal" level of output given by the unique frontier.

Table 3 Average TFP growth and country rankings. *Source*: Authors' computations on ESS and AMECO data

Country	TFP_W	TFP_I	TFP_O	*rankW.*	*rankI.*	*rankO.*
BE	– 0.40	– 0.30	– 0.40	8	10	9
CH	9.70	9.80	9.60	1	1	1
CZ	9.50	9.40	9.50	2	2	2
DE	1.00	0.80	1.00	4	5	4
DK	– 1.20	– 1.10	– 1.10	13	12	13
EE	– 4.50	– 4.50	– 2.00	18	18	15
ES	– 3.10	– 3.10	– 3.10	16	17	17
FI	– 0.70	– 0.70	– 0.40	10	11	10
FR	– 1.10	0.80	– 1.10	12	8	12
GB	– 8.30	– 7.80	– 8.30	20	20	20
GR	– 3.20	– 2.90	– 3.20	17	16	18
HU	– 7.80	– 7.20	– 7.80	19	19	19
IE	– 1.60	– 1.30	– 2.70	14	13	16
NL	0.40	0.80	0.40	6	7	6
NO	– 0.50	0.10	0.10	9	9	8
PL	0.30	1.40	0.30	7	4	7
PT	– 0.80	– 1.50	– 0.80	11	14	11
SE	0.70	0.80	0.60	5	6	5
SI	– 2.50	– 2.50	– 1.30	15	15	14
SK	4.00	4.10	3.50	3	3	3
Spearman					0.96	0.98

Period averages of TFP growth rates (in %). Average growth rates have been computed as geometric means over the period. Thus, *TFP* denotes productivity indices computed without life satisfaction; TFP_I and TFP_O denote TFP measures computed including life satisfaction respectively as input (I) and output (O) to production. The second last three columns report the positions of the countries in a ranking formulated according to their productivity performances. Spearman is the Spearman's rank correlation

Spearman rank test for ordinal data. We argue that, if the ranks are correlated, then the LS-adjusted productivity scores are valid.

This preliminary step is necessary because one could add *nuisance* variables—variables that are not linked with the production process—and still obtain a "spurious" measure of productivity. Nonetheless, if the nuisance variables are neither inputs nor outputs in the sense of production economics,[10] the new measure is likely to behave differently from valid ones. Thus, if life satisfaction were a legitimate (valid) input or output of production, we would expect that LS-adjusted productivity measures and standard productivity measures that use capital and labour as inputs should not be "too" different from each other. Table 3 presents the results. The first three columns report three measures of TFP, computed according to the different assumptions on the role of life satisfaction in production. The

[10] In a DEA framework, valid inputs are those that are under the control of the decision maker, or are quasi-fixed inputs. Other variables that might influence the outcome but are not under the control of managers are regarded as exogenous, and they are referred to as contextual variables.

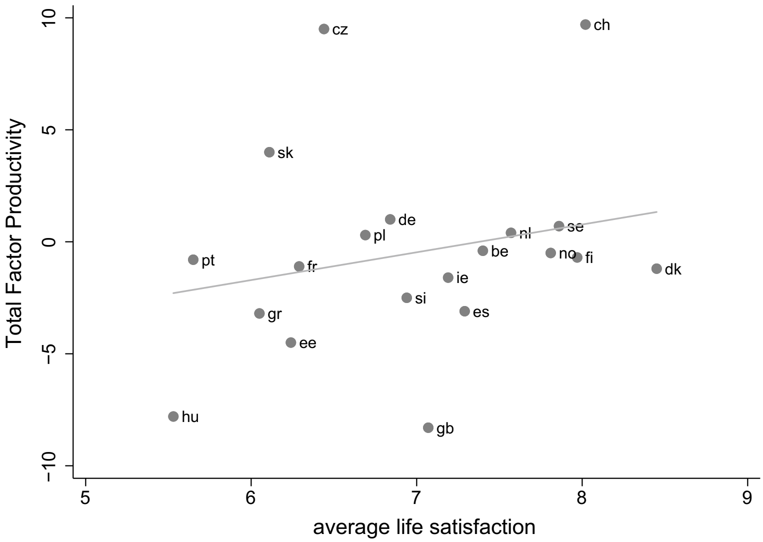


Fig. 2 Correlation between TFP growth (in %) and life satisfaction (period averages). *Source*: Authors' own elaboration on AMECO and ESS data

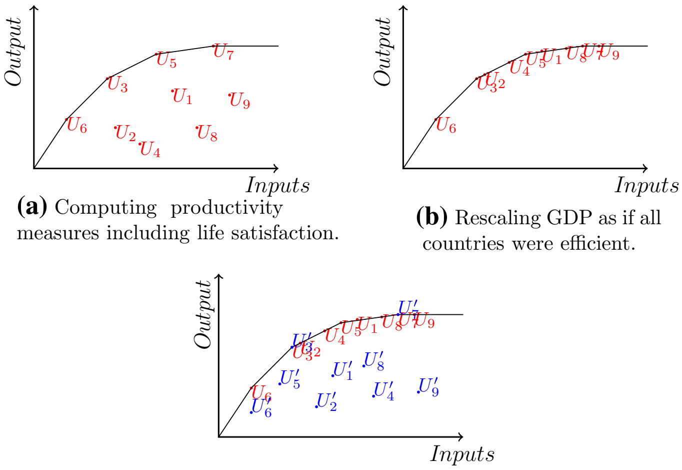
last three columns report the ranking of the countries according to their productivity performances. The last row in the table reports values of Spearman test for rank correlation. The test does not indicate significant differences among the rankings. This confirms that all proposed TFP measures are valid, and that life satisfaction can be regarded as a *candidate* variable for being an input or an output to production.

4.2 The Impact of Life Satisfaction on Productivity

The significant correlation between TFP and LS-adjusted TFP found in previous section indicates that life satisfaction can be included in a production framework of analysis as an input/output to production. This section tests whether life satisfaction has a significant effect on productive efficiency, i.e. whether higher life satisfaction is conducive to higher productivity. It also checks whether life satisfaction is an input or an output to production, which, in this framework, amounts to performing a test of reverse causality of the relationship between life satisfaction and productivity.

To this aim, we implement a variable-selection test procedure for DEA models proposed by Pastor et al. (2002). The test is based on the comparison of productive efficiency measures computed including and omitting life satisfaction from the input set; significant differences between the two measures are interpreted as efficiency losses attributed to the omitted variable, i.e. life satisfaction.

As described in Sect. 2, DEA permits to compute measures of efficiency of producing units by solving linear programs that maximise a ratio of weighted outputs to weighted inputs. The resulting efficiency scores are "distances" from an efficient frontier, which depicts the maximum amount of output that can be produced given a certain level of inputs use. Here, countries are assigned efficiency scores in the interval between zero and one



(a) Computing productivity measures including life satisfaction.

(b) Rescaling GDP as if all countries were efficient.

(c) Changes in the productivity measures after omitting life satisfaction.

Fig. 3 The variable selection test

(where a score equal to one indicates that the country is efficient). As an example, a score of 0.5 means that the country could double its output by using its inputs more efficiently.

The test works as follows (see Fig. 3 for a graphical illustration of the test procedure): let us consider the hypothesis that life satisfaction is an input to production. Firstly, we compute countries' productivity scores by comparing output (value added as measured by GDP) to inputs used in production, namely the stock of physical capital (K), labour (L), *and* life satisfaction (see Fig. 3a). The efficiency scores D are as follows:

$$D_i^I(K, L, LS; GDP) \tag{1}$$

where D denotes the distance of country i from the frontier; the super-scripts I indicates that life satisfaction is included in the input set; variables included in the inputs and output set are in brackets.[11]

Secondly, we compute efficient levels of output, that is, the output that countries would produce if they were efficient (Fig. 3b depicts the new frontier). One can see that all countries are now efficient. This is achieved by dividing country i's GDP by the distances obtained in the previous step, as follows:

$$GDP_i^{r,I} = \frac{GDP_i}{\left(D_i^I(K, L, LS; GDP)\right)} \tag{2}$$

Here, GDP_i^r denotes the efficient value of GDP for country i; GDP_i is country's i observed output; D_i is country's i efficiency score. Note that, if country i is efficient and $D = 1$, then $GDP_i^r = GDP_i$; in contrast, if country i is inefficient and $D < 1$, then $GDP_i^r > GDP_i$.

Finally, we compute new productivity measures by comparing the efficient values of GDP, GDP_i^r, to an input set that omits life satisfaction (in Fig. 3c, the position of the

[11] Largely speaking, in DEA the definition of inputs and output set characterises the production technology. No functional form is specified for the transformation of inputs into outputs.

countries in the new production possibility set is denoted U_i'). This gives new productivity scores denoted as:

$$D_i^I\left(K, L; GDP^{r,I}\right) \tag{3}$$

Pastor et al. (2002) argue that the comparison of the productivity measures from Eq. 1 with the measures computed using the rescaled outputs from Eq. 3 permits to estimate the contribution of life satisfaction to productivity.[12] To perform this comparison, we compute the following ratios:

$$R_i = \frac{D_i^I\left(K, L, LS; GDP^{r,I}\right)}{D_i^I\left(K, L; GDP^{r,I}\right)} \tag{4}$$

The numerator in Eq. 4 is, by construction, always equal to one. This is because rescaling the GDP amounts to impose that all countries are efficient when life satisfaction belongs to the input set. The denominator can take any value between zero and one. As a result, R_i will take values greater or equal to one. Values of R_i equal or close to one suggest that life satisfaction does not have an effect on country i's productivity performance; in contrast, values well above one indicate that life satisfaction has a significant effect on productive efficiency. If, after omitting life satisfaction from the input set, a country remains close to the frontier, then life satisfaction does not generate significant efficiency gains for that country. In contrast, if a country is displaced from the frontier and experiences "large" efficiency losses, then life satisfaction plays a significant role in the production process of that country.

To test whether life satisfaction is an output to production we repeat the same procedure detailed above, this time including life satisfaction in the output set. We compute productivity measures by comparing a vector of output (GDP and life satisfaction) to standard inputs, that is, capital and labour. These computations give the following productive efficiency scores:

$$D_i^O(K, L; LS, GDP) \tag{5}$$

where the super-script O means that life satisfaction is included in the output set. Then, as above, we rescale the outputs produced "as if" all countries were efficient, as follows:

$$GDP_i^{r,O} = GDP_i / D_i^O(K, L; LS, GDP) \tag{6}$$

The rescaled outputs are necessary to "fix" the frontier and compute the new efficiency scores omitting life satisfaction in the output set $D_i^O(K, L; GDP^{r,O})$. The ratios that serve to establish whether life satisfaction is an output to production are computed analogously as in Eq. 4, and are given by:

$$R_i = \frac{D_i^O\left(K, L; LS, GDP^{r,I}\right)}{D_i^O\left(K, L; GDP^{r,O}\right)} \tag{7}$$

[12] Note that the use of the rescaled GDP as output guarantees that changes in efficiency can only be attributed to the omitted variable (life satisfaction in our case). Intuitively, to meaningfully compare the efficiency scores, we need to "fix" the frontier. This is depicted in Fig. 3b.

where the values of the ratios are interpreted in a similar manner as above. Ratios above one indicate that life satisfaction is an output for the countries' production processes, while ratios close or equal to one suggest that life satisfaction is not an output to production for those countries.

Table 4 presents results from the computation of the ratios of equations 4 (columns two to five) and 7 (columns seven to eleven). For each procedure outlined above, the first three columns give the ratios for each country and for each year of observation. The last column, labelled as "average" gives the average ratios for the four sample periods (recall that the ESS survey is biennial).

One can see that, when life satisfaction is included in the production set as an output, the ratios R_i seldom depart from 1. The only exceptions are Estonia (EE) and Slovenia (SI), where ratios are largely above one. Overall, results show that efficiency scores computed under the assumption that life satisfaction is an output are not different from scores obtained form a technology where the output set omits life satisfaction. Thus, life satisfaction should not be considered an output to production.

In contrast, when life satisfaction is an input to production, the ratios of interest depart from one in a sizeable proportion of countries. Namely, 13 out of 20 countries exhibit a value of the ratio R_i greater than 1; in 10 countries the efficiency score is more than 10% larger when life satisfaction is included in the input set compared to the basic technology which includes only capital and labour. Thus, life satisfaction should be regarded as an input to production.

A binomial test confirms, at the 1% significance level, that life satisfaction should be regarded as an input to production. Following Pastor et al. (2002), the test requires an improvement in efficiency by at least 10% in at least 15% of countries for the null hypothesis not to be rejected. When considering a proportion of 30% of countries, the same conclusion can be reached at a 5% confidence level. These results are consistent over time.[13]

Figure 4 provides a graphical summary of the results presented above. The figure ranks countries according to the average percent efficiency gain per unit of life satisfaction. The bar plot shows for each country how much gain in efficiency can be attained if average life satisfaction increases by one unit. For instance, the productive efficiency in France would increase by 4% if the average life satisfaction increases by one point.[14] The countries where life satisfaction contributes the most to efficiency gains are Germany, France and Poland. We also document that, in 7 out of 20 countries, life satisfaction does not play any significant role on productivity. In this group we find countries such as Slovakia, Slovenia, Estonia, but also Denmark, Finland, Norway and Ireland. Estonia and Slovenia are two important exceptions because, as documented in the last column of Table 4, in these cases life satisfaction is an output of production, rather than an input.

Summarising, our results are as follows:

- Data support the view that life satisfaction has a role in countries' production processes.

[13] Following Simar and Wilson (1998, 2000a, b), efficiency estimates were also obtained using a bootstrap procedure, rescaling GDP so that bootstrap estimates were close to unity. Results are available from authors on request.

[14] The changes in efficiency following a unit change in life satisfaction should not be interpreted as the elasticities computable in a standard econometric framework. Note that it is not possible to compute derivatives of a piece-wise linear frontier.

Table 4 Efficiency gains generated by life satisfaction. *Source*: Authors' calculations on ESS and AMECO data

	Input					Output				
	2004 ratio	2006 ratio	2008 ratio	2010 ratio	Average	2004 ratio	2006 ratio	2008 ratio	2010 ratio	Average
BE	1.06	1.04	1.04	1.00	1.04	1.00	1.00	1.00	1.00	1.00
CH	1.08	1.06	1.04	1.00	1.05	1.00	1.00	1.00	1.00	1.00
CZ	1.10	1.10	1.18	1.14	**1.13**	1.00	1.00	1.00	1.00	1.00
DE	1.32	1.29	1.17	1.26	**1.26**	1.00	1.00	1.00	1.00	1.00
DK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00
EE	1.00	1.00	1.00	1.00	1.00	1.39	1.49	1.72	1.80	**1.60**
ES	1.11	1.08	1.25	1.23	**1.16**	1.00	1.00	1.00	1.00	1.00
FI	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.02	1.01
FR	1.27	1.26	1.15	1.32	**1.25**	1.00	1.00	1.00	1.00	1.00
GB	1.11	1.07	1.27	1.27	**1.18**	1.00	1.00	1.00	1.00	1.00
GR	1.08	1.06	1.16	1.09	**1.10**	1.00	1.00	1.00	1.00	1.00
HU	1.13	1.14	1.26	1.20	**1.18**	1.00	1.00	1.00	1.00	1.00
IE	1.00	1.00	1.01	1.00	1.00	1.03	1.02	1.01	1.03	1.02
NL	1.13	1.10	1.07	1.10	**1.10**	1.00	1.00	1.00	1.00	1.00
NO	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PL	1.18	1.15	1.32	1.29	**1.24**	1.00	1.00	1.00	1.00	1.00
PT	1.11	1.10	1.20	1.12	**1.13**	1.00	1.00	1.00	1.00	1.00
SE	1.06	1.04	1.04	1.00	1.04	1.00	1.00	1.00	1.00	1.00
SI	1.00	1.00	1.00	1.00	1.00	1.12	1.15	1.18	1.26	**1.18**
SK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Bold indicates figures that change by more than 10% when life satisfaction is considered as an input (output) of the production

The first four columns provide the R_i ratios from Eq. 4 for each period of the sample and each country when life satisfaction is an input to production; the fifth column reports period averages for each country. The remaining columns give the same information when life satisfaction is an output to production

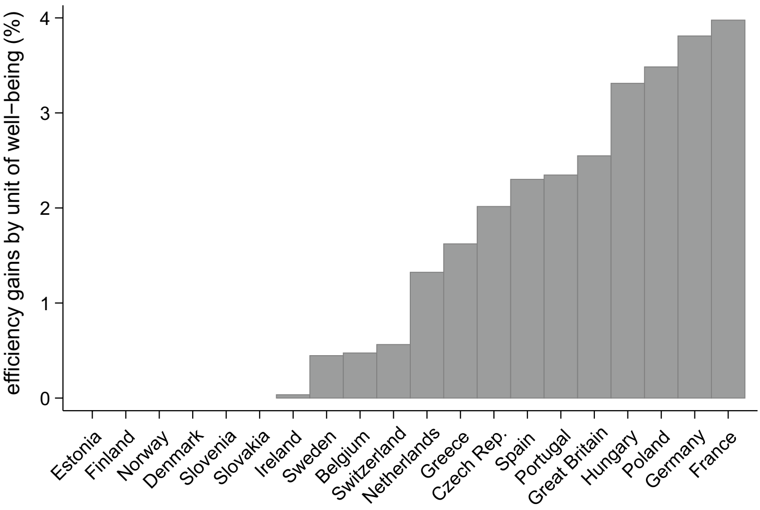


Fig. 4 Efficiency gains from life satisfaction. *Source*: Authors' computation on ESS and AMECO data.

- Data do not support the view that life satisfaction is an outcome of production.
- While the role of life satisfaction is not homogeneous across countries, life satisfaction is better modelled as an input rather than an output to production in a majority of countries.
- Improvements in life satisfaction can generate sizeable productivity gains.

4.3 Job Satisfaction

Our results use life satisfaction at aggregate level. Yet, one may argue that what matters for productivity is not the general level of life satisfaction of a society, but the well-being of those who participate to production activities. Unfortunately, the ESS provides limited information on job satisfaction, which prevents us from replicating our estimates. To overcome this problem, we repeated our analysis using the life satisfaction of people in working age, i.e. individuals with an age comprised between 18 and 65 years. Our results are robust to this new specification and they confirm our conclusion that well-being contributes to productivity.[15] This evidence suggests that not only policy-makers should promote policies for well-being, but also entrepreneurs should care for the well-being of their employees as a way to increase firms' productivity.

5 Conclusions

This article focuses on subjective well-being, productive efficiency and TFP. Several studies provided theoretical and empirical support to the hypothesis that subjective well-being leads to productivity gains through efficiency gains. These studies, however,

[15] Results available upon request to the authors.

are largely based on the analysis of individual-level data, and ad hoc experiments. We contribute to this literature testing whether well-being explains Total Factor Productivity (TFP) using Data Envelopment Analysis (DEA) on aggregate data. Results rest on a sample of 20 European countries observed between 2004 and 2010. Data on well-being are drawn from the European Social Survey, while labor, capital and GDP are sourced from the AMECO database.

We identify significant efficiency gains when life satisfaction—our measure of subjective well-being—is an input to production. In other words, countries in which people report higher life satisfaction are characterised by higher efficiency in production. The contrary does not hold true: gains in productive efficiency do not lead to increased life satisfaction. Present results are confirmed also after relaxing the hypothesis of free disposability of life satisfaction, and after substituting people's satisfaction with life with the one of individuals in working age.

The evidence that life satisfaction is an input and not an output to production confirms the results of previous literature (Harter and Schmidt 2000; Harter et al. 2003; Edmans 2012). This result also suggests that, at least in our sample of countries, productivity gains—and therefore economic growth—do not contribute to well-being, providing an alternative test of the Easterlin paradox (Easterlin et al. 2010).

In summary, the main implication of this analysis is that life satisfaction can be regarded, along with other economic variables, as one of the determinants of TFP, that is, one of the components of the productivity "black-box". Following an interpretation first suggested by Edmans (2012), life satisfaction can be regarded as one of economies' intangible assets.

Contrary to the common belief of a trade-off between people's well-being and the achievement of economic objectives, our findings imply that policies may foster economic growth through the promotion of life satisfaction. Many studies have shown that it is possible to take concrete actions to support and promote people's satisfaction with life beyond the traditional economic policies. In particular, enhancing individuals' freedom and autonomy, self-expression, social participation, feeling of belonging, and control over their own time and space would significantly contribute to people's well-being (Helliwell 2011; Bartolini 2019). Our results also support the view that incentive schemes based on intrinsic rather than extrinsic motivations (that is, incentives aiming at promoting job commitment rather than monetary-based ones) may help foster job satisfaction hence firms' economic performances (Kasser and Ryan 2001; Deci and Flaste 1996; Deci and Ryan 1985).

One issue with this study is that DEA is essentially a cross-sectional framework to study productive efficiency. It departs from traditional econometric regression-based modelling and, as such, it does not allow to test causality (in the Granger time-series sense). Another problem is that the relation between well-being and productivity may be affected by a simultaneity bias. Endogeneity has received little attention in the field of Data Envelopment Analysis, but a recent contribution has highlighted that it may lead to biased estimates of efficiency (Cordero et al. 2015). We can not rule out this possibility. However, it is plausible that if the relationship we estimate is endogenous, then we should find that life satisfaction is at the same time an input and an output to production, but the data do not support this conclusion.

A possible interpretation of this result is that subjective well-being is an intangible factor to production related to job satisfaction, social capital, trust, quality of the management, and other relational aspects which complement other intangible assets—such as human capital, and skills—that have been identified in the productivity literature. Moreover, our results support Easterlin's view that economic growth does not necessarily lead to higher well-being. Viceversa, we find that higher aggregate well-being leads to higher productivity, which, in turn, generates higher rates of economic growth. A further implication of this analysis is that it is possible to construct productivity measures that take into account intangible factors of production using self-reported measures of well-being.

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Appendix 1: The DEA Method

DEA rests on a theoretical framework where, given certain levels of inputs use and the available technology, there exists a level of output that cannot be exceeded—and might not be attained—by the operating economic units (Farrell 1957). Operating units can be firms, industries, or countries. These maximal levels of output define the so-called *efficient (or best-practise) frontier*. The *distance* between the frontier and the level of production recorded for each operating unit gives a measure of the productive inefficiency of that unit. For more details on the method, one can see Färe et al. (1994a). These authors present the theoretical foundation of the approach, while Coelli et al. (2005) provide an accessible introduction to efficiency measurement.

Formally, let **y** and **x** denote, respectively, the vectors of outputs and inputs to production. Assume convexity, free disposability of inputs and outputs, and constant returns to scale (CRS).[16] Computing measures of operating units' productive efficiency requires solving, for each unit j and each period t, linear programs (LP) formulated as follows:

$$Max_{\theta,\lambda}\ \theta_j^t \tag{8}$$

$$s.t.\ \sum_{k=1}^{K} \lambda_k^t y_{mk}^t \geq y_{mj}^t \theta_j^t \quad m = 1, \dots, M \tag{9}$$

$$\sum_{k=1}^{K} \lambda_k^t x_{nk}^t \leq x_{nj}^t \quad n = 1, \dots, N \tag{10}$$

[16] The CRS assumption is easily relaxed in this setting, by adding the constraint that the λs parameter sum to unity.

$$\lambda_k^t \geq 0 \quad k = 1, \ldots, K \tag{11}$$

(Here, units are indexed by k, inputs by n and outputs by m; the λs denote a set of weights.) The linear program constructs a virtual technology given by linear combinations of inputs and outputs used/produced. The goal is to maximize the output of unit j, under the constraint that no unit can operate beyond a convex set defined by the virtual technology and that weights are non negative. The value taken by θ tells to what extent a unit could increase its produce by using available resources more efficiently.

$$\theta^{-1} = D^t\left(\mathbf{x}^t, \mathbf{y}^t\right) \tag{12}$$

the parameter θ^{-1} represents the distance of an operating unit to the frontier. It takes values between zero and one. If a unit is efficient, then $\theta^{-1} = 1$, meaning that the unit cannot attain higher levels of production without increasing the use of inputs. In contrast, values of θ^{-1} below unity could produce more using more efficiently its existing resources. Thus, D provides an estimate of the producing units' efficiency at time t; it is interpreted as a measure of TFP, as it compares output to inputs to production.

DEA technologies are time specific. TFP growth rates are computed by linking the efficiency scores θs computed for two adjacent time periods. Developing an idea first suggested by Malmquist (1953), Caves et al. (1982) defines the (Malmquist) productivity index as follows:

$$M^{t+1} = \frac{D^t\left(x^{t+1}, y^{t+1}\right)}{D^t(x^t, y^t)}; \tag{13}$$

For each operating unit k, this index is the ratio of the distances to the efficient frontier at time t computed comparing output and inputs of two subsequent periods (t and $t + 1$). Thus, the Malmquist index indicates how the efficiency of operating units evolves between two periods. Doing so requires "fixing" the technology (expressed by the frontier) at a certain point in time. Clearly, it is also possible to write the same index using the technology in $t + 1$. To avoid the arbitrary choice of a reference technology, Färe et al. (1994a) propose to use a geometric average of the Malmquist indices obtained using the technologies available in t and $t + 1$:

$$M^{t,t+1} = \left[\left(\frac{D^t\left(x^{t+1}, y^{t+1}\right)}{D^t(x^t, y^t)}\right)\left(\frac{D^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D^{t+1}(x^t, y^t)}\right)\right]^{\frac{1}{2}}; \tag{14}$$

Equation 15 considers how much a unit could produce using the inputs available in $t + 1$, if it used the technology at time t, and how much a unit could produce using the inputs available in t, if it used the technology available in $t + 1$, and takes the geometric mean of the answers to these two questions. If, for example, the output resulting from the use of inputs in $t + 1$ were halved when using as reference technology the frontier in t, and the output from the use of inputs in t were doubled when using as reference technology the frontier in $t + 1$, the index above would show that a substantial technology progress has occurred from period t to $t + 1$. Here, the CRS assumption is crucial to the interpretation of the Malmquist index as a TFP index (Grifell-Tatje and Lovell 1985).

Equations 12 and 14 are used in this study to compute measures of productivity and productivity changes.

The second part of the study establishes whether an additional input to production, life satisfaction, is an output or an input to production.

To this purpose, a test developed by Pastor et al. (2002) is implemented. The test proves to perform well under most situations (Nataraja and Johnson 2011). This procedure is as follows. Firstly, we compute efficiency indices using the linear program of Eq. 8. This is done twice, one time with life satisfaction included in the input set, another time with sLS included in the output set. Then, we compute the level of output that would be attained if countries were efficiently using their inputs. (This is done by multiplying the efficiency scores by the observed values of output.) Finally, we re-calculate efficiency scores by comparing the optimal values of output to physical inputs, capital and labour, thus omitting life satisfaction in the set of inputs (or outputs). This allows us to interpret any resulting loss of efficiency as the effect of (omitted) life satisfaction. If a country is close to the frontier, then results indicate that subjective well-being does not generate significant efficiency gains. In contrast, if a country is displaced from the frontier and experience "large" efficiency losses, results suggest that subjective well-being plays a significant role in the production framework of that country.

To test significance of the results, Pastor et al. (2002) suggest to perform a simple binomial test. Assume to assign a value of 1 when efficiency changes by more than 10% and 0 otherwise. The sum of such 1s over the countries in the sample follows a Binomial distribution. Therefore,

$$T = \sum_{j=1}^{N} T_j \sim \mathit{Binomial}\,(N - 1, p_0 = 0.15) \tag{15}$$

where:

$$T_j = \begin{array}{ll} 1 & \text{if change in efficiency} > 0.1 \\ 0 & \text{otherwise, } j = 1, \ldots, N \end{array}$$

Following Pastor et al. (2002), a change in efficiency of more than 10% obtained for at least 15% of countries would signal a significant role of well-being as an input (or output) to production.

Appendix 2: TFP Growth

See Table 5.

Table 5 Average TFP growth and country rankings. *Source*: Authors' computations on ESS and AMECO data

Country	TFP_W	TFP_I	TFP_O	$rank_W$	$rank_I$	$rank_O$
BE	0.996	0.997	0.996	8	10	9
CH	1.097	1.098	1.096	1	1	1
CZ	1.095	1.094	1.095	2	2	2
DE	1.01	1.008	1.01	4	5	4
DK	0.988	0.989	0.989	13	12	13
EE	0.955	0.955	0.98	18	18	15
ES	0.969	0.969	0.969	16	17	17
FI	0.993	0.993	0.996	10	11	10
FR	0.989	1.008	0.989	12	8	12
GB	0.917	0.922	0.917	20	20	20
GR	0.968	0.971	0.968	17	16	18
HU	0.922	0.928	0.922	19	19	19
IE	0.984	0.987	0.973	14	13	16
NL	1.004	1.008	1.004	6	7	6
NO	0.995	1.001	1.001	9	9	8
PL	1.003	1.014	1.003	7	4	7
PT	0.992	0.985	0.992	11	14	11
SE	1.007	1.008	1.006	5	6	5
SI	0.975	0.975	0.987	15	15	14
SK	1.04	1.041	1.035	3	3	3
Spearman					0.96	0.98

The first three columns gives average values of the Malmquist productivity indices computed under different assumptions on the role of life satisfaction in the production process. TFP_W denotes productivity indices computed without life satisfaction; TFP_I and TFP_O denote TFP measures computed including life satisfaction respectively as input (I) and output (O) to production. Spearman is the Spearman's rank correlation

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