Happiness matters: productivity gains from subjetive well-being

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Happiness matters: productivity gains from subjective well-being

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Abstract

This article studies the link between people's subjective well-being, defined as life satisfaction, and productivity in the framework of efficiency analysis. We adopt Data Envelopment Analysis to compute productive efficiency indices using European Social Survey and AMECO data for 20 European countries. While accounting for reverse causality, we find significant efficiency gains when subjective well-being is an input to production. This supports the view that

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promoting subjective well-being results in higher productivity.

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1 Introduction

Over the last 30 years, work organization underwent deep restructuring to pursuit competitiveness and productivity. If the good entrepreneur is the one who is able to effectively mobilize all the necessary resources to fulfil his or her goals, than he or she needs to design a system of controls and incentives to ensure that every resource is used to its best. We share the view that work activity does not need to be unpleasant to be economically rewarding: as previous literature showed, promoting people's well-being can result in productivity gains. We contribute to this literature using macro-level data on productivity and subjective well-being. Additionally, we adopt Data Envelopment Analysis to assess if and to what extent subjective well-being results in productivity gains through efficiency gains. We focus on the relationship between subjective well-being and a key driver of economic growth, namely productivity. We use a non-parametric frontier technique to assess whether higher well-being leads to higher productivity using country-level data. This technique allows us to account for reverse causality.

A growing number of studies have analysed how poverty, inequality, unemployment and inflation affect people's subjective well-being (Di Tella and MacCulloch, 2008; Alesina, Di Tella and MacCulloch, 2004; Diener et al., 2009; Clark, Flèche and Senik, 2012; Clark, D'Ambrosio and Ghislandi, 2013). The scientific debate on whether economic growth is associated with higher well-being is still open. Yet, no evidence exists on the link between productivity and life satisfaction at the aggregate level. Some evidence at firm level links job and life satisfaction to measures of firms' performance. 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' value. Harter and Schmidt (2000); Harter, Schmidt and Keyes (2003) report significant positive correlations between employees' average well-being levels and companies' returns.

Recent experimental evidence provides micro-level foundations to the modelling of the relationship productivity-well-being. Oswald, Proto and Sgroi (2014) observe that positive shocks to happiness result in significant productivity gains. Such gains stem from increased effort rather than from high precision in executing tasks. In a related article, Proto, Sgroi and Oswald (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, have better relationships with colleagues and customers

(George and Brief, 1992; Pavot and Diener, 1993*a*; Spector, 1997; Wright and Cropanzano, 2000). These studies evidence possible channels through which life satisfaction might affect productivity.

Our study contributes to the literature by examining the link productivity-well-being using aggregate data, and by implementing a methodology from the operational research literature. We adopt Data Envelopment Analysis (DEA) to compute measures of productive efficiency, total factor productivity (TFP), for 20 European countries using data and physical capital stock, employment, GDP and life satisfaction from 2004 to 2010. We proceed as follows. We first compute measures of TFP that account for subjective well-being. We find that these measures are significantly correlated to standard TFP measures. This result provides support for the reliability of the well-being-adjusted TFP measures. Subsequently, we test whether well-being has a significant positive impact on productive efficiency.

Results indicate that well-being induces significant gains in productive efficiency, while they exclude the possibility of reverse causation: subjective well-being is not a by-product of the production process. Results also hold when life satisfaction is substituted by a measure of job satisfaction. In sum we found evidence suggesting that well-being should be regarded as a determinant of productive efficiency.

The paper is structured as follows: section 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 section 5 provides some final remarks.

2 Methodology

The productivity concept adopted in this study is total factor productivity (TFP). Broadly speaking, TFP compares output to the inputs used in producing those output. 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.

This study uses Data Envelopment Analysis (DEA), a non-parametric computational technique, to measure countries' productive efficiency. DEA is a deterministic technique widely applied in management and economic studies to analyse production processes at the firm and industry level. It is also applied to study productivity at country level (see, for example Färe et al., 1994); in this context, the advantage of DEA is that it permits to compute productivity indices from small datasets without the need of specifying the functional form of the production process (or production function).

In particular, DEA applies linear programming methods to available data on outputs and inputs to construct indices of productive efficiency. Such indices measure the distance of producing units from an efficient frontier, where those units closer to the frontier are more efficient. Appendix A provides more details about the method.

As our data consists of country-level observations, the use of DEA technique allows us to overcome the problem of the small sample size, which limits the inferential power of traditional econometric techniques.

To investigate the link between well-being and productivity we proceed in two stages:

- Firstly, we establish whether productivity measures that account for subjective well-being are valid. We do so by checking the significance of the correlation between well-being-adjusted productivity measures and traditional productivity measures accounting for physical inputs to production (Färe et al., 1994). DEA will always produce an index, independently from the variables at hand. The study of the correlation between the index accounting for well-being and the traditional measure of TFP allows us to ascertain that our index is still a reliable measure of TFP.

- Secondly, we analyse the contribution of well-being to productive efficiency using a variable-selection test for DEA models. This procedure allows us to test whether well-being has a statistically significant effect on productivity under different assumptions on the role of well-being in production. Namely, we consider well-being both as an input or an output to production. This serves also as a test of reverse causality for the relationship well-being-productivity.

A crucial assumption of this study is that subjective well-being can be treated as a conventional factor to production, i.e. that well-being 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 suggesting 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, Stevenson and Wolfers, 2012).

3 Data

This analysis uses annual observations on GDP, labour, capital stock, and subjective well-being to construct countries' productivity indices. Annual observations on GDP, employment and capital stock are sourced from AMECO, a database published by the European Commission aimed at providing internationally comparable series on macroeconomic variables. 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 subjective well-being comes from the European Social Survey (ESS) and covers four time periods, 2004, 2006, 2008 and 2010.[1] The ESS database includes observations on individuals which were interviewed over 4 time periods along with sample weights.[2] Table 1 reports descriptive statistics on the main variables in this analysis.

Subjective well-being is measured using answers to the following question from the ESS: "*All things considered, how satisfied are you with your*

[1]The year 2002 is not included as some of the countries in our sample were not surveyed.

[2]ESS survey documentation is available at http://ess.nsd.uib.no/ess/.

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.[3] 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 well-being, whereas life satisfaction is a cognitive evaluation of well-being and it is thus considered a more reliable measure than happiness (Diener, 2006). This is why this study adopts life satisfaction as the preferred proxy of subjective well-being. Indeed, an extensive literature, involving various disciplines and scientific domains, supports its reliability. Subjective well-being correlates 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, different 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).

Country data on subjective well-being are constructed as weighted averages of individuals' well-being. To retain all observations and use the sample weights provided in the original database, missing values on individuals have been replaced using a simple imputation scheme that employs the

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

mode of the observations on individuals in the same strata. In other words, for a given country, missing values are filled by taking the sample mode of the individuals having the same weight. 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 country-average well-being scores for each year in the survey.[4]

Table 2 lists the 20 European countries in the sample together with average subjective well-being for each period, average growth rates between periods, and overall average scores. We observe that subjective well-being 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 well-being over the period, whereas the trend is flat in France, Denmark and Finland. Greece and Ireland, on the contrary, experienced the largest fall in well-being over the period considered. Overall, data suggest that well-being changes have been more sustained in new European member states than in older ones, possibly suggesting that some convergence mechanism is at play.

TABLE 1 APPROXIMATELY HERE

TABLE 2 APPROXIMATELY HERE

Figure 1 plots TFP growth rates versus average levels of well-being.

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

The super-imposed OLS regression line suggests a mildly positive correlation between average TFP and subjective well-being across countries. The dataset, however, is small and this simple correlation does not allow us to draw conclusions on the nature of the relation between the two variables, which motivates the following analysis.

FIGURE 1 APPROXIMATELY HERE

4 Results

4.1 Reliability of TFP indices

To check the validity of well-being adjusted TFP indices, we exploit the fact that DEA efficiency measures permit to rank countries according to their productivity performance, and compare the country rankings given by standard TFP measures to those produced by the TFP indices adjusted for well-being using the Spearman rank test for ordinal data.

This preliminary step is necessary because DEA compares an aggregate measure (weighted-sum) of variables in the so-called output sets to an aggregate measure of variables in the input set.[5] Thus, one could add *nuisance* variables, that is variables that are not linked with the production process, and still obtain a "spurious" index. Nonetheless, if the nuisance variables are neither inputs nor outputs in the sense of production economics, the new index is likely to behave differently from TFP indices, computed using the same methodology. If well-being can be considered an input or an output of productivity, we expect that country rankings provided by DEA

[5]Linear program problems compute optimal weights so that the ratio of such aggregates lies between 0 and 1 (see Appendix A).

productivity indices should not be "too" different from each other.

We proceed as follows. Countries are ranked from 1 to K according to increasing values of productivity performance. Let $d_k = m_k - m_k^a$ be the difference between the position of each observation on two different rankings.[6] The following test statistics is computed:

$$r_s = 1 - \frac{6\sum_{k=1}^{K} d_k^2}{K(K^2-1)} \tag{1}$$

The observed values of the test statistic are then compared to adequate critical values of the Spearman's rank correlation coefficient. This checks whether the rankings obtained comparing standard TFP indices and those obtained with the "adjusted" indices are significantly different.

Table 3 presents three measures of TFP computed according to different hypothesis on the role of subjective well-being in production: the first one excludes subjective well-being (TFP_W); the second and the third measures include subjective well-being as an input (TFP_I) and as an output(TFP_O) of production, respectively. 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 subjective well-being can be regarded as a *candidate* variable for being an input or an output to production.

TABLE 3 APPROXIMATELY HERE

[6] In other words, d denotes the discrepancy between the rank of country k given by the of TFP index m and the rank of the same country according to the well-being-adjusted TFP index m_k^a.

4.2 The impact of well-being on productivity

The result of the previous section suggests that it is legitimate to include well-being in a production framework. In this section we explore the role of subjective well-being in the production process. In particular, we check whether well-being has a significant impact on productivity. In doing so, we also check whether well-being is an input or an output to production, thus performing a test of reverse-causality of the relationship well-being - productivity.

To study the role of well-being in production, we implement a simple variable-selection test procedure for DEA models first suggested by Pastor, Ruiz and Sirvent (2002). Let us assume that we want to test whether well-being is an input to production, i.e. higher well-being generates productivity gains. The test computes efficiency indices twice, one time with subjective well-being included in the input set, and another time with subjective well-being included in the output set. This permits to compute an optimal level of output (as measured by GDP), that is the output that would be produced if countries were efficiently using their inputs. Finally, new productivity indices are computed using such optimal values of GDP, which omit subjective well-being from the set of inputs. This allows us to interpret any resulting loss of efficiency as the effect of (omitted) subjective well-being. If a country remains 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 of that country.

In more detail, productivity measures are computed comparing the value added of production (as measured by GDP) to the used inputs, namely the stock of physical capital, labour, *and* subjective well-being. An additional productivity measures is computed by comparing a vector of output (GDP and well-being) to standard inputs, that is, capital and labour. These computations give the following *efficiency* (productivity) scores:

$$D_i^I(K, L, SWB; GDP)$$
$$D_i^O(K, L; SWB, GDP)$$

Here, D denotes the distance of country i from the production frontier; the super-scripts I and O mean, respectively, that subjective well-being is included as an input or as an output to production.[7] Secondly, country i's GDP is multiplied by the distance to the frontier to obtain the optimal output value for that country (denoted by GDP_i^r), as follows:

$$GDP_i^{r,I} = GDP_i * D_i^I(K, L, SWB; GDP) \tag{2}$$
$$GDP_i^{r,O} = GDP_i * D_i^O(K, L, SWB; GDP) \tag{3}$$

These are GDP values that should be obtained if inputs were used efficiently. Lastly, new distances to frontier are computed by comparing the rescaled GDP to capital and labour inputs. Thus, omitting well-being from the output (input) set gives new productivity measures denoted, re-

[7] DEA produces productivity measures which allow for inefficiency and are referred to as distances. As the efficient frontier depicts the maximum amount of output that can be produced given a certain level of inputs use, it is possible that some countries are efficient and others are not. The efficient countries are assigned a score of 1, whereas the inefficient countries, for whom the level of output corresponds to a point below the frontier, are assigned scores between 0 and 1.

spectively, as $D_i^I(K, L; GDP^{r,I})$ and $D_i^O(K, L; GDP^{r,O})$.

The key point of this procedure is that the comparison of the efficiency measures computed with and without subjective well-being provides a measure of the productivity gains generated by subjective well-being and, therefore, of the contribution of subjective well-being to TFP. The idea of Pastor, Ruiz and Sirvent (2002) is that the use of rescaled GDP as measure of output guarantees that changes in efficiency can only be attributed to the omitted variable (subjective well-being in this case). The productivity gains generated by well-being are computed as follows:

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

Note that rescaling GDP amounts to impose that all countries are efficient when subjective well-being belongs to the output (input) set. Thus, the top term in the ratio R_i is, by construction, always equal to one, while the bottom term can take any value between zero and one. Any significant deviation of the efficiency scores from 1 indicates that subjective well-being matters to efficiency. In particular, significantly large efficiency gains generated by well-being imply values of R_i well above 1. Table 4 presents the ratio of equation 4 for all periods, as well as overall averages.

TABLE 4 APPROXIMATELY HERE

Figures reveal that when subjective well-being is included in the production set as an output, the ratio of the efficiency scores does not depart from 1, with the exception of Estonia (EE) and Slovenia (SI). These results tell us that well-being should not be considered an output to production (or, in other words, regarded as a positive externality of a production process).

We repeat the same computations considering well-being an input to production. Results show that, in this case, 13 out of 20 countries exhibit a value of the ratio R_i greater than 1; in 10 countries the improvement in performance amounts to more than 10 percent (reported in bold in the table).[8] A binomial test confirms, at the one percent significance level, that well-being should be regarded as an input to production. Following Pastor, Ruiz and Sirvent (2002), the test requires an improvement in efficiency by at least 10 percent in at least 15 percent of countries for the null hypothesis not to be rejected. When considering a proportion of 30 percent of countries, the same conclusion can be reached at a 5 percent confidence level. These results are consistent across countries and over time.[9]

Figure 2 provides a graphical summary of the results presented above. The figure ranks countries according to the average percent efficiency gain per unit of subjective well-being. The bar plot shows for each country how much gain in efficiency can be attained if average subjective well-being increases by one unit. For instance, the productive efficiency in France would increase by 4% if the average subjective well-being increases by one point. Hence, figure 2 can also be interpreted as a representation of the contribution of productive efficiency to subjective well-being.[10] The countries where subjective well-being contributes the most to efficiency

[8]A score of 1.26, for example, as in the case of Germany, means that the rescaled GDP of a country could be increased by 26% by including well-being in the input set.

[9]Following Simar and Wilson (1998, 2000*b*,*a*), efficiency estimates were also obtained using a bootstrap procedure, rescaling GDP so that bootstrap estimates were close to unity. This confirmed the main result in the article that subjective well-being should not be regarded as an output to production: also in this case, ten countries exhibit a large marginal effect when well-being is included as an input to production. Results are available from authors on request.

[10]The changes in efficiency following a unit change in well-being 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.

gains are Germany, France and Poland. We also document that, in 7 out of 20 countries, subjective well-being 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 subjective well-being is an output of production, rather than an input.

FIGURE 2 APPROXIMATELY HERE

These results are mirrored by the TFP indices reported in column 3 of tab. 1 in the Appendix. In this case it is possible to compare the scores of the TFP computed with and without the input of subjective well-being. As pointed out above, the inclusion of subjective well-being in the computation leads to slightly larger scores than in absence of well-being. This further confirms the observation that subjective well-being is part of the ingredients of TFP and that its role is not homogeneous across countries.

4.3 Job Satisfaction

Our results use subjective well-being at aggregate level. Yet, one may argue that what matters for productivity is not the general level of well-being of a society, but the well-being of those who participate to production activities, i.e. what the literature refers to as job satisfaction. 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 different measure of subjective well-being and they confirm our conclusion that people's well-being contributes to productivity.[11] 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, 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 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 subjective well-being, and after substituting people's life satisfaction with the one of individuals of working age.

[11] Results available upon request to the authors.

The evidence that subjective well-being is an input and not an output to production confirms the results of previous literature (Harter and Schmidt, 2000; Harter, Schmidt and Keyes, 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.

In summary, the main implication of this analysis is that subjective well-being 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), subjective well-being 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 well-being 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, 2013). Our results also support the view that incentive schemes based on intrinsic rather than extrinsic motivations (that is, incentive 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, Santín and Sicilia, 2015). We can not rule out this possibility. However, if one considers efficiency computed using only capital and labour as an unbiased estimate of true efficiency scores, than the correlation between well-being and efficiency is only 0.49 for the whole sample (0.29, 0.41, 0.60, and 0.68 for 2004, 2006, 2008 and 2010, respectively). Furthermore, it is plausible that if the relationship we estimate is endogenous, then we should find that well-being 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 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.

A Appendix: 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, Grosskopf and Lovell (1994). These authors present the theoretical foundation of the approach, while Coelli et al. (2005) provide an accessible introduction to efficiency measurement.

Formally, let $\mathbf{y}$ and $\mathbf{x}$ denote, respectively, the vectors of outputs and inputs to production. Assume convexity, free disposability of inputs and outputs, and constant returns to scale (CRS). (Later in the paper we will discuss the assumption of inputs' free disposability.)[12] Computing measures of operating units' productive efficiency requires solving, for each unit j and each period t, linear programs (LP) formulated as follows:

$$Max_{\theta,\lambda}\ \theta_j^t \tag{5}$$

$$s.t.\ \sum_{k=1}^{K} \lambda_k^t y_{mk}^t \geq y_{mj}^t \theta_j^t \qquad m = 1, \ldots, M \tag{6}$$

$$\sum_{k=1}^{K} \lambda_k^t x_{nk}^t \leq x_{nj}^t \qquad n = 1, \ldots, N \tag{7}$$

$$\lambda_k^t \geq 0 \qquad k = 1, \ldots, K \tag{8}$$

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

(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. Note that the parameter θ^{-1} 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, θ^{-1} provides an estimate of the units' efficiency "scores".

DEA technologies are time specific. TFP growth rates are computed by linking the efficiency scores θs computed for two adjacent time periods. Let $\theta^{-1} = D^t(\mathbf{x}^t, \mathbf{y}^t)$, where D denotes the distance of an operating unit to the frontier. Developing an idea first suggested by Malmquist (1953), Caves, Christensen and Diewert (1982) defines the (Malmquist) productivity index as follows:

$$M^{t+1} = \frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}; \tag{9}$$

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, Grosskopf and Lovell (1994) propose to use a geometric average of the Malmquist indices obtained using the technologies available in t and $t+1$:

$$M^{t,t+1} = \left[\left(\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \right) \left(\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \right) \right]^{\frac{1}{2}}; \qquad (10)$$

Equation 10 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).

The second part of the study establishes whether subjective well-being is an output or an input to production.

To this purpose, we implement a test developed by Pastor, Ruiz and Sirvent (2002), which 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 equation 5. This is done twice, one time with subjective well-being included in the input set, another time with subjective well-being included in the output set. Then, we compute the level of GDP that would be attained if countries were efficiently using their inputs. (This is done by multiplying the efficiency scores by the observed values of GDP.) Finally, we re-calculate efficiency scores by comparing the optimal values of GDP to capital and labour, thus omitting subjective well-being in the set of inputs (or outputs). This allows us to interpret any resulting loss of efficiency as the effect of (omitted) subjective well-being. 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, Ruiz and Sirvent (2002) suggest to perform a simple binomial test. Assume to assign a value of 1 when efficiency changes by more than 10 percent and 0 otherwise. The sum of such 1s over the countries in the sample follows a Binomial distribution. Therefore,

$$T = \sum_{j=1}^{N} T_j \sim \quad Binomial \quad (N-1, p_0 = 0.15) \tag{11}$$

where:

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

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

B Appendix: TFP growth

Table 1: **Average TFP growth and country rankings.**

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

Legend: the first three columns gives average values of the Malmquist productivity indices computed under different hypothesis on the roles of subjective well-being in the production process. TFP_W denotes productivity indices computed without subjective well-being; TFP_I and TFP_O denote TFP measures computed including subjective well-being 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.
Source: authors' computations on ESS and AMECO data.

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Tables

Table 1: **Descriptive Statistics.**

Country	**Codes**	**GDP**	**Labour**	**Capital**	**Well-being**
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	56585.50	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	32810.57	3336.86	7.29
Finland	FI	163.77	4171.95	410.43	7.97
France	FR	1754.61	39633.90	5369.06	6.29
United Kingdom	GB	1644.47	47830.28	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	11812.95	1452.38	7.57
Norway	NO	236.76	3538.00	641.63	7.81
Poland	PL	274.68	31010.17	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

Legend: Country average values over the period. Units: GDP and capital stock are in billion euros and converted using purchasing power parities (PPP); employment is measures in thousand workers (FTE).
Data source: AMECO, ESS.

Table 2: **Subjective well-being by country.**

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

Legend: figures are average subjective well-being levels; % growth is the average of the variable's yearly rates of growth.
Data source: ESS, 2004 - 2010.

Table 3: **Average TFP growth and country rankings.**

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

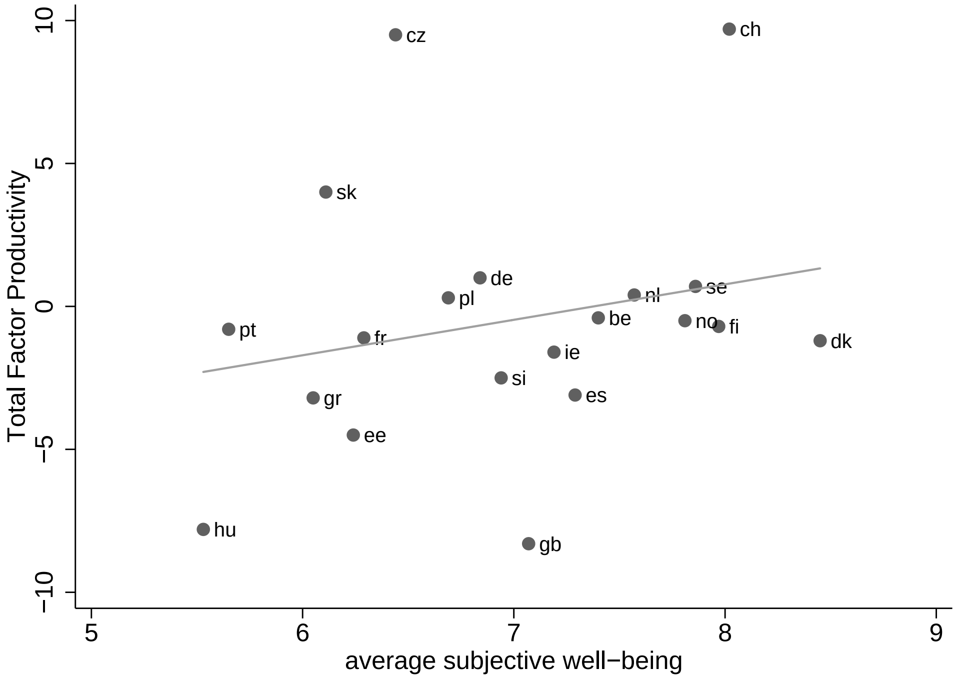
Legend: the first three columns give average TFP growth (in percent) under different hypothesis on the roles of subjective well-being in the production process. Average growth rates have been computed as geometric means over the period. Thus, TFP denotes productivity indices computed without subjective well-being; TFP_I and TFP_O denote TFP measures computed including subjective well-being 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.
Source: authors' computations on ESS and AMECO data.

Table 4: **Efficiency gains generated by subjective well-being.**

	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

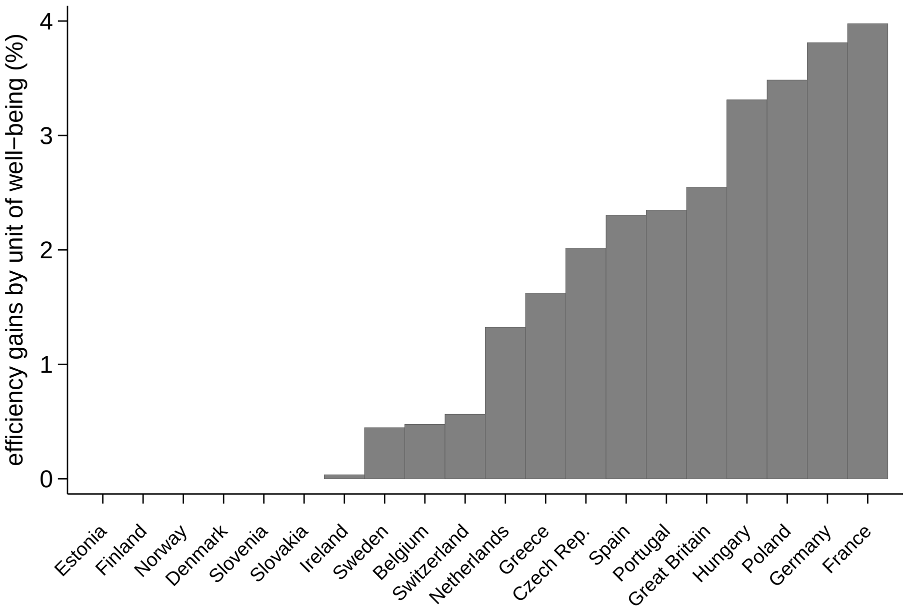
Legend: the first four columns provide the R_i ratios from equation 4 for each period of the sample and each country when subjective well-being is an input to production; the fifth column reports period averages for each country. The remaining columns give the same information when subjective well-being is an output to production.
Source: authors' calculations on ESS and AMECO data.

Figures



*Source: authors' own elaboration on AMECO and ESS data.

Figure 1: Correlation between TFP growth and SWB.*



* *Source: authors' computation on ESS and AMECO data.*

Figure 2: Efficiency gains from subjective well-being.*