Well-being and Productivity: A Capital Stocks Approach

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Abstract

In the widely used capital stocks approach to conceptualizing intergenerational well-being, the well-being of the current generation is considered a function of produced capital, human capital (labour), social capital, and natural capital. Most discussion of the sustainability of levels of well-being into the future is focused on considering whether the quantity of these capital stocks left for future generations will be the same, larger, or smaller than the quantity available to the current generation. However, the efficiency with which the capital stocks are used to produce well-being also matters. Because the capital stocks approach is grounded in a framework with strong parallels to that underpinning growth accounting, total factor productivity (TFP) provides a potentially useful way of examining this issue.

This article explores the relationship between well-being and TFP. An econometric approach is used to develop methodologically comparable estimates of traditional TFP (where the output in question is national income) and total well-being productivity (where the output is mean national life satisfaction). The differences between the two measures are compared and the impact on this of confounding factors — including the roles of social capital, natural capital, and cultural bias in responses to subjective well-being measures — is explored. We find that there are large differences in total well-being productivity across countries. More generally, interpreting the capital stocks model in terms of an aggregate production function for well-being produces plausible results.

Human well-being is one of the primary goals of public policy. This is reflected in the conceptual framework of standard neoclassical economic analysis which is centred on utility maximization. However, in practice, economic analysis has traditionally focused on income as the primary policy-relevant outcome. This reflects the obvious importance of consumption — and hence income — to human well-being as well as

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the conceptual and technical issues associated with measuring well-being in practice. However, in the last 20 years significant progress has been made in the measurement of well-being. The ability to directly measure well-being opens the door to investigating whether the use of well-being, as opposed to income, as the focus for analysis would lead to substantially different policy judgements.

Key developments in the conceptualization and measurement of well-being over the last 20 years have come from two directions. On the one hand, there is a growing body of literature focusing on the measurement of subjective well-being and the use of such measures as a proxy for utility in an economic context (Kahnemn, Diener, and Schwarz, 1999; OECD, 2013a; Frijters *et al.*, 2020). Much of this literature is grounded firmly in the utilitarian tradition and sees well-being as something experienced in the mind. The other main tradition is grounded in the work of Sen and focuses on well-being as the ability of a person to live the kind of life they have reason to value (Sen, 1993). This approach conceptualizes well-being as comprising a vector of distinct capabilities that collectively describe a multi-dimensional frontier within which an individual is able to function.

In principle, these two approaches to well-being are quite distinct. In practice, however, the distinction between the neo-utilitarian and the capabilities approach to well-being is much less clear. The *Report of the Committee on the Measurement of Economic Performance and Social Progress* (Stiglitz, Sen, and Fitoussi, 2009) identifies subjective well-being as an important capability in its own right, suggesting that the distinction between the two approaches is not absolute. Perhaps more importantly, it is clear that some evaluative measures of subjective well-being — such as measures of overall life satisfaction — function empirically as summary measures capturing the impact of the most commonly identified capabilities (Boarini *et al.*, 2013).

Following the release of the Sen/Stiglitz/Fitoussi report, a widely used framework for conceptualising and measuring intergenerational well-being has emerged (OECD, 2011; Arrow *et al.*, 2012; UNECE, 2014). This framework — referred to here as the capital stocks model — draws on the approach to measuring the current well-being of people outlined in Sen, Stiglitz, and Fitoussi (2009). It places this approach in a coherent economic framework where current well-being draws on stocks of productive resources (the capital stocks). Typically, four capital stocks are identified: produced capital, human capital, social capital and natural capital. The flow of resources from the capital stocks can either be used for current consumption (well-being) or re-invested in the capital stocks. An attractive feature of this approach is that a definition of sustainable development that is consistent with the Brundtland declaration on sustainable development (Butlin, 1989) falls directly out of the framework:

> sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

In terms of the capital stocks framework, a sustainable level of well-being is defined as one where capital stocks do not decrease over time (Arrow *et al.*, 2012). This can be considered either in terms of soft sustainability (where the total value of the four capital stocks does not decrease over time) or hard sustainability which requires than none of the four capital stocks is allowed to decrease.

There is an extensive literature on the determinants of current well-being, often focused on the use of an over-arching measure of subjective well-being such as life satisfaction (Boarini *et al.*, 2012; Helliwell, Huang and Wang, 2015; Clark *et al.*, 2018). However, far less attention has been paid to the capital stocks. The most substantive contributions on this front have been from the OECD as part of its Better Life Initiative (in particular, see OECD, 2013b, chapter 6; and OECD, 2015, chapter 3), the World Bank (2006), and Arrow *et al.* (2012). Where capital stocks have been considered the focus has been entirely on the levels of the capital stocks rather than how efficiently they are used (OECD, 2015).

The lack of investigation into the efficiency with which the capital stocks are used to produce well-being represents an important theoretical and empirical gap in the literature. Assuming that the size of the capital stocks and the size of the population whose well-being they need to support are held constant, the Brundtland definition of sustainable development necessarily requires an improvement in the efficiency with which the capital stocks are used if there is to be an increase in sustainable well-being. Put simply, the well-being productivity of the economy and society matters.

This article presents an initial exploration of well-being productivity and its relationship to more conventional productivity measures. Life satisfaction is used as a measure of overall well-being and analysis focuses on the relative importance of the different capital stocks in driving overall well-being. Compared to the extensive literature on the determinants of current well-being (Boarini *et al.*, 2012; Helliwell, Huang, and Wang, 2015, 2017), the focus of this article is less on identifying the causal impact and relative importance of different drivers of subjective well-being and instead centres on developing an estimate of well-being productivity that is methodologically comparable to more traditional measures of total factor productivity.

Section two sets out the conceptual framework and describes the capital stocks model of intergenerational well-being and defines total well-being productivity (TWP) in this context. In the third section, an extended Swan-Solow growth model is used to place the capital stocks model of well-being on a clear conceptual basis and a formal definition of TWP is derived. On the basis of this, an empirical strategy to estimate TWP is proposed and a series of testable hypotheses about the well-being production function and its relation to the four capital stocks are explored.

Section four of the article describes the dataset used to estimate TWP and explore its relationship to more conventional productivity measures. This draws on data from the European Social Survey (ESS) on well-being and cross-country economic statistics from the Penn World Tables (PWT). The Biodiversity Intactness Index (BII) is used to capture variation in natural capital per capita while the Corruption Perceptions Index from Transparency International is used as a measure of social capital. Empirical results are discussed in section five.

The final section considers the implications of the main empirical findings. We find that TWP is only weakly correlated with more traditional measures of total factor productivity (TFP) and that levels of TWP vary widely across countries. The aggregate production functions for market and non-market goods implied by the analysis are quite different, although the importance of the different capital stocks to well-being is affirmed in most model specifications which is consistent with the capital stocks model. An exception is natural capital which is largely non-significant. This may be due to measurement issues or it may reflect that the relationship between natural capital and well-being is negative in the short term due to impacts from current consumption on the natural environment.

Conceptual Framework

In well-being economics, the capital stocks framework is the dominant analytical model used for thinking about intergenerational well-being and sustainability. However, because the measurement of well-being has been the primary focus of well-being economics there has been relatively little development of the capital stocks model beyond the level of a measurement framework. This is reasonable as any empirical analysis of the capital stocks model is dependent on the ability to measure well-being. However, with the emergence of a coherent approach to the measurement of well-being over the last decade, it is now possible to look at the relationship between the capital stocks and well-being.

Before proceeding to outline the model that will be applied to examine TWP, it is useful to review the main approaches to conceptualizing and measuring well-being. The economic literature on well-being identifies two main approaches.[2] The first of these is the so-called capabilities approach (Sen, 1993), while the second is the neo-utilitarian or subjective well-being approach (Frijters *et al.*, 2020).

Sen (1999) defines well-being as peoples' ability to "lead the kinds of lives they value — and have reason to value." In taking this approach Sen grounds well-being in a liberal framework that prioritizes (reasoned) individual choice over other values. Well-being in this sense, Sen argues, can be conceptualized as a set of capabilities that collectively define a multi-dimensional consumption possibility frontier for each person. Within this framework command over market goods and services — measured by

2 In addition to the two approaches that form the focus for the economic literature, a third approach to well-being can be identified in the public health/medical literature. This approach identifies well-being as "wellness" conceived of as positive health states (Roscoe, 2009). Compared to the economic approaches that form the focus of this article, the wellness literature has a narrower focus. Consider that health is commonly identified as a core capability within Sen's approach to well-being and is an major empirical driver of subjective well-being, thus making health a sub-dimension or driver of well-being within the economic approach. In contrast, the "wellness" approach sees well-being as an element of health.

income — is one important dimension of a person's capabilities. However, non-market outcomes such as health status or knowledge and skills also represent important capabilities in that they limit the range of desired functionings that a person can achieve and cannot easily be purchased directly.

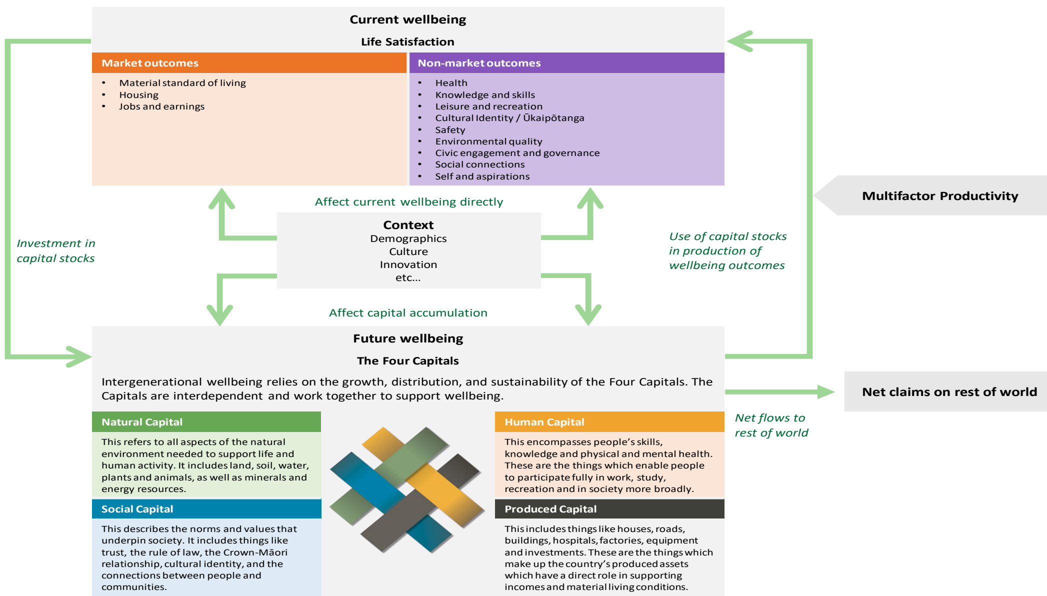
The capabilities approach is widely used in government and related policy contexts (OECD, 2011) for two reasons. First, the capabilities approach is consistent with the standard neo-classical economic framework of ordinal utility and thus integrates easily into conventional policy frameworks. In addition, the multi-dimensional nature of the capabilities framework and the strongly liberal framing of the capabilities approach allows for well-being indicators to be presented in a "dashboard" without the introduction of strong — and potentially contentious — assumptions about the relative importance of different outcomes.

The main alternative to the capabilities approach is the neo-utilitarian conception of well-being. Building on significant evidence that measures of subjective well-being are meaningful and valid (OECD, 2013a) this approach frames well-being in terms of subjective mental states. Fundamentally, a person is deemed to have high well-being if they experience positive mental states. In contrast to the multi-dimensional indicator dashboards used to measure well-being under the capabilities approach, the neo-utilitarian approach tends to focus on the use of a single over-arching measure of subjective well-being. The most commonly used such measure is overall satisfaction with life (OECD, 2013a).

The capital stocks framework builds on the measurement of well-being by placing well-being in an explicitly inter-temporal context and linking well-being as an outcome with the resources required to produce well-being. In effect, the capital stocks model links consumption and the utility function on the one hand (well-being) with resources available for production on the other (the capital stocks). Chart 1 is taken from a report prepared for the New Zealand Treasury (Smith, 2018) and illustrates the capital stock framework. This particular diagram is used because it is relatively simple and it clearly identifies the nature of the resource flows in the model in terms of production and investment, but is fundamentally the same as diagrams of the capital stocks framework from the OECD (2011, 2013b, 2015), Arrow *et al.* (2012), Costanza *et al.* (2016) and others.

It is clear from Chart 1 that the capital stocks model can be thought of in terms of production and consumption. The four capital stocks (natural capital, social capital, human capital, and produced capital) function as factors of production that are combined to produce a range of outputs that either directly contribute to well-being (market and non-market outcomes) or are invested in maintaining the level of the capital stocks. Conceptually, this framework can be seen as an extended version of a Solow-Swan growth model (Solow, 1956; Swan, 1956). This is reflected both in an implicit production function involving the four capital stocks and a decision about the investment rate that determines the maximum sustainable level of market and non-market consumption (and therefore well-being).

Chart 1: The Capital Stocks Framework



Source: Smith, 2018.

Given the focus of this paper on the capital stocks, it is important to be clear about what the capital stocks represent and their role in the model. The scope of produced capital and human capital should be relatively clear as these are used in the same way in the capital stocks model as in growth accounting more generally. Produced capital captures those material assets that contribute to the production process such as roads, buildings, machinery and equipment as well as net financial assets (which represent a claim on the same). Human capital encompasses the productivity ability of human labour including knowledge, skills and the quantity of labour (itself a function of the labour force and participation rates).

Social capital might appear to be a somewhat fuzzy concept, but for the purposes of the capital stocks model, it can be defined in relatively straight-forward terms as productive shared norms and values such as social trust, the rule of law and other intangible assets that allow for constructive engagements between people. Natural capital, on the other hand, is more complex. At the general level, natural capital refers to all aspects of the natural environment that support human life and well-being. This includes not only natural assets used directly in the production process such as minerals, forests, and soil, but also natural assets valued by people for cultural, recreational, or aesthetic reasons and assets valued for the ecosystem services that they provide such as flood control or carbon absorption and sequestration.[3] Unlike produced capi-

3 The issue of climate change provides a useful illustration of the difference between well-being and the capital stocks in the capital stocks model. Current well-being may be enhanced by the use of fossil fuels which allows for higher consumption in the present. However, by exceeding global capacity to absorb atmospheric carbon the use of fossil fuels reduces the natural capital stock. This will impact on the levels of well-being able to be produced for future generations.

tal and (to a lesser degree) human capital – which are traded in the market and can therefore be valued using money as a common metric – natural capital has no single over-arching measure of value and is inherently multi-dimensional.

A second important point regarding the capital stocks model relates to issues of aggregation. While it is possible to analyse the distribution of current well-being across the population (and this is a major focus of the well-being measurement agenda — see, for example, Stiglitz, Sen, Fitoussi, 2009; UNECD, 2014), this is not possible for the well-being of future generations where we do not know the size and make-up of these generations nor their endowments, preferences and constraints. To address this issue, the capital stocks model focuses on the aggregate levels of each capital stock to assess the intergenerational sustainability of well-being. Although it is not possible to know the distribution of the well-being of future generations, it is conceptually possible to assess whether the current generation passes on a greater or lesser total endowment of the resources required to produce well-being (i.e. the capital stocks) to future generations.

While viewing the capital stocks framework through the lens of a Solow-Swan growth model represents a ruthless simplification of a complex issue, such an approach also has significant advantages. In particular, it provides a framework for examining the relationship between the capital stocks and well-being in empirical terms. In contrast to the extensive literature on the measurement of well-being and the determinants of well-being at an individual level, there is comparatively little empirical literature focusing on the relationship between the capital stocks and well-being, and even less that considers this from the perspective of productivity.

The closest study to our approach in terms of scope is Vemuri and Costanza (2006), who model well-being on the basis of capital stocks using data from the UNDP and propose a National Well-being Index based on this analysis. They find natural capital to have a significant impact on life satisfaction along with the joint impact of human and produced capital as reflected in the Human Development Index. Engelbrecht (2015) explores the contribution of both social and natural capital to well-being and finds a significant relationship in both cases. However, neither Vemuri and Costanza nor Engelbrecht directly consider issues of productivity. Another empirical examination of the relationship between well-being and the capital stocks is Qasim and Grimes (2021), who consider how the relationship between genuine savings and well-being varies in the short and long run. Genuine savings is typically defined as aggregate net savings less depreciation in stocks of both natural and produced capital. They find support for the capital stocks model in that genuine savings is negatively related to well-being in the short run but has a positive correlation in the long run. This is consistent with the capital stocks model in that there is a trade-off between savings and consumption in the short run, but in the long run, a higher genuine savings rate implies greater investment in the capital stocks and higher future consumption.

One of the few papers that does investigate the capital stocks model from an empirical perspective, and which also discusses the TFP in this context is Arrow *et al.* (2012). However, the focus of Arrow *et al.* is to define comprehensive wealth (the discounted present value of the capital stocks) rather than to investigate the relationship between the capital stocks and well-being. Consequently, while a conventional measure of TFP is incorporated into their model, Arrow *et al.* do not investigate productivity from the perspective of the efficiency with which the capital stocks contribute to overall well-being. It is, however, precisely this issue that is the focus of this article.

Method

To begin, it is necessary to provide a definition of well-being. Consider the following utility function:

$$U = f(C, Y) \tag{1}$$

where Y is income and C is a vector of non-market outcomes important to a person's well-being. If we are willing to accept a measure of subjective well-being, such as life satisfaction, as a (noisy) proxy for utility then it is possible to empirically estimate a utility function as follows:

$$W_i = \beta_0 + \beta_1 C_i + \beta_2 \ln(Y_i) + \varepsilon \tag{2}$$

In this equation W_i is the life satisfaction (well-being) of person i, C_i is a vector of non-market drivers of life satisfaction (e.g. health status, knowledge and skills, safety) experienced by person i and Y_i is the income of person i. Note that life satisfaction is a bounded measure (typically from 0 to 10) while income is unbounded on the upward side. This imposes the log-linear relationship between life satisfaction and income in equation (2) and is widely supported empirically (Deaton, 2008; Sacks, Stevenson, and Wolfers, 2012). In contrast, C_i is assumed to have a linear relationship with life satisfaction since most of the non-market outcome measures typically included in regressions of this type (Boarini *et al.*, 2013), are bounded themselves.

To incorporate the capital stocks into the model it is necessary to set out an approach to production. The simplest way to approach this is simply to consider well-being as the single output of an aggregate production function. Equation (3) sets out this approach where W_c is mean life satisfaction of country c, $\acute{A}_c$ is TWP for country c, K_c is the per capita (produced) capital stock of country c, and L_c is the per capita human capital stock of country c which is assumed to be a function of the labour utilisation rate and the mean level of education.

$$W_c = \acute{A}_c K_c^{\rho_1} L_c^{\rho_2} \tag{3}$$

While something like equation (3) is implicit in the capital stocks model, this very reduced form approach fails to take the utility function seriously and is difficult to decompose in any useful way to provide an insight into what drives the underlying relationships. An alternative — or possibly complementary approach — is to consider the market and non-market contributions to well-being separately. Equations (4) and (5) below specify respectively an aggregate production function for market goods, which we can assess through income (Y) and a similar production function for non-market goods.

$$Y_c = A_c K_c^{\alpha_1} L_c^{\alpha_2} \tag{4}$$

$$C_c = \ln\left(a_c K_c^{\gamma_1} L_c^{\gamma_2}\right) \tag{5}$$

Equation (4) is relatively straightforward, with A_c being the TFP of country c, Y_c being per capita income of country c, K_c and L_c capture produced and human capital as in equation (3). Note that this is the standard growth accounting aggregate production function and can be used to estimate TFP. Non-market production — equation (5) — is similar, with a_c being the non-market TFP of country c and C_c being a vector of mean non-market outcomes for country c. For simplicity it is assumed that the production of non-market outcomes and market outcomes is non-rival in terms of K and L.[4]

Given information on Y_c, K_c, and L_c it is possible to estimate α_1, α_2, and A_c, capturing the elasticity of output with respect to produced and human capital respectively and TFP. Taking the log of equation (4) we can estimate the relationship as model (6):

$$\begin{aligned} \ln(Y_c) &= \ln(A_c) + \alpha_1 \ln(K_c) \\ &+ \alpha_2 \ln(L_c) + \varepsilon \end{aligned} \tag{6}$$

Solving equation (6) for A_c is trivial and gives an estimate of TFP as the Solow-Swan residual. While this is not the preferred approach to estimating TFP in most circumstances, it has the appeal here that a similar approach can potentially be applied to equation (5). Estimating A_c and a_c using the same method in turn allows for a comparison between the two measures of productivity without bias introduced due to method effects.

Estimating equation (5) is a little more involved than is the case for equation (4). In particular, we lack a definitive list of non-market outcomes and, even were such a list available, there is no common metric on which we could assess them. Rather than estimating equation (5) directly, it is therefore necessary to approach the issue via measures of overall well-being. In particular, we can estimate the contribution of non-market outcomes to overall well-being by looking at how levels of overall well-being vary after accounting for the impact of market outcomes. Equation (7) presents the country level equivalent of equation (2):

$$W_c = \beta_0 + \theta_c + \beta_1 C_c + \beta_2 \ln(Y_c) + \varepsilon \tag{7}$$

All variables in equation 7 are country means. The constant θ_c has been introduced to capture cultural response bias that might introduce non-random measurement error across countries. Rearranging (7) we can define $\not{W}_c$ as non-market variance in life satisfaction as follows:

$$\not{W}_c = W_c - \beta_0 - \beta_2 \ln(Y_c) \tag{8}$$

If we then substitute in equation (4) this then gives the following identity (9):

$$\begin{aligned} \not{W}_c &= \theta_c + \beta_1 C_c \\ &= \theta_c + \beta_1 \ln\left(\alpha_c K_c^{\gamma_1} L_c^{\gamma_2}\right) \end{aligned} \tag{9}$$

4 In reality, some aspects of the capital stocks will be non-rival and others will be rival. The issue of allocating capital across the non-market and market sectors is left for further work. It should be noted, however, that conceptually the assumption that market and non-market goods are non-rival between equations (3) and (4) is not different to the assumption that the issue of rival uses of capital can be ignored within the equation (3) on its own (i.e. between different market goods).

If a credible control for cultural response bias in life satisfaction can be identified, it is then possible to estimate non-market TFP directly as follows:

$$W_c - \theta_c = \beta_1 a_c + \beta_1 \gamma_1 \ln(K_c) + \beta_1 \gamma_2 \ln(L_c) + \varepsilon \tag{10}$$

If equation (10) is estimated empirically, we cannot observe γ_1 and γ_2 directly as the coefficients on produced capital per capita and human capital per capita will be $\beta_1\gamma_1$ and $\beta_2\gamma_2$. However, the ratio of the two coefficients $\frac{\beta_1\gamma_1}{\beta_2\gamma_2}$ can be compared directly to the ratio of the two elasticities from equation (4): $\frac{\alpha_1}{\alpha_2}$. Similarly, the residual estimate of non-market TFP from equation (9) will be a linear transformation of actual non-market TFP (i.e. we observe $\beta_1\alpha_c$ rather than α_c). However, since β_1 is a constant and non-market TFP is an index with no natural units, the observed value ($\beta_1 a_c$) is sufficient to identify countries where market TFP and non-market TFP differ.

Empirically estimating the model in equation (9) requires, in addition to the underlying data, good estimates of β_2 (the income coefficient on life satisfaction) and θ_c (cultural response bias in life satisfaction). The former is easy to obtain and can be estimated from a cross-country life satisfaction regression along the lines of that presented in equation (7) or taken directly from the substantial existing academic literature (Sacks, Stevenson, and Wolfers, 2012). Cultural response bias, on the other hand, is more difficult to estimate.

The key challenge in estimating cultural response bias is that it is difficult to distinguish between cultural response bias (a measurement error that should be corrected for) and genuine cultural impacts on well-being or omitted variables affecting life satisfaction (both of which should not be corrected for). A number of approaches have been proposed to identify cultural response bias including the use of anchoring vignettes (Kapteyn, Smith, and van Soest, 2010) and leveraging differences between country of birth and country of residence (Senik, 2014; Exton, Smith, and Vandendreische, 2015). While vignettes require extensive data collection, it is possible to estimate a value for θ_c from any dataset with information on life satisfaction, country of residence and country of birth. The simplest approach[5] to this is as follows:

$$W_{i,r,b} = \beta_0 + \beta_1 D_i + \theta_b + \mu_r + \epsilon \tag{11}$$

In equation (11) $W_{i,r,b}$ is the life satisfaction of individual i residing in country r and born in country b, while D_i is a vector of demographic controls. Finally, θ_b and μ_r are vectors of dummy variables for country of residence and country of birth each having a value of 0 for all countries except for those where the respondent was born and currently resides. From this regression we can interpret the coefficient on θ_b as the impact of having been born in a specific country independently of the impact of current influences on life satisfaction from where one lives (μ_r). Thus θ_b captures the impact of residual social ties to one's country of birth as well as the impact of culture on

5 Adopting a more sophisticated approach to estimating cultural response bias by following Senik (2014) more closely is an obvious extension to this article.

life satisfaction responses.

The approach presented above in equations (4) to (10) breaks TWP down into two elements: market and non-market. This is useful to understand why countries differ in well-being and the relative roles of productivity and the capital stocks in explaining cross-country variation in well-being. Importantly, this provides a framework for empirically assessing aspects of the capital stocks model. In particular, there are three key relationships to be tested:

I. If the capital stocks are not important drivers of non-market outcomes (i.e. $\beta_1\gamma_1 = 0$ or $\beta_1\gamma_2 = 0$) then the capital stocks model is fundamentally broken.

II. We can also compare whether the role of the capital stocks in producing non-market outcomes is similar to that for market outcomes (i.e. test whether $\frac{\beta_1\gamma_1}{\beta_2\gamma_2} = \frac{\alpha_1}{\alpha_2}$).

III. Finally, it is interesting to see whether the relationship between TFP for market outcomes is similar to that for non-market outcomes (i.e. is there a consistent linear relationship between A_c and a_c).

The models discussed above focus on developing an estimate of non-market productivity comparable to traditional estimates of TFP. However, the capital stocks model of well-being usually incorporates four different capital stocks rather than just two: produced capital, human capital, natural capital, and social capital. If measures of natural capital and social capital are available, extending equations (3), (4) and (5) to include the full range of capitals in the capital stocks model is straight forward. If S_c is a measure of country-level social capital, such as generalized trust (Smith, 2020), and N_c is a measure of the overall stock of natural capital then:

$$W_c = A_c K_c^{\rho_1} L_c^{\rho_2} N_c^{\rho_3} S_c^{\rho_4} \tag{12}$$

$$Y_c = A_c K_c^{\alpha_1} L_c^{\alpha_2} N_c^{\alpha_3} S_c^{\alpha_4} \tag{13}$$

$$C_c = \ln\left(a_c K_c^{\gamma_1} L_c^{\gamma_2} N_c^{\gamma_3} S_c^{\gamma_4}\right) \tag{14}$$

This extension of the model allows testing the significance of social and natural capital and the impact of their inclusion in the model on the coefficients for produced capital and human capital.

All of the models estimated in the article use a simple cross-sectional regression strategy with robust standard errors to control for clustering of observations at the country level. While a fixed effects regression would be possible with the cross-country panel dataset used here, the residual in such a regression could not be interpreted as a measure of TFP. We are, however, able to test directly for the impact of bias in the cross-sectional model by comparing estimated TFP from the model with methodologically independent estimates of TFP from the Penn World Tables.

Data

Four data sources are used in the empirical section of this article. These are the European Social Survey (ESS), the Corruption Perceptions Index, the Penn World Tables, and the BII (Phillips *et al.*, 2021).[6] Information on life satisfaction and trust is provided by the ESS. The ESS is a biennial survey of attitudes, values, and beliefs run across 38 countries in Europe since 2002. Using the ESS cumulative dataset gives information on 9 waves of the survey covering 2002 to 2018 and 427,656 valid responses. This information is collapsed to produce a cross-country panel dataset containing the mean life satisfaction and mean generalized trust score for each country and survey wave. Individual level data from the ESS is also used to provide an estimate of cultural response bias.

Interpersonal trust is, perhaps, the best single measure of social capital (Smith, 2020) in the sense in which it is used in the capital stocks model (i.e. as a productive resource). However, there is a risk that the correlation between interpersonal trust and life satisfaction at the country level might be biased due to shared method variance (OECD, 2013a). The Corruption Perceptions Index is a composite indicator of public sector corruption produced by Transparency International. It covers 180 countries and is comparable for time series purposes from 2012 onwards. Sources for the Corruption Perceptions Index come from 13 different surveys and expert assessments (Transparency International, 2020). Importantly, these assessments are external to the countries under evaluation meaning that — unlike the ESS trust measure — there is no risk of correlation with life satisfaction due to survey effects or cultural response bias. However, as illustrated in Chart 2, the Corruption Perceptions Index is strongly correlated with generalized trust across countries. On this basis the Corruption Perceptions Index is used as a proxy measure of social capital in the growth regressions that form the core of this article.

Information on GDP, produced capital, human capital, and market TFP[7] was obtained from the Penn World Tables (Feenstra, Inklaar, and Timmer, 2015), covering the same period as for the ESS. Although estimates of TFP in the next section are derived directly from the Solow-Swan residual, the Penn World Table measure of TFP provides a useful validity check to ensure that the cruder approach required here for consistency with the TWP measures is not introducing any systematic bias.

Table 1 presents the variables used in the analysis along with basic descriptive information. Real GDP per capita is output GDP at constant prices (PPP) across countries in 2017 US dollars and divided by population. Following Inklaar, Woltjer, Albarrán and Gallardo (2019), the capital services measure from the PWT divided by population is used for produced capital per capita (K_c). Human capital per capita is an index calculated as persons engaged in the labour market multiplied by average hours worked multiplied by the PWT human capital index divided by population.

6 The dataset constructed herein is available to researchers upon request.

7 The term market here is used to distinguish production that falls within the scope of measured GDP from other wider drivers of life satisfaction such as health status, safety, or social contact rather than in the sense of distinguishing private sector from government activity. Market TFP is therefore used to refer to the Penn World Tables measure of TFP for the total economy.

Chart 2: Comparison of the Corruption Perceptions Index and ESS Interpersonal Trust Scores, 2012 to 2018

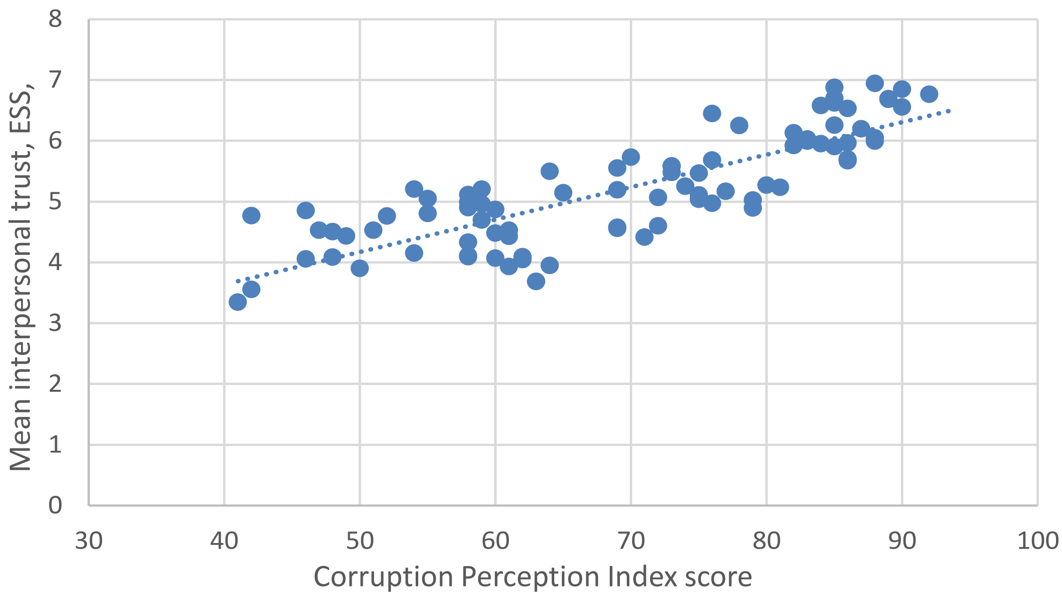


Table 1: Cross-Country Dataset

Variable	Min	Max	Mean	Observations	Country coverage	Years covered	Source
Real GDP per capita in 2017 $US (Y)	13082	92226	35667	206	31	2002-2018	PWT
Capital services level per capita million 2017 $US (K)	0.00037	0.00628	0.00232	206	31	2002-2018	PWT
Human capital per capita (L)	1165	3547	2504	206	31	2002-2018	PWT
TFP at current PPP (cTFP)	0.549	1.511	0.869	206	31	2002-2018	PWT
Mean life satisfaction (W)	4.54	8.54	7.15	206	31	2002-2018	ESS
Mean interpersonal trust	3.35	6.95	5.2	206	31	2002-2018	ESS
Corruption perceptions index (S)	41	92	69	102	34	2012-2020	Transparency International
Biodiversity Intactness Index(N)	0.406	0.96	0.715	223	36	2002-2018	Natural History Museum
Cultural response bias (θ)	-0.321	0.593	0.169	31	31	n/a	ESS - derived

The BII is an index developed by the UK Natural History Museum (Phillips *et al.*, 2021) that summarises the impact of human pressures on ecosystems. It is based on the estimated percentage of the original species that remain and their abundance within a given area. The BII is intended as a proxy measure for total natural capital per capita that is more inclusive than alternative estimates such as that produced by the World Bank (2006) which are built from a "bottom-up" approach with individual components added over time (Engelbrecht, 2015). The land-cover approach taken here avoids the bias due to missing components issues with the World Bank dataset at the expense of greater measurement error. It also helps avoid some of the issues of multicollinearity associated with the World Bank's dollar value estimates of capital stocks.[8]

Previous studies of well-being and the four capital stocks (Vemuri and Costanza, 2006) found multicollinearity between measures of capital caused significant econometric issues in estimating the relationship between different capital stocks and well-being. The datasets used here suffer significantly less from multicollinearity than those used by Vemuri and Costanza. The only statistically significant bivariate correlation between the capital stocks in this study is between produced capital and social capital which are correlated with an r value of 0.67. This difference in capital stock measures is almost certainly due to the fact that the dataset used by Vemuri and Costanza reports the dollar value of the capital stocks – thus ensuring that stock measures are correlated at the country level through price levels[9] — while the measure of human capital used here is a simple index of labour force variables.

Adjusting for cultural response bias is one of the most significant empirical challenges associated with the proposed analysis. The estimates of cultural response bias in Table 1 are derived from an analysis of the ESS based on equation (11). The full results of the model are not reported here[10] as the regression structure is relatively uninteresting and consists largely of two long vectors of dummy variables. Ideally it would be possible to test these estimates against other comparable estimates of cultural response bias, but there are relatively few comparable estimates available in the literature that could form the basis of a direct comparison.

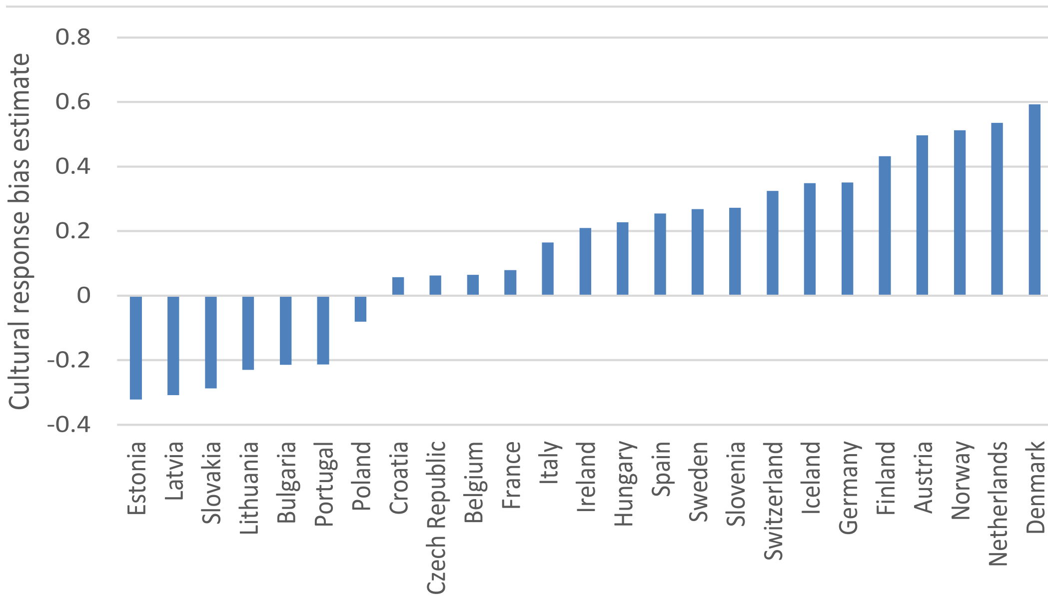
Exton, Smith, and Vandendreissche (2015) use a similar approach to identifying cultural response bias and find that it accounts for a maximum of approximately 20 per cent of cross-country variation in life satisfaction. However, they do not provide country-specific estimates. Senik (2014) uses a slightly more sophisticated version of the same approach and obtains estimates of

8 Additional information on the methodology of the BII can be found at https://www.nhm.ac.uk/our-science/data/biodiversity-indicators/about-the-biodiversity-intactness-index.html.

9 For example, the price of human capital — the wage rate — is a function not only of years of schooling and work experience, but also of the capital to labour ratio in the country and is therefore correlated with measures of produced capital.

10 Full regression results are available on request from the authors.

Chart 3: Estimated Cultural Response Bias



Notes: 1. Y-axis values are mean cultural difference in life satisfaction (0-10)

cultural response bias for a relatively small number of countries. In Senik's analysis the Nordic countries (Norway, Sweden, and Denmark) are characterized by a high positive bias in life satisfaction, while Portugal and France have a small negative bias. The only ex Eastern-bloc country reported by Senik has the largest negative coefficient. This pattern is replicated in Chart 3, which shows the cultural response bias estimates used in this paper.

Results

Table 2 reports the results of a well-being regression based on equations (3) and (12). This captures the combined effect of the capital stocks on well-being from both market and non-market outputs. Columns (A) and (E) correspond to model (3) while columns (D) and (H) correspond to model (12). The intermediate columns (B), (C), (F), and (G) add natural capital and social capital independently to model (3). As a sensitivity test, the same analysis is repeated twice. The first four columns of Table 2 (A) to (D) use mean life satisfaction adjusted for cultural response bias as the dependent variable, while the second four columns (E) to (H) use unadjusted mean life satisfaction. The data underlying these regression models cover the period from 2002 to 2018.

A comparison of the models using adjusted life satisfaction and those using unadjusted life satisfaction shows very little qualitative difference between them with the exception that produced capital (K) has a larger impact on unadjusted life satisfaction under all model specifications than it does on adjusted life satisfaction. Both human capital (H) and produced capital are consistently significant across all model specifications as is social capital (S) when it is included. Natural capital (N) is significant when included alongside human capital and produced capital but loses significance when social capital is added. An examination of the R^2 shows that the nat-

Table 2: Full Capital Stocks Model

Variable	Life Sat (adjusted for cultural response bias)				Life Sat (not adjusted for cultural response bias)			
	(A)	**(B)**	**(C)**	**(D)**	**(E)**	**(F)**	**(G)**	**(H)**
$\ln(L)$	1.31**	1.17*	0.99**	0.94*	1.33*	1.20^	0.94^	0.92^
$\ln(K)$	0.79**	0.81**	0.24*	0.27	1.15***	1.17***	0.48^	0.49^
$\ln(N)$		0.53*		0.20		0.50		0.09
$\ln(S)$			1.85***	1.79***			2.25***	2.22***
Adj. R^2	0.457	0.482	0.681	0.682	0.531	0.542	0.733	0.730

Notes: $^{***}p < 0.001, ^{**}p < 0.01, ^{*}p < 0.05, ^{\wedge}p < 0.1$

Table 3: Market and Non-market Decomposition

Variable	$\ln(Y)$	$\ln(Y)$	$\ln(Y)$	$\ln(Y)$	$\not{W}_c - \theta_c$	$\not{W}_c - \theta_c$	$\not{W}_c - \theta_c$	$\not{W}_c - \theta_c$
	(J)	**(K)**	**(L)**	**(M)**	**(N)**	**(P)**	**(Q)**	**(R)**
$\ln(L)$	0.32	0.35^	0.23	0.28^	0.93*	0.75*	0.71^	0.61^
$\ln(K)$	0.66***	0.65***	0.51***	0.48***	0.02	0.04	-0.36^	-0.30
$\ln(N)$		-0.12		-0.22		0.67		0.46
$\ln(S)$			0.51**	0.57**			1.25***	1.12**
Adj R^2	0.767	0.769	0.813	0.826	0.085	0.168	0.279	0.310

Note: 1. $^{***}p < 0.001, ^{**}p < 0.01, ^{*}p < 0.05, ^{\wedge}p < 0.1$

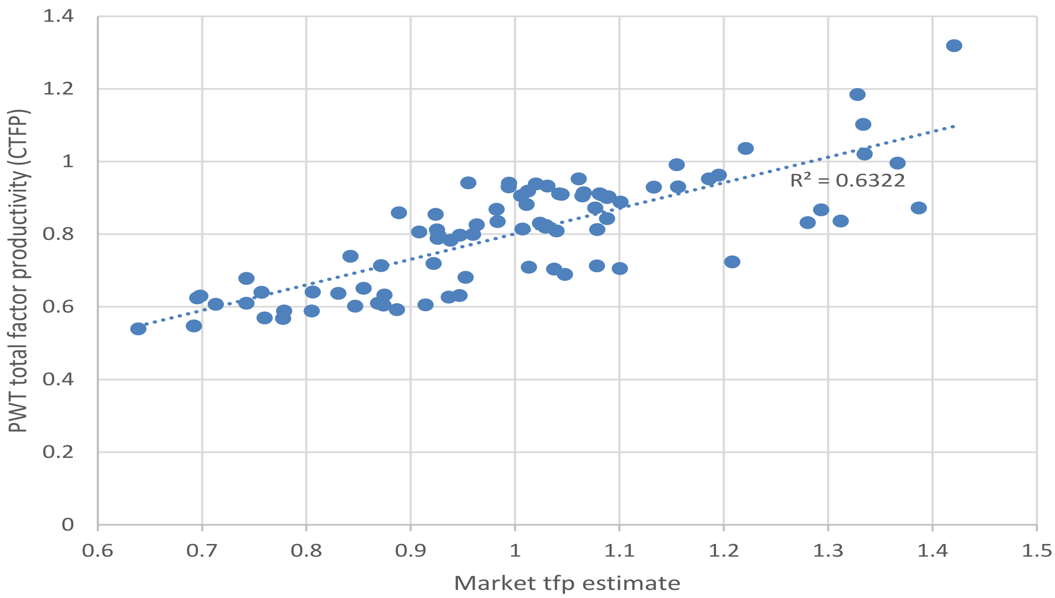
ural capital measure used here adds relatively little to the total variance explained compared to the other three measures.

Broadly speaking the results in Table 1 can be considered supportive of the capital stocks model in that all coefficients have the expected sign and all are significant except natural capital in columns D, F, and H. There is clearly some evidence of an interaction between the social capital measure used here and produced capital, with produced capital having a much lower coefficient once social capital is included in the model. This may reflect the impact of omitted variable bias in the regression where produced capital is correlated with TFP and social capital explains a significant proportion of conventional TFP measures (Smith, 2020; Coyle and Lu, 2020).

Table 3 examines the relative contributions of the capital stocks to market and non-market output. Columns (J) to (M) estimate equation (6) while columns (N) to (R) estimate equation (10). It is apparent that the picture for market outcomes is generally similar to that for overall well-being (Table 2). Human capital, produced capital, and social capital all have positive and significant coefficients. In contrast to Table 2, human capital has a smaller impact than produced capital on market outcomes and is insignificant when social capital is included on its own (L) and is very marginally insignificant in the basic model ($p = 0.104$). The main difference between market outcomes in Table 3 and the results in Table 2 is that the relationship between natural capital and market output is negative and not significant.

The situation for non-market outcomes

Chart 4: Model Estimates of Total Factor Productivity vs Penn World Table Estimates



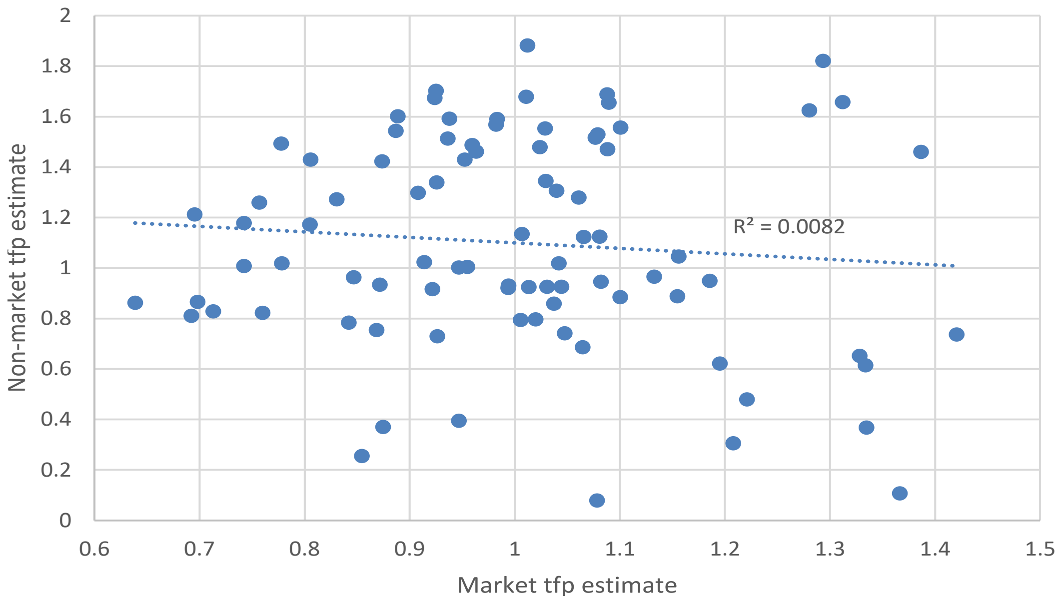
is quite different. Both human capital and social capital are significant in all versions of the model. Produced capital is insignificant in the first two model specifications (N) and (P) but has a marginally significant negative coefficient in model Q, which includes social capital. This result is robust to the choice of adjusted or raw life satisfaction data as the dependent variable and to the choice of mean trust or the corruption perceptions index as the measure of social capital. This counter-intuitive result is likely to be grounded in our approach to estimating non-market well-being (equation 5) in that the empirical estimate of the effect of income on life satisfaction may also capture the positive impact of produced capital on life satisfaction since income and produced capital are correlated with each other.[11]

It should be noted that the coefficients in columns (N) to (R) cannot be directly compared to the coefficients for market goods in columns (J) to (M) as the non-market coefficients represent $\beta_1\gamma_n$ rather than γ_n. Coefficient ratios can be compared between the market and non-market regressions and it is interesting to note that the ratio of the coefficient for human capital to that for social capital is relatively similar across both sets of regressions. However, this is clearly not the case for produced capital.

With the results presented in Tables 2 and 3 it is possible to calculate a range of measures of TFP. These include TWP (TFP with respect to life satisfaction) from columns (A) to (D) of Table 2, market TFP from columns (J) to (M) of Table 3, and non-market TFP from columns (N) to (R) of Table 3. A useful validity test of the models presented in these Tables is to compare market TFP from column (J) of Table 3 to the estimates of TFP from the PWT (cTFP). Chart 4 shows a scat-

11 An example of this is that the non-market benefits provided by a roading system are likely to be highly correlated across countries with the impact of a roading system on market outcomes.

Chart 5: Model estimates of market and non-market productivity



terplot of market TFP against cTFP from the PWT. Although the correlation is only moderate[12], there is a clear linear relationship between the two measures.

Given that the estimate of market productivity is reasonable, it can be compared with an estimate of non-market productivity calculated in a similar way from column (N) of Table 3. This is presented in Chart 5. It is immediately evident from Chart 5 that there is essentially no correlation between market productivity and non-market productivity. This suggests that the production "technologies" of the market and non-market sectors are fundamentally different (i.e the way resources are combined to produce well-being is not similar for market goods and non-market goods).

Moving from non-market productivity, Chart 6 compares TWP to market TFP. Panel A of Chart 6 illustrates the relationship where productivity is calculated on the basis of produced and human capital only (columns A and J). In this instance the impact of social capital is folded into TFP. Panel B of Chart 6 compares productivity estimates based on columns (D) of Table 2 and (M) of Table 3. This gives a narrower measure of TFP with social capital now accounted for in the capital stocks and therefore not reflected in the productivity measure.

Since well-being is considered a function of both market and non-market output in the capital stocks model, it is unsurprising to see that there is a correlation between market TFP and TWP. However, this relationship is weak. It is evident in Panel A, but only barely exists in Panel B. Both panels in Chart 6 show significant differences in TWP across countries. Chart 7 explores this further, presenting the mean TWP over the 2002-2020 period for all the countries covered in Chart 6. Be-

12 Observations with high productivity in PWT but not in the residual are Ireland, Poland, and one observation for Bulgaria.

cause Chart 7 shows country mean values while Chart 6 includes estimates for each country/year observation, Chart 7 contains fewer data points.

One common criticism of TFP as a concept is that measures of it can be hard to interpret. This is doubly the case for the estimates of TWP provided here both because the dataset used is exploratory and because there is little literature to provide the basis for comparison. A few observations, however, can be made. First, accounting explicitly for stocks of social capital changes the picture of the Nordic countries in terms of the production of well-being. With the exception of Denmark — which records a relatively high TWP — most of the Nordic countries perform at around the average level despite relatively high life satisfaction. Norway is actually towards the bottom of the table which is consistent with the country's relatively high level of human, produced, social, and natural capital stocks contrasted against well-being levels not very different to the other Nordic countries.

Similarly, while a cross-country analysis of life satisfaction shows a strong post Eastern-bloc effect associated with lower levels of subjective well-being (Senik, 2014), looking at TWP shows a more diverse picture. While some former Eastern-bloc countries have a very low TWP (Bulgarian, Hungary), others are amongst the best performing (Poland, Croatia). All four countries are associated with similar low levels of social trust, but Poland and Croatia have far better well-being outcomes than would otherwise be expected.

Conclusion

This article investigates the concept of productivity from within the framework of the capital stocks model of well-being. In particular, it estimates TWP — the efficiency with which resources (the capital stocks) are used to produce well-being — as a Solow-Swan residual in a modified cross country growth regression. Although the dataset used here is more exploratory than definitive, it is possible to identify some interesting themes.

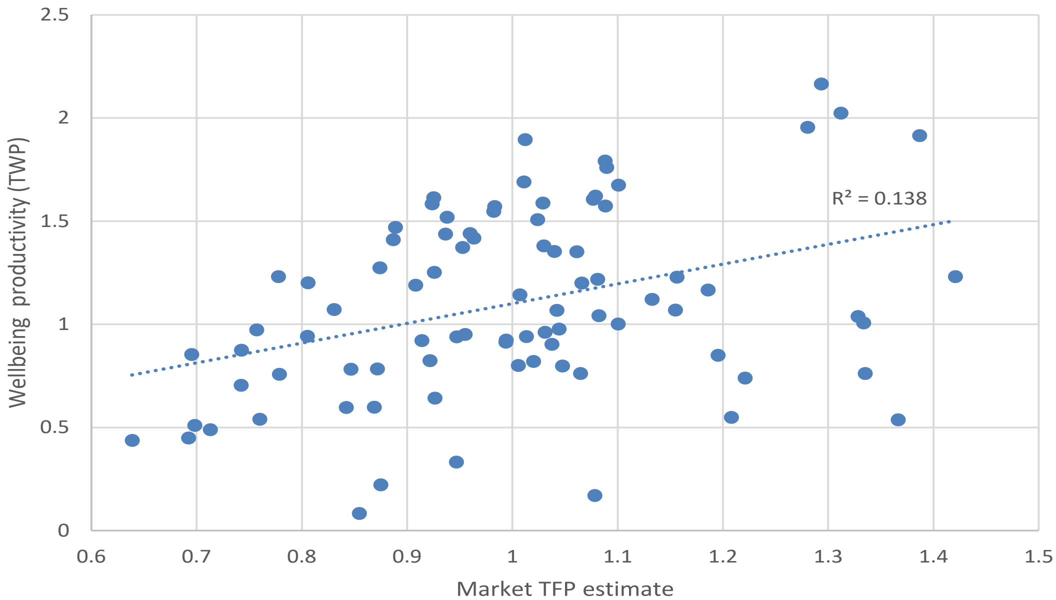
Main findings

There are three key findings from our initial exploratory analysis. First, there is considerable variation in TWP across countries. In other words, once differences in factor endowments are controlled for, there are still important differences in levels of well-being across countries. This is important because it suggests that there are ways to improve well-being that do not involve increasing the levels of the capital stocks. Reconciling the moral imperative to improve the well-being of the population living in less developed countries with the limits of a finite planet is, perhaps, the defining global policy challenge of the present time. Further investigation of TWP is therefore of some potential policy interest if it can offer insights into how some countries are able to achieve higher levels of well-being from a given capital endowment than others.

The second main finding is that the aggregate production functions for market and non-market outcomes appear to be very different. This can be seen both in the different coefficients for the capital stocks in the market production function com-

Chart 6: Well-being productivity compared to TFP with and without including social capital

Panel A: TFP includes social capital



Panel B: TFP does not include social capital

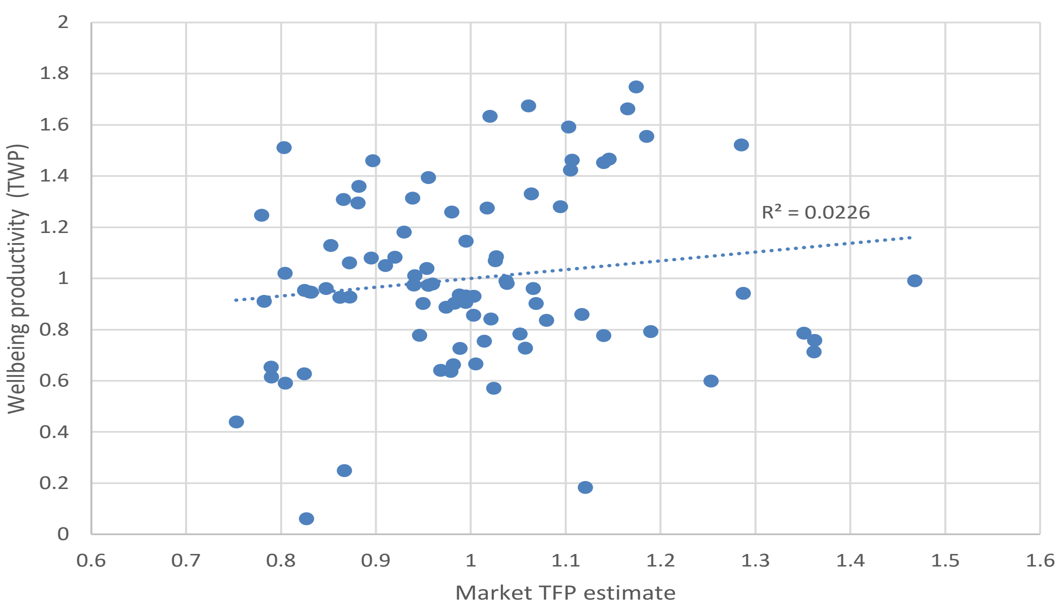
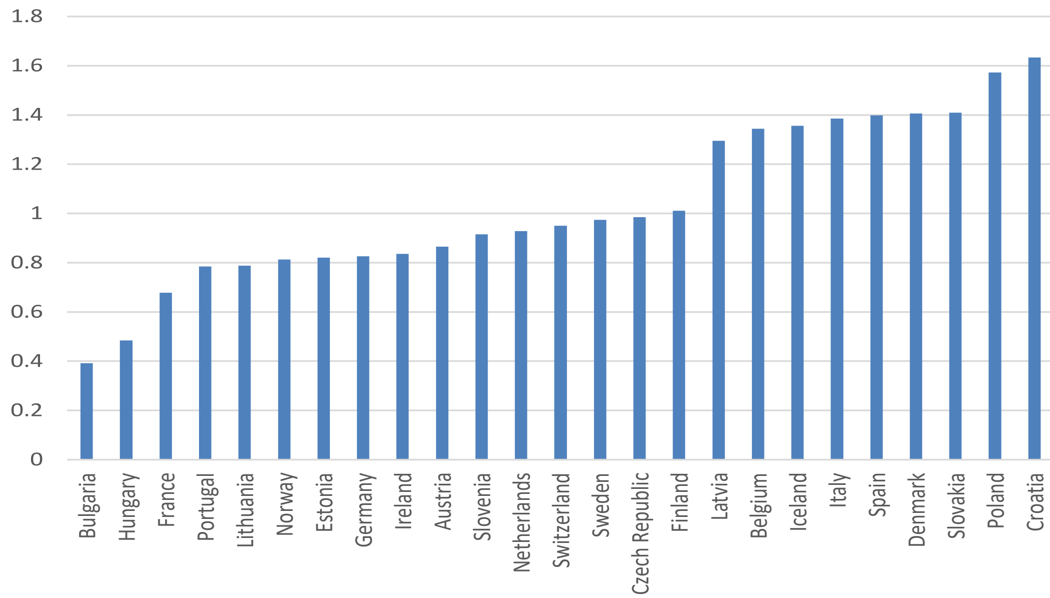


Chart 7: Mean Well-being productivity (TWP), 2002-2020



pared to the non-market production function and also in the lack of correlation between TWP and traditional TFP measures. One empirical implication of this is that policies aimed at maximizing market output will not necessarily maximise total well-being as the non-market elements of well-being have very different drivers. If the relationships estimated in this article hold, it also suggests that investments in human and social capital — which have a clear positive impact on both market and non-market outcomes — might be expected to have a larger impact on overall well-being than investments in produced capital (which has a positive correlation only with market outcomes). This is consistent with the case made elsewhere for the importance of social and human capital (World Bank, 2006; Helliwell, Huang, and Wang, 2017)

Finally, the empirical analysis confirms that the capital stocks are significant in the production function for well-being. The levels of produced, human, and social capital all have the expected relationship with overall well-being which supports the relevance of the capital stocks model as a way of conceptualising intergenerational well-being. Natural capital is an exception here, showing only a weak relationship with life satisfaction which vanishes when social capital is included in the model. The decomposition of well-being into market and non-market outcomes illuminates this issue showing a negative relationship between natural capital and market outcomes but a strong positive relationship between natural capital and non-market outcomes. One hypothesis suggested by this is market output is associated with the depletion of natural capital resources now and in the past (Qasim and Grimes, 2021) which results in a negative relationship between the current level of market output and natural capital. Non-market outcomes, on the other hand, might be associated more closely with nondepleting uses of natural capital.[13]

Limitations

This article is intended to be exploratory, and it is important therefore to acknowledge that it has significant limitations. Three of these are particularly important. First, the residual approach to estimating TFP faces the inherent issue that the residual of any regression analysis will also incorporate the error term. This is compounded in estimating TWP in that it is necessary to adjust life satisfaction to account for potential cultural response bias. This means that the estimate is effectively a residual of a residual, with potential error on both sides of the equation.

The issue of adjusting for cultural response bias, however, goes beyond the issues associated with calculating productivity as a residual. As discussed earlier in the paper, cultural response bias is challenging to estimate. Because it cannot be observed directly and is difficult to distinguish from substantive differences in well-being caused by unobserved omitted variables, cultural response bias is difficult to control for in a robust fashion. Perhaps the best that can be hoped for here is to test the sensitivity of results to estimates of cultural response bias based on different methodologies.

Even if issues in the estimation of TWP are ignored, there are still significant challenges in interpreting the results. The decomposition of TWP into market productivity and non-market productivity illustrates this issue. While market productivity is simply conventional TFP and can be interpreted as such[14], non-market productivity is more complicated to interpret. Because non-market consumption (C_c) is a vector not a quantity (i.e. consists of multiple different outcomes with no obvious common metric such as health status, safety, and social contact), estimated differences in non-market productivity might be due to differences in the relative make-up of C_c across countries rather than differences in the effectiveness with which the capital stocks are used. Different aspects of non-market consumption — such as health status and social contact — might be expected to have different production technologies. With the approach to estimating non-market productivity adopted here it is impossible to distinguish between different non-market consumption bundles and differences in the quality of non-market production technology.

Given the issues identified above, what is the value of attempting to estimate TWP? First, looking at TWP is important simply because the concept is implicit in the most widely adopted approaches to measuring well-being and assessing sustainability. This can be seen in the academic literature on the capital stocks model (Engelbrecht, 2009; Arrow *et al.*, 2012; Qasim and Grimes, 2018), the approach taken by international organizations (World Bank,

13 For example, consider a forest. The use of the forest's wood resources for market outcomes is likely to have a negative impact on the forest ecosystem in a way that the forest's provision of ecosystem services for non-market outcomes (such as air quality or recreational use) does not.

14 Note that the interpretation of conventional TFP is not, itself, uncomplicated. TFP has no natural units and the aggregate production function approach to estimating TFP has been criticized (Felipe and McCombie, 2006).

2206; OECD, 2013, 2015; Hamilton and Liu, 2013), and in the analytical frameworks adopted by governments (OECD, 2016; Ormsby, 2018, National Economic and Social Development Office, 2021). Because the capital stocks model is used to inform and evaluate policy decisions it is important to test it. The limitations identified above exist, regardless of whether the model is used in a quasi-anecdotal fashion to justify indicator dashboards or if it is taken more seriously as a quantitative model. However, it is only by exploring the implications of the capital stocks model in a quantitative fashion that some of these limitations are identified.

It is also important to reflect that the challenges associated with estimating TWP are not unique. Market consumption may have a common metric in terms of market prices, but it is fundamentally just as much a vector of different elements as is non-market consumption. This is of particular relevance in the context of the produced capital stock (K). The so-called Cambridge capital controversy, for example, largely revolved around precisely the issue of whether the capital stock could reasonably be treated as a single quantity when it, in fact, consisted of a wide range of different capital items that were not necessarily good substitutes for each other (Cohen and Harcourt, 2003). What is interesting in this comparison is that, while the criticisms of the notion of a single capital stock are clearly valid, this has not prevented analyses of economic growth based on aggregate production functions contributing useful insights. Modern endogenous growth theory, for example, builds on and extends this framework (Romer, 1994).

Next steps

If the idea of TWP is worth exploring further, what are the next steps in this research agenda? There would appear to be two obvious directions to explore. First, better data would significantly improve the quality of TWP estimates compared to the analysis in this paper. The ESS focuses only on a relatively small number of high-income countries with relatively high levels of well-being and is thus not the ideal dataset from the perspective of examining variation in well-being outcomes. This could be addressed either through extending the analysis to include other similar datasets such as the World Values Survey or various national general social surveys (Fleischer, Smith, and Viac, 2016). Alternatively, the Gallup World Poll would provide a potentially suitable dataset covering a wider range of countries and with better ability to model cultural response bias (Exton, Smith, and Vandendreissche, 2015).

Better measures of the capital stocks are also important. While social capital might seem relatively abstract, the most widely used proxy measures function well (Smith, 2020). Natural capital, on the other hand is extremely difficult to measure. Existing measures tend to be either account for only a small proportion of the total natural capital stock or — as is the case with the proxy measure used in this paper — simply perform poorly.

There is also clearly scope to move beyond the relatively simplistic analytical framework used in this paper. Two obvious extensions would be to explore treating non-market consumption explicitly as a multi-dimensional vector and looking at whether there is evidence of different production "technologies" across the different aspects of non-market production. Introducing non-market consumption also raises the issue as to whether use of the capital stocks is rival across different outputs. Clearly, some elements of the capital stocks are strictly rival in that, if they are used to produce one output, they cannot be used to produce another. However, for other elements this is less the case. An educated worker is more productive in the paid market and is also likely to be more effective in producing non-market outputs.

Finally, if TWP can be measured — even with significant noise — it becomes possible to ask what drives differences between countries. This is a tremendously important policy issue globally, since there is limited scope to increase consumption of some capital stocks globally — particularly natural capital — but low levels of well-being in much of the world suggest that there is likely to be significant pressure to raise well-being. This tension suggests that identifying the drivers of TWP adds a potentially important dimension to growth economics.

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