When the mix matters:

Complementarities in Multidimensional Well-Being

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1. Introduction

Casual observation suggests that the question that one answers most often in a given day is : How are you?

This inquiry illustrates the omnipresence of the notion of well-being in conversations and in everyday life. Indeed, the concept of well-being and its desirability seem to be so fundamentally rooted in society and culture that "leading a good life" is sometimes quoted as the purpose of life itself. Recently, well-being has also been gaining increasing attention in the academic and policy sphere. In particular, since well-being is conceptually close to the theoretical notion of utility and allows a much broader analysis, a range of national and international initiatives call for application of well-being-based measurements of development for policy making (EC, 2009; Franco-German Ministerial Council, 2010; OECD, 2011a; Stiglitz, Sen, & Fitoussi, 2009)

The exclusive use of GDP as a measure of welfare has been criticised extensively, both on methodological and theoretical grounds (see e.g. Stiglitz et al., 2009). The use of GDP, in line with neoclassical economic theory, assumes that income allows the fulfilment of people's needs and wants and therefore follows utility closely. However, people's needs and wants are manifold as illustrated for instance in Maslow's pyramid of needs (Maslow, 1943). While income certainly facilitates the attainment of many goals, there are some fundamental dimensions of well-being that are unrelated or even negatively related to income (e.g. a promotion could imply higher income but also less leisure time for an individual). Therefore, well-being is an inherently multidimensional concept and focusing on income as the only dimension neglects the importance of other factors.

The multidimensionality of well-being and the related concepts of human development and poverty (essentially being the deprivation of well-being) is widely accepted in the literature (see e.g. Bennett & Mitra, 2013; French, Moore, & Canning, 2013; McGillivray & Shorrocks, 2005; OECD, 2011a) and reflected in its definitions. For instance, Stiglitz and colleagues define well-being to include "the full range of factors that influence what we value in living" (2009 p. 41). The OECD definition of well-being more specifically lists material and non-material aspects that are thought to contribute to a "good life" such as income, quality of housing, employment, health, environmental quality and education (OECD, 2011a). However, despite the general agreement that well-being is multidimensional, there has been little research done on the relation among the dimensions of well-being.

More specifically, in line with the micro-economic assumption of non-satiation, well-being is usually thought to increase with beneficial changes in any of its dimensions. Therefore, well-being is assumed to exhibit a certain degree of substitutability among its dimensions. This assumption is explicit when well-being is modelled through a *composite indicator*, i.e. aggregated into a single value, which is the most common approach in empirical comparisons of well-being and is also the approach undertaken in this project. For reasons of simplicity, composite indicators of well-being often assume perfect substitutability among their components. In this case, the negative effect of such factors as a bad health status or low quality housing can be compensated entirely by good values on other dimensions. However, it could be argued that, as an individual's situation in one dimension of well-being deteriorates relative to the others, the shortcomings in this dimension may become more salient and influential. If this is the case, the dimensions of well-being could be characterised as complements rather than substitutes.

Complementarity among the dimensions of well-being is a relevant concept for two main reasons. First, it would suggest diminishing marginal returns of well-being for each of its dimensions, which is a defining feature when specifying well-being as a function of its different dimensions. Second, in line with the recent interest in using well-being to inform policy interventions, complementarities among the well-being dimensions would have to be reflected in policy approaches. In particular, if well-being dimensions are complementary, it would be desirable to implement policies such that the situation across the dimensions is balanced rather than unbalanced. Therefore, rather than focus on one dimension at a time, complementarity in well-being would suggest that policy should address the different dimensions simultaneously. This argument is applied in the literature on policy complementarities, where simultaneous reform of complementary policy areas is found to be positively related to output growth (see e.g. Braga de Macedo & Oliveira Martins, 2008; Braga de Macedo, Oliveira Martins, & Rocha, 2013, in press; Coricelli & Maurel, 2011).

Although complementarity among the dimensions would be a characteristic of the concept of well-being generally, the effect and relevance of complementarities will likely differ with the level of analysis. In particular, while analysis at the national level is facilitated by better data availability, considering national averages usually disguises the extent of variation within a country. This is especially problematic for the issue of well-being because an individual's well-being is influenced by their direct environment rather than by the average situations and the regional factors are therefore dominant determinants of well-being (Aslam & Corrado, 2011). Therefore, well-being is to a large degree influenced by regional level policies. In this sense, complementarities among the dimensions of well-being are especially relevant on a regional level, where policy makers could attempt to target policies to benefit from complementarities in their region.

In the existing literature on multidimensional well-being, the possibility of complementarities has not been considered explicitly. Methodological literature mentions complementarity as an alternative assumption on how to aggregate the dimensions of well-being (e.g. Decancq & Lugo, 2013) and the most recent revision of the *Human Development Index* assumes imperfect substitutability (Klugman, Rodríguez, & Choi, 2011). In general, no thorough theoretical conceptualisation of the concept of complementarity in well-being or empirical results on this topic have been presented.

This research project addresses this gap in the literature by presenting an exploratory analysis of the concept of complementarities among the well-being dimensions. In particular, this research addresses two questions: First: Is the concept of complementarities relevant in the context of multidimensional well-being? And, second, if it is, then how can this theoretical concept be applied to the cross-sectional comparison of well-being on a regional level?

In order to address these questions, an empirical analysis of the role of complementarities in influencing the overall level of well-being was implemented. Although the effects of complementarities may be more evident on a regional level, regional analysis is also more demanding in terms of data availability. For this reason, the first research question was addressed on the basis of an empirical analysis of a European panel dataset at the national level. Based on the results from this analysis, the notion of complementarity was applied to a composite indicator of well-being and used for cross-sectional comparison of the OECD territorial level 2 (TL2) regions.

The remainder of this article is organised as follows. First, a background of relevant literature regarding well-being and the notion of complementarities is provided. Second, the theoretical framework for application of complementarities to well-being is presented and justified. Third, the operationalisation of the theoretical framework is discussed, focusing especially on the methodological details of construction of the indicators required for analysis. Fourth, the sample and methods used for the empirical analysis on a national level are described. Fifth, the national results are presented and discussed. Sixth, on the basis of the national estimation, a regional cross-sectional comparison of well-being is implemented and consequences of different specifications of well-being indicators are compared. Finally, the results of this research are summarised and discussed in the context of theory, methodology and relevance for policy making before offering concluding remarks.

2. Overview and Background

Before describing the details of the implemented analysis, it is informative to survey the three main fields of theoretical and empirical literature, which are relevant for this project. First, the broad topic of this thesis is well-being analysis, which itself comprises a large and diverse literature. An extensive literature review on the topic of well-being analysis is beyond the scope of this analysis , which is why the focus is on positioning the research approach of this project within the broad strands of existing literature. Second, regional perspectives on well-being have lately attracted more attention and several empirical studies of well-being on a regional level were suggested. Third, since the research approach undertaken here follows similar approaches on the topic of policy complementarities, it is useful to discuss the existing research in this area.

2.1. The Concept of Well-Being

When discussing the notion of well-being, it is important to note that, especially within psychology, the term of is often taken to be synonymous with *subjective well-being*, i.e. an individual‘s evaluation of their well-being. In contrast, when speaking of well-being as an indicator of development or welfare, it is often defined as including both subjective and objective facets (e.g. OECD, 2011a), which is also the definition adopted here. In particular, Moss (2013), argues that using subjective well-being does not correspond to the philosophical principles of welfarism because subjective measures may confound the actual well-being effect of a policy. He therefore suggests that broader conceptualisations, as for example within the *capability approach* (see e.g. Sen, 1993, 1999) are preferable when intending to use well-being in a policy context. Within this project, well-being is understood as an inherently multidimensional concept including monetary and non-monetary as well as objective and subjective factors. In this we closely follow the OECD conceptualisation underlying the *OECD Better Life Index*[1] (OECD, 2011a).

Research on the topic of well-being generally falls in one of two research strands: analysing the determinants of well-being or using well-being for comparisons among countries or over time. The first strand of research follows the tradition of well-being research within (positive) psychology, from which a large and diverse literature on the determinants and correlates of subjective well-being, emerged (for an overview see e.g. Deci & Ryan, 2006; Diener, Suh, Lucas, & Smith, 1999). Current research on the determinants of well-being is no longer restricted to the discipline of psychology and a variety of studies use subjective indicators, especially survey answers regarding life satisfaction, to analyse what people value in their lives (Boarini, Smith, Manchin, Comola, & de Keulenaer, 2012; Dolan, Peasgood, & White, 2008; Fleche, Sorsa, & Smith, 2012). A prominent topic of research remains the relation between income and life satisfaction (Easterlin & Angelescu, 2009; Kahneman & Deaton, 2010; Sacks, Stevenson, & Wolfers, 2012) although other factors, for example environmental quality (e.g. MacKerron & Mourato, 2009; Silva, Johnstone, & de Keulenaer, 2012), are addressed as well.

The research undertaken within this project follows the second strand of research, which uses well-being as an alternative indicator of welfare and implements empirical comparisons (e.g. Blanchflower & Oswald, 2004; Stanca, 2010; Veenhoven, 1992). Results from this strand of research suggests strong national differences and usually find that richer countries exhibit higher levels of well-being (e.g. Assi, Lucchini, & Spagnolo, 2012; Sacks et al., 2012) although the level of democracy and cultural factors seem to be influential as well (Inglehart & Klingemann, 2000).

2.2. Types of Well-Being Indicators

Subjective measurements are used extensively in the literature on well-being. This is due to the fact that self-reported life satisfaction or happiness are thought to approximate the theoretical concept of utility relatively directly, thus providing a different perspective on cross-sectional comparisons (Diener, 2000; Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004; Oswald & Wu, 2010). However, some methodological issues of using self-reported well-being measures, such as individuals‘ tendency to adapt to their circumstances and to compare themselves to others, can potentially distort results. Moreover, in contrast to more objective measures of well-being, self-reported happiness or life satisfaction cannot be targeted by policy interventions. Therefore, when policy makers aim to increase well-being, the effect would need to be transmitted through policies that impact the underlying determinants of reported life satisfaction. An alternative approach is to model well-being directly as being “produced” by different underlying factors and model the multidimensionality explicitly. This approach offers the benefit of avoiding problems of subjectivity and focusing on the effect of factors that can be targeted by policy interventions.

[1] It should be noted that, within the OECD (2011) definition of well-being, the term “quality of life“ is used to denote the non-market aspects of well-being. However, Stiglitz et al. (2009) and other authors use the term interchangeably with the notion of well-being. In order to avoid confusion, no distinction between quality of life and well-being is made within this project and market and non-market aspects of well-being are identified as such.

With the increasing attention directed towards using well-being as an alternative measure of welfare, methodological difficulties of multidimensional measures have become an important topic of research. In particular, one of the main difficulties of a multidimensional concept of well-being is its interpretation. Two types of methods for interpretation of multidimensional well-being have been proposed: a *dashboard* of indicators or a *composite indicator*. In a dashboard, one would consider the dimensions of well-being dimension-by-dimension, while a composite indicator aggregates them to a one-dimensional index (see e.g. Decancq, 2011). The dashboard approach is advocated in some publications that are meant for policy makers because it has the advantage of describing the full extent of available data (e.g. Franco-German Ministerial Council, 2010; Stiglitz et al., 2009). However, for more than two dimensions, it becomes difficult to interpret a dashboard intuitively. For instance, if one region scores highly on most dimensions but poorly on one dimension, a dashboard does not provide an obvious interpretation on how to conciliate these results (see figure 1 for a simple example using regional data on the Netherlands[2]). An interpretation of a well-being dashboard can be derived for example by application of multi-criteria decision methods (OECD, 2008).

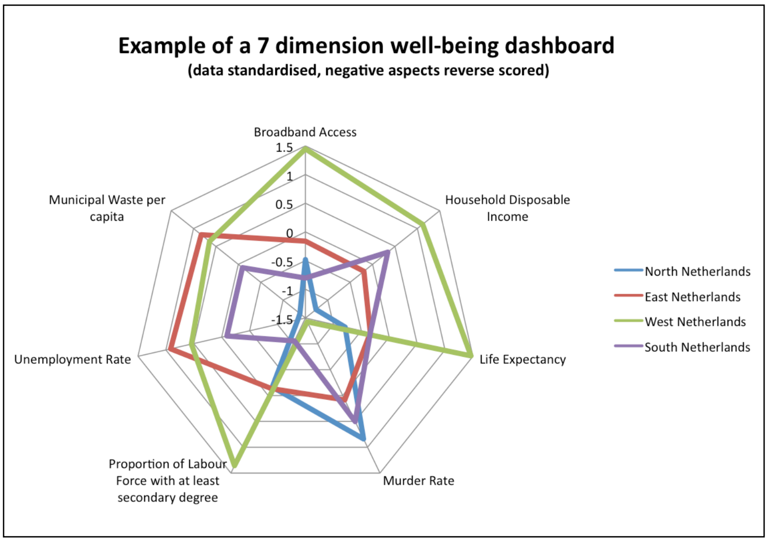


Figure 1: Example of a well-being dashboard for the Netherlands[2].

The second alternative, constructing a composite indicator, is implemented more frequently in practice. A wide variety of composite indicators of well-being have been proposed and used for cross-sectional comparisons (for an overview see Booysen, 2002; Glatzer, 2007; Hagerty et al., 2001). Most prominently, the *Human Development Index (HDI)*, draws on the Sen‘s *capability approach* (e.g. Sen, 1993) and is based on the dimensions of standard of living (income), health status (life expectancy) and knowledge (education and literacy). Some indices, such as the *Gallup-Healthways Well-Being Index* (applied for instance in Florida, Mellander, & Rentfrow, 2013) are themselves based largely on survey data and thus attach a strong weight on subjective measures. Other approaches, such as the HDI, include only objective measures (see e.g. Bérenger & Verdier-Chouchane, 2007; Giannias, Liargovas, & Manolas, 1999). Most encompassing are conceptualisations of well-being that combine subjective and objective dimensions of well-being, as in the *OECD Better Life Index* (2011a), but these approaches are also relatively demanding in terms of data requirements. In general, aggregating the multidimensionality into a single number requires a

[2] The data in figure 1 are obtained from the OECD regional database at TL2 level for the year 2009. Data was standardised and negative dimensions (murder rate, unemployment, waste) scored in reverse to show performance in terms of well-being.

range of strong simplifications and assumptions regarding weights and implied trade-offs but also facilitates interpretation (Decancq & Lugo, 2013; Ravallion, 2010).

Alternative suggestions to capture well-being without a composite indicator include for instance the use of *equivalent income,* i.e. income that is adjusted for the effects of health status, unemployment and other factors relevant to well-being (Fleurbaey & Gaulier, 2009). The use of equivalent incomes is a highly promising way to unify well-being with priced-based measures of development but also relies on strong assumptions regarding preferences and the valuation of non-market goods. It has also been proposed to derive well-being from stated preferences (Benjamin, Heffetz, Kimball, & Szembrot, 2012; Decancq, Van Ootegem, & Verhofstadt, 2011) or revealed preferences (Faggian, Olfert, & Partridge, 2011) although these approaches face similar criticism as the use of survey data of subjective well-being.

Despite the methodological issues associated with constructing a composite indicator, a range of theoretical literature suggests that it remains an effective method of representing a multidimensional conceptualisation of well-being (e.g. Booysen, 2002; Hagerty et al., 2001; OECD, 2011a) . Especially for the aim of cross-sectional comparisons of well-being that do not rely solely on subjective measures, a composite indicator is preferable for reasons of simplicity and interpretation. Thus, since this project adopts a definition of multidimensional well-being and aims to present cross-sectional comparisons of well-being, the implemented methodological approach relies on the construction of composite indicators.

2.3. Well-being Analysis on a Regional Level

It is a general finding in studies of economic development that regional disparities within countries often exceed the differences between countries. These disparities include income but also other dimensions of well-being such as life expectancy or the level of unemployment (see figure 2). Focusing on national averages therefore disguises disparities on sub-national levels. However, an individual‘s well-being is affected by the direct circumstances she experiences rather than the national average. Therefore, the regional geographic dimension of the factors influencing well-being is influential and should not be neglected. Indeed, the extent of regional disparities represents the main motivation for the implementation of regional policy. Although regional policy, e.g. EU Co-

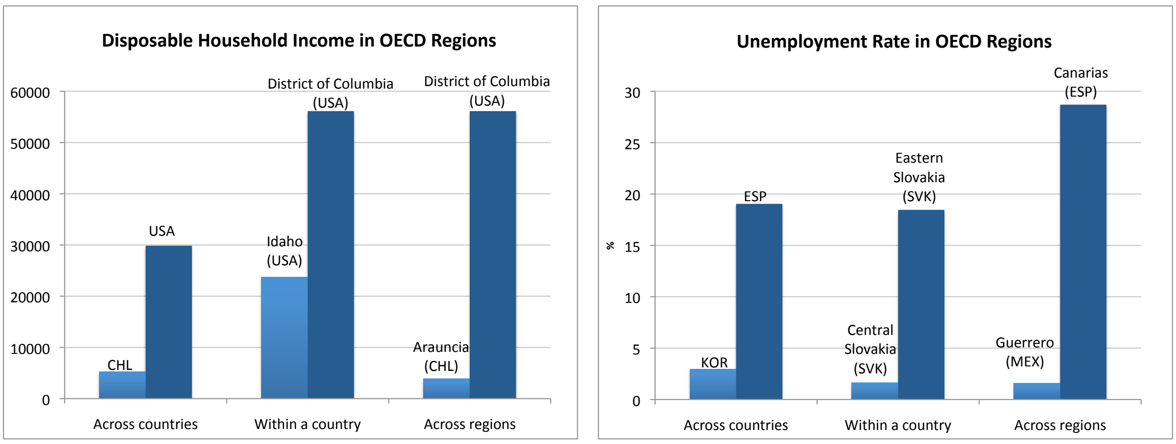


Figure 2: Illustration of disparities within OECD TL2 regions.

hesion Policy, predominantly focuses on decreasing disparities in economic prosperity, the described theoretical advantages of taking a broader perspective on well-being are attracting increasing attention among policy makers (EC, 2009; Laurent, 2013).

Nevertheless, the majority of existing empirical analyses of well-being concern the national level. This is largely due to the fact that data on a regional level is scarce. Considering that the widespread interest in well-being analysis is a relatively recent phenomenon, data collection on the regional level still needs to adjust to the new demands. In particular, while data on life satisfaction is available for a range of countries, and for some countries even for a relatively long time period, regional level life satisfaction is generally not reported. In some cases it can be derived from combining micro-data from household surveys (such as the German Socio-Economic Panel) with the geographic location of the respondent. However, this requires reliable survey data that is representative at the regional level, while most large scale surveys (e.g. the Eurobarometer) are designed to be representative for countries only. In addition to data on life satisfaction, other indicators that are relevant to measure specific dimensions of well-being, such as information on housing quality, work-life-balance or social connectedness are not widely available. The limited data availability implies the risk that the implemented measures of well-being are chosen on grounds availability rather than theoretically determined reasons, thus limiting the internal validity of the research.

Despite these issues, some recent studies have addressed the topic of regional well-being. Pittau, Zelli and Gelman (2009) find significant differences in well-being among regions within Europe with the capital city usually exhibiting the highest level of well-being. For the US, some evidence regarding differences in subjective well-being among states exists and is assumed to be related to differences in socio-economic circumstances and human capital (Plaut, Markus, & Lachman, 2002; Rentfrow, Mellander, & Florida, 2009). Furthermore, regional disparities in well-being are also analysed in the context of convergence within a specific country, for instance Italy (Ferrara & Nisticò, 2012) and Spain (Marchante, Ortega, & Sánchez, 2005).

A related body of research addresses differences in subjective well-being between urban and rural regions although the results are not conclusive. In line with studies highlighting the importance of income, human capital and other factors often found in urban areas (Florida et al., 2013), some empirical studies suggest that urban areas exhibit slightly higher subjective well-being (e.g. Shucksmith, Cameron, Merridew, & Pichler, 2009). In contrast, Sørensen (2013) finds subjective well-being to be higher in rural regions. This type of research is closely related to discussions of a spatial equilibrium in terms of utility and amenities as well as inter-regional migration. Faggian and colleagues (2011) therefore propose to approximate regional well-being differences by relative population change although this approach requires the unrealistic assumption of frictionless movement of people.

More generally, using a multi-level approach to model well-being, Pittau and colleagues (2009) estimate that strong regional disparities persist even when controlling for individual level characteristics. The authors come to the conclusion that regional factors may dominate national ones in their influence on well-being, which is supported by evidence presented by others (Aslam & Corrado, 2011; Helliwell, 2002; Okulicz-Kozaryn, 2011). In contrast, Ballas and Tranmer (2011) estimate a multi-level model for district areas within the UK and find no significant effect of the regional level when controlling for individual and household characteristics. However, the authors note that their result may be caused by insufficient sample sizes.

In line with the described first strand of research on well-being, most studies on regional well-being focus on explaining differences in subjective indicators. Such an analysis is particularly interesting on a regional level because people‘s preferences may not be independent of where they live. For instance, it could be argued that an individual derives more well-being from employment when the regional level of unemployment is high (Clark, 2009; Clark, Knabe, & Rätzel, 2009). However, as described previously, the subjectivity inherent in self-reported measures implies methodological problems. There are relatively few regional-level studies that rely primarily on objective measures of well-being although some studies implement and extend versions of the HDI (Ferrara & Nisticò, 2012; Marchante et al., 2005). Furthermore, although studies on regional well-being exist within countries and for within the EU, a broader comparison of regions is usually not implemented. This project attempts to address these gaps in the literature by focusing on the construction of a primarily objective multidimensional well-being indicator and applying it to the territorial level 2 regions within the OECD.

2.3 Policy Complementarities – an Overview of the Literature

A non-technical definition of the notion of complementarities between two factors, as it is common within economics, is that complementarities occurs when "having more of one [factor] increases the marginal return to having more of the other" (Amir, 2013, p.636). Clearly, in this general specification, complementarities can occur in a variety of situations where using more than one factor is relevant, for example when considering consumption or production. However, the notion of complementarities has also been applied to the area of policy making, precisely because there is generally a wide variety of possible policy reforms. In particular, when faced with a number of interdependent reform areas, policy makers need to decide which ones to implement– and in which order. The OECD emphasises the importance of complementarities within policy areas especially on a regional level as it allows for an integrated approach to regional development (OECD, 2011b). Since well-being is also multidimensional, the analysis implemented in this project draws on the methods used when analysing policy complementarities. For this reason, it is instructive to provide a short overview of the use of the concept of complementarities in the area of policy reforms.

Justification for the application of the concept of complementarities in economic reform is derived primarily from the theory of the second best (Lipsey & Lancaster, 1956), which states that in situations of many distortions, implementing reforms one-by-one may actually reduce welfare. A "radial" reform strategy that removes distortions along each of the policy issues simultaneously is therefore found to be preferable (see e.g. Foster & Sonnenschein, 1970). However, modelling such a radial reform strategy requires strong assumptions on the shape of the utility function and is not easily applicable to an empirical study. Therefore, De Macedo and Oliveira Martins (2008) suggest to capture the essence of a radial reform strategy through the concept of complementarities: if complementarities among the reform areas exist, the optimal strategy is to implement the reforms in parallel. In this sense, a policy maker‘s concern for a radial reform strategy and the effect of complementarities among reform areas is observationally equivalent. The authors present theoretical evidence for the existence of policy complementarities in the form of illustrations of interdependencies and policy linkages between structural indicators compiled by the European Bank for Reconstruction and Development. Also, De Macedo and Oliveira Martins suggest to measure the extent of complementarities by an indicator based on the Hirschmann-Herfindahl index (HHI), which indicates the degree to which reform areas are addressed simultaneously. This index was one of the approaches taken within this project to measure the degree of dispersion among the well-being dimensions.

A comprehensive review of the empirical results on the effect of policy complementarities is beyond the scope of this project and can be found in De Macedo, Oliveira Martins and Rocha (2013, in press). Generally, the evidence suggest that complementarity among policy areas has a positive effect on growth and on the beneficial effects from implementing policies such as trade liberalisation. For example, using their index for reform complementarity, De Macedo and Oliveira Martins (2008) find that the level of economic reforms and the complementarities between them are positively related to GDP growth. Coricelli and Maurel (2011) implement the same indicator of reform complementarity for transition countries and find that the relatively slow growth performance of the countries of the Commonwealth of Independent States may be explained in part by the piecemeal reform strategy. Also, the authors find that more unequal levels of reform in the different areas are associated with longer and deeper recessions.

Since the methodology used in this project relies strongly on the literature on policy complementarities, it is important to note the different approaches taken to model the effect of complementarities. In particular, approaches to capture policy complementarities are either to implement the described indicator based on the HHI (Braga de Macedo & Oliveira Martins, 2008, 2010; Coricelli & Maurel, 2011), to measure dispersion through the standard deviation of reform levels across areas (Braga de Macedo et al., 2013, in press) or to include interaction effects among policy areas (e.g. Chang, Kaltani, & Loayza, 2005). Of these three approaches, using the standard deviation is, arguably, the simplest method, whereas – as shall be shown in the following – a complementarity index is methodologically much more complex. Using interaction effects, is in principle a straightforward way to include complementarities, but is less feasible when many dimensions are considered or when the dimensions are highly correlated. Thus, for studying complementarities in well-being, the latter approach is less applicable.

3. Theory and Conceptualisation

The previous section presented the existing approaches and evidence of, on the one hand, the analysis of well-being and, on the other hand, the notion of complementarities. The discussion illustrated that well-being has been analysed and measured in very different conceptualisations. Drawing on the discussed literature, the following sections will define the theoretical conceptualisations applied in this project. It should be noted that due to the topic of this project being to a large degree methodological itself, it is difficult to make a distinction between true theoretical and true methodological concepts. Therefore, this section focuses on using theoretical and methodological literature to describe the concepts to be used. In particular, a more precise conceptual framework for measuring well-being is presented. Then, a theoretical justification for the relevance of complementarities among the well-being dimensions is provided. Finally, the two strands of theory are combined within an integrated framework illustrating the hypothesis of this research.

3.1. A Theoretical Framework for the Measurement of Well-Being

As emphasised throughout this text, the defining feature of the notion of well-being is its multidimensionality. Recognising its multidimensional nature is crucial for understanding well-being because people have multiple needs, wants and desires. Clearly, some of people‘s wants, and especially many of the basic needs, are primarily material. For instance, in terms of Maslow‘s (1943) hierarchy of needs, the two most basic classes of needs, i.e. physiological and safety needs, are highly correlated with having sufficient income to pay for food, shelter and basic services such as health care. However, other needs are non-material altogether (e.g. social connections) and for some needs the limiting factor of their attainment may not be income but other circumstances (e.g. a wealthy individual may be able to afford superior health care, but his health status is not determined by income alone).

The notion that not all human needs and wants are satisfied with income is captured in the distinction between economic and human development and also represents the fundamental premise of the capability approach (Sen, 1993, 1999). Although the capability approach is more specific in its positions, as it proposes to measure development by the extent to which people have the ability to reach certain desirable states, the fundamental theoretical justifications for using well-being closely align with theories of human development. Indeed, the possibility that well-being indicators can be used to approximate human development rather than focusing exclusively on economic development is likely on of the main reasons driving the interest in the topic.

However, while multidimensionality of well-being is realistic it is also a large challenge theoretically and methodologically. In particular, well-being measurements suffer from what is commonly termed the *index problem* (e.g. Rawls, 1971): which of the many dimensions should be included in considering well-being (i.e. assigned non-zero weights) and how should they be weighted? A related problem of conceptualising well-being is the possibility that people value the dimensions differently because this would confound the results of cross-sectional comparisons. Clearly, these problems of multidimensionality would not occur when focusing on one-dimensional measures such as income or life satisfaction. However, one-dimensional measures also neglect the interesting conclusions to be drawn from modelling well-being as it really is: multidimensional.

There currently exists no integrated theory that could guide the decision, which dimensions of well-being to measure. Therefore, the choice can only be based on statistical analyses, such as provided in the empirical literature on the determinants of well-being, or on the basis of normative perspectives (Decancq & Lugo, 2013). The approach taken within this project is the latter one, using the conceptualisation of individual well-being within OECD Better Life framework (OECD, 2011a) as a starting point. On the basis of this framework, the conceptualisation of well-being used within this research is presented in figure 3. It is important to note that the presented definition does not focus on the individual but rather takes a macro-level view on well-being. This implies that micro-level factors such as marital status, employment status and age are not included in this framework. In line with the focus on regional disparities and implications for policy, the unit of analysis is therefore the regional or national level.

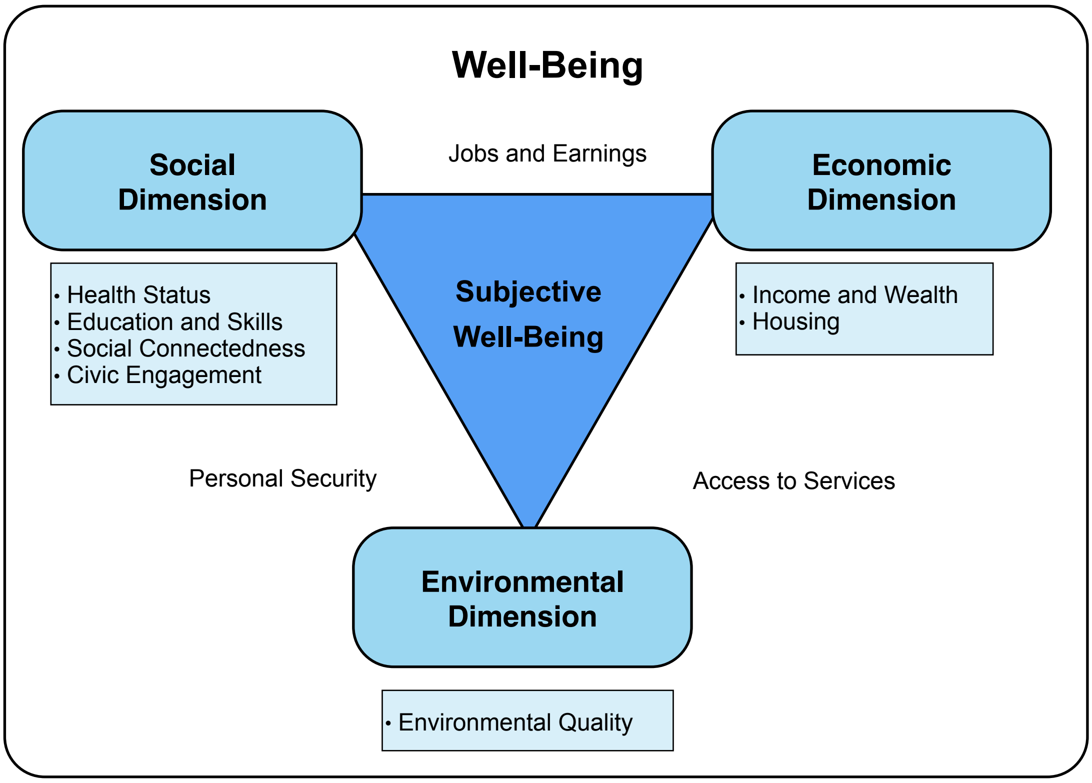
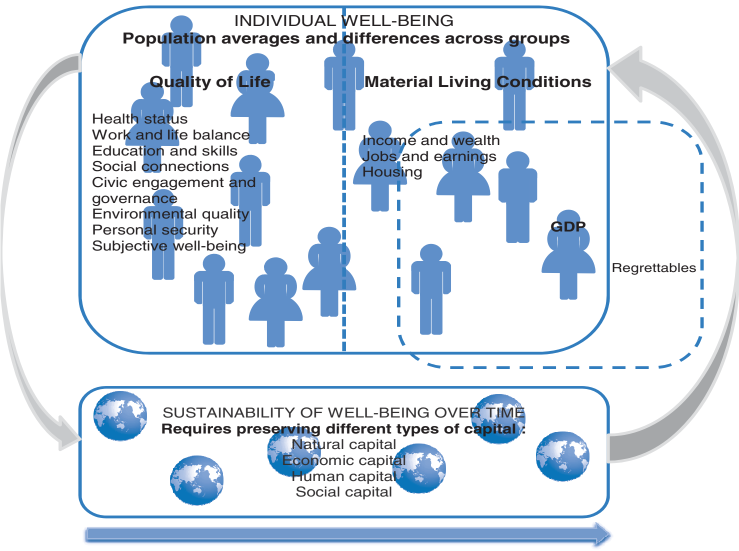


Figure 3: Conceptual framework of multidimensional well-being

The proposed framework of well-being for this project distinguishes between three dimensions, which represent different nuances of well-being: economic, social and environmental. These dimensions were derived from grouping the 11 indicators of well-being included in the OECD definition (figure 4: OECD, 2011a, p.19) according to their broader underlying themes. Additionally, and in line with current research on well-being within the OECD, the factor of access to services was included, which is particularly relevant on a regional scale.

In particular, the indicators that are termed “material living conditions“ in the OECD definition, correspond broadly to economic factors of well-being. The large group of non-material factors includes primarily aspects that describe the the communal life and its challenges. This includes such factors as social connectedness, civic engagement and education. Broadly, health status is also considered part of the social dimension because, besides being highly influential for each individual, it has a profound impact on the functioning of a society. In contrast to the OECD definition, the notion of environmental well-being is considered a distinct dimension of well-being, which is related to concern for stable well-being over time, i.e. sustainability of well-being.



Source: OECD.

Figure 4: OECD definition of well-being (OECD, 2011a, p.19)

This three dimensional conceptualisation of well-being rather than a more extensive framework was chosen primarily because data for many of the 11 individual variables of the Better Life Index are not available, especially when considering a regional level. Moreover, many of the indicators are strongly correlated to each other thus raising the question whether they can be included as separate variables. For these reasons, it was decided to conceptualise well-being as a condensed version of the OECD definition, which includes the same indicators but groups them according to the main underlying themes of well-being. More generally, these themes are also represented widely in recent agendas on development, for instance in the Europe 2020 strategy (EC, 2010) and the OECD‘s *stronger, cleaner, fairer* agenda (e.g. OECD, 2011b).

Since the distinction in social, economic and environmental dimensions of well-being is very broad, some of the aspects mentioned in the original OECD framework cannot be categorised clearly. In particular, “Jobs and Earnings“ are both economic and social because the degree of unemployment indicates economic productivity but also affects society more broadly. Access to services is a factor of economic wealth (e.g. availability and affordability of a service) but also environmental to a certain degree because the environment influences the ease of reaching the location where a service is provided. Personal security is usually interpreted as a social factor and associated with the level of crime, but in a broader sense, the risk of natural disasters also affects people‘s perceptions of security.

A second relevant feature of the presented conceptualisation of well-being is that it does not include subjective well-being as one of a variety of non-material factors as is the case in the OECD framework. Instead, subjective well-being is considered a separate component of well-being. In this sense, subjective well-being represents an individual‘s personal evaluation of the situation of each of the three dimensions. This conceptualisation has the benefit of still allowing subjective well-being to be used as an indicator of overall well-being although also other measures of well-being can be constructed using the three dimensions. This is especially important for the present analysis because the aim is not only cross-sectional comparisons as in the OECD Better Life Index, but also includes explanatory analysis, for which subjective well-being represents an informative variable.

3.2 Theoretical Approaches to Complementarities

When thinking of well-being as a multidimensional concept, this implies that each of the dimension contributes to overall well-being. How much each aspect of well-being contributes depends both on the “value“ of that dimension (i.e. good versus bad health) and on the weight attached to this dimension. An individual‘s well-being (WB) is then a function of the dimensions (D) and the assigned weights (p).

(1) $$WB = f(D_1, D_2, ...D_n, p_1, p_2, ...p_n) \; with \sum_{i=1}^{n} p_i = 1$$

In this formulation, the similarity between a multidimensional conceptualisation of well-being and the specification of a utility function is evident. Indeed, the fact that well-being is conceptually close to the notion of utility makes it an attractive concept in analysing welfare and development. It also illustrates that, despite including factors that are not traditionally included in economic considerations (i.e. non-material, non-market goods, subjective evaluations), well-being can be analysed within a micro-economic framework.

In particular, when considering well-being as a function of its dimension, the relation between the dimensions need to be specified. One aspect of this relation is the assignment of weights, which defines the possible trade-offs among the dimensions (Decancq & Lugo, 2013). A second aspect is the question whether the well-being dimensions act as substitutes or complements for one another, which determines the shape of the well-being function.

3.2.1 An economic intuition for well-being complementarities

Drawing on the notion of substitute goods, two dimensions of well-being are substitutes if well-being derived from one dimension can be replaced with well-being derived from the other one. Thus, compensation within well-being is possible: a low value on one of the dimensions can be compensated by a higher value in another. The details of the substitution of two well-being dimensions depend on the weighting scheme applied. Essentially, the weights associated with each dimension define the possible trade-offs within well-being. However, regardless of the weighting, the assumption of perfect substitutability implies constant marginal returns to well-being derived from each dimension: increasing the value of one dimension while holding the other constant increases well-being by a fixed amount.

At first glance, substitutability across the well-being dimensions is a sensible assumption because it is likely that, for example, people derive equal amounts of well-being when income increases by a small amount or when the environmental quality improves by a small amount. For this reason, virtually all composite indicators of well-being assume some degree of substitutability and the vast majority even assumes perfect substitutability. However, while the assumption of perfect substitution may be adequate for small changes, it leads to unintuitive predictions when the situation across the dimensions is unbalanced. For instance, the constant marginal returns to each dimension of well-being imply that an individual with very high income but very poor health would face equal gains from increasing income even further or improving her health status. The assumption of perfect substitution yields the theoretical prediction that an individual in this scenario would be indifferent with respect to the dimensions although, when imagining this situation for oneself, intuition would suggest otherwise. When applying this result to development in a broader sense, an extreme conclusion would be that policy makers can ignore problematic issues in terms of health, environment, personal security or education as long as they ensure increasing income. This perspective is not only unrealistic but also assigns a very limited role to the multidimensionality of well-being: if one assumes perfect substitutability, a true multidimensional approach to well-being is not absolutely necessary. While this may be an extreme example, it nevertheless illustrates the intuitive problems of assuming perfect substitution among well-being dimensions.

In contrast to the assumption of perfect substitutability stands the notion that the gains derived from one dimension may depend on the values of the other dimensions. Intuitively, it could be argued that as the situation in one dimension of well-being deteriorates relative to the others, this dimension could actually become more important for overall well-being. Besides being an intuitive representation of how well-being is commonly perceived, this suggestion is supported by arguments of relative scarcity (i.e. people want what they have little of) or the psychological notion of a *contrast effect*, which posits that a situation may be evaluated differently when considered independently or jointly with a number of "contrasting" situations (see e.g. Plous, 1993).

This alternative view on the relation between the dimensions of well-being can be expressed in terms of the notion of Edgeworth-Pareto complementarity. Originally applied to the relation of goods used in consumption or production, two goods X and Y are complementary if "an increase in the supply of X (Y constant) raises the marginal utility of Y" (Hicks, 1946, p. 42). In the classical example of two perfectly complementary goods (e.g. a left and a right shoe) utility only increases when both are consumed together and in a fixed proportion (one of each for the case of shoes). If well-being dimensions are complements, this would thus imply diminishing marginal returns for each dimension. It would, also yield the conclusion that the well-being gains to be derived from one dimension can be increased by increasing the value of the other dimensions. Therefore, when aiming to increase well-being, complementary dimensions of well-being should be increased in parallel. Otherwise, when considering the theoretical case of perfect complementarity, an individual's level of well-being would strictly be defined by the dimension with the lowest value, representing a minimum function. This would imply Leontief -type indifference curves.

Clearly, in their theoretical forms of perfect substitutability and perfect complementarity (as illustrated in terms of indifference curves in the first two panels of figure 5) neither of the two concepts adequately describes the reality of well-being. In order to provide a realistic picture of well-being, substitution between the dimensions should be possible. However, a degree of complementarity would be necessary as well to capture the notion that people would likely prefer a more balanced distribution of well-being across the dimensions. Therefore, a model of multidimensional well-being would ideally be one of imperfect substitution, corresponding to the typical assumption of convex, non-linear indifference curves.

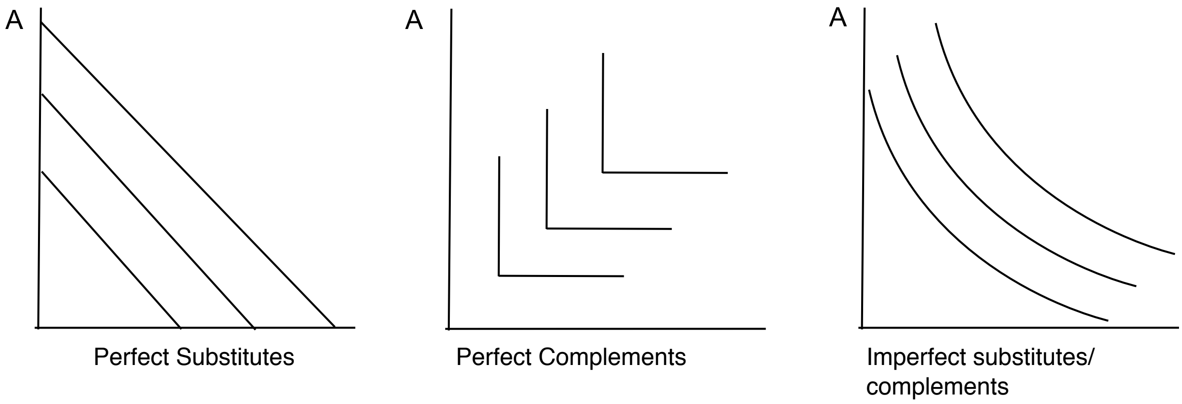


Figure 5: Indifference curves for substitutes and complements

3.2.2. Supermodularity and complementarity

Drawing on the economic concept of complementary goods allows for an intuitive interpretation and justification for applying complementarity to the well-being dimensions. However, technically, this argumentation implies a positive mixed partial derivative of a well-being function and therefore requires assumptions regarding its shape (i.e. the mixed partial derivative must exist). To avoid these assumptions, De Macedo and Oliveira Martins (2008) suggest to derive policy complementarity from the modern concept of complementarity as suggested by Topkis (1998). In order to apply this reasoning to well-being, assume, for example, that well-being only has two dimensions: $x$and y. Denote an improved situation in the specific dimension with $\bar{x}$ and $\bar{y}$ respectively. Then, well-being as a function of these two dimensions is *supermodular* if it has increasing differences:

(2) $$F(\bar{x},\bar{y}) - F(\bar{x},y) \geq F(x,\bar{y}) - F(x,y) \qquad \forall \quad \bar{x} > x, \quad \bar{y} > y$$

Supermodularity provides a formal definition of complementarities without restricting the shape of the well-being function. More specifically, the difference in $F(.)$ when comparing y and $\bar{y}$ is larger for $\bar{x}$ than x, which describes precisely the intuitive concept. Also, for smooth functions, it can be shown that the characteristic of increasing differences is equivalent to

(3) $$\frac{\delta^2 F(x,y)}{\delta x \delta y} \geq 0$$

and supermodularity therefore includes the definition of Edgeworth-Pareto complementarity but also applies in cases where this definition fails (Amir, 2013). It should be noted that supermodularity and complementarity are symmetric: if the marginal gains in well-being derived from x increase with y, the marginal returns from y must also increase with x.

For the case of more than two dimensions, Amir (2013) illustrates that a multidimensional function is supermodular if the function is supermodular for each pair of included variables. Therefore, the concept of complementarities can be extended to more than two dimensions but then requires applications of *lattice theory.* Following the explanation provided by De Macedo and Oliveira Martins (2008, p. 162), "a lattice [...] is a set X with the property that for any x and y in X there exists an element in X larger than or equal to x and y, and there exists an element smaller than or equal to x and y". Multidimensional supermodularity, as it would be required for analysing a multidimensional conceptualisation of well-being, then implies:

(4) $$f(x \vee y) + f(x \wedge y) \geq f(x) + f(y) \qquad \forall \quad x, y \in X$$

where $f(x \vee y)$ denotes the least upper bound (smallest element equal or larger than x and y also called *join operation*) and $f(x \wedge y)$ denotes the greatest lower bound (largest element equal or smaller than x and y also called *meet operation*). Although this multidimensional definition of supermodularity still captures the notion of complementarity, the intuition is not as evident as in the two-dimensional case. However, as multidimensional supermodularity necessarily implies two-dimensional supermodularity for each of the variable pairs, the intuition presented in the two-dimensional case still applies.

3.3. Complementarity Within a Three-Dimensional Well-Being Framework

The preceding discussion presented the theoretical assumptions necessary for applying complementarities to the well-being dimensions. For the case of well-being, the discussion of multidimensional supermodularity therefore implies that complementarities between the well-being dimensions exist if well-being is a supermodular function for each pairwise combination of the dimensions. Consider well-being to be a function of economic, social and environmental dimensions as presented in Figure 3. Then, complementarities among the three dimensions of well-being exist if all of the following three requirements are satisfied:

1. Well-being is a supermodular function of the economic and social dimension
2. Well-being is a supermodular function of the economic and environmental dimensions
3. Well-being is a supermodular function of the social and environmental dimensions

It is important to note that within the proposed framework of well-being only these three assumptions are necessary because the separate factors that contribute to well-being were grouped into broader dimensions. The framework and the following analysis can clearly be extended to include any number of dimensions as long as supermodularity between these dimensions can be established. However, for a generalised model of well-being including n dimensions, the number of pairwise supermodular relations that need to be satisfied is given by:

(5) $$\binom{n}{2} = \frac{n!}{(n-2)!\,2!} = \frac{n(n-1)}{2}$$

Thus, if one considers each factor included in the original OECD Better Life Index (see figure X) as a separate dimension, complementarities among the 11 dimensions of individual well-being would technically require 55 pairwise supermodular functions of well-being.

When aiming to include well-being dimensions as complements, a further logical step is to establish that that well-being is indeed a supermodular function of its components. This can either be done empirically or theoretically. For a simple empirical approach, one could test for a positive interaction effect between each set of dimensions in explaining a measure of well-being (e.g. life satisfaction). However, many of the relevant dimensions of well-being are highly correlated thus introducing severe multicollinearity into a regression. Instead, in the following a theoretical justification for the existence of complementarities within the proposed framework of well-being is presented. This is based on the approach taken in the existing literature on policy complementarities (Braga de Macedo & Oliveira Martins, 2008; Braga de Macedo et al., 2013, in press). The complementarities among the three dimensions of well-being are summarised in table 1, which is based on the policy complementarity matrix presented in OECD (2011b).

In particular, complementarities among the economic and social dimensions exist because economic progress has an effect on social well-being and vice versa. This notion is captured in the term of *inclusive growth*, which represents one of the priorities of the Europe2020 strategy (EC, 2010): economic growth with a concern for the societal concerns and with a focus on decreasing inequality through increasing employment and education. Indeed, inclusive growth can be understood to draw on the underlying assumption of a complementary relationship between economic and social issues.

More specifically, complementarities imply that close correlations between economic growth and some of the factors included in the social dimension exist: for example, health is typically thought to improve with income. Economic growth increases employment, provides financial means to be invested in public goods, and could thus potentially decrease inequality. It also stimulates innovation, which could benefit social well-being, for instance by improving a societies‘ health status. Simultaneously, improvements in the social dimension are themselves important for well-being (e.g. Helliwell & Putnam, 2004) and may in turn influence economic well-being. Education (and to some degree, health) increases human capital available to firms thus increasing productivity, and potentially economic growth (e.g. Barro, 2001; Mankiw, Romer, & Weil, 1992). Also, the degree of social connectedness may increase social capital and determinants of good civic engagement and governance as well as personal security (for instance as an indicator for the protection of property rights) determine crucial aspects of the institutional framework, which could foster or impede economic growth (e.g. Knack & Keefer, 1997; Rodríguez-Pose, 2013).

		EFFECT ON		
		Economic Dimension	Social Dimension	Environmental Dimension
EFFECT OF	Economic Dimension	-	***inclusive growth:*** • economic well-being correlated with social dimensions: e.g. health, employment • economic growth and policies can decrease social disparities and inequality	***green growth:*** • efficient use of resources ensures sustainability • higher income is correlated with more concern for environmental quality
	Social Dimension	***inclusive growth:*** • human capital increases with improvements in the social dimension and contributes to economic growth • institutional framework influenced by social dimension (social capital, governance, personal security) and affects economic well-being	-	***social and environmental sustainability*** • social concern for environment is reflected in institutions: laws, regulations, and values • responsibility to conserve environment for future generations is a social obligation • education may increase concern for environmental issues
	Environmental Dimension	***green growth*** • may boost innovation • concern for environment may cut costs • ensures long term growth	***social and environmental sustainability*** • environmental quality affects health • environment provides basis of livelihood (for individuals) and basic supply of goods (agriculture, resource extraction) • effect on inclusiveness: poor people are more vulnerable to environmental factors	-

Table 1: Supermodularity matrix

In contrast to the complementarities described between the economic and social dimension, synergy effects among economic and environmental well-being require a more explicit shift in perspective. This is due to the fact that, traditionally, economic growth has been perceived as being at odds with environmental quality because economic production requires the use of resources and creates processes, such as the generation of waste and pollution, which negatively affect the environment. Therefore, a short-term perspective of maximising profits may lead to economic growth at the cost of the environment. However, in line with the increasing concern for sustainability, it has been proposed that economic growth can be achieved with little impact on the environment and that this approach of *green growth* will be beneficial for the environment and economic performance (OECD, 2013).

Complementarities between economic and environmental dimensions, as assumed within the notion of green growth, arise because a concern for environmental quality implies that resources are used efficiently and sustainably thus ensuring long-term economic growth while not endangering the environment. While the effect of sustainable economic growth may only materialise itself over time, there are also short run synergies between the dimensions of economic and environmental well-being. For instance, a concern for improving the environment may actually foster innovation, which will allow using resources more efficiently, cutting costs and thus increasing productivity. Also, it could be argued that improvements in the economic dimension of well-being manifest themselves in higher income, which may increase a society‘s willingness to protect the environment, as represented in the debated notion of an environmental Kuznets curve (see e.g. Dinda, 2004).

In comparison to the notions of green and inclusive growth, complementarities between environmental and social aspects of well-being are not discussed as widely and there is no specific term for this concept. This is likely due to the fact that the role of economic growth is so prominent in discussions of development that a concept that excludes economic factors is only of limited use. Nevertheless, there are channels of influence connecting the social and environmental dimensions of well-being. First, people‘s health status is closely related to environmental quality because factors such as air and water pollution may cause or worsen a variety of medical conditions. Also, an intact environment is important to social well-being because it offers spaces to use for leisure and social contact and, for some professions, provides the basis of their livelihoods (e.g. for all professions related to resource extraction but also agriculture or tourism). More generally, negative developments in the environment are likely to have a larger impact on economically vulnerable groups because groups with higher incomes have better chances of avoiding the negative effects of a deteriorating environment. Therefore, the dimension of environmental well-being is closely linked to issues of inequality within a society. This situation gains in importance when considering that the situation of the environment can introduce a significant factor of personal insecurity into people‘s lives, for instance because it threatens their livelihood (see e.g. OECD, 2013).

Thus, it can be concluded that the social dimension of well-being seems to be affected quite fundamentally by changes in environmental quality. The reverse relation is more difficult to justify on theoretical grounds. It could be argued that people‘s concern for an intact environment increases with the factors included in the social dimension of well-being. For instance, the awareness of the importance of an intact environment and the acknowledgement of a responsibility to conserve it for future generations are features of a society, which directly affect environmental well-being. This concern could be reflected in institutional aspects, such as laws and regulations and informal values that help protect the environment. Also, education plays a large role in creating awareness environmental issues and may thus also affect how much pleasure people derive from environmental quality. In this sense, if education increases but environmental quality deteriorates, these changes may have a larger effect on overall well-being than each individual change, thus suggesting a complementary relationship.

3.4. Specification of Hypotheses

On grounds of the relations summarised in table 1, it can be concluded that well-being may indeed be supermodular in each pair of the three proposed dimensions. It has been illustrated there are many theoretical reasons to support the existence of a complementary relationship reflecting the principles of inclusive and green growth. For the last relation, there are fewer reasons to assume that the marginal well-being gains from the environmental dimension increase with the value of the social dimension. This may be due to the fact that this relation typically attracts less interest than the economic dimension of well-being. For these theoretical reasons, it seems likely that the proposed three-dimensional conceptualisation of well-being is characterised by complementarities.

As a consequence, gains from improving the situation in the three dimensions of well-being are maximised if the dimensions are improved in a balanced manner. More specifically, if one of the dimensions is relatively lower than the other two (see Figure 6), improving the dimension with the worst situation by a certain amount will increase well-being more than improving one of the relatively good dimensions. This result derives directly from the definition of complementarity: the returns from increasing any dimension increases with the value of the other ones. Thus, when considering the set of dark blue bars in figure 6, due to complementarities, improving the social dimension of well-being by a given amount will improve overall well-being more than improving economic or environmental well-being. In order to maximise the gains from improving each individual dimension of well-being, the dimension with the worst situation should be increased up until the level of the others before switching to a radial reform strategy, which increases the dimensions in parallel. Following this argumentation, and assuming that the overall well-being to be distributed among the dimensions is fixed, well-being is maximised, ceteris paribus, when the situation in each of the dimensions is equal. Otherwise, implementing policies to “re-distribute“ from the best to the worst dimension of well-being would increase the overall level of well-being, indicating that it is not an equilibrium situation.

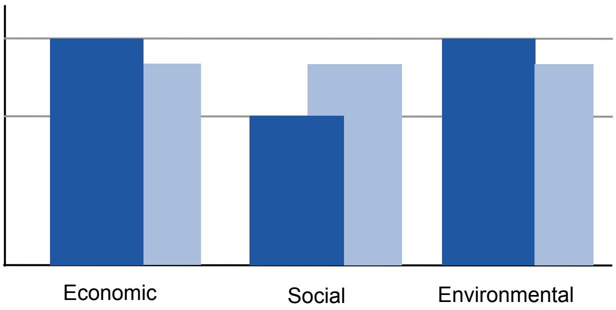


Figure 6: Balanced versus unbalanced distributions of well-being

It is important to note that the theoretical concept of complementarities only refers to the *relative* levels of well-being in each dimension. Clearly, the absolute levels of economic, social and environmental well-being are determining fundamentally the overall level of well-being: a set of a higher average well-being across the dimensions also implies higher overall well-being. This a consequence of conceptualising each of the dimensions as contributing to overall well-being and assuming non-satiation within each dimension. The theoretical concept of complementarities is unrelated to the absolute levels of well-being across dimensions. More specifically, the existence of complementary relations among the well-being dimensions implies that – *for the same average level of well-being across the dimensions* – a balanced distribution (the light blue bars in figure 6) is associated with higher overall well-being than an unbalanced one (the dark blue bars in figure 6). The theoretical assumption underlying this research project is therefore that a balanced situation among the three dimensions of economic, social and environmental well-being is, ceteris paribus, associated with a higher overall level of well-being than when the situation across the three dimensions exhibits more dispersion. From this expectation the the set of main hypotheses of this research is:

H_0: There is no effect of the degree of dispersion among the well-being dimension on overall well-being.

H_a: There is a negative relation between the degree of dispersion among the dimensions and overall well-being.

In principle, complementarities among the well-being dimensions are a characteristic of the well-being function and should therefore occur for all units of analysis, which is why the hypotheses could be tested for countries, regions or on even smaller levels of aggregation. However, the effect of complementarities is likely to be larger for the regional than for the national level, due to two reasons. First, some of the supermodular relations described depend crucially on processes taking place in the same location. For instance, the effect of environmental pollution is clearly related to the precise place where this pollution is experienced. Therefore, the environmental dimension of well-being is place-specific and people can only benefit from complementarities with the other dimensions if they are in the same location. Thus, an improvement in environmental quality in a given place will imply larger gains from the economic and social dimensions only within a certain radius – people who live too far away to experience the change in environmental quality will not be affected. The same conclusion holds when considering the reversed relations: if economic growth benefits the quality of the environment, the largest effect will be in the direct vicinity. Since the effect of complementarities is restricted to a certain location, aggregating well-being may disguise the complementary effects and it is desirable to consider the effect of well-being on a regional rather than national level.

Second, since the effect of complementarities may be restricted to specific locations, policies designed to use the complementary nature of well-being should be applied on a regional level. This is also the recommendation by the OECD (2011b, p. 17), which suggest that complementary effects are likely to be both "most evident - and manageable - where they occur, in specific places". In terms of well-being complementarities, if policy makers strive for a radial reform strategy, which ensures that all dimensions of well-being develop in a balanced manner, this is likely to be easier on a regional level because the complementary effects for one specific region are more easily measured, analysed and addressed in terms of policy. Thus, implementing policies to accommodate the complementary relations between well-being dimensions is in line with a place-based perspective on policy making (Barca, McCann, & Rodríguez-Pose, 2012). Moreover, since complementarities occur in specific places, national policies are often restricted to analysing the trade-offs between the dimensions, whereas regional-level policies may also be able to make use of complementary relations.

For these reasons, complementarities may be especially relevant on a regional scale and the relation proposed in H_a would also imply a profound impact on the extent of regional disparities. Since data on subjective well-being measures is still very scarce on a regional level, regional comparisons generally need to draw on composite indicators to measure well-being. However, including the concept of complementary relations between well-being dimensions into the analysis of regional differences, could potentially yield a different picture of disparities. For instance, regions that have invested extensively in economic growth but less in other dimensions of well-being attain high rankings when using a traditional (income-based or substitutable composite) indicator. However, when accounting for the possibility of complementarities among dimensions, these regions would benefit relatively less than a region with a weaker economic performance but a more balanced situation overall. Thus, when well-being is compared on the basis of a composite indicator, which is predominantly characterised by the assumption of substitutability, it might be worthwhile to include an adjustment for the existence of complementarities in order to obtain more information on the regional distribution of well-being.

A second substantive part of this research project, besides addressing the hypotheses, is therefore to present an exploratory and descriptive analysis as to how complementarities could be used to augment regional comparisons of well-being. The second aim of this research focuses less on finding an empirically conclusive result and more on illustrating the challenges and possibilities of extending regional level comparisons of well-being to include a concern for complementarities. More generally, the two described aims of this research can be summarised as addressing two different, and sequential, aspects of complementarities in well-being.

The first step is to test whether dispersion among the dimensions is related to overall well-being, representing empirical evidence for the theoretical relations described in the previous subsection. As shall be described in more detail in the following section, subjective well-being data is required to test the hypotheses and these measures are generally unavailable on a regional level. Therefore, the first stage of this research project concerned testing the effect of complementarities on overall well-being using a panel data set of EU countries rather than regions. The second stage of research, then used these results to illustrate how the concept of complementarities could be included in well-being analysis on a regional level and whether it is informative to do so.

4. Operationalisation of Well-Being and Complementarities

As described in the previous section, the implemented analysis takes as starting point a three-dimensional framework of well-being and the theoretical justification for pairwise supermodularity among the dimensions. This section describes the operationalisation of these concepts in detail. However, in order to clarify the methodological reasoning behind the chosen operationalisation, it is useful to first describe the logic of the research approach.

4.1. Research Approach

One of the aims of this research is to empirically test whether a balanced distribution of average well-being across the dimensions is indeed associated with higher overall well-being, as predicted by the concept of complementarities. Thus, hypothesis H_0 can generally be addressed by estimating a regression model that relates a measure of complementarities to a measure of overall well-being. However, there are three theoretical and methodological features that determine the possible specifications of such a regression model.

First, complementarity among the well-being dimensions can, by definition, only be analysed within a multidimensional conceptualisation of well-being. Thus, a first crucial component of the estimated empirical model is a composite indicator, which is based on the presented framework of multidimensional well-being in figure 3. Second, since the existence of complementarities implies that a balanced distribution of average well-being across the dimensions is associated with higher overall well-being, it is necessary to measure how balanced an observed distribution is. Thus, a measure of dispersion among the dimensions included in the composite indicator of well-being is required. Third, a crucial methodological aspect to note is that a composite indicator of well-being is an artificial construct rather than an exogenous, random variable; it is determined completely by the assumptions of its construction. Therefore, testing for the effect of complementarities on a composite indicator of well-being is moot: the effect of complementarities on the indicator are determined by the assumptions of its construction. For this reason, testing the effect of complementarities requires a second measurement of well-being, which is not endogenous in the analysis.

From the theoretical framework in figure 3, well-being can be measured at two different points in the conceptualisation. First, it can be constructed as a composite of the three dimensions, essentially interpreting each of the dimensions as an input to overall well-being. Second, it can be measured by means of a subjective evaluation of overall well-being (e.g. life satisfaction), which is closer to measuring the “output“ of well-being from the three dimensions. In order to solve the problem of endogeneity of a composite indicator of well-being, both approaches are taken within this project. Subjective well-being (SWB), while being influenced by the dimensions of well-being can be considered an exogenous factor and can therefore be used as dependent variable[3]. A composite indicator of well-being is then required to allow for the conceptualisation of complementari-

[3] Technically, subjective well-being could also be included in a composite indicator as a fourth dimension of well-being as illustrated, for example, in the Better Life Index. This is not feasible within this project because subjective well-being is already used as the dependent variable.

ties and to control for the average level of well-being across the dimensions. Therefore, the estimated regression models are of the general form:

$$(6) \qquad Subjective\,Well\text{-}Being_{it} = \beta_0 + \beta_1\,Average\,Well\text{-}Being_{it} + \beta_2\,Dispersion_{it} + \varepsilon_{it}$$

where *Average Well-Being* denotes the average level of well-being across the dimensions and *Dispersion* refers to a measure of how balanced the average level is distributed across the dimensions. Thus, H_a predicts β_2 to be negative because a larger dispersion implies a more unequal distribution across the well-being dimensions and less benefit from complementarities. In the following, the operationalisation of the components of (6) is described in detail.

4.2. Operationalisation of Well-being

It has been emphasised throughout this article that well-being is inherently difficult to represent because it is multidimensional and because it has subjective facets. Of the two operationalisations of well-being used in this research, one is primarily multidimensional and the other subjective. However, since complementarity among well-being dimensions can, by definition, only be tested when well-being is modelled multidimensionally, the first operationalisation of well-being represents the main focus of this research. Since the aim was to use this measurement in regression analysis, a composite indicator rather than a dashboard of well-being indicators was implemented. Although the single value of a composite indicator compresses the available data relatively strongly, it allows for an explicit modelling of the relationship among indicators and is easily included in econometric analysis. Therefore, in line with the majority of empirical literature on the topic of well-being comparisons, the framework of multidimensional well-being in figure 3, was operationalised by constructing a composite indicator that aggregates the three dimensions into a single value of well-being.

4.2.1 Construction of a composite indicator of well-being

The components included in the composite indicator are defined by the dimensions in the presented framework of well-being: economic well-being, social well-being and environmental well-being. For each of these dimensions, one associated indicator was selected, normalised, weighted and then aggregated with the other two to yield a single indicator ranging from zero to one. Since two versions of a composite indicator were constructed for the purpose of the analysis, the general assumptions and methods are presented before going into detail on the variables included in the aggregation.

Method of aggregation

Since the effect of complementarities was measured explicitly by including a measure of dispersion in the analysis the constructed index was built on the assumption of perfect substitutability. Therefore, the indicator is defined as a linear aggregation of the dimensions, which corresponds to the arithmetic mean of the values of each of the three dimensions. This approach facilitates testing whether the degree of dispersion among the dimensions affects overall well-being because it separates the variable that measures complementarities from the general composite indicator of well-being. In this sense, restricting the operationalisation of complementarities to the measure of dispersion, allows to test whether dispersion explains variation in overall well-being beyond the variation explained by a traditional composite indicator based on substitutability.

Alternatively, a composite indicator with imperfect substitutability among the dimensions could have been constructed. The most recent revision of the HDI, for instance, is based on the geometric mean of its components (see Klugman et al., 2011). Using the geometric mean implies a multiplicative form of the composite indicator. Therefore, the mixed partial derivatives of such a composite indicator are positive as the definition of complementarities requires. However, specifying the HDI as a geometric mean has been criticised because it implies that the marginal returns to each component depend on the value of the other components. While this is desirable for imperfect substitutability, it also implies that the trade-offs between the components depend on their level, which leads to the result that the implicit value attached to an extra year of life expectancy is less (in monetary terms) in a poor country than in a rich one (Ravallion, 2012). However, other specifications, that limit the problem of unintuitive trade-offs, are possible (see e.g. Decancq & Lugo, 2013; Ravallion, 2012). Essentially, all aggregation methods of a composite well-being indicator, which represent a concave function, will imply some degree of complementarity. Nevertheless, the example of the HDI illustrates that modelling an indicator as including complementarities raises a range of methodological issues. Since operationalising the complementary relationships separately from the composite indicator facilitates the testing of their effect, it was more convenient for this project to implement a linear aggregation, which is consistent with perfect substitutability among dimensions and then model the complementarities separately.

Weighting

Determining the weights to be attached to each of the components is a highly influential step in the construction of a composite indicator. Although, weights within a composite indicator are often interpreted as a measure of relative importance, Munda and Nardo (2005) illustrate that weights always define the relative trade-offs when a linear aggregation method is used. Therefore, weights are essential in describing the ease of substitution between two dimensions. In this sense, weights can be used to differentiate among the dimensions and make the substitution of one dimension relatively more difficult. While this affects the ease of substitutability, it does not represent complementarities because the trade-offs defined through weighting within a linear aggregation are constant and do not depend on the values of the other dimensions.

Decancq and Lugo (2013) suggest that weights can be derived from the analysis of data (e.g. based on frequency or statistical methods such as principal component analysis), set on normative grounds (e.g. expert opinions), or be determined through a mixture of the two (e.g. stated preference approaches or hedonic weighting). Choosing one of these approaches already represents a normative statement itself because there is little information on the relative desirability of the weights. In practice, the applied weighting scheme often seems to be determined by data availability. The majority of studies using composite indicators use an equal weighting scheme (Decancq & Lugo, 2013). Assigning equal weights is a convenient but very simplistic viewpoint and, due to the fact that it is an arbitrary choice, does not offer a lot of supporting evidence. Nevertheless, considering that many studies, and e.g. the HDI, use equal weights, the composite well-being indicator in this project was also constructed with an equal weighting scheme. The choice of equal weights of the dimensions is advantageous because it does not require additional data and it is adequate for the exploratory nature of this project. However, it would be desirable to apply different weighting schemes in order to test for robustness of the results.

Based on the described methodological choices of the aggregation method and weights, composite well-being indicators were constructed. They were of the general form:

$$Composite\,Well\text{-}Being = \frac{Economic + Social + Environmental}{3} \quad (7)$$

This form of a composite indicator of well-being was based on the framework presented in Figure 3. However, it could easily be extended to comprise more than three dimensions or it could be refined by introducing a different weighting scheme.

Choice of indicators

After having decided and justified the general format of the composite well-being indicator, the next step of construction was to select the indicators to represent each of the three dimensions. The presented theoretical framework of well-being includes several components for each dimension, which are based on the OECD definition of well-being. While all of these components are relevant to overall well-being, some are more difficult to operationalise than others. In particular, issues such as housing quality, social connectedness or civic engagement are difficult to measure and data on these areas of well-being is scarce. Due to the empirical approach of this project, data availability is an important concern. More specifically, since testing H_1 requires a regression analysis, minimum sample size needs to be considered. Moreover, since the aim of this project is an application of a composite well-being indicator to the OECD TL2 regions, it is crucial that the indicator can be constructed for a sufficient number of these regions.

On the grounds of data availability and theoretical relevance for overall well-being, four areas of well-being were selected to represent the dimensions of well-being. For the economic and environmental dimensions only one component met the criteria of adequate data availability, while there are two possible components for the social dimension (see table 2).

Dimension	Component
Economic	Income
Social	Health Status Labour Market Situation
Environmental	Air Quality

Table 2: Selected components of well-being dimensions

For the economic dimension, selecting income as component of well-being was a clear choice for three reasons. First, it is a monetary measure of economic performance such as GDP per capita and is therefore correlated with the general economic situation of a country or region. Second, focusing on income has the advantage of measuring how much people are actually able to afford, which is thought to be more important for well-being than measures that are based on the value of production (see e.g. Stiglitz et al., 2009). Third, there is a large body of literature documenting the importance of income for well-being (e.g. Boarini et al., 2012; Kahneman & Deaton, 2010; Sacks et al., 2012). In constructing the composite indicator, the component of income was measured by means of disposable household income, which most closely corresponds to the notion of income.

In order to operationalise the social dimension of well-being, health status and the job market situation were selected. Health status is an influential determinant of well-being as illustrated by an extensive literature on the relation between health and life satisfaction (for an overview see e.g. Dolan et al., 2008). Clearly, being healthy matters to individuals and is also an indicator of the functioning of a society. Indeed, health is not only assumed to be conducive for well-being but is also a more general indicator of development, of the provision of services and, when taking a time perspective, of the progress of science and technology. The job market situation lies at the intersection of social and economic well-being. This is due to the fact that unemployment is influenced by the general economic situation. However, unemployment is also an important determinant of well-being beyond its effect on income (e.g. Dolan et al., 2008; Frey & Stutzer, 2000). As an indicator of social well-being a high level of unemployment is associated to a variety of social issues such as, for instance, a high degree of economic insecurity.

These two components of the social dimension were selected because they are both highly relevant for overall well-being. However, the choice to include both of these components was also motivated by the fact that health status and employment concern different time frames. The health status of a society is a long-term development, which does not exhibit much variation over time. In contrast, the labour market situation varies quite strongly as illustrated for instance by the effect of financial crises on unemployment levels. It is possible that the time dimension of these indicators influences the resulting composite indicator, which is why both specifications were calculated and compared throughout the analysis.

Health status was approximated with the indicator of life expectancy at birth. While life expectancy is by some considered to relate to "quantity of life" rather than quality of life (e.g. Becker, Philipson, & Soares, 2005), it is determined to a large degree by rates of mortality and the incidence of disease. Thus, it can be considered as a representation of a society's health status and is widely used as such, for instance within the HDI and the Better Life Index. Since the effect of the labour market situation is largely reflected in the unemployment rates, this indicator was selected. It is widely available and represents a reliable indicator of the job market situation.

For the environmental dimension of well-being, it is more difficult to find a good measure because data is relatively scarce. Air quality is on of the only indicators, which is available and measured consistently for a sufficient amount of regions[4]. However, it is likely that air quality is correlated with other types of pollution generally associated with large-scale industrial production and traffic, such as, for example, water quality and therefore represents a good indicator of overall environmental well-being. Also, despite the fact that air quality is relatively difficult to observe directly, as only extreme cases (e.g. smog) are noticeable for an individual, there is some evidence suggesting that it affects subjective well-being (MacKerron & Mourato, 2009). Air quality is usually measured either by the degree of pollution in the air (for instance in terms of particulate matter) or in terms of the pollution created within a given region or country. For reasons of data availability, CO_2 emissions were selected to measure air quality.

Using the described indicators to approximate the dimensions of well-being, two composite indicators were calculated (see table 3). The first one uses life expectancy to measure social well-being, while the second one includes unemployment. Alternatively, the two measures of social well-being could have been averaged in order to provide a single indicator for the social dimension. However, since health status and labour market situation differ with respect to their time frames, it was decided instead to compute two separate indicators and compare them directly.

Dimension	Composite Indicator 1: WB_{LE}	Composite Indicator 2: WB_{UN}
Economic	• Disposable household income per capita	• Disposable household income per capita
Social	• Life expectancy at birth	• Unemployment rate
Environmental	• CO_2 emissions per capita	• CO_2 emissions per capita

Table 3: Components of constructed composite indicators WB_{UN} and WB_{LE}

Normalisation and aggregation

When considering the aspects included in the two constructed composite indicators, it is evident that some of the components have a positive effect on well-being, while others have a negative effect. Moreover, the scale of the included indicators clearly differs, as income is measured in monetary terms, whereas life expectancy is measured in years. In order to aggregate these indicators into a composite, it is therefore necessary to convert them to a comparable scale.

There are different approaches to normalisation such as simple ranking of observations, standardisation or categorisation *(see OECD, 2008)*. The normalisation procedure applied here is commonly referred to as *max-min normalisation* and is widely used, for example in the HDI and the Better Life Index. For the normalisation of a given variable, each observation x_{it} is transformed into a normalised value $\hat{x}_{it}$ between zero and one by subtracting the overall minimum value and dividing by the range of observed values:

(8) $$\hat{x}_{it} = \frac{x_{it} - min(x)}{max(x) - min(x)}$$

[4] Some data regarding water quality is also available, but not on a regional level.

For those indicators, where a higher value is thought to be associated with lower overall well-being (i.e. unemployment and CO_2 emissions) the normalised value was calculated as:

$$\check{x}_{it} = 1 - \frac{x_{it} - min(x)}{max(x) - min(x)} \quad (9)$$

For those indicators that concern "bads" rather than "goods", (9) yields an inversely coded normalised value: a high level of unemployment will yield a normalised value of close to zero, whereas a low value will be close to one.

It is important to note that the minimum and maximum values used for the normalisation are the overall observed minima and maxima for all countries and all years. Therefore, the observation that corresponds to the highest value overall has the normalised value of one, while the lowest value has the value of zero. This is necessary to allow cross-sectional comparisons as well as comparisons over time. In the present case, using the overall observed extreme values also facilitates dealing with an unbalanced dataset because the normalised values apply regardless of when the first observation occurs. However, normalising by means of observed extreme values has the disadvantage of being very sensitive to outliers: if the minimum (maximum) is a strong outlier, the remaining normalised values will be skewed to be relatively high (low).

To avoid the effect of outliers, it is also possible to set benchmark values as the minimum and maximum, as is the case in recent publications of the HDI. However, for the used indicators and the specific sample there is no theoretical reason to specify a given value as benchmark. Since picking an arbitrary benchmark value imposes another assumption on how to construct the composite indicator, it was decided to use the data-driven perspective of using observed values. Another possibility would be to standardise the variables using the observed mean and standard deviation. However, this method yields negative values that would then require shifting the scale upwards. Since the necessary shift differs among indicators, this is a tedious and arbitrary correction. Also, since the composite indicator is constructed as a simple average of the normalised indicator values, it automatically falls in the range between zero and one, which is convenient for interpretation.

4.2.2. A note on the logic of composite indicators

On the basis of the detailed description of operationalisation and methods of construction, the computed composite indicators of well-being are WB_{LE} and WB_{UN}, both of which aggregate normalised indicators across the economic, social and environmental dimension. These indicators are in line with the theoretical framework proposed in figure 3. However, as mentioned earlier in this section, the constructed composite indicators are not sufficient to test the effect of complementarities on well-being. Now that the details of the construction were discussed, it is useful to revisit this point and emphasise again its methodological importance.

In particular, the composite indicator was constructed under the assumption of perfect substitutability in order to allow a separation of the well-being concept and the complementarity concept. Therefore, there is no point in testing for the effect of complementarities in this measure of well-being. Indeed, a correlation between the composite indicator and a measure of dispersion across the dimensions does not indicate the effect of dispersion on overall well-being but rather whether countries with less dispersion usually exhibit a higher *average* level of well-being across the dimensions. This is a subtle but important difference because the assumed relation within the composite indicator remains one of perfect substitutability.

Since the aim of this research is to test the effect of complementarities on overall well-being, it is necessary to operationalise complementarities as a separate variable rather than modelling them within a composite indicator. This research design also implies, necessarily, that a second indicator of well-being is required, which is not defined by the dimensions of well-being. It should also be noted that modelling a composite indicator as including complementarities, e.g. in terms of a geometric mean, would not solve this problem. This is due to the fact that, when a composite indicator is modelled according to a certain specification of complementarities, testing for the effect of complementarities is superfluous. These considerations are crucial when working with composite indicators, because the nature of designing a measurement according to the researcher‘s ideas implies that it is not a random, exogenous variable but a representation of its underlying assumptions. For this reason, testing the effect of well-being requires a second operationalisation of well-being. This operationalisation uses the second possibility of measuring well-being within the theoretical framework of figure 3: subjective well-being.

4.2.3 Measuring subjective well-being

The term of subjective well-being refers to people‘s evaluations of their well-being. The main source of subjective well-being data is large-scale surveys although other elicitation methods of subjective well-being exist[5]. There are generally two types of subjective indicators commonly used to measure well-being. The first type refers primarily to the concept of *happiness* and is often accompanied by measures of positive or negative affect. Generally, this type of subjective well-being measurement describes the experience of well-being, often in terms of emotions or moods. The second type of subjective well-being measurement concerns the concept of *life satisfaction* and takes an approach of cognitive evaluation rather than experience.

For the aim of measuring well-being on a macro rather than individual level and in the broad context of regional development, the latter conceptualisation is more fitting. Since well-being is understood within this research as a combination of different objective and subjective factors, using a cognitive evaluation of life as a whole represents the theoretical concept of well-being. It is also more adequate for this purpose because measures of life satisfaction are usually assumed to be relatively stable, while happiness measures are prone to change on the basis of short term personal experiences (see e.g. Diener, 2000). Nevertheless, life satisfaction measures also incorporate a number of disadvantages, which are mostly related to the reliance on self-reported values. For instance, people tend to interpret Likert scales differently and there is some evidence that culture norms lead some countries to report generally lower or higher life satisfaction than others (Inglehart & Klingemann, 2000). Also, despite not being as volatile as happiness, life satisfaction is still

[5] For example, the Day Reconstruction Method or Experience Sampling (see e.g. Kahneman et al., 2004)

influenced by a variety of factors, such as moods or comparisons with others (Kahneman et al., 2004). However, since surveys are currently the only widely applied method of data collection, there is no other possibility but to consider the heterogenous factors influencing reported life satisfaction as random disturbances and assume that they do not represent systematic biases.

Despite these disadvantages, life satisfaction is commonly used to approximate well-being in cross-country comparisons. In line with this broad literature (see Section 2), subjective well-being was measured as an evaluation of life in general as captured in the question: "How satisfied are you with your life, in general?". Answers were recorded on a Likert scale indicating different degrees of satisfaction and aggregated across individuals to yield an average level of life satisfaction per country. As previously noted, despite the popularity of life satisfaction as a measure of subjective well-being, data on this indicator are scarce and only widely available on a national level. While it would theoretically be possible to derive life satisfaction on a regional level from national surveys, this procedure is tedious and the scales and questions are not necessarily comparable. Thus, in order to be able to use relatively reliable life satisfaction data in order to measure subjective well-being, the analysis of the effect of complementarities on overall well-being was conducted on a national level.

4.3. Operationalisation of Complementarities

In line with the presented theory, analysing the effect of complementarities among the well-being dimensions on overall well-being, requires a measure of complementarity. As described from a theoretical point of view, presence of complementarities implies that situations where the situation in each of the dimensions of well-being is similar are preferable to situations were the situations differ strongly. In the optimal case, the situation in each of the dimensions would be equally good (or bad). As mentioned previously, the effect of complementarities only concerns the relative level of well-being across the dimensions, which is why it is important to control for the absolute level by including the value of the constructed composite indicator in the regression model. In order to measure the degree of balance or unbalance among the three dimensions of well-being, two types of indicators were used, which are described and compared in the following.

4.3.1. Measuring dispersion among the well-being dimensions

A simple but powerful method to conceptualise complementarities is by measuring the degree of dispersion among the dimensions. Thus, instead of measuring how balanced the distribution among the three dimensions of well-being is, it is straight-forward to measure how unbalanced it is by considering a standard deviation (SD). In particular, when computing the standard deviation across the three normalised values included in the composite indicator, this simple indicator captures the degree of deviation of each of the components of the indicator from the mean. Since the composite well-being indicator WB_{it} is defined as the arithmetic mean of the normalised indicators $\hat{x}_{jit}$ representing each of the N dimensions of well-being (j), the standard deviation is defined as:

(10) $$SD_{it} = \sqrt{\frac{1}{N}\sum_{j=1}^{N}(\hat{x}_{jit} - WB_{it})^2}$$

Intuitively, when the standard deviation across the dimensions of well-being is zero, the normalised values representing each dimension are equal. Thus, a higher standard deviation indicates more variation among the dimensions for a given country and year and should, theoretically, be associated with a lower overall level of well-being. This measure of dispersion has been used to estimate the effect of complementarities on GDP growth (Braga de Macedo et al., 2013, in press).

4.3.2. Measuring the degree of equality among well-being dimensions

An alternative indicator to measure the effect of complementarities, is the *Complementarity Index* (CI)[6], suggested by De Macedo and Oliveira Martins (2008). It is based on the Herfindahl-Hirschmann Index (HHI), which was designed to measure industry concentration and market power in a context of competition policy. The HHI ranges from zero to one where zero refers to perfect competition (i.e. an infinitely small degree of concentration) and one refers to a monopoly (i.e. complete concentration). Applied to the notion of well-being dimensions, a small degree of concentration implies that the contribution of each dimension of well-being is roughly equal. The highest concentration within the constructed composite indicator of well-being would be observed, for example, if one dimension has the normalised value of one (indicating the highest observed value in the sample) whereas the other two dimensions have the normalised value of zero (lowest observed values). CI, the inverse of the HHI, thus ranges from a minimum of one to the number of dimensions included in the index (three in this case) and is defined as:

(11) $$CI_{it} = \frac{1}{\sum_{j=1}^{N}\left(\frac{\hat{x}_{jit}}{WB_{it}\cdot N}\right)^2}$$

Due to its roots in the popular and elegant HHI, this index has been applied in several publications on the role of policy complementarities (e.g. Bicaba, 2013; Braga de Macedo & Oliveira Martins, 2008; Coricelli & Maurel, 2011) and was also implemented in this research.

The CI is more difficult to explain intuitively. It is based on the relative proportion of each dimension of well-being to the sum across well-being dimensions squared. In contrast to the standard deviation, which measures dispersion by the difference to the mean, the CI is inherently nonlinear in its components. In order to provide a sense of the behaviour of the function, three-dimensional plots of CI and SD were constructed. For this, the indicator was plotted against hypothetical values of two of the three well-being dimension while fixing the third dimension to a specific parameter.

[6] The indicator is called RC (Reform Complementarity) in the original article.

Varying this parameter then provides a three-dimensional and dynamic view of the indicator[7]. Figure 7 shows static three-dimensional graphs of the two indicators for some parameters side by side.

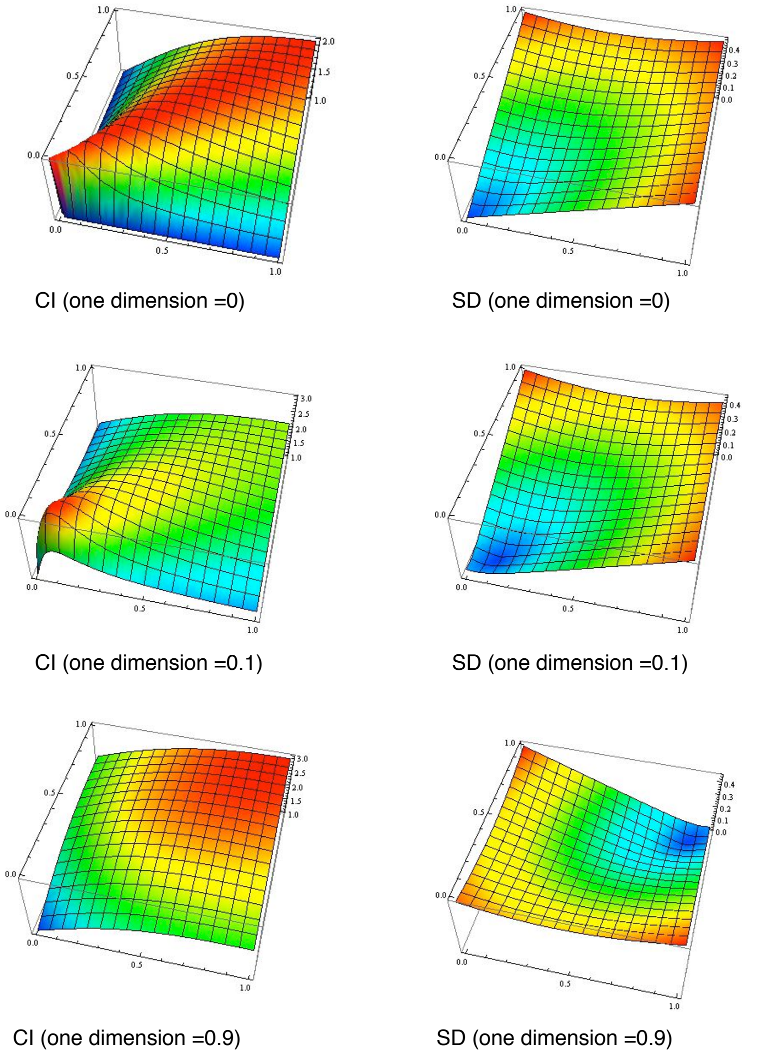


Figure 7: Three-dimensional plots of CI (left) and standard deviation (right). z-dimension reflects value of indicator, one parameter fixed at specified value.

Examining the three-dimensional graphs and the mathematic definition, it is evident that, in comparison to the relatively simple standard deviation, the CI has several undesirable properties, which should be noted. First, the CI is not an accurate measure of concentration when one or more of the normalised values included in the composite well-being index is zero. In particular, when, for a given observation, the value of one of the dimensions is the lowest observed value in the sample (thus assigning the normalised value $\hat{x}_{it} = 0$) this dimension is dropped from the calcula-

[7] The dynamic representations of these plots is uploaded online and can be viewed when opening the links in a browser.
CI: https://dl.dropboxusercontent.com/u/21100991/CI01.gif
SD: https://dl.dropboxusercontent.com/u/21100991/SD1.gif

tion of CI because $\frac{0}{WB_{it}} = 0$. Therefore, all minimum values in the sample do not contribute to the concentration or dispersion when measured by CI. For instance, when $\hat{x}_{1it} = 0$ and the other two dimensions are equal, CI yields a value of 2 regardless of whether the three dimensions are overall relatively similar (e.g. $(\hat{x}_{1it}, \hat{x}_{2it}, \hat{x}_{3it} = (0, 0.1, 0.1)$) or very different (e.g. $(\hat{x}_{1it}, \hat{x}_{2it}, \hat{x}_{3it} = (0, 0.9, 0.9)$). This situation is illustrated in the first panel in figure 7. Similarly, if two of the dimensions have the value of zero, the CI always yields the value of 1. For example if $\hat{x}_{1it} = 0$ and $\hat{x}_{2it} = 0$:

(12) $$CI(\hat{x}_{1it}, \hat{x}_{2it}, \hat{x}_{3it},) = CI(0,0,1) = CI(0,0,0.1) = CI(0,0,0.5) = 1$$

Although these clearly are special cases, these examples illustrate that the CI is not a smooth function of the normalised indicator values per dimension, but is characterised by irregularities and kinks. The irregularities caused by including a value of zero can be adjusted by simply adding a small arbitrary number to all normalised values. However, this adjustment is a bit rough and could, theoretically, affect the relative distribution of the normalised values. Measuring dispersion through the standard deviation does not create problems with zero-values.

Second, in contrast to the standard deviation, CI is asymmetric. The same amount of dispersion between the three dimensions leads to a smaller value of CI when the average level WB_{it} is relatively low than when it is high. The two lower panels in figure 7 illustrate the function of CI when one dimension is fixed at $\hat{x}_i t = 0.1$ and when it is set at $\hat{x}_i t = 0.9$. It is evident that, for $\hat{x}_i t = 0.1$ the area corresponding to the highest values (i.e. close to CI=3) is much smaller than for the case where $\hat{x}_i t = 0.9$. In contrast, for the standard deviation measure, the area corresponding to the lowest values (i.e. the situation where all three dimensions are almost equal) is of the same size for all specifications. The asymmetry of CI implies that the indicator is less sensitive to dispersion among the well-being dimensions when the average level (WB_{it}) is relatively high. It also yields the unintuitive result that two sets of normalised values with the same standard deviation are associated with different degrees of concentration in terms of the CI (see table 4).

It can be argued that the asymmetry of CI is intuitive because unequal distributions for high values should be less detrimental for overall well-being than for low values. However, this characteristic integrates the measure of the relative distribution (dispersion) with the measure of the absolute level (composite indicator). The same arguments as for the case of aggregating the composite indicator to already include complementarities applies here: it is preferable to separate the effect of complementarities in order to be able to test the effect of a balanced distribution among the well-being dimensions beyond the effect of a higher level. Additionally, since the CI is a nonlinear function, it is difficult to extend the analysis here to more than three dimensions. For standard deviations, it is straight-forward to apply this measure of dispersion to any conceptualisations of multidimensional well-being. For the presented reasons, using the standard deviation to

$\hat{x}_{1it}$	$\hat{x}_{1it}$	$\hat{x}_{1it}$	SD_{it}	CI_{it}
0.2	0.8	0.8	0.3464	2.4545
0.2	0.2	0.8	0.3464	2.0

Table 4: Example of asymmetry in CI

measure the degree of dispersion among the well-being dimensions is theoretically and methodologically preferable. However, since the complementarity index is a relatively established measure in the literature on policy complementarities, this indicator is applied for the sake of completeness and comparison.

5. Sample and Estimation Methods

The previous section discussed the general research approach and the operationalisation of the relevant concepts. Based on these descriptions, it is now possible to present the specific empirical models estimated and describe the sample used as well as the estimation methods. In particular, the previous section described a total of five indicators, which were used in the estimation:a measure of subjective well-being, two composite indicators of well-being ($WB_{LE}$and WB_{UN}) and two indicators to measure whether the situation across the different well-being dimensions is rather similar or different (CI and SD), which are summarised in table 5. Drawing on the previous discussion of the general form of a regression model to test the effect of complementarities on overall well-being the following four models were estimated.

(13) $$LS_{it} = \beta_0 + \beta_1\, WB_{UN_{it}} + \beta_2\, SD_{it} + \beta_3\, Year\ Dummies + \varepsilon_{it}$$

(14) $$LS_{it} = \beta_0 + \beta_1\, WB_{UN_{it}} + \beta_2\, CI_{it} + \beta_3\, Year\ Dummies + \varepsilon_{it}$$

(15) $$LS_{it} = \beta_0 + \beta_1\, WB_{LE_{it}} + \beta_2\, SD_{it} + \beta_3\, Year\ Dummies + \varepsilon_{it}$$

(16) $$LS_{it} = \beta_0 + \beta_1\, WB_{LE_{it}} + \beta_2\, CI_{it} + \beta_3\, Year\ Dummies + \varepsilon_{it}$$

Abbreviation	Indicator
WB_{LE}	composite well-being indicator based on: • disposable household income per capita • life expectancy • CO_2 emissions
WB_{UN}	composite well-being indicator based on: • disposable household income per capita • unemployment rate • CO_2 emissions
LS	measure of subjective well-being: Life Satisfaction
SD	measure of dispersion across dimensions of well-being: Standard deviation
CI	measure of dispersion among dimensions of well-being: Complementarity Index (inverse HHI)

Table 5: description of indicators included in regression models

The structure and logic of each specification is the same: it relates an average life satisfaction score to a measure of dispersion across well-being dimensions while controlling for the average level of well-being among the dimensions. Moreover, all models include a set of year dummies, in order to account for the fact that life satisfaction may be affected by specific events or time trends, such as, for example, the financial crisis in the last 4 years of the sample.

Since the described standard deviation indicator measures dispersion, while the CI measures the inverse of dispersion, theory would predict a higher standard deviation to be associated with lower life satisfaction, while a higher CI indicator would imply a higher level of life satisfaction. Thus, according to the hypothesis H_a β_2 is expected to be negative in equations (13) and (15) and positive in equations (14) and (16).

5.1. Sample and Variable Description

As mentioned previously, the requirement to use subjective well-being in the estimated model implies that regional data, although more fitting to the general research theme, is not available. Instead, the regression models in (13) - (16) were estimated for a national panel data set. Using national data does not only imply that life satisfaction scores are relatively widely available, it also allows to introduce a time dimension to the analysis. In contrast to regional level data, subjective well-being data for some countries is available for relatively long time series, thus allowing the use of panel data.

Since the true determinants of well-being are often unobservable, regression analyses of the topic of well-being are at risk of omitted variable biases, which would imply biased estimates. Especially for life satisfaction, where it is often found that cultural preferences influence individuals‘ answers (Inglehart & Klingemann, 2000), it is therefore important to attempt to control for unobserved variables. For this reason, using panel data in estimations of well-being is especially valuable because it curtails the risk of omitted variables. Additionally, since the specified regression models are relatively simplistic, it is likely that there are some characteristics influencing life satisfaction, which one should controlled for.

Since regional variables regarding life satisfaction are scarce and some of the variables to be included in the composite indicator are not widely available (e.g. data on household income and environmental quality), it was not feasible for this project to estimate the described regression models for a regional dataset. The sample used for the estimation of equations (13) - (16) was therefore a unbalanced panel data set on 22 European countries on time periods between 1990 and 2011 (see appendix A for an overview of the sample). All in all, the sample comprised 299 observations across 22 countries with an average of 13.6 time periods available per country. This sample was selected because it offered the largest cross-section and longest time series to be estimated using life satisfaction data collected within the same survey and therefore using the same answer scale and coding. Nevertheless, the sample is generally rather small for a panel estimation, which limits the power of the analysis.

Data on life satisfaction was obtained from the Eurobarometer, a yearly public opinion survey conducted by the European Commission in all European Union member states (and some other European countries) since 1973. The sample used for analysis was unbalanced mostly because countries enter the survey in the year of their accession to the European Union. With the exception of Norway, all countries were observed continuously from the year of their first survey until 2011, the latest year included in the sample. For the data from 1990 until 2002 data was obtained from the Mannheim Eurobarometer Trend File (Schmitt & Scholz, 2005), which aggregates the Eurobarometer survey up until 2002. From 2003 onwards data was obtained directly from the GESIS Eurobarometer Data Service database. Along with the data on life satisfaction, the appropriate post-stratification weights were obtained and applied in order to ensure comparability of the survey answers.

The indicator for life satisfaction refers to the Eurobarometer question: "On the whole, are you very satisfied, fairly satisfied, not very satisfied or not at all satisfied with the life you lead?". In data preparation within this project, the answer possibilities were recoded to numerical values with the value of four corresponding to "very satisfied" and one to "not at all satisfied". An average value of life satisfaction was computed by applying the proportion of people answering in each category to the associated numerical value.

It should be noted that the Eurobarometer survey generally provides data on a regional level, which has been used in a few empirical studies (Okulicz-Kozaryn, 2011; Pittau et al., 2009). Indeed, the sampling procedure of is based on NUTS1 regions. However, Eurobarometer surveys are representative at the country level only and no post-stratification weights are available for regional data. An exception is wave 44.2bis in 1996, which was designed to be representative at regional levels (see e.g. Okulicz-Kozaryn, 2011). Moreover, the regional categorisation applied in the Eurobarometer does not correspond to the OECD TL2 definitions used for analysis. Due to these reasons it was not possible to derive a sample of sufficient size for TL2 regions.

All remaining variables were obtained from OECD.Stat. The indicators used were average life expectancy at birth, the unemployment rate, man-made CO_2 emissions and net adjusted real household income. Net adjusted household income implies that it is corrected for differences in transfers and public services, which is desirable in order to measure the actual disposable income available. CO_2 emissions and household income were converted to per capita values in order to be comparable across countries with different population size. Moreover, the household income data provided by the OECD was in national currency, so it was converted to purchasing power parity (PPP) by using the OECD 2005 Benchmark PPP values. It should be noted that all countries and time periods, for which one of the required variables was missing, were excluded from the sample. This is due to the fact that the composite indicator (and its dispersion across the dimensions) can only be constructed and compared consistently if all three of its components are available.

5.2. Econometric Estimation Methods

In order to benefit from the panel structure of the data, fixed effects (FE) and random effects (RE) panel estimation was used to fit the described regression models. Fixed effects models acknowledge the heterogeneity among countries and account for stable unobserved characteristics, which are assumed to be correlated with the independent variables. Since the unit of analysis is countries and the fitted regression models are simple, it is likely that unobserved country heterogeneity affects the average level of the well-being dimensions or the dispersion. Also, since the models do not include any time-invariant variables, the main disadvantage of FE models, namely that they cannot incorporate dummy variables, is of no consequence here. For these reasons, fixed effect estimation represents the preferred estimation method for this analysis.

As an alternative, random effects estimation was also estimated. RE models are based on the assumption that the unobserved characteristics of countries, which affect life satisfaction, are uncorrelated to the independent variables. In the present analysis, this seems to be an unrealistic assumption because country characteristics probably also affect the average level of well-being across the dimensions. Despite this theoretical concern, random effects estimation was implemented to allow for comparisons with the fixed effects model.

6. Effect of Dispersion Across Dimensions on Overall Well-Being

Before presenting the estimation results of the described regression models, it is informative to consider some descriptive statistics of the dependent variable, life satisfaction. Examining plots of life satisfaction over time illustrates two features of the variable (see figure 8). First, when considering life satisfaction for all countries simultaneously, it is evident that some countries exhibit generally higher life satisfaction than others. Denmark‘s values of life satisfaction exceed the values of all other countries for all time periods. Other countries with high life satisfaction are the Netherlands and Sweden, while Hungary and Portugal report rather low values. Second, life satisfaction is relatively stable over time and does not exhibit large amounts of variation. Both of these observations are in line with empirical results on life satisfaction (e.g. Inglehart & Klingemann, 2000).

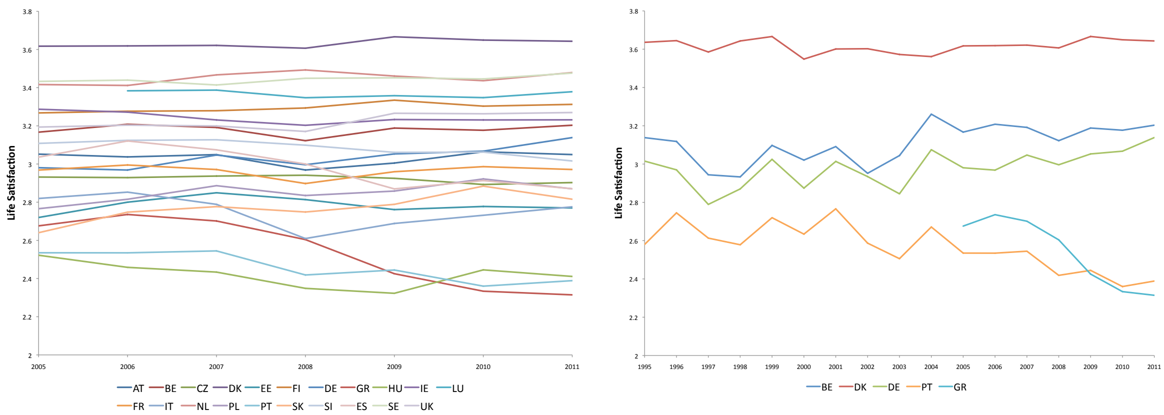


Figure 8: Time series plots of life satisfaction per country

However, when considering a subset of the sample for a longer time horizon, it is evident that some variation in life satisfaction does occur. In particular, while Denmark remains relatively stable, life satisfaction in Belgium and Germany exhibits a slight positive trend. In contrast, Portugal and Greece have experienced falling life satisfaction since 2005[8]. This observation is especially interesting in the context of the effect of the recent financial crisis on these countries as it indicates that the unfavourable socio-economic situation may be reflected in people‘s evaluations of life in general. It also represents a justification for including time dummies in the regression models, as life satisfaction seems to be influenced by general events and time trends.

Table 6 illustrates some general descriptive statistics for the entire sample and the indicators used in the estimated regression models. Comparing the two different specifications of the composite indicator (WB_{UN} including unemployment as the social dimension and WB_{LE} including life expectancy) WB_{UN} is associated with a higher average composite well-being level, but also with a higher degree of dispersion across the well-being dimensions than WB_{LE}.

Variable	Mean	St. Dev.	Min	Max
Life Satisfaction	3.062	0.300	2.315	3.666
Average Composite Well-Being: WB_{UN}	0.645	0.088	0.314	0.802
Average Composite Well-Being: WB_{LE}	0.607	0.116	0.216	0.867
Dispersion Composite Well-Being SD_{UN}	0.196	0.079	0.068	0.425
Dispersion Composite Well-Being SD_{LE}	0.178	0.084	0.043	0.400
Complementarity Index WB_{UN}	2.691	0.274	1.448	2.967
Complementarity Index WB_{LE}	2.676	0.359	1.064	2.984

Table 6: Descriptive statistics of considered variables

6.1. Estimation Results on a National Level

Tables 7 and 8 present the results of estimating the regression models described in section 5. For both computed composite indicators two specifications were estimated: one model using the standard deviation measure of dispersion (SD) and one using the complementarity index (CI) proposed by De Macedo and Oliveira Martins (2008). Each specification was estimated using fixed effects panel estimation and random effects estimation.

The estimates of all the implemented regression models illustrate a consistent picture of the effect of complementarities on subjective well-being. In particular, the average level of well-being across the three dimensions of well-being (measured by the composite indicator) is highly significant and positive for all models. This is in line with the general notion that a higher level of well-being in

8 A longer time series of life satisfaction of Greece was used to confirm this trend but is not presented here as these years could not be included in the dataset due to other missing data.

Regression models using WB_{UN} (composite indicator: income, unemployment, CO_2)

Dependent variable: Life Satisfaction	(1) Fixed Effects	(2) Random Effects	(3) Fixed Effects	(4) Random Effects
Average across Dimensions	0.883*** (0.111)	0.898*** (0.109)	0.850*** (0.146)	0.862*** (0.144)
Standard Deviation	-0.487*** (0.159)	-0.494*** (0.156)		
Complementarity Index			0.0573 (0.046)	0.0613 (0.045)
Constant	2.624*** (0.0871)	2.615*** (0.105)	2.380*** (0.0924)	2.353*** (0.106)
Joint significance time dummies (p-values)	5.89*** (0.000)	125.79*** (0.000)	5.67*** (0.000)	120.36 *** (0.000)
R^2 : within	0.441	0.441	0.424	0.424
R^2: between	0.240	0.240	0.247	0.248
R^2 : overall	0.201	0.202	0.186	0.187
Joint F-test fixed effects	235.7***		226.1***	
Sargan-Hansen statistic (p-value)	56.52*** (0.000)		22.85 (0.118)	
Observations	299			
Minimum obs per group	6			
Maximum obs per group	22			
Average obs per group	13.59			

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Regression models using WB_{LE} (composite indicator: income, life expectancy, CO_2)

Dependent variable: Life Satisfaction	(5) Fixed Effects	(6) Random Effects	(7) Fixed Effects	(8) Random Effects
Average across Dimensions	0.939*** (0.328)	0.839*** (0.265)	1.166*** (0.343)	1.003*** (0.277)
Standard Deviation	-0.649*** (0.220)	-0.698*** (0.212)		
Complementarity Index			0.0310 (0.048)	0.0519 (0.047)
Constant	2.732*** (0.179)	2.800*** (0.156)	2.399*** (0.159)	2.429*** (0.133)
Joint significance time dummies (p-values)	4.22*** (0.000)	89.57*** (0.000)	4.33*** (0.000)	91.28*** (0.000)
R_2 : within	0.307	0.307	0.284	0.284
R_2 : between	0.221	0.227	0.174	0.184
R_2 : overall	0.162	0.173	0.0930	0.105
Joint F-test fixed effects	174.8***		158.2***	
Sargan-Hansen statistic chi-square:16 p-value	52.27*** (0.000)		48.582*** (0.000)	
Observations	299			
Minimum obs per group	6			
Maximum obs per group	22			
Average obs per group	13.59			

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7 and 8: Regression estimates

either of the well-being dimensions (which contributes to a higher average level) is positively related to life satisfaction. This is an important result because it confirms that the artificial composite well-being indicator is, at least to some degree, measuring well-being.

Furthermore, in all specifications using the standard deviation measure of dispersion of well-being across the three dimensions, the effect of dispersion on life satisfaction is significantly negative. Thus, a higher standard deviation among the three variables forming the composite indicator is associated with a lower level of life satisfaction and this relation is significant at a confidence level of 1%. This finding presents evidence in support of the notion that a more balanced distribution of well-being across the three dimensions is correlated with higher overall well-being as suggested by the theoretical concept of complementarities. Interestingly, when using the complementarity index to measure how balanced the distribution of a given average level of well-being is across the dimensions, the estimated coefficients are not significantly different from zero. Although the average level of the composite indicator is still significant, these estimations suggest that countries with a more balanced set of well-being across the dimension do, on average, not experience higher levels of life satisfaction. Considering that the other measure of dispersion is estimated to be highly significant, this is result is surprising. However, it is likely that the non-significant result for this indicator is caused by some of the characteristics described in section 4.3.2, such as its nonlinearity and the fact that its sensitivity varies with the average level across dimensions.

Although the estimated coefficient of SD is significantly negative, it should be noted that it is relatively small in size. A one unit increase in the standard deviation indicator, is associated with a fall in life satisfaction of 0.49 for the composite indicator including unemployment. However, due to the normalisation underlying the composite indicator, the standard deviation cannot increase by this amount. This is due to the fact that the normalised values are all in the range [0,1] thus restricting the standard deviation for three dimensions to a maximum of 0.577[9]. Realistic changes in the standard deviation measure are therefore much smaller and so is the estimated effect on life satisfaction: if the standard deviation measure increases by 0.1 life satisfaction falls, on average, by 0.049. However, considering that the scale of life satisfaction ranges only from 1 to 4 and is relatively stable for most countries, a change by 0.05 may still represent an noticeable difference. In comparison to the indicator including unemployment, the effect size of the estimated coefficient is larger for the specification using life expectancy.

It should be noted that the included time dummies are highly significant for all specifications illustrating that life satisfaction is indeed related to specific events or episodes. Furthermore, the included fixed effects are also highly significant, which supports the methodological choice of estimating a panel model in contrast to pooling the data. Due to the structure of the (unbalanced) panel, the relatively strict necessary assumptions to implement a Hausman specification test were not met. Thus, it was not possible to use this test for differentiating between the fixed effect and random effect specifications of the model. In particular, the fixed effect estimator is consistent but may be less efficient than the random effects estimator. Instead of the Hausman test, an alternative

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[9] The theoretical maximum standard deviation across three dimensions occurs if the distribution is (0,1,1) or (0,0,1), see the plots in section 4.2.2.

test using overidentifying restrictions was implemented as suggested by Schaffer and Stillman (2006). The test strongly rejects the hypothesis that the unobserved effects are uncorrelated with the explanatory variables for most specifications thus indicating that the random effects estimator is not consistent. This is in line with the theoretical assumptions regarding the structure of the unobserved effects and the theoretical preference for fixed effects estimation.

A further point to be noted is that the independent variables explain a relatively large proportion of the variation in life satisfaction. For the models using the unemployment specification of well-being, the models explain over 40% of the variation in life satisfaction within a country over time, and the other specification still explains 30%. A large degree of this explanatory power is derived from the inclusion of time dummies. However, even when excluding time dummies, this simple model still explains a relatively large amount of variation when compared to typical R^2 values in the social sciences[10].

From a technical perspective, a few statistical caveats should be mentioned. First, the panel is relatively small for a panel estimation. It is neither a long panel (few cross-sections, many years) nor a wide panel (few years, many cross-sections). Since the majority of panel estimations concern one of these two cases (i.e. macro or micro panels) , there is relatively little theoretical literature on the effect of violations of regression assumptions in small panels and how to correct for them. In particular, implementing post-estimation tests yielded a rejection of the assumption of homoskedasticity for all models. In a regular wide panel, this could be controlled for by including cluster-robust standard errors. However, according to Angrist and Pischke (2008), 22 clusters may not be sufficient to apply clustered standard errors. Also, considering the small size of the sample, it is not clear whether the sample can sustain robust standard errors.

Similarly, conventional tests of serial correlation in the residuals indicate a possible problem. However, judging from conventional recommendations for wide panels, serial correlation does not usually indicate a problem if the sampled time period is less than 10 to 15 years. According to this rule of thumb, the possibility of serial correlation in the present sample could be ignored. However, theoretically, since life satisfaction is relatively stable over time, it is likely that it is related to life satisfaction in previous years, which would indicate the need to estimate a dynamic panel model. However, due to the unbalanced structure of the dataset and its small size, modelling serial correlation, e.g. through specifying a AR(1) process, proves to be difficult. For these reasons, and in line with the exploratory nature of this research, the results reported in tables 7 and 8 did not control for heteroscedasticity or autocorrelation. Hoechle (2007) suggests a method to implement Driscoll-Kraay estimators for heteroscedasticity and autocorrelation robust inference, which is appropriate in small samples. When using this estimation method, all significant coefficients in the non-robust estimations remain significant while regular cluster robust standard errors turn most significant estimates insignificant (see appendix C for output tables using robust standard errors).

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[10] When fitting a model that excludes time dummies in order to test for the changes in the explained variation, a fixed effects regression of WB_{UN} and SD_{UN} on life satisfaction explains 16.85 % of within and 21.59% of between variation.

6.2. Discussion of Estimation Results

Two conclusions from the estimation of the described regression models merit discussion at this point. First, when using the standard deviation measure of dispersion, the regression models estimate precisely the relation that was predicted by the theoretical discussion. However, the fact that this effect cannot be replicated when using the other proposed measure of dispersion, raises questions regarding the robustness of results.

The described problematic characteristics of the complementarity index likely contribute to this result, because of the inherent non-linearity. As described, the relation between the average level and the complementarity index is difficult to analyse and grasp, even for the relatively simple case of three dimension. Simple correlation analysis suggests that the complementarity index is, on average, more strongly correlated with the constructed composite indicator than the standard deviation (see table 9). This could contribute to the result that the complementarity is found to be insignificant when included along with the composite indicator. However, due to the theoretical model, the composite indicator needs to be included in the model to control for the average level of well-being and can therefore not be excluded.

	WB_{UN}	SD_{UN}	CI_{UN}	WB_{LE}	SD_{LE}	CI_{LE}
WB_{UN}	1					
SD_{UN}	-0.405	1				
CI_{UN}	0.686	-0.894	1			
WB_{LE}	0.701	-0.489	0.607	1		
SD_{LE}	-0.434	0.922	-0.849	-0.41	1	
CI_{LE}	0.578	-0.825	0.884	0.702	-0.868	1

Table 9: Correlation matrix of well-being and dispersion indicators

Besides the non-robust results when measuring dispersion with the different indicators, there is also a general issue of robustness, which is important to illustrate. In particular, although the constructed composite indicators are based on the presented theoretical framework, there are clearly a variety of possible indicators that could have been included in place of the selected ones. If the estimation results are indeed related to the existence of complementary relationships among the dimensions, they should be robust to the selection of different indicators. For example, health status could be measured by infant mortality or age-adjusted mortality rates instead of life expectancy; the labour market situation could be approximated by employment rates or long-term unemployment; and instead of CO_2 emissions one could measure the amount of waste or water quality. Formal robustness tests of the results in comparison to alternative specifications of the composite indicator are not feasible within this project because data availability does not allow for one balanced dataset. Thus, depending on how the alternative composite indicator is constructed, observations from the original dataset need to be dropped due to missing data and other observations need to be included to assure minimum sample size. Nevertheless, informal comparisons of alternative specifications were conducted and indicate that the results are overall robust to inclusion of other indicators for the social dimension. For the environmental dimension, only one alternative indicator was available, municipal waste, and testing the same regression models for composite indicators using this variable yielded only insignificant results (see Appendix C for an overview of alternative indicators).

Another important point to note is that the relations analysed in the regression models indicate correlations rather than causality. No convincing case can be made that would suggest that the degree of dispersion across the three dimensions of well-being causally affects life satisfaction. Rather, the theoretical intuition is that the existence of complementary relations among the dimensions leads people to experience lower levels of overall well-being when the dispersion among the dimensions is high. Therefore, in order to illustrate the effect of complementarities on overall-well-being, it is sufficient for this exploratory analysis to rely on correlations.

The results using the standard deviation indicator of dispersion thus suggest that countries that experience a relatively high degree of dispersion exhibit lower life satisfaction than would be expected from considering only the composite indicator of well-being. Despite some doubts regarding its robustness, this finding highly relevant for this research project because it indicates that approximating overall well-being by a perfectly substitutable composite indicator ignores an important influence on well-being. Although the analysis was conducted for 22 European countries, the effect of complementarities is likely to apply to the regional level as well and, considering that complementarities may be especially relevant on a regional scale (OECD, 2011b), may even be more influential. Therefore, when applying the concept of well-being to studies of regional development and disparities, the presented results illustrate that it may be necessary to adjust a regular (substitutable) composite indicator to allow for an effect of complementarities. The following section explores and illustrates how such an adjustment could be implemented and how it affects the relative ranking of regions by using the example of the OECD TL2 regions.

7. Complementarity-Adjustment for Regional Well-Being indicators

As mentioned previously, there is a large degree of variation in many indicators of prosperity and development across regions. These disparities concern differences in economic performance but also extend to the non-material aspects of well-being (see e.g. OECD, 2011c). Thus, well-being as conceptualised in the presented framework is likely to differ quite strongly between regions.

In order to analyse the extent of disparities in well-being on a regional level, it is straight-forward to extend the constructed composite indicators (WB_{UN} and WB_{LE}) to regional data. Since one of the requirements for selection of the included indicators for each of the dimensions of well-being was availability of data on a regional level, a cross-sectional comparison of the composite indicators on a regional level is possible. Unfortunately, time-series regarding regional indicators are not currently available: for some of the included indicators, only one year of data is available (CO_2 emissions), for others short time series exist but have many missing values. Therefore, a time series perspective on regional well-being was not possible within this research project. Moreover, as has been emphasised throughout this text, since life satisfaction data was not available for the analysed sample of the OECD TL2 regions, the analysis conducted in section 6 could not be estimated for regional data.

Indeed, the unavailability of subjective well-being measurements on a regional level represents another reason why composite indicators are important on a regional level. Since the “output“ of well-being cannot be measured through life satisfaction, only the alternative approach of measuring well-being through the “inputs“ in each of the three well-being dimensions can be implemented. However, as was illustrated for the national level, the existence of complementary relations between the well-being dimensions suggest that a more balanced distribution of well-being across the dimensions is preferable to an unbalanced one. In order to capture this relation a regular substitutable composite indicator can be adjusted to penalise a larger dispersion across the well-being dimensions.

7.1 Regional Data and Adjustment to Composite Indicator

The dataset used for an illustration on how an adjusted composite indicator could be constructed consists of a cross-section of the OECD regions at territorial level 2 (TL2). The TL2 classification of OECD countries concerns a total of 362 macro-regions, which largely correspond to the NUTS2 level for European countries (OECD, 2011c). However, in contrast to using only European data, using a sample of OECD regions allows a broader analysis, which also covers regional differences on other continents. Simultaneously, focusing on the OECD countries implies that the countries are comparable in terms of economic organisation and general status of development[11]. Since the OECD itself provides data on a regional level, within the *OECD Regional Database*, restricting the sample to OECD regions also ensures that the data is consistent and comparable.

The indicators described in section 4.1.1 were obtained for the TL2 regions from the most recent dataset version to be used in the *OECD Regions at a Glance* report in 2014. At the time of writing, the data is still being revised and has not been published yet. Plausibility analysis of the data was undertaken in order to check for obvious flaws in the dataset and several observations were excluded from analysis[12]. Also, since all the variables need to be available in order to compute the relevant indicators, observations with missing values were excluded. The final dataset comprised 281 observations for WB_{UN} and 258 for WB_{LE}.

Data on life expectancy, the unemployment rate and CO_2 emissions are reported at TL2 level with the identical definition as on a national level. Household income data on a regional level differs slightly in terms of definition, as it refers to disposable household income using constant prices at the 2005 level, whereas the national level data was “net adjusted“ for transfers and public services and deflated using actual consumption. However, since the definition is the same for all regions (and all countries), this technical difference does not affect the results.

As the analysis is cross-sectional, it was based on only one year of data. Where available, the year 2010 was selected as datasource because it represents the latest available data. However, for some

[11] Clearly, the OECD countries are still very heterogeneous and include a large degree of cross-country and within-country variation in income and well-being. However, compared to other possible samples including countries from America, Europe and Asia, the OECD countries represent a more comparable sample.

[12] In particular, Mexico and Korea were excluded from analysis because of a different scale of the reported household income. Also, the two autonomous Spanish cities Ceuta and Melilla were excluded from the dataset due to unrealistical values, which created influential outliers.

countries and indicators data from 2010 was not available and the most recent year of data was used instead (see Appendix D for an overview of the sample).

For the analysis, the described composite indicators WB_{UN} and WB_{LE} were constructed as described in section 4. However, in contrast to the national level data, household income and CO_2 emissions exhibited a large degree of skewness for the regional sample. Skewed distributions affect the average values of the composite indicator because they influence the normalisation. For example, when a variable is skewed to the right, the observed maximum value will be uncharacteristically high and the normalised values of the majority of observations will thus be too low. In order to address the skewness of the data, the variables for disposable household income and CO_2 emissions were log-transformed before normalisation. After the composite indicators were constructed for the regional sample, the dispersion across the well-being dimensions was measured by calculating the standard deviation indicator described in section 4.

In order to adjust the original composite indicator to take into account the negative effect of dispersion on overall well-being, several points need to be taken into account. First, the value of the composite indicator was found to be positively related to life satisfaction, indicating that it represents an important component of measuring overall well-being. Therefore, the value of an adjusted composite indicator needs to increase when WB increases. Second, countries with a higher standard deviation indicator within the composite indicator exhibited lower life satisfaction ceteris paribus. Thus, an adjustment of the composite indicator should decrease the indicator values proportionally to the degree of dispersion across the well-being dimensions so that, ceteris paribus, an increase in SD decreases the adjusted indicator. Although this adjustment could be implemented in different ways, a simple adjustment method was selected: for each observation, the calculated standard deviation across the well-being dimensions was subtracted from the original composite well-being indicator. Thus, the adjusted composite well-being indicator (ADWB) is defined as:

(17) $$ADWB_{UN_i} = WB_{UN_i} - SD_{UN_i}$$

(18) $$ADWB_{LE_i} = WB_{LE_i} - SD_{LE_i}$$

This linear adjustment ensures that a region‘s composite well-being indicator depends on the degree of its dispersion. The adjustment does not depend on the level of the original composite well-being indicator but shifts all observations downwards by a certain amount. A small disadvantage of this adjustment method is the fact that, in certain cases of low WB values and high SD, the adjusted composite indicator is negative. This problem could be addressed by adding a constant to (17) and (18). However, in the present analysis the well-being was compared by rankings within the same indicator of well-being so that the possibility of negative values is of no consequence.

An alternative adjustment that would avoid the problem of negative values, would be to define the adjusted indicator as the ratio of the composite indicator and the dispersion. However, this specification implies an assumption of a non-linear relationship in terms of the effect of complementarities. Since it is not theoretically clear whether such a non-linear relation exists, the linear adjustment method was selected for simplicity.

7.2 Application of Indicators to Regional Data

The original and the adjusted version of the composite indicators were applied to a cross-sectional sample of OECD regions. Additionally, in order to obtain a benchmark value for comparison, the regions were also ranked according to disposable household income. Although the majority of cross-country comparisons focus on differences in GDP per capita, income was selected here because it is included in the composite indicator and is often judged to be more directly related to the notion of well-being as advocated for example by Stiglitz and colleagues (2009). Household income is strongly correlated with GDP and either indicator can be used to provide an overall picture of regional disparities when only considering monetary factors.

Figure 9 presents an overview of the differences in disposable household income across and within countries. Strikingly, the US exhibit by far the highest levels of household incomes although Australia also ranks quite highly. When considering a map of all OECD countries simultaneously, the disparity within the US is not evident although there is substantial variation. Indeed, household income in the lowest ranked region in the US (Idaho) is only roughly 42% of the average disposable income in the region with the highest value in the US and the sample in general (District of Columbia)[13]. Since disposable income in the US exceeds disposable income in most other countries, the European region with the highest income level (Luxembourg) only reaches rank 41. Within Europe the patterns are as expected from GDP rankings. Disposable income is very low in the Eastern European countries, a north-south division is visible in Italy and Spain, and a west-east division in Germany.

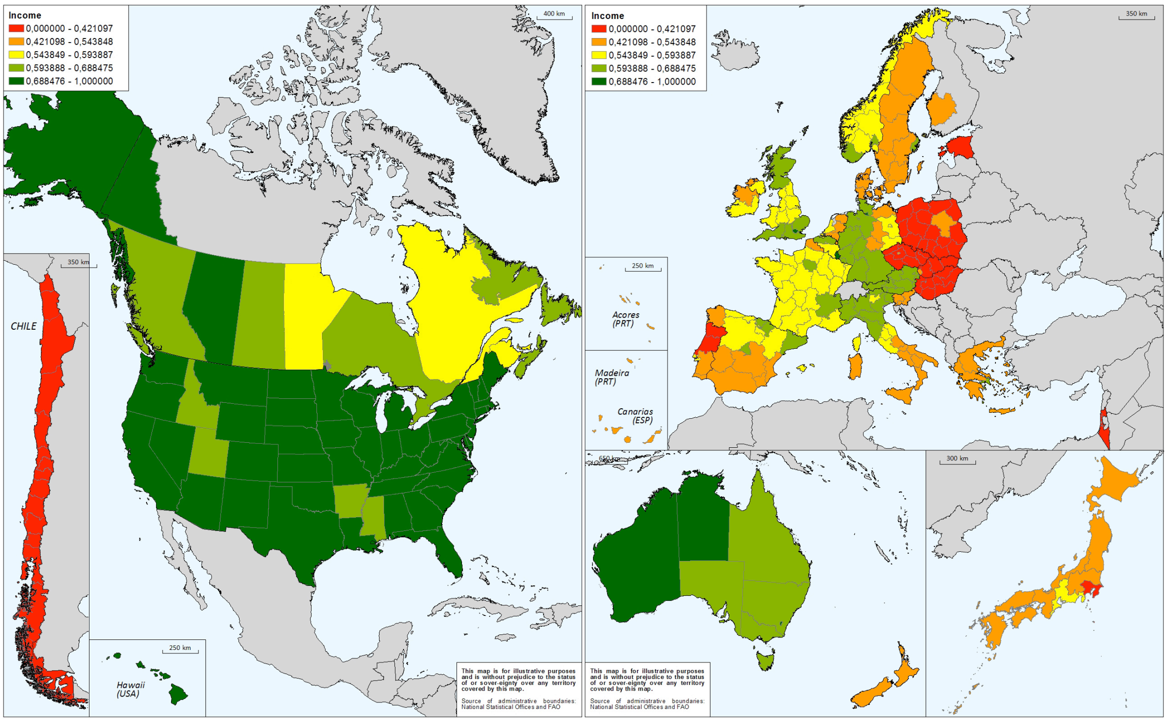

Figure 9: Disparities in disposable household income among the OECD TL2 regions. (Map template courtesy of OECD GOV/RDP)

[13] Although the District of Columbia seems to be an outlier, it should be noted that it is not the only region in the US with very high disposable income. Indeed, the ratio of Idaho's income to the 10th ranked region in the US (North Dakota, 11th overall) is still only 73%.

When measuring well-being in terms of the three-dimensional conceptualisation including economic, social and environmental factors, rather than focusing exclusively on income, the map of the OECD regions changes quite drastically. Figure 10 illustrates the values of the original composite well-being indicator WB_{UN}, i.e. the unweighted arithmetic average of income, unemployment and CO_2 emissions. For this indicator, the identified patterns in the disparities of income no longer apply. The US regions overall do not exhibit exceptionally high values in this specification

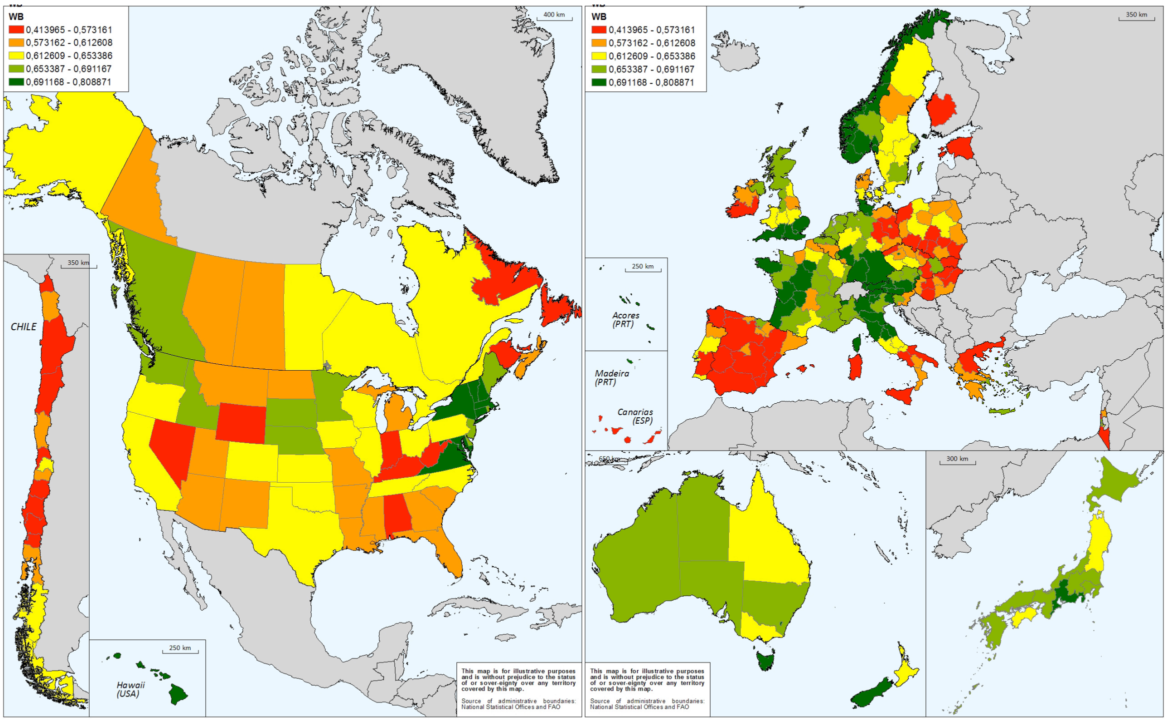

Figure 10: Disparities in unadjusted well-being indicator WB_{UN} among the OECD TL2 regions. (Map template courtesy of OECD GOV/RDP)

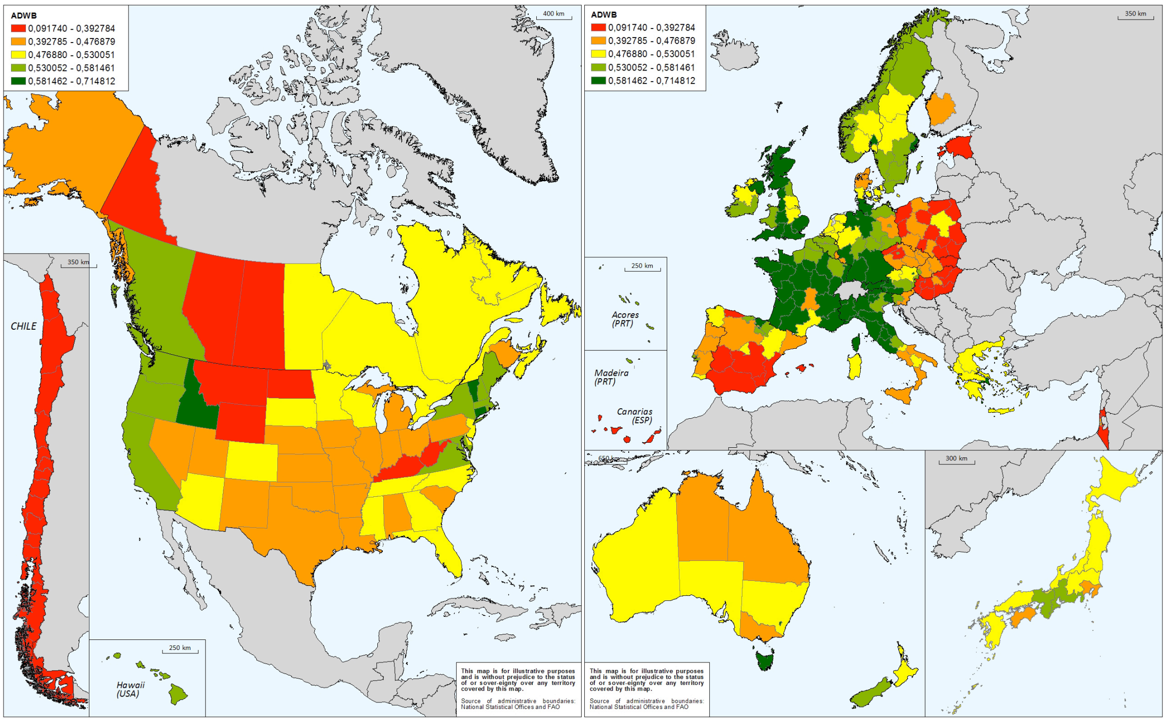

Figure 11: Disparities in complementarity-adjusted well-being indicator $ADWB_{UN}$ among the OECD TL2 regions. (Map template courtesy of OECD GOV/RDP)

and there is clear evidence of disparities between the regions. The regions in Japan attain a higher ranking when considering other factors besides income as do some regions in Eastern Europe, indicating that these regions do not have high values of household income but seem to do relatively well on the other two dimensions of well-being. In contrast, many Spanish regions are ranked much lower when considering unemployment and CO_2 emissions along with income. In general, Figure 10 illustrates a larger geographical variation than Figure 9: most regions within a country, or more generally, most neighbouring regions, were ranked relatively similarly in Figure 9.

In all these comparisons, it is important to note that the values of the composite well-being indicator are dynamic as they depend on the relative performance of a region. Thus, although the absolute level of well-being could be higher when considering a composite indicator rather than income alone, a region‘s ranking could still fall because other regions have relatively higher values on the other dimensions. Since the colour coding of the presented maps is based on quantiles rather than absolute benchmark values, a region‘s change in colour should be interpreted with care. The presentation of quantiles was chosen to accommodate the fact that the observed maximum and minimum values change when considering different types of indicators. Thus, in order to allow comparisons of the different indicators, comparisons of regions should be made in terms of their relative ranking rather than the absolute value of the indicator.

An interesting example to note is the change in the ranking of regions in Denmark when moving from a purely income-based indicator to a three-dimensional composite indicator. With respect to income, all Danish regions are ranked towards the lower end of the scale. Considering that Denmark exhibited the highest national level of life satisfaction, the low ranking in terms of income is surprising. However, when including unemployment and CO_2 emissions, the ranking of all Danish regions improves (on average by 52.8 positions). While the relative position within the sample is still towards the middle rather than the top of the ranking, this example illustrates two important points. First, ranking regions in terms of a composite well-being indicator rather than a purely income-based measure can affect the relative position of regions strongly. Second, using a composite measure of well-being may allow conciliation of subjective and objective measures of well-being if the composite indicator approximates subjective well-being more closely than an income-based measure.

Figure 11 illustrates the situation after applying the described adjustment to the original composite indicator. Again, the relative ranking of regions changes quite strongly when shifting the composite well-being index downwards by the amount of the standard deviation. When using the adjusted well-being indicator, the regions with the highest ranking are predominantly located in Central Europe, especially France, Italy and Southern Germany. When considering Australia, adjusting for complementarities shifts the relative position of most regions downwards, except for the Australian Capital Territory and Tasmania which both exhibit relatively little dispersion across the well-being dimensions. In general, when comparing the adjusted composite indicator to the unadjusted one, it is interesting to note that the adjustment seems to lead to a stronger geographical clustering. Whereas the original composite indicator illustrated a lot of variation within a country, using the adjusted indicator emphasises geographical areas within a country that seem to exhibit equal well-being. This is especially visible for the case of the US and Canada, where the adjusted composite indicator is relatively high for the west coast and relatively low in the central and southern regions of the US.

When considering the other specification of the composite well-being index, which uses life expectancy instead of unemployment, most of the described conclusions remain valid (see figures 12 and 13). Again, the US regions, which dominated the ranking based on an income-measure only,

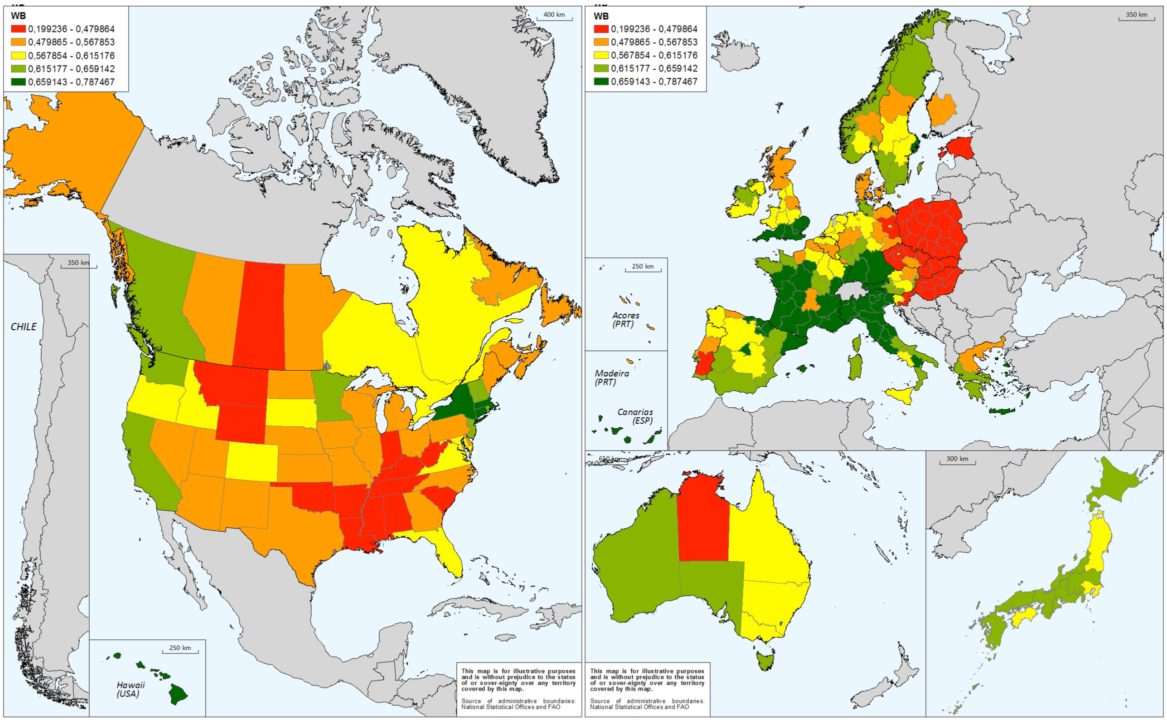

Figure 12: Disparities in unadjusted well-being indicator WB_{LE} among the OECD TL2 regions. (Map template courtesy of OECD GOV/RDP)

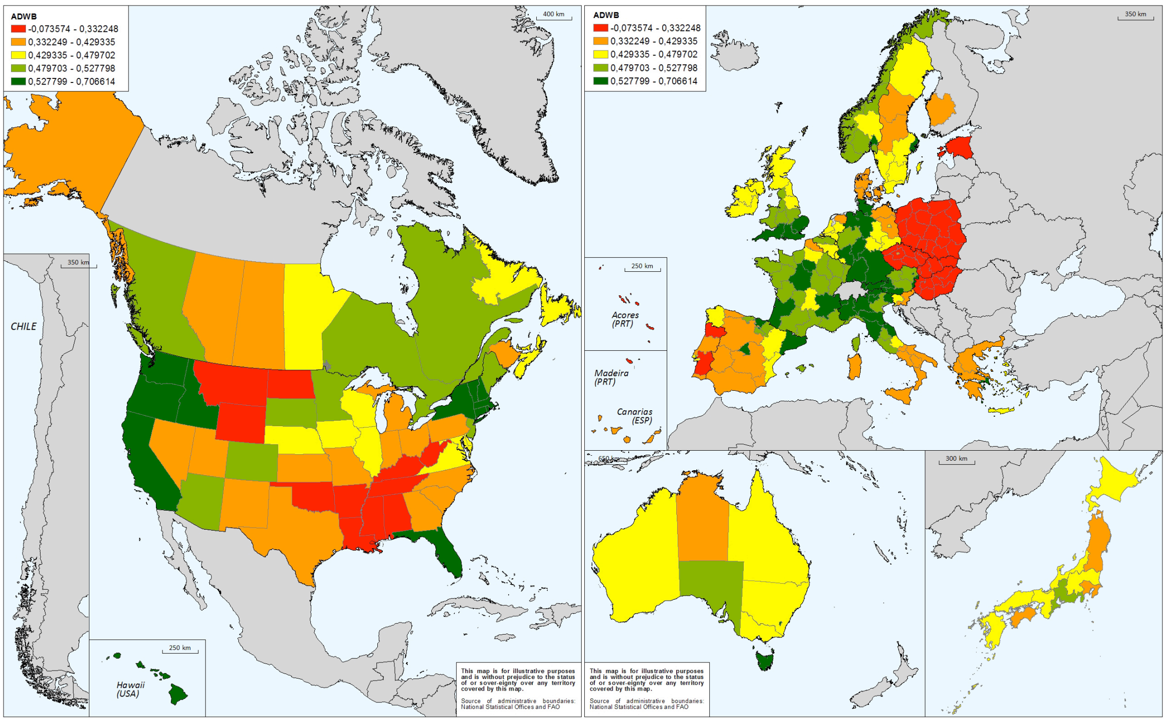

Figure 13: Disparities in complementarity-adjusted well-being indicator $ADWB_{LE}$ among the OECD TL2 regions. (Map template courtesy of OECD GOV/RDP)

do not perform as highly when considering a composite index. Instead,the central European regions, especially Northern Italy, France and Southern Germany are ranked highly on a composite indicator. In contrast to the maps on the WB_{UN} indicator, this second set of maps does not show clear evidence of the pattern that the adjusted composite indicator implies more geographical clustering than the non-adjusted one. Nevertheless, the adjustment clearly changes the relative rankings of many regions.

Moreover, for the indicator based on life expectancy, it could be argued that the adjustment produces a relative ranking of regions, which more closely follows the general impression of differences in development. For example, it is surprising that regions in the south of Italy, which are often characterised as lagging regions in comparison to the regions in the north, attain a higher ranking than regions in the Netherlands, Belgium and north-west Germany. Clearly, this impression is influenced strongly by the portrayal of mostly economic aspects in regional comparisons. When applying the adjustment, this observation no longer applies. This result for Italy is likely caused by the fact that the average life expectancy in all Italian regions is relatively high. This applies also to the regions in Southern Italy, which do not perform well on the economic dimension of well-being. When considering perfect substitutability among dimensions, these regions move up but since the high average level is caused mostly by high life expectancy, they also exhibit relatively large dispersion. The example of Italy illustrates the inherent differences in measuring well-being as a substitutable or complementary function of its dimensions.

From examining the presented maps of the OECD regions using different specifications of well-being measurements, it is evident that the presented indicators perform quite differently. McGillivray and Noorbakhsh (2004) discuss that measures of well-being can only represent an alternative to conventional measures if they actually produce a ranking of countries (or regions) that differs from a ranking based on income. Following this argument, the usefulness of alternative well-being indicators to capture other aspects of development *besides* income, can be measured by analysing the correlation between the produced rankings. The correlation results presented in table 10 illustrate that there is a significant degree of correlation between all the implemented indicators.

McGillivray and White (1992) suggest testing statistical redundancy by comparing the correlation coefficient between the rankings to two threshold values of redundancy: if the correlation is above 0.9 one of the indicators is “level 1 redundant”; if the correlation is between 0.9 and 0.7, it is

WB_{UN}	Rank Income	Rank WB_{UN}	Rank $ADWB_{UN}$
Rank Income	1		
Rank WB_{UN}	0.466	1	
Rank $ADWB_{UN}$	0.471	0.791	1

WB_{LE}	Rank Income	Rank WB_{LE}	Rank $ADWB_{LE}$
Rank Income	1		
Rank WB_{LE}	0.301	1	
Rank $ADWB_{LE}$	0.551	0.841	1

Table 10: Correlations among rankings based on different indicators

“level 2 redundant”. Clearly, when comparing the two composite indicators to the ranking based on income, neither indicator can be considered statistically redundant by this standard. However, the correlations between the adjusted and unadjusted well-being indicators are quite high, indicating that it may be redundant to consider both simultaneously. Indeed, this result is in line with the theoretical justification for the adjusted and unadjusted specifications of the composite indicator: if one assumes a substitutable relation among the well-being dimension, the adjustment is unnecessary; if one assumes a complementary relation considering the unadjusted indicator does not add any relevant information.

Table 10 also shows that the ranking based on the adjusted well-being indicator is more strongly correlated with the income ranking than the unadjusted one. This observation indicates that the extent of adjustment (and thus the degree of dispersion across the well-being dimensions) may be be related to a region‘s income level. Figure 14, plots the regions‘ rankings in terms of income and in terms of the composite well-being indicators agains each other. In contrast to the relation between the income rank and the rank for the unadjusted composite indicator, the lower two panels indicate a specific curve pattern. Regions with a relatively high income seem to be ranked less favourably when considering the adjusted indicator. Regions with medium income values are mostly shifted to a higher rank when considering ADWB and regions with very low income values remain relatively close to their original rank. This curved pattern is explained by the fact that, within the dataset, regions with a higher income level are more likely to have a lower dispersion among the indicators. This is a somewhat unintuitive result because it implies that regions with relatively low

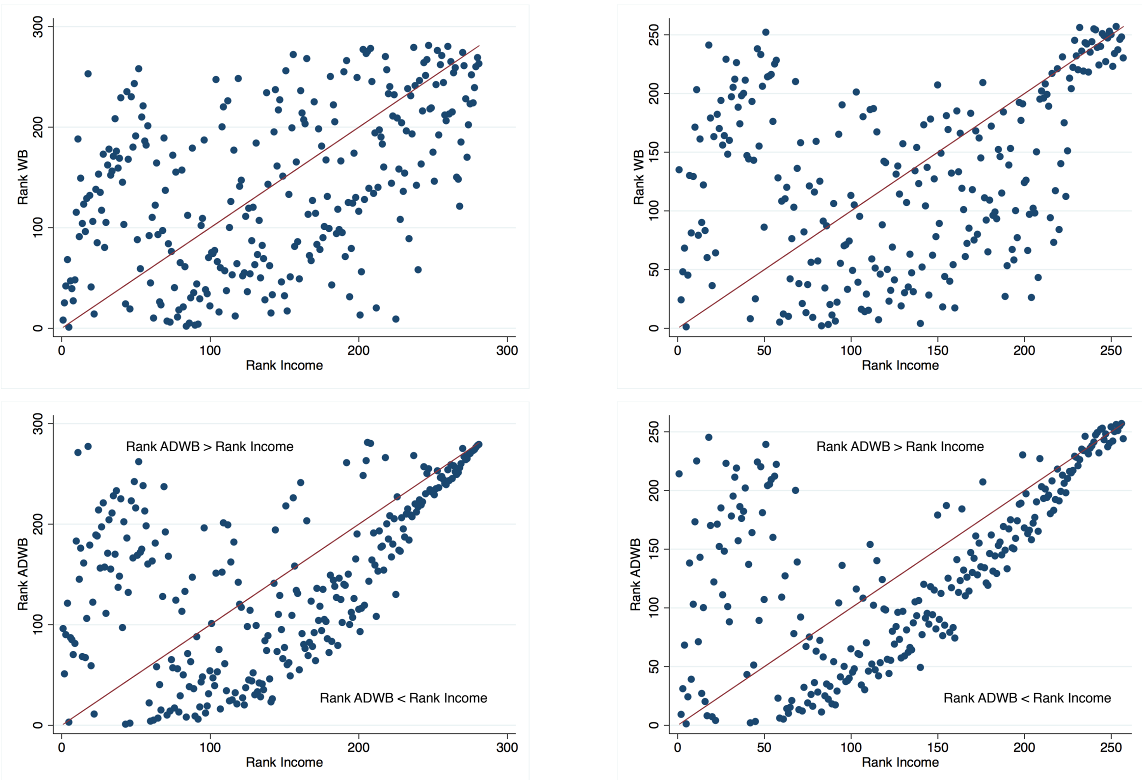

Figure 14: Scatter plots of ranking based on income versus ranking based on unadjusted composite well-being indicator (upper panels) and adjusted indicator (lower panels). Left panels refer to WB_{UN}, right panels refer to WB_{LE}

income are likely to perform well enough on one of the other well-being dimensions to cause a relatively large dispersion. It remains for further research to explore whether this pattern is related to the choice of indicators (for example because high income is correlated with bad air quality as measured by high CO_2 emissions) or whether it occurs more generally.

A last result from this exploratory application of well-being indicators to the OECD regions is the fact that the choice of indicator influences the degree of regional disparities. As illustrated using Lorenz curves in Figure 15 the most unequal distribution of well-being across regions occurs when well-being is approximated by income. Using the unadjusted well-being indicator yields less overall inequality among the OECD TL2 regions, whereas the Lorenz curve for the adjusted indicator lies between the other two. A similar analysis could be done to compare the effect of selecting one of the indicators on the degree of regional disparities within a country, but is beyond the general

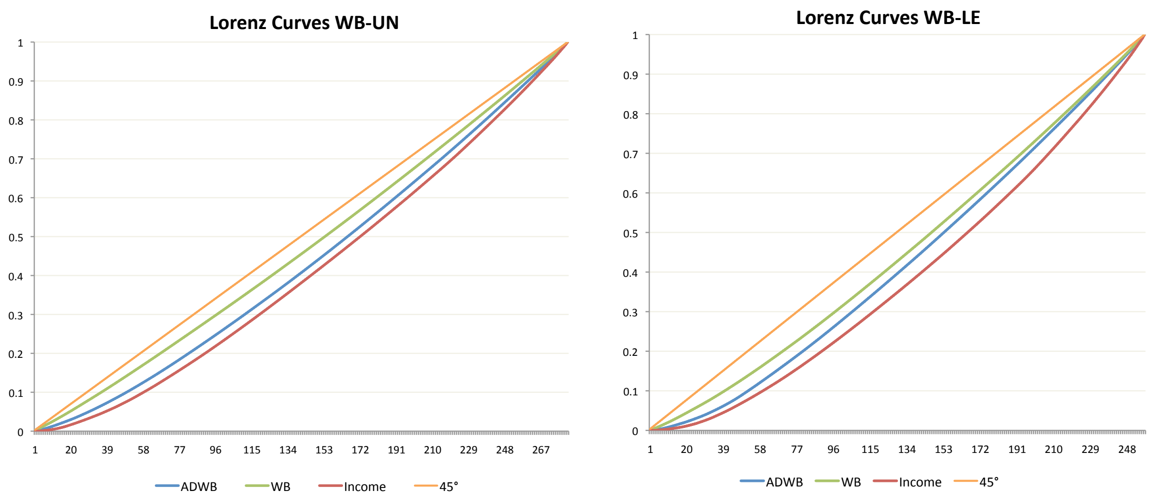

Figure 15: Lorenz curves for inequality of well-being when using different indicators

perspective of this research.

More generally, the application of three types of well-being indicators to a regional level illustrates that a composite well-being indicator indeed adds relevant information to the analysis of well-being disparities, which is not captured by income data only. It also shows that the assumptions regarding the relation between the dimensions of well-being are influential in determining the relative ranking of regions. Moreover, in the current sample and using the described method, adjusting the composite indicator for complementary relationships among the dimensions actually implies a larger implicit weight on the income dimension. In this sense, the adjusted composite indicator is positioned “between” the other two measures and, at least for some countries, provides relative rankings of regions, which seem to be in line with the generally assumed status of development.

8. Discussion and Conclusion

The previous two sections described a range of empirical results regarding the application of the theoretical concept of complementarities to the well-being dimensions. In general, the presented results can be grouped into an empirical investigation into the effect of complementarities on well-being (on a national level) and an illustration of the practical consequences of applying the notion of complementarity to regional comparisons. This section jointly discusses the conclusions to be drawn from the results, positions the results in the theoretical literature and illustrates their relevance for policy making.

The regression analysis on a national level presented some evidence for a negative correlation between the degree of dispersion across the well-being dimensions and life satisfaction. If we consider life satisfaction as an indicator for overall well-being, this finding suggests that people may prefer a more balanced distribution of well-being across the dimension because they derive a higher level of well-being from it. Clearly, this is a relevant result concerning the shape of people‘s preferences because it indicates that it is not the average level of well-being alone that determines overall well-being: the relative situation across the dimensions matters as well.

Therefore, the empirical results support the theoretical notion that the different dimensions of well-being may be complements for each other rather than perfect substitutes. It is important to consider this theoretical implication in the context of the implemented research approach in order to illustrate a subtle point of the implemented research design. In particular, the research approach undertaken in this project was to theoretically justify that well-being may be supermodular in its dimensions and then to test the effect of dispersion on life satisfaction. This approach is in line with research presented by the OECD (2011b) and the literature on policy complementarities (e.g. Braga de Macedo & Oliveira Martins, 2008; Braga de Macedo et al., 2013, in press). Therefore, instead of testing empirically the existence of complementarities in the well-being dimensions, complementarities were assumed on theoretical grounds. Under these assumptions, the fact that the observed relation between dispersion among the well-being dimensions and subjective well-being corresponded to the hypothesised relation is consistent with the existence of complementarities. Thus, the support for the notion of complementarity in well-being did not derive from collecting empirical proof of the existence of complementarity but, technically, from a failure to reject it.

Drawing on the theoretical result that a more balanced distribution of well-being seems to be preferable in terms of overall well-being, this preference should be reflected in the indicators used to measure well-being. Indeed, with the recent interest in applying multidimensional measures to comparisons of development and progress, the question of how the dimensions interact is no longer purely theoretical. Rather, in order to realise the recommendations of the recent publications on the relevance of measuring progress beyond GDP (EC, 2009; OECD, 2011a; Stiglitz et al., 2009) it is important to analyse the details of construction of such measurements and their consequences. Therefore, the empirical findings presented in section 6 do not only represent theoretical results but are also relevant in the context of practical application as illustrated using the case of the OECD TL2 regions.

The exploratory analysis focused on illustrating how a regular composite indicator of well-being could be adjusted to include the theoretical result that dispersion decreases overall well-being. The results suggest three main observations. First, using composite well-being indicators instead of purely income-based measures strongly affects the observed patterns of well-being across regions. Second, although the regional rankings produced with the adjusted and unadjusted composite well-being indicators are relatively highly correlated, the spatial distributions of well-being still differ quite distinctly between the panels in figure 10 and 11 (12 and 13). It would be theoretically inconsistent to use both indicators simultaneously because the measures are based on contradictory assumptions (perfect substitutability versus imperfect complementarity) and the high correlation indicates statistical redundancy (McGillivray & Noorbakhsh, 2004; McGillivray & White, 1992). However, deciding to measure well-being using a regular composite well-being indicator or using a specification that adjusts for complementarity, clearly represents an influential methodological choice, which may be determining the results of an analysis of the spatial distribution of well-being across regions. Third, within this sample and using the described specifications of the composite indicators, the adjusted composite indicator seems to behave as a mixture of the other two measures. This implies on the one hand, that it may provide characterisations of regional disparities that seem more intuitive (e.g. consider the example of South Italy provided in the previous section). On the other hand, these intuitive results may only be intuitive because they are influenced more strongly by a region‘s income.

The empirical results of this project illustrate that the assumption of perfect substitutability among well-being dimensions may be too simplistic. This does not imply that the necessary adjustment is perfect complementarity but rather that the well-being dimensions may be imperfect substitutes and imperfect complements. Indeed, it should be noted that within this research the concept of perfect complementarity was not applied; only imperfect complementarity was used. Although the literature on the methodology of composite well-being indicators generally acknowledges that the concept of complementarity is intuitively valuable, complementarity is not applied widely in cross-sectional comparisons. An exception is represented by the HDI, which has been specified to include the a complementary relationship among its components and has been criticised extensively for this methodological choice (Ravallion, 2012).

When using composite indicators of multidimensional well-being to determine the extent of regional disparities or guide policy it is important to keep in mind that findings generally reflect the assumptions underlying the constructed indicator However, despite the associated methodological difficulties of measuring well-being, the concept of complementarities in multidimensional well-being has the potential to be applied to policy making for two main reasons.

First, a broader measure of progress allows closer alignment between policies and people‘s needs and wants. Although income is clearly relevant for well-being, other factors are important in their own right. Thus, assuming perfect substitutability of the components of well-being is a simplification that allows focusing primarily on one dimension of well-being. In contrast, a complementary perspective on the dimensions of well-being necessarily implies that policy approaches should address all dimensions of well-being simultaneously. This implies an integrated approach to policy making where the consequences of a policy (in one dimension) on well-being in the other dimensions is explicitly considered. For instance, when environmental well-being is assumed to be a relevant dimension of well-being, a complementary perspective implies that the effects of economic growth on the environment need to be taken into account in policy making. Similarly, the notion of policy complementarity in well-begin suggests that effects of a policy can be augmented by integrating it with complementary policies in the other dimensions.

Second, acknowledging the existence of complementarities among the well-being dimensions may also represent more general guidance on how policy makers can attempt to improve overall well-being. For example, when considering the dimensions of economic, social and environmental well-being as perfectly substitutable, the optimal approach to increase overall well-being would be to focus on the dimension that is least costly to improve. However, intuitive reasoning as well as the results presented in this research indicate that, as one dimension increases continuously relative to the others, the marginal returns in terms of well-being may fall. Instead, a complementary view on the dimensions of well-being would imply that the optimal policy strategy is to target the dimension with the worst situation until all dimensions are equally good. From then on, well-being gains would be maximised by implementing a radial reform strategy, i.e. improving all dimensions in parallel.

More generally, it has been discussed from a theoretical view that spatial factors matter in determining well-being. An individual‘s well-being is determined by the circumstances that she faces specifically and – as has been illustrated by analyses of regional disparities in a range of socio-economic indicators (e.g. OECD, 2011c) – these circumstances (i.e. economic, social and environmental well-being) differ among places. When considering well-being as consisting of a range of dimensions, which all exhibit regional differences, overall well-being naturally differs among regions as well. This is reflected in the presented application of well-being indicators to the OECD TL2 regions, which exhibit a large degree of variation within and across countries. In terms of policy relevance, this research project therefore supports the notion that policy regarding well-being should take into account a regional perspective and place-based perspective.

Moreover, regions also differ in terms of the observed dispersion of well-being across its dimensions thus implying that the ranking of regions changes when adjusting a composite indicator for the existence of complementarities. Thus, when using well-being measurements to compare regional welfare, for instance in the context of regional development policy on a national or EU level, allowing for complementarities implies that regions generally identified as leading or lagging may change status. However, a concern for the existence of complementarities is not only relevant in identifying lagging and leading regions, it also shifts the focus to the question of why well-being in some regions is less dispersed across dimension than in others. Clearly, presenting evidence that a balanced distribution is desirable does not provide information on the difficulties associated with obtaining such a balanced distribution. It remains for future research to analyse which factors contribute to a balanced distribution of well-being across its components and how these factors can be influenced by policy measures.

As emphasised throughout this research, there are several methodological and theoretical caveats associated with the implemented analysis. Three general points should be emphasised especially. First, data availability strongly restricts the research design. This is reflected in the requirement to implement the regression analysis with national data because the necessary regional data is not available. Since there are theoretical reasons to believe that complementarity among the well-being dimensions is more influential on a regional level (see e.g. OECD, 2011c) it would have been preferable to implement the entire analysis on a regional level. At the moment, reliable regional data on subjective well-being can only be obtained when aggregating national micro-surveys by region. While this is a feasible approach of data collection when only one or two countries are considered, it is more difficult for broader cross-sectional comparisons. Besides representing an elaborate task, this is also due to the fact that not all countries have reliable micro-surveys, and scale and phrasing of questions may differ among surveys. Considering the increasing interest in the topic of well-being at a national scale it is likely that regional data to be used for the construction of well-being indicators will become available eventually. In the mean time, data derived from national micro-surveys or national surveys such as the Eurobarometer, the World Value Survey or the Gallup World Poll represent a second-best alternative to implement empirical analyses as the one presented in this research.

Second, robustness issues represent an important concern for this research project. Issues of robustness play a role in several aspects of the implemented research. The fact that dispersion had a strong significant effect on life satisfaction when measuring standard deviations but not using the complementarity index implies that the presented results are sensitive to how dispersion is measured. While there are some characteristics of the complementarity index, which may explain the results, it would be an important step of further research to repeat the present analysis with a wider range of different measures for dispersion. Also, since the panel dataset used in analysis is relatively small, there may be econometric issues of heteroskedasticity and autocorrelation. It is beyond the scale of this research to address these concerns, but future research may need to obtain a larger (and preferably balanced) dataset in order to increase the power of the significance tests.

Third, and perhaps most importantly, issues of robustness are also a general problem in the construction of the composite indicators. Selection of the indicators to be included directly affects the rankings of regions or countries with respect to overall well-being. Additionally, depending on which sets of indicators are included, dispersion will naturally be higher or lower. This is due to the fact that a high degree of positive (negative) correlation among the variables included in a composite well-being indicator implies that dispersion is generally likely to be smaller (larger). Since selection of variables influences both the level of the composite well-being indicator and its dispersion it is difficult to predict theoretically whether exchanging one of the included indicators for another one will leave the significance of results unchanged.

The issue of robustness to different specifications of the well-being indicators represents one of the core challenges of further research on the topic of complementarities. For instance, the present research was restricted to a three-dimensional conceptualisation of well-being. While this framework captures the essence of discussions of multidimensional well-being, it would be interesting to also consider more than three dimensions. In principle, the presented analysis could be extended to an arbitrary amount of dimensions as long as theoretical justifications for all the pairwise supermodular relations can be made. However, practically, the pattern of correlations among the dimensions becomes more difficult to discern as the number of dimensions increases and selecting a specific indicator may affect the results more strongly. Thus, a more detailed analysis of the effect of correlation among the indicators composing overall well-being would be required to extend the present analysis.

The aim of this research project was to apply the theoretical concept of complementarity to a framework of multidimensional well-being. The presented results indicate that a more balanced distribution of well-being across its dimensions may not only be preferable on theoretical grounds but that this notion can also be illustrated empirically. The results also indicate that the choices underlying the construction of composite indicators profoundly affect conclusions to be drawn from cross-sectional comparisons. If well-being measures are to be used widely in order to compare regional development and inform policy making, it is therefore important that these measures are not based on the simplest assumptions but on assumptions that are supported by theoretical and empirical models. From a methodological standpoint, the choice of how to construct an indicator of multidimensional well-being is an influential and difficult one. Since small methodological choices can change the results drastically, this research project attempted to illustrate precisely, which assumptions and methodological decisions were taken and what alternative possibilities exist. Due to the sensitivity of results to the details of construction it is beyond this project to provide guidance on what an ideal composite indicator of well-being would look like. However, based on the assumptions underlying the present analysis, empirical results suggest that it may be justifiable and informative to consider the well-being dimensions as imperfect complements rather than perfect substitutes.

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Appendix A: Overview of national sample

Country	Time Period	Observations
Austria	1995-2011	17
Belgium	1995-2011	17
Czech Republic	2004-2011	8
Denmark	1995-2011	17
Estonia	2004-2011	8
Finland	1995-2011	17
France	1990-2011	22
Germany	1995-2011	17
Greece	2005-2011	7
Hungary	2004-2011	8
Ireland	2002-2011	10
Italy	1990-2011	22
Luxembourg	2006-2011	6
Netherlands	1990-2011	22
Norway	1990-2001	9
Poland	2004-2011	8
Portugal	1995-2011	17
Slovak Republic	2004-2011	8
Slovenia	2004-2011	8
Spain	2000-2011	12
Sweden	1995-2011	17
United Kingdom	1990-2011	22
Total	**1990-2011**	**299**

Appendix B: Alternative specifications of indicators

Model	Economic	Social	Environmental	Average Level	SD	CI	Obs
WB_{UN}	Income	Unemployment	CO_2 emissions	$+^{***}$	$-^{***}$	0	299
WB_{LE}	Income	Life Expectancy	CO_2 emissions	$+^{***}$	$-^{***}$	0	299
Alternative 1	Income	Infant Mortality	CO_2 emissions	$+^{***}$	$-^{**}$	0	298
Alternative 2	Income	Employment	CO_2 emissions	$+^{***}$	$-^{**}$	0	299
Alternative 3	Income	Life Expectancy	Waste	$+^{***}$	0	0	287
Alternative 4	Income	Unemployment	Waste	$+^{***}$	0	0	287

Sign of estimated coefficient and significance level: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix C1: Estimates with Robust Standard Errors

Stata cluster robust standard errors

Regression models using WB_{UN} (composite indicator: income, unemployment, CO_2)

Dependent variable: Life Satisfaction	(1) Fixed Effects	(2) Random Effects	(3) Fixed Effects	(4) Random Effects
Average across Dimensions	0.883***	0.898***	0.850**	0.862***
	(0.240)	(0.230)	(0.344)	(0.326)
Standard Deviation	-0.487	-0.494		
	(0.325)	(0.311)		
Complementarity Index			0.0573	0.0613
			(0.087)	(0.084)
Constant	2.624***	2.615***	2.380***	2.353***
	(0.193)	(0.204)	(0.131)	(0.155)
Joint significance time dummies (p-values)	0.000	0.000	0.000	0.000
R^2 : within	0.441	0.441	0.424	0.424
R^2: between	0.240	0.240	0.247	0.248
R^2 : overall	0.201	0.202	0.186	0.187

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Regression models using WB_{LE} (composite indicator: income, life expectancy, CO_2)

Dependent variable: Life Satisfaction	WB_{LE} Fixed Effects	(6) Random Effects	(7) Fixed Effects	(8) Random Effects
Average across Dimensions	0.939*	0.839***	1.166**	1.003***
	(0.481)	(0.3134)	(0.529)	(0.314)
Standard Deviation	-0.649	-0.698		
	(0.510)	(0.480)		
Complementarity Index			0.0310	0.0519
			(0.99)	(0.093)
Constant	2.732***	2.800***	2.399***	2.429***
	(0.277)	(0.230)	(0.327)	(0.232)
Joint significance time dummies (p-values)	0.000	0.000	0.000	0.000
R_2 : within	0.307	0.307	0.284	0.284
R_2 : between	0.221	0.227	0.174	0.184
R_2 : overall	0.162	0.173	0.0930	0.105

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix C2: Estimates with Robust Standard Errors

xtscc: Driscoll-Kraay standard errors robust to heteroskedasticity and auto-correlation for fixed effect estimation (Hoechle, 2007)

Regression models using WB_{UN} (composite indicator: income, unemployment, CO_2)

Dependent variable: Life Satisfaction	(1) Fixed Effects	(3) Fixed Effects
Average across Dimensions	0.883***	0.850**
	(0.110)	(0.167)
Standard Deviation	-0.487***	
	(0.147)	
Complementarity Index		0.0573
		(0.043)
Constant	2.624***	2.380***
	(0.089)	(0.065)
Joint significance time dummies (p-values)	0.000	0.000
R^2 : within	0.441	0.424
R^2: between	0.240	0.247
R^2 : overall	0.201	0.186

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Regression models using WB_{LE} (composite indicator: income, life expectancy, CO_2)

Dependent variable: Life Satisfaction	WB_{LE} Fixed Effects	(7) Fixed Effects
Average across Dimensions	0.939***	1.166**
	(0.184)	(0.218)
Standard Deviation	-0.649**	
	(0.264)	
Complementarity Index		0.0310
		(0.058)
Constant	2.732***	2.399***
	(0.136)	(0.081)
Joint significance time dummies (p-values)	0.000	0.000
R_2 : within	0.307	0.284
R_2 : between	0.221	0.174
R_2 : overall	0.162	0.0930

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix D: Overview of regional sample

Country	Number of TL2 Regions	Disposable Household Income	Unemploy-ment Rate	Life Expec-tancy	CO_2 Emissi-ons
Austria	9	2009	2010	2010	2005
Australia	8	2010	2010	2010	2005
Belgium	3	2009	2010	2010	2005
Canada	11	2010	2010	2006	2005
Chile	15	2009	2010	-	2005
Czech Republic	8	2009	2010	2010	2005
Denmark	5	2009	2010	2010	2005
Estonia	1	2009	2010	2010	2005
Finland	2	2009	2010	2010	2005
France	22	2009	2010	2009	2005
Germany	16	2009	2010	2010	2005
Greece	4	2009	2010	2010	2005
Hungary	7	2009	2010	2010	2005
Ireland	2	2009	2010	2010	2005
Israel	6	2010	2010	-	2005
Italy	21	2008	2010	2010	2005
Japan	10	2008	2010	2010	2005
Luxembourg	1	2009	2010	2010	2005
Netherlands	4	2009	2010	2010	2005
Norway	7	2007	2010	2010	2005
New Zealand	2	2010	2010	-	2005
Poland	16	2009	2010	2010	2005
Portugal	7	2009	2010	2010	2005
Slovak Republic	4	2009	2010	2010	2005
Slovenia	2	2009	2010	2010	2005
Spain	17	2009	2010	2010	2005
Sweden	8	2009	2010	2010	2005
United Kingdom	12	2009	2010	2010	2005
USA	51	2010	2010	2007	2005
Total observations	**281**			**258**	