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The complications of measuring green growth:
Current pitfalls, further developments, and impact on cross-country longitudinal analyses

by

Nikoline Egerod Leth
ni0118le-s@student.lu.se

Abstract

There is no consensus on how to define and measure green growth. Consequently, we can neither state if growth is actually green nor econometrically explore important questions such as what determines green growth. This thesis takes a three-step approach to move one step closer to a unifying longitudinal cross-country measure of green growth. It analyzes how green growth has been quantitatively measured and how the choice of measure affects econometric explorations on determinants of green growth. Using these insights, the study asks how a measure of green growth is to be designed. The analysis finds three overarching approaches to measuring green growth (single-indicators, data envelopment analyses, and composite indexes) and from 30 articles a total of 29 different measures are identified. Due to the multidimensionality of the concept, it is found that composite index measures are suitable, but sustainability should be incorporated into the normalization and compensatory aggregation should be avoided. Using 27 indicators from the social, economic, and environmental dimensions a green growth measure is computed for 72 countries in 1990-2019. Fixed effect regressions indicate that changing green growth measure impacts analysis results. Oppositely to results in other analyses (using other green growth measures) institutional quality is found strongly related to the refined green growth measure. Determinants of green growth are furthermore indicated differing between higher-, middle-, and lower-income countries. This concludes that a lack of agreed green growth measure hinders advancements within the literature field.

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1 Introduction

On what basis can the argument be made, that a country's growth path is *green*? At present time there is no satisfactory answer to this question. Since the industrial revolution economic growth has relied on natural resource exploitation and environmental degradation (Michelsen et al., 2016; Acemoglu et al., 2012). As a result, green growth has emerged as a strategy to align economic growth and environmental preservation (Khan and Ulucak, 2020; Ates and Derinkuyu, 2021), albeit there is a lack of consensus on how to define and measure the concept (Stepping and Stoever, 2014; Sun et al., 2020). Green growth is nevertheless applied vividly throughout the scholarly and public debate without any streamlined understanding of the concept or its achievability (Rockström et al., 2009; Baniya et al., 2021). In other words, green growth is slowly being diluted and used for *greenwashing*.

This gives leeway for environmentalists giving up on green growth and rather increasingly argue for *degrowth*, a theory which argues that economic growth is incompatible with environmental preservation and avoidance of climate change (Kallis, 2011). However, degrowth is neither publicly nor politically feasible and some argue therefore not a viable strategy for avoiding climate change and global warming (Rockström et al., 2009). One argument why degrowth is not a feasible strategy is since the poorest countries in the world are in need of increasing their wealth and living standards, hence growth cannot be abandoned altogether (Houssini and Geng, 2021; Kararach et al., 2018; Barbier, 2016; Dercon, 2014).

Aside from diluting the concept of green growth, the lack of empirical measuring of green growth makes it difficult to explore the requirements to accomplish green growth. It is necessary to understand the determinants of green growth to decide how to invest for it to succeed (Ates & Derinkuyu, 2021). Determinants of green growth have been explored by e.g. Tawiah et al. (2021) and Huang and Quibria (2013), however, using completely different measures of green growth. Where Tawiah et al. (2021) measures production-based carbon productivity, Huang and Quibria (2013) computes a composite index using principal component analysis. Thus, we end up comparing apples and oranges when trying to understand their findings relative to one another. This hinders advancements in the understanding of determinants and underlines the importance of obtaining an agreed measure of green growth.

The empirical literature on green growth has focused mainly on two approaches. The first being developing and assessing indicators on green growth to compare and track country performance on a number of variables without computing an overall measure of green growth (e.g. OECD, 2017; Schenau, 2017; Lyytimäki et al., 2018; AfDB, 2014). The other focuses on developing indexes that can rank countries relative to each other based on an indicator selection and final index score (eg. Kararach et al., 2018; Acosta et al., 2019; Jha et al., 2018; Ates and Derinkuyu, 2021; Li et al., 2021). Neither of these approaches allow for an examination of the determinants of green growth as they cannot measure if countries have in fact achieved green growth. The argument being that these analyses only follow the weak sustainability goal (Rische et al., 2014; Rockström et al., 2009).

To understand this critique, keep in mind that green growth emerged as a strategy to achieve sustainable development (Rische et al., 2014). Because of this the critique towards many of the different definitions of green growth also evolves around them being too 'weak' and not taking into account the social dimension (but only the environmental and economic dimensions) (Jänicke, 2012). In light of this critique, this thesis applies the following definition of green growth: "*... the process of transition towards a low-carbon and resource-efficient society with economic development that safeguards the functioning of ecosystems and enhances human well-being and social equality.*" (Lyytimäki et al., 2018, p. 51). This is in line with a stronger sustainability understanding, which some argue to be too ambitious, but is what ensures keeping within social and planetary boundaries. Hence this must be the aim for green growth to remain relevant (Leach et al., 2013; Michelsen et al., 2016).

The increasing number of articles empirically assessing green growth first and foremost calls for an overview of how green growth has previously been measured. Existing literature reviews on green growth do not map the specific measurement designs nor cover sufficient parts of the literature (eg. Šneiderienė et al., 2020; Narloch et al., 2016). Furthermore, to the author's knowledge no other article has explored the impact of using different measures of green growth in econometric analyses. This could provide essential information on whether alignment in measurement is needed. This thesis intends to tap into these literature gaps.

The aim of this thesis is to contribute to the literature by moving one step closer to a measure of green growth that complies with the theoretical understanding of the concept (ensuring strong sustainable development) and allows for cross-country longitudinal assessments. Based on the gaps in the literature, the aim of this thesis is divided into three. First, mapping the quantitative measures used in the articles empirically measuring green growth. Secondly, measuring green growth aligned with the theoretical understanding while also allowing for cross-country longitudinal assessment. Thirdly, uncovering the implications of applying different green growth measures in analyses on determinants of green growth.

To achieve the aims outlined above, the thesis is guided by three research questions. *How has green growth been measured?* The process towards an agreed green growth measure must seek to align and improve the existing measures. Thus, the theory and literature section will present qualitative analysis results of a literature review of 30 articles published within the last 8 years quantitatively measuring green growth. The goal is through an in-depth analysis of the identified articles to map the measures and discuss the challenges of each of them.

What does the theoretical understanding imply for a measure of green growth, and based on the measures identified, how are these implications incorporated into a cross-country longitudinal measure of green growth? The conceptual theory must back measurement, thus the theoretical requirements for a green growth measure are explored in the theory and literature section. The implications and the mapping of existing measures shall guide the development of a refined green growth measure in the methodology section. The refined green growth measure will be assessed on its performance in the analysis section. Thus, answering this question requires continuous exploration throughout most of the study.

Does applying this refined green growth measure change prior analysis results on determinants of green growth and the differences between developed and developing countries? If so, how? This will be the topic of the analysis in section 4. The analysis serves two purposes, primarily it will illustrate possible effects of not having an agreed measure of green growth. Secondly, it will increase the knowledge on determinants of green growth.

Answering all three questions, will underpin how and if a common and mutual agreed upon measure of green growth is to be further developed. Each question builds on the insight retrieved from the previous questions, which is reflected both in the research design and final structure of the study.

The findings in this study support the argument, that too many different quantitative measures of green growth are applied in the literature. Furthermore, many of these measures lack concordance with the theoretical understanding of green growth. It is further argued that a measure of green growth for cross-country longitudinal assessments is to be a partial compensatory composite index, where sustainability is incorporated into the measure procedure. Current data allows for computing such a measure of green growth with 27 indicators within the environmental, economic, and social dimensions. Finally, panel data analyses on 72 countries (see Table 9 for a full list) from 1990-2019 supports the argument that the chosen measure of green growth impacts the result of analyses on determinants of green growth: results diverged when using different green growth measures and oppositely to findings in Tawiah et al. (2021) (who measure green growth as carbon productivity) results indicate strong correlations between institutional quality and green growth levels. This emphasizes the need for an alignment and agreement on just a single measure.

The thesis applies the following structure. In Section 2 the theoretical understanding of green growth is presented, as is the literature review on applied measures of green growth and theoretical arguments for determinants of green growth. In Section 3 the composite index measure of green growth is developed before the econometric panel data model and the data used are presented. Section 4 will describe the refined green growth measure through descriptive data assessments before presenting the regression analysis results and following robustness checks. Section 5 will discuss the interpretation and implications of the results, and the limitations and areas that will need future research. Finally, some concluding remarks will be presented.

2 Theory and literature

To provide insights on how to work with green growth it is essential to ask what has previously been done in terms of defining and empirically measuring green growth. This section intents to provide a thorough understanding of the green growth concept.

2.1 The concept of green growth

Green growth has emerged as a relatively new concept during the last 20 years. The scholarly and public debate on the relation between economic growth and environmental degradation dates back to Meadows et al. (1972) who questioned the limits of economic growth. The possibility of having economic growth while also meeting the objectives of social development and environmental protection has existed under the label of “sustainable development” since the Brundtland report in 1987 (Brundtland, 1987). Mentioning of green growth can be traced almost as far back to Colby and Mundial (1989) and Goodstein (1996). It was, however, not until the early 2000s that green growth entered more prominently into the debate, e.g. in the book by Ekins (2000) on the prospects for green growth. Green growth afterwards rose on the policy agenda as it was seen as a necessary means to achieve sustainable development (Rische et al., 2014). The entrance of green growth in the debate on sustainable development marks a rhetorical shift from a normative concept to claiming that growth can be green in theory and in reality (Jacobs et al., 2012).

In 2005 52 governments from the Asia-Pacific region were the first to officially aim for green growth at the Fifth Ministerial Conference on Environment and Development (MCED) in Seoul (UN-DESA, 2012). Likewise South Korea was the first country to integrate green growth into their national strategy in 2008 (Ateş, 2015). It was, however, only after the financial crisis in 2008 that the concept emerged as a prominent strategy when more world leaders and international organizations acknowledged it as an essential contributor to sustainable development at the G20 Seoul Summit in 2010 (UN-DESA, 2012).

Definitions of green growth

An understanding of green growth is based on the understanding of *growth*. Growth here refers to economic growth measured through gross domestic production (GDP) (Jacobs et al., 2012). Economic growth theory dates back to Smith (1776), Malthus (1798), and Ricardo (1817) who provided the building blocks for neoclassical modern economic growth theories (Barro & Sala-i-Martin, 2003). Throughout the literature and history of economic growth, it has been acknowledged that economic growth has increased resource scarcity and environmental issues (Stern et al., 1996; Acemoglu et al., 2012; Khan and Ulucak, 2020). So while economic growth has led to significant improvements in living conditions it has also accelerated world-wide carbon emissions, which has forced governments into reevaluating their growth paths (Ateş, 2015).

Thus, by putting *green* before growth, the concept distinguishes itself from traditional growth by claiming growth processes can be resource-efficient, cleaner and

Table 1: Green growth definitions

Institution/Source	Definition
OECD (2011)	"Green growth is about fostering economic growth and development while ensuring that the natural assets continue to provide the resources and environmental services on which our well-being relies. To do this it must catalyse investment and innovation which will underpin sustained growth and give rise to new economic opportunities."
The World Bank (2012)	"We argue that what is needed is green growth—that is, growth that is efficient in its use of natural resources, clean in that it minimizes pollution and environmental impacts, and resilient in that it accounts for natural hazards and the role of environmental management and natural capital in preventing physical disasters. And this growth needs to be inclusive."
European Commission (2016)	"The aim is to create more value while using fewer resources, and substituting them with more environmentally favorable choices wherever possible"
UNEP (2011)	"Green economy is one that results in improved human well-being and social equity while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy is low-carbon, resource-efficient and socially inclusive"
UNESCAP (2012)	"...an implementing strategy to achieve sustainable development that focuses on improving the eco-efficiency of production and consumption and promoting a green economy, in which economic prosperity materializes in tandem with ecological sustainability"
Global Green Growth Institute (2013)	"Green growth is the new revolutionary development paradigm that sustains economic growth while at the same time ensuring climatic and environmental sustainability"

Source: Adapted from Sun et al. (2020) and Engelmann and Al-Saidi (2019).

more resilient, even without slowing down growth (Hallegatte et al., 2012). In this concept the green transition is seen as an engine for growth with the hypothesis that environmental sustainability provides opportunities for growth rather than challenges (Capasso et al., 2019; Bowen, 2012).

Meanwhile the literature on green growth lacks consensus as to the definition of the concept. This is problematic as it is a prerequisite for knowing when growth paths can be characterized as green (Stepping & Stoever, 2014). The development of the concept is driven by international organizations, such as OECD, UNEP, and the World Bank. Table 1 presents a selection of their green growth definitions. It must be emphasized that (although often included) the definitions by UNEP and UNESCAP pertains to a definition of *green economy* and not *green growth.*

Distinguishing green economy from green growth is complicated. Georgeson et al. (2017) argues that the two concept are linked into a hierarchy based on the conceptualization by Brink et al. (2012), where green growth is a contribution to the green economy, as a means of achieving sustainable development. As both concept lacks operationalization they are diffcult to seperate and used interchangeably (Engelmann et al., 2019; Loiseau et al., 2016; Toman, 2012; Kararach et al., 2018). However, it is problematic since *economy* and *growth* are distinct concepts. Hence this thesis will handle green economy (and articles exploring it) as different from green growth.

With the definitions in Table 1 in mind, the discussion on the different definitions evolves around two subjects; inclusion of all three pillars of sustainable development (social, environmental and economic) and opting for the “weak” or “strong” sustainability goal. The OECD is claimed to follow ’weak’ sustainability, whereas the UNEP definition represents ’strong’ sustainability (Smulders et al., 2014). The sustainability literature argues that weak sustainability relies on the perception of a trade-off between the environment and growth, whereas strong sustainability insists that economic growth must evolve without trespassing the planetary boundaries (Chaminade, 2020; Michelsen et al., 2016). Since green growth is a strategy for ensuring sustainable development, we must define which type of sustainable development it seeks to achieve (Rische et al., 2014).

The discussion of strong vs. weak sustainability is related to the critique that all definitions in Table 1 lack a measurable criterion for when growth is green (Stoknes and Rockström, 2018; Baniya et al., 2021). Rische et al. (2014) argues a distinction must be made between *green* vs. *greener* growth. The latter is a relative environmental improvement in the growth path while the former serves as an absolute improvement. In other words, *greener* growth corresponds to the weak and green growth to the strong sustainability understanding.

The OECD definition is claimed to be the weakest of the definitions because it does not include the social dimension (Jänicke, 2012; Rische et al., 2014). This relates to a current confusion in the literature where some scholars name the concept *inclusive green growth* to indicate that the social dimension is included. As will be evident in the literature review below, articles use the two concepts interchangeably. Nonetheless, if green growth is to be relevant for all countries it must include social improvements, such as poverty alleviation, which is needed and thus a prerequisite for any growth strategy in developing countries (Barbier, 2016; Dercon, 2014).

On the dimensional aspect of green growth, it is argued that each of the three dimensions consists of several sub-dimensions (OECD, 2017; Lyytimäki et al., 2018; Acosta et al., 2019). For instance, Jha et al. (2018) divide the economic dimension into economic performance, dependency, and sustainability (and likewise divide the environmental and social dimensions). The point here is not to clarify the specific sub-dimensions but merely to understand that the theoretical comprehension of green growth entails that a green growth measure must incorporate and measure sub-dimensions in order to capture the three overlying dimensions.

As other empirical articles this thesis applies the definition of green growth put forward by Lyytimäki et al. (2018) "*... the process of transition towards a low-carbon and resource-efficient society with economic development that safeguards the functioning of ecosystems and enhances human well-being and social equality.*" (Lyytimäki et al., 2018, p. 51). This includes all three dimensions and by arguing that it must safeguard the functioning of eco-systems and enhance human well-being it places itself within the 'strong' sustainability goal, in which human activities must change to not threaten the eco system but stay within planetary boundaries necessary for human well-being (Steffen et al., 2011; Stoknes and Rockström, 2018).

The subsequent understanding is that green growth is a multidimensional concept based on three pillars: economic, environmental, and social development. When conceptualizing and measuring green growth there should be a clear threshold for when growth is green, that corresponds with the aim of strong sustainability.

Arguments for green growth

Theoretically, different arguments exist on why growth can be green. The standard argument for green growth originated in the Stern Report on the economics of climate change (Stern, 2007). It presented a cost-benefit analysis concluding that the cost of preventing environmental damage will not offset economic growth, whereas not preventing environmental damage is more offsetting for growth (Jacobs et al., 2012). The argument has, however, been highly contested. Economically, criticism has focused on the trade-off between long-term benefits and high present costs. The argument being that due to future technological improvements and increasing wealth, it will be cheaper to adapt and prevent global warming later (Nordhaus, 2007).

Because of the criticism, an even stronger argument for green growth emerged; that environmental protection can promote economic growth. Underlying this argument are three different theories. First, in line with Keynesian theory governmental investments in measures aimed at improving the environment can work as an environmental stimulus to restart economies after crises, which was seen following the global financial crisis in 2008 (Jacobs et al., 2012). Investments in public transport, renewable energy, and pollution control can stimulate employment and consumption growth (Pollin et al., 2008; Zenghelis, 2012). These types of green sectors are labor intensive and thus argued better to use for economic stimulus as they create many jobs and thereby increase employment and consumption (Kammen & Engel, 2009). Meanwhile, the argument is prone to the general critique that Keynesian stimulus is ineffective and crowd-out private investments (Jacobs et al., 2012).

Secondly, a stream of research has argued that the natural environment is a (so far ignored) production factor or natural capital (Nordhaus, 1974; Solow, 1974). The current growth path is argued to be sub-optimal due to undervaluation of natural capital leading to exploitation of common goods which causes market failures (Jacobs et al., 2012). This argument has been much debated and criticized due to history indicating that with higher environmental degradation comes higher economic growth, which makes it questionable that it is sub-optimal in economic terms to be environmental harmful. The counterargument is that the scarcer resources today has made the former optimal growth path sub-optimal (Rockström et al., 2009).

Finally, innovation and industrial policies can push for a new industrial revolution to low-carbon emission economies in which growth is enhanced through employment in the new environmental industries (Perez, 2010). The assumption being that due to first-mover advantages the first economies entering these sectors will achieve a net increase in job creation compared to environmental-harming "old" sectors of the economy. Critiques, however, argue that it is too hypothetical to rely on governments ensuring a new industrial revolution (Winston, 2007).

Empirically, the argument for green growth is rather vague exactly because no criteria exists for when growth is green. The most consistent empirical assessments has evolved around decoupling of economic growth and carbon emissions. The empirical arguments in this discussion are rather inconclusive. Some studies as Hickel and Kallis (2020) finds no empirical support for absolute decoupling of resource use and economic growth globally and argue that absolute decoupling from carbon emissions will most likely be too slow to prevent global warming. This has given rise to the degrowth and zero-growth movements e.g. found in Kallis (2011).

On the other hand, some articles find opposite evidence (Jackson & Victor, 2019). For instance, Rockström et al. (2009) shows that carbon productivity increases in

Sweden, Finland, and Denmark, are on path of achieving the Paris Agreement. The decoupling debate is further complicated, as some studies find that decoupling only happen due to outsourcing of carbon emissions (Peters et al., 2011). This have been counter-argued since outsourcing can also improve environmental efficiency if goods are produced less environmentally harmful elsewhere (Baumert et al., 2019).

However, decoupling is only one dimension of green growth, and empirical evidence for green growth should rely on measures of the entire concept Hence, the next section analyzes the currently used measures of green growth.

2.2 Literature review: measures of green growth

Narloch et al. (2016) previously reviewed the literature to identify data gaps and approaches to measuring green growth. But their assessment did not allow for in-depth review of how the actual measures are designed. Neither did it focus explicitly on measures that allow for longitudinal cross-country econometric assessments. Other articles developing green growth measures e.g. Šneiderienė et al. (2020), Wang and Shao (2019), and Wu and Zhou (2021) merely review a minor part of the literature in argument for their approach. As a result the first step in the present thesis is to conduct a systematic and thorough literature review analysis to identify how different studies measure green growth for quantitative assessments. The analysis of the literature identifies three approaches to measure green growth: Using a single indicator (SI); a composite index (CI); and data envelopment analysis (DEA). Before going into each of these and present the articles within, it is necessary to explain the methodology for reaching these findings.

Method for the qualitative literature review analysis

The literature review has been limited to articles explicitly claiming that *green growth* (GG) or *inclusive green growth* (IGG) is measured. Both GG and IGG are explored, as they are used interchangeably. This is evident in the literature tables, where some say that they measure IGG without including a social dimension (e.g. Chen et al., 2020 and Sun et al., 2020) and some say that they measure GG but do include a social dimension (e.g. Šneiderienė et al., 2020 while Jadoon et al., 2021). Articles that claim they measure "green economy" are left out (as earlier argued). Furthermore, articles presenting a dashboard of indicators such as Schenau (2017) or simply an indicator framework as Lyytimäki et al. (2018) are also left out, since these approaches cannot empirically measure green growth for econometric analyses.

The review is carried out systematically using Google Scholar and the university library search pages LUBsearch and AU Library. Initial search items include variations of "measuring green growth", ""green growth" AND "econometric"", "Inclusive green growth index". Relevant articles are identified through title and abstract assessments. For the relevant articles their reference lists, literature and methodology paragraphs are browsed systematically identifying other relevant articles. The search is not limited to specific years, but since the empirical measures of green growth has been developed within the last decade, no earlier articles than 2014 were found. The review has evolved with the knowledge gained through the process e.g. when it was discovered that one method to measure green growth is DEA, this guided new search items aiming to find articles applying this method. Also worth noting is that only articles in English are included.

This systematic process identified 30 relevant articles written within the last eight years. All articles are described in Table 2, 3, and 4. The tables include the thorough assessments from the analysis, whereas the most important findings and arguments are discussed in the text. This overview is the first step towards a clearer understanding of how green growth can be measured, what distinguishes these measures, and the pros and cons of the different measures.

Single indicators

The identified articles using a SI measure as a proxy for green growth are presented in Table 2. They view green growth as a two-dimensional concept of the environmental and economic dimensions. Thus, they apply different measures of economic productivity adjusted for environmental factors such as carbon productivity, resource productivity or environmentally adjusted multifactor productivity (Fernandes et al., 2021; Hao et al., 2021;Tawiah et al., 2021; Stoknes and Rockström, 2018). Finally, both Khan and Ulucak (2020) and Mensah et al. (2019) measure green growth through carbon emissions, which indicate an assumption that decoupling of carbon emissions and economic growth is the only dimension of green growth. Using these SI proxies is therefore dismissive to the theoretical multidimensional understanding of the concept outlined in the former paragraph.

An article worth highlighting is the work done by Stoknes and Rockström (2018).

Table 2: Literature overview - Single indicator measures of green growth

Author	GG measure	Measure of	Application
Fernandes et al. (2021)	Environmentally adjusted multifactor productivity	Economic and environmental performance	Effect of sustainable technology transfer and sustainable innovations on green growth in 32 OECD countries, 1990-2013
Hao et al. (2021)	Environmentally adjusted multifactor productivity growth	Green growth	Effect of green growth on CO2 emission in G7 countries, 1991-2017
Khan and Ulucak (2020)	CO2 emissions (total and production based)	Green growth	Effect of environmental technologies on green growth in BRICS countries, 1992-2014
Mensah et al. (2019)	CO2 emissions (total, consumption-based, and production-based)	Green growth	Effect of technological innovation on green growth in 28 OECD economies, from 2000-2014
Stoknes and Rockström (2018)	Resource productivity / Carbon productivity	Genuine green growth	Analysis of green growth progression in the 4 Nordic countries, 2000-2015
Tawiah et al. (2021)	Environmental and resources productivity	Green growth / greening of growth	Analyze determinants of green growth in 123 countries, 2000-2018

Source: Developed by author

They evaluate whether carbon productivity increases are extensive enough to reach the Paris Agreement, by calculating a threshold for what they term *genuine green growth* which requires an increase in carbon productivity above 5 per cent. Using a threshold for the needed improvement of measures required to reach the green targets, is important for the debate on when growth is green. Furthermore, interestingly all the SI measures are used for cross-country longitudinal assessments, which might be explained by these studies having better data availability, due to only measuring one variable.

A challenge when interpreting the SI literature is the lack of comparability. One example is the variables that Tawiah et al. (2021) and Mensah et al. (2019) explore as determinants of green growth, are used in other articles as dimensions of green growth, making it impossible to compare the different results. In short, the major shortcoming of the SI method, is that it does not correspond to the theoretical understanding and definition but only reflect one dimension of green growth .

Data envelopment analysis

The adjusted productivity measures used in the SI literature, is closely related to the DEA method, which is used to measure productivity under environmental constraints. Analyses using DEA to measure green growth is presented in table 3. DEA is a non-parametric method based on production theory, which can be used to calculate production frontiers by evaluation of multiple inputs and outputs (Qu et al., 2020; Cao et al., 2020). Based on the production theory developed by Debreu (1951) and Shephard (1953), the idea is that one can maximize desirable outputs (most commonly GDP) and minimize undesirable outputs (most commonly CO2 emissions) given the number of inputs (most commonly capital, labor, and energy) to measure green growth efficiency (Houssini & Geng, 2021). The different underlying methods that the articles in table 3 use include the slack-based measure of the directional distance function proposed by Tone (2001), a non-radial directional distance function proposed by Zhou et al. (2012), a Malmquist index proposed by Malmquist (1953), and a Malmquist-Luenberger index proposed by Luenberger (1992). All these methods seek to overcome shortcomings of general methods for evaluating productivity with environmental constraints (Cao et al., 2020).

Without going further into the theory behind these methods, it can be argued that they conflict with the definition and underlying theory of green growth. For instance, Zhu and Ye (2018) are the only including a social indicator (income disparity) and generally, not enough sub-dimension are included to reflect multidimensionality. Furthermore, the process of maximizing and minimizing certain input and output directly implies a trade-off criticized by the strong sustainability literature. DEA techniques include more dimensions than the single indicator methods and thus closer to the theoretical understanding (Wang & Shao, 2019). However, the methods are still single-dimensional in their evaluation and thereby not in line with the theoretical interpretation of green growth (Wu & Zhou, 2021).

It seems that the applications of green growth measures are different across the three approaches. As evident in Table 3 most DEA articles aim to measure the "efficiency" or "performance" of growth within a single country or industry. As an example of this Song et al. (2020) aim to estimate concrete GDP losses due to green growth, which would not be possible with other methods. Contrastingly, the only identified DEA article aiming to do an index of green growth is Zhu and Ye (2018).

However, Zhu and Ye (2018) recognizes they actually measure "inclusive green total factor productivity" although naming it inclusive green growth. This is a general - and the most prominent - problem with the DEA methods: That they measure different total factor productivity levels and claim this to be green growth although it is only one dimension of green growth. The findings here indicates that the DEA

Table 3: Literature overview - Data envelopment analysis measures of green growth

Author	GG measure method	Measure of	Application	Inputs	Desirable output(s)	Undesirable output(s)
Cao et al. (2020)	ML index model	Green growth efficiency of manufacturing	Environmental regulation on green growth in China's manufacturing industry	Capital, labor, technological innovation, and energy consumption	Industrial sales value of each manufacturing input	Index of "three wastes" in various industry sectors
Chen et al. (2020)	Super-effciency SBM model to compute a Metafrontier ML index	Inclusive green growth efficiency	IGG levels in 108 YREB cities	Capital, labor, land, and energy	Per capita GDP, Afforestation	Air pollution, waste pollution
Houssini and Geng (2021)	Integrated TOPSIS and SBM model.	Green growth efficiency	GG in Morocco, 2000-2018	Energy, capital, and labor	GDP	Environmental pollution measured as CO2 emissions
Qu et al. (2020)	UPI and EEPI based on the unified non-radial DDF and the energy environment non-radial DDF.	Manufacturing industry green growth	GVC embedding degree on China's manufacturing industry GG	Capital, labor and energy	Gross value of industrial output	CO2 emissions from energy consumption
Song et al. (2020)	Green global Malmquist index based on DDF model & output-oriented SBM model	Green growth performance	GG effect on GDP losses in 30 Chinese provinces	Labor and capital	GDP	CO2 emissions
Sun et al. (2020)	Arithmetic mean of Luenberger productivity indicator based on a DDF-SBM model	Inclusive green growth	Decomposition of drivers of IGG levels in 285 Chinese cities	Labor, capital, and energy	GDP	Water pollution, sulfur dioxide, and industrial soot emissions
Wang and Shao (2019)	Hybrid Global ML index	National green growth performance	Effect of formal and informal ER on GG in G20 countries, 2001-2015	Labor, capital, and energy	GDP	CO2 emissions
Zhu and Ye (2018)	Super-efficient SBM model with and without unexpected output.	Inclusive green growth index	Effect of FDI on IGG in China	Labor, capital, and energy consumption	GDP	Income disparity and environmental pollution

Note: IGG = Inclusive green growth; ML = Malmquist-Luenberger; SBM = Slacks-Based Measure; UPI = Unified performance index; EEPI = Energy-environment efficiency index; DDF = Direction distance functions; GVC = Global value chain; ER = Environmental regulation. *Source: Developed by author* method is highly relevant for certain purposes but not necessarily for computation of a longitudinal cross-country measure of green growth.

Composite indexes

Lastly, as presented in Table 4 several articles use a CI of underlying indicator frameworks as a measure of green growth. A CI is formed by compiling individual indicators based on an underlying model and can measure multidimensional concepts that are not capturable by the individual indicators (Nardo et al., 2008). First and foremost, the benefit of making green growth CIs is that it justifies the multidimensional theoretical understanding. Furthermore, CIs are useful for benchmarking country performance and are easily interpreted by the general public and policymakers (Saltelli, 2007). This has led to a growing number of composite indexes being computed every year as is evident from Table 4.

However, many subjective choices of the CI design will affect the final scores (Nardo et al., 2008). As seen in Table 4, all articles use different dimensions, indicators, weighting, and normalization methods, hence the results are not directly comparable and increases the confusion of the label *green growth*.

Normalization is important as it aligns scaling of all indicators for them to be aggregated. Most studies simply use the min-max standardization where indicators are scaled 0-1 (Jha et al., 2018; Kararach et al., 2018; Li et al., 2021; Šneiderienė et al., 2020; Wu and Zhou, 2021; Zhang et al., 2022). The choice of normalization affects the interpretation of the CI. For instance, Kim et al. (2014) score indicators based on the 10th percentile scoring country. The final CI thereby measure how *green* growth is relative to other countries but does indicate whether countries actually experience green growth.

Furthermore, Narloch et al. (2016) claims that most CI weighting and aggregation methods implies weak sustainability since they allow improvements in one dimension to offset other dimensions' deterioration. The simplest weighting is equal weighting, which is also used in four of the green growth articles, usually with the defense that all dimensions are equally important (Baniya et al., 2021; Jha et al., 2018; Kararach et al., 2018; Jadoon et al., 2021; Šneiderienė et al., 2020). Another method is expert assessment on how to weight indicators. Interestingly Lee and Chou (2018) find that using expert or equal weighting does not impact their findings.

Table 4: Literature overview - Composite index measures of green growth

Author	Measure of	Dimensions	Application	Indicators	Normalization	Weighting
Acosta et al. (2019)	Green Growth Index	(i) Efficient sutainable resource use; (ii) Natural capital protection, (iii) Green economic opportunities; (iv) Social inclusion	GG index of 115 countries in 2019	36	Min-max (plus threshold)	Equal
Ates and Derinkuyu (2021)	Green growth performance	(i) Economic indicators; (ii) Environmental & resource productivity, (iii) Economic opportunities & policy responses; (iv) Natural assets	Ranking of GG in OECD countries	11	I-distance method	I-distance method
Baniya et al. (2021)	Greening of growth	(i) Economic; (ii) Environmental	Development of GG in Nepal and Bangladesh	6	Normalized index	Equal
Gu et al. (2021)	Index of Inclusive Green Growth	(i) Economic growth; (ii) Social opportunity fairness; (iii) Green production & consumption; (iv) Ecological environmental protection	Influence of EPU on IGG in 30 Chinese provinces, 2006-2016	33	Fixed-base efficiency coefficient	Fixed-base range entropy
Guo et al. (2017)	Regional Green Growth performance	(i) CO2 per unit of GDP; (ii) Energy consumptions per unit of GDP	Relation of ER, TI, and RGGP in 30 Chinese provinces, 2011-12	2	Z-score normalization	SEM
Huang and Quibria (2013)	Green growth index	(i) Environmental & resource productivity; (ii) Natural asset base; (iii) Environmental quality of life; (iv) Economic opportunities and policy responses; (v) Socioeconomic context	Determinants of GG in 42 OECD and BRICS countries, 1990-2009	22	NI	PCA
Jadoon et al. (2021)	Green Growth index	(i) Social equity; (ii) Economic performance; (iii) Environmental performance	Effect of GG on fiscal stability in 90 countries 2010-15	21	Z-score normalization	Equal
Jha et al. (2018)	Inclusive green growth index (IGGI)	(i) Economic; (ii) Social; (iii) Environmental	IGGI scores in 25 Developing Asia countries	28	Min-max (1-6 scale)	Equal
Kararach et al. (2018)	African Green Growth Index (AGGI)	(i) Socioeconomic context & characteristics of growth; (ii) Environmental & resource productivity; (iii) Monitoring the natural asset base; (iv) Gender; (v) Governance	AGGI scores in 22 African countries	48	Min-max	Equal and expert
Kim et al. (2014)	Status of green growth	(i) Environmental efficiency of production; (ii) Environmental efficiency of consumption; (iii) Natural capital stocks & environmental quality, (iv) Quality of life; (v) Economic response	Green growth status in 30 countries	12	Scored based on 10th percentile score	Equal
Lee and Chou (2018)	Green Growth Index	(i) Environmental and resource productivity; (ii) Natural resource stock; (iii) Environmental living quality; (iv) Economic opportunities & policy response	Progress towards GG in Taiwan, 2002-2012	20	Normalized index	PCA and AHP
Li et al. (2021)	Inclusive Green Growth Indicator	(i) Economic prosperity, (ii) social inclusion, (iii) resource utilization, and (iv) environmental sustainability	Ranking of IGG level in 37 Asia-Pacific countries	26	Min-max	Factor & cluster analysis, entropy
Liu et al. (2021)	Inclusive Green Growth Index	(i) Economy, (ii) social opportunities, (iii) green production and consumption, and (iv) the environment	IGG differences within and between 3 YRB city clusters	26	Range standardisation	Fixed-base range entropy
Šneiderienė et al. (2020)	Green Growth Index	(i) Economy; (ii) society; (iii) environment	Ranking GG of 27 EU countries	32	Min-max	Equal
Wu and Zhou (2021)	Inclusive Green Growth evaluation index	(i) Inclusive; (ii) green; and (iii) economic development	IGG level 2007-18 in China and 30 provinces	30	Min-max	Entropy
Zhang et al. (2022)	Inclusive Green Growth index system	(i) Social and (ii) environmental dimension	Effect of IGGI on tourism industry in 30 Chinese provinces, 2010-19	28	Min-max	Entropy

Note: GG = Green growth; IGG = Inclusive green growth; EPU = Economic policy uncertainty; YRB = Yangtze river belt; ER = Environmental regulation; TI = Technological innovation; RGGP = Regional green growth performance; PCA = Principal component analysis; AHP = Analytical hierarchy process; SEM = Structural equation modeling. NI = Not indicated. Source: Developed by author

Other analyses use the more objective statistical weighting methods of principal component analysis (PCA), factor analyses, and entropy weighting methods that are regarded less biased by some (Li et al., 2021). However, these methods have limits as well. For instance, PCA is not always feasible based on the specific data at hand. Furthermore, although it makes statistically sense to use weighting based on the contribution of each indicator to the final CI (entropy method), Li et al. (2021) shows how this entropy method has a considerable error of excessive weighting on single indicators. In their example India's green growth performance increased with 25 per cent when using the method due to high weights given to land output efficiency.

Although these pitfalls exists composite indexes are often used to measure multi-dimensional concepts, and attempts have extensively been constructed on green growth related areas. Examples (out of many) are the index of sustainable economic welfare (ISEW), the global green economy index (GGEI) by Dual citizen, the Green Economy Benchmark Index (QGREEN), and the Inclusive development index by WEF (Jha et al., 2018; Kararach et al., 2018). It is out of scope to go into the discussion on each of these, but it does serve to emphasize some advantages and dis-advantages of applying CIs. On one hand they are appealing in nature as they allow for simplifying complex multidimensional concepts and hereby allow for comparisons (Nardo et al., 2008). On the other hand, the construction process entails many subjective assessments, which in turn leads to different indexes being constructed on similar topics, where any of them may end up being misused to obtain the desired results (Kararach et al., 2018).

Overall findings of the literature review analysis

Overall, only two articles use the same measure of green growth (SI of carbon emission). From 30 articles 29 different measures of green growth are identified. This finding is striking and emphasizes the main problem for research advancements on green growth: using many different measures dilutes the applicability of the concept, since readers must dissolve what is meant by green growth in any specific article. GDP has evolved as a broadly used measure, because it is easy to use, understand, and interpret. Green growth is everything besides this, entailing that the foremost obstacle is the lack of consensus in order for the concept to develop, be used actively, and provide insights for policy makers and researchers.

Another problem is the mismatch between the theoretical understanding and the empirical measures of green growth. The SI and DEA methods have substantial limitations in terms of including the needed number of dimensions. The CI allows for multidimensional indicators, but in doing so often allow for compensability between the dimensions. As such current measures all have, in different ways, issues capturing the theoretical understanding of the concept. Meanwhile, non-compensatory methods for CIs do exists, suggesting this is most likely the least theoretic compromising measure method.

A third problem is the lack of empirical assessments of cross-country green growth levels that go beyond ranking countries' position to one another. When reviewing the application of measures, only one and three articles from the DEA and CI approaches perform cross-country longitudinal assessments. Interestingly, all the identified SI studies do this, but when they in fact are not measuring green growth, their results are not of much use. If green growth, theoretically, is a viable strategy for achieving sustainable development, we need to answer questions on the prerequisites for green growth success. To accomplish this, there is a need for cross-country longitudinal measures that allow for econometric assessments. This will help further general understandings of the concept, and based on stronger empirical evidence to assess whether countries are actually achieving green growth.

Based on these findings, it seems that the theoretical understanding is best incorporated into a non-compensatory CI measure of green growth. How to incorporate this into the design of a CI measure that allows for the needed longitudinal cross-country assessment is explored in Section 3.1. First, some short comments must be presented on the theoretical expectations for determinants of green growth.

2.3 Determinants of green growth

To assess how the measure used for green growth impacts econometric analyses the aim is to reassess the analysis on determinants of green growth done by Tawiah et al. (2021). As will be further explained in Section 3.3 the studied determinants from this analysis are institutional quality and foreign direct investments (FDI). Also, government consumption and investments are examined as possible determinants inspired by Huang and Quibria (2013). The following section will outline the theoretical explanations, empirical findings, and the specific findings in Tawiah et al. (2021) and Huang and Quibria (2013) on the four possible determinants.

Institutional quality

Many scholars such as North and Thomas (1970), Rodrik et al. (2004), and Acemoglu et al. (2005) argue that institutional quality is important for economic growth. But the question remains how to understand 'insitutional quality' when more definitions of institutions exist than scholars exploring it (Acemoglu, 2012). Since the world governance indicators are used to measure institutional quality in this study, the understanding here is based on the following definition of governance: " *... the set of traditions and institutions by which authority in a country is exercised. This includes (1) the process by which governments are selected, monitored, and replaced, (2) the capacity of the government to effectively formulate and implement sound policies, and (3) the respect of citizens and the state for the institutions that govern economic and social interactions among them.*" (Kaufmann et al., 1999 pp. 1).

Salman et al. (2019) finds that institutional quality lead to the cut of carbon emissions while also promoting growth. More specifically Sarkodie and Adams (2018) find that political-institutional quality promotes cutting carbon emissions by providing the social, governance, and economic "readiness". Some institutional parameters might though be dismissive for growth because strong environmental law enforcement and changing regulation may lessen incentives for innovation and creativity as it will harm firms' growth (Nguyen et al., 2018; Abid, 2017). The empirical evidence on this argument is weaker, and the general hypothesis is; that higher institutional quality promotes green growth. Nonetheless Tawiah et al. (2021) find insignificant effects of institutional quality on green growth.

Foreign Direct Investments

The theoretical expectations as to how FDI impact green growth is explained by the pollution haven and halo hypotheses. The pollution haven hypothesis argues that FDI is a way of channeling pollution-intensive operations to other countries (Walter & Ugelow, 1979). Both Haug and Ucal (2019) and Salahuddin et al. (2018) find evidence that increasing FDI lead to environmental degradation in developing countries. Whereas Ayamba et al. (2020) questions the long-term effects in China.

The pollution halo hypothesis instead argues that FDI facilitate technology transfer which is positive for green growth. This argument has received substantial empirical support (Ayamba et al., 2019; Mihci et al., 2005; Zhu et al., 2016; Pao and Tsai, 2011). Interestingly in this context Bokpin (2017) find evidence in Africa that the positive effect of FDI on the environment requires high institutional quality. In conclusion theory implies two completely opposite hypotheses on how FDI impact green growth. In their study Tawiah et al. (2021) find negative insignificant effects of FDI on green growth and no strong support for either hypothesis.

Government consumption and investments

Following the arguments in Section 2.1 government consumption in green sectors and investments into new technology are prerequisites for green growth. Therefore, both determinants are expected to positively impact green growth, especially since governments play a key role in fostering green growth (UN-ESCAP et al., 2012).

The formal theoretical framework for these hypotheses is provided by the green Solow model (Brock & Taylor, 2010). Without going into the mathematical derivations of the model, the important feature is; by integrating an emission and abatement function into the capital accumulation equation derived from the Cobb-Douglas production function, emission growth can be mathematically related to technological progress and abatement expenditures. This emphasizes the crucial role of climate-friendly technological development and green investments for green growth (Huang & Quibria, 2013). On the empirical site Huang and Quibria (2013) finds a significant positive effect of government consumption on green growth, while a positive but not significant effect of investments on green growth.

Developing vs. developed countries

Finally, Tawiah et al. (2021) find that determinants of green growth vary between developed and developing countries. In support of the pollution haven hypothesis, they find a significant negative relationship between FDI and green growth only in developing countries, supported by findings in Khan et al. (2020) and Tang (2015).

The straightforward reason for divergent determinants is the different prospects for green growth. The applicability of green growth in developing countries has been questioned on the grounds that green growth requires structural transformation, technological innovations, high human capital, and well-functioning institutions, all of which are more compatible with the structures in developed economies (Fankhauser et al., 2013; Barbier, 2014; Klein et al., 2013). Additionally, a prerequisite for green growth in developing countries is compatibility with natural resource dependency and poverty alleviation which has also been questioned (Barbier, 2016; Klein et al., 2013). On the other hand, developing countries have undertaken less "lock-in" decisions on e.g. infrastructure, easing the green transition (OECD, 2012; Fay, 2012).

The present analysis will divide countries based on income group: lower-, lower-middle-, upper-middle-, and high-income countries[1]. This categorization is chosen as it is more specific than using "developing vs. developed countries" and allows for differences within the large group of developing countries.

3 Data and methodology

Taking outset in the above outlined theory on green growth and its determinants the thesis is mainly built upon a deductive approach. This allows for testing existing theories through empirical data. This goes in particular for the analysis on determinants of green growth, where it must though be emphasized that the research design is correlational rather than causal. The aim is to improve the understanding on how possible determinants and green growth interact within countries over time.

The refinement of a green growth measure was approached inductively, as the first ambition was to review the literature in Section 2.2 to see if this provided a solid and broadly used measure. However, as this was not found the approach became deductive, where the outset was on how to best align the theoretical understanding of green growth with the possible ways of measuring such concepts. As argued in Section 2.2 this is done through a composite index

3.1 A refined green growth composite index

Composite indexes must be based on a theoretical framework, outlining why the indicators theoretically can be expected to explain the concept wished to be measured (Nardo et al., 2008). The theoretical framework of the green growth index was

[1]The World Banks' income classification on gross national income per capita in current USD: LICs = average GNI beneath \$1,036. LMICs = average GNI between \$1,036 and \$4,045. UMICs = average GNI between \$4,046 and \$12,535. HICs = average GNI above \$12,535.

presented in Section 2.1. In short, the review of the literature shows that green growth is a multidimensional concept including three overall dimensions (social, economic, and environmental) as well as an undefined number of sub-dimensions. It is considered a strategy towards achieving strong sustainable development, and thus needs a clear clarification of when growth is green.

Adhering to the guideline for computing composite indexes as presented by Nardo et al. (2008) the following presents the data/indicator selection, missing data imputation, multivariate analysis assessment, normalization procedures, weighting method, and the aggregation method.

Data selection

The indicators included in the composite index must reflect sub-dimensions within each of the three dimensions of green growth. As was evident in Section 2.2 exactly how many sub-dimensions and indicators included in the composite index varies from study to study. In this thesis the 27 indicators presented in Figure 1 are chosen to reflect the economic, social, and environmental dimensions. The choice is based on the selection of indicators by Jha et al. (2018) and Šneiderienė et al. (2020). Both articles use their CIs to comprehensively assess cross-country levels of green growth in the EU and Asia respectively, thus their indicator selection is approriate for the aim of this study. Šneiderienė et al. (2020) develop their indicators based on the indicators in Jha et al. (2018), Kararach et al. (2018), Nahman et al. (2016), and Yang et al. (2019) due to which this indicator selection represents advancements in the literature within the last decade.

Acosta et al., 2019 also present a thorough assessment of which indicators to use. They develop a persuasive and comprehensive green growth index with 36 indicators and 14 sub-dimensions, of which four indicators are incorporated into the refined measure. This is especially since the environmental sub-dimensions are not sufficiently covered by the other eight indicators.

As noted by Kim et al. (2014), Narloch et al. (2016), Ates and Derinkuyu (2021), and Engelmann et al. (2019) the selection of green growth indicators is often influenced by data availability. This thesis is no exception. The aim is to cover as many countries as possible from 1990-2019 to indicate general patterns on determinants of green growth, which in turn limits the pool of potential indicators due to data

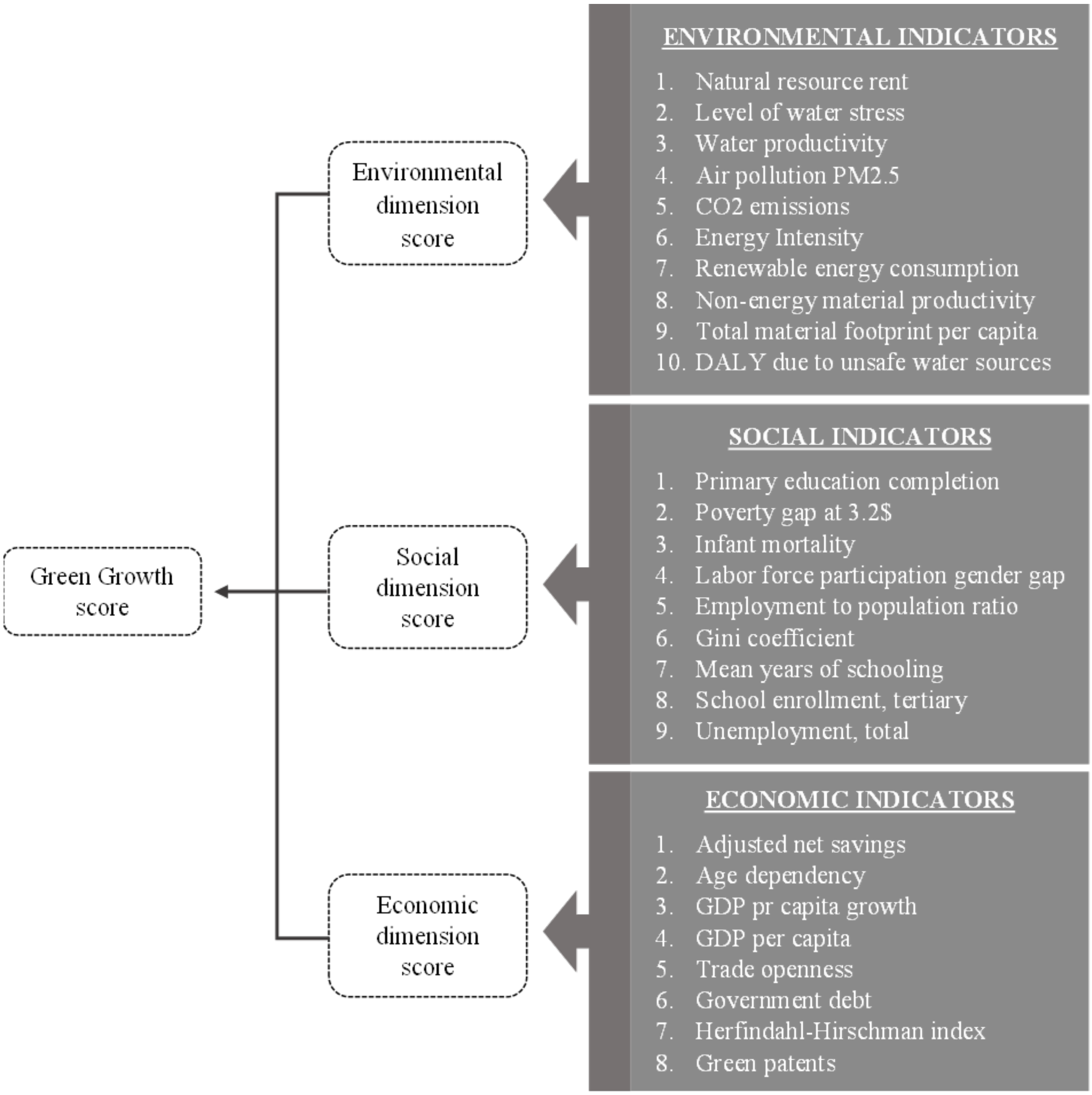

Figure 1: Green growth indicator structure
Source: Developed by author

availability. All indicators must have available data for at least 3 periods for all countries without systematically lacking information in certain periods. Comparably, since Jha et al. (2018), Acosta et al. (2019), and Šneiderienė et al. (2020) do index rankings of countries for one year only, they can use variables unavailable for this study due to missing data. The included indicators are though considered to reflect the most important sub-dimensions within each dimension.

Missing data imputation

One way of overcoming issues with data availability is the appliance of data imputation. However, data imputation is risky as it may bias the results (Kararach et al., 2018). Therefore, data imputation is only applied to the important indicators of poverty and Gini index of the social dimension through the tool PovCalNet developed by the World Bank. The outcome of the imputation is thoroughly examined here to ensure that it does not bias the results [2].

Multivariate analysis

Multivariate analyses must be carried out to assess the overall structure of the data (Nardo et al., 2008). By computing a Pearson pairwise correlation matrix the association of the individual indicators is explored to identify redundant indicators with high correlation. Although no clear rules exist for when correlations are considered "too high" Acosta et al. (2019) argues that correlations in the span 0.1-0.9 (for statistically significant correlations at the 0.1 level) are acceptable for variables to be included into the same index. In the data used in this study, *life expectancy* and *access to electricity* are left out due to high correlations with *infant mortality* (0.91) and *poverty* (0.94) respectively. This resulted in the final 27 indicators as presented in Figure 1. In Section 4 analyses will include a measure using the two indicators, to examine how/if excluding them affects regression results.

Normalization

Normalization is essential to assure comparability between the indicators as they are often measured in different units causing issues when aggregated. Based on the data at hand and the CI measuring aim, several different techniques for normalization have been developed (Nardo et al., 2008). Sironen et al. (2015) explores how to measure a sustainable society index corresponding to strong sustainability understandings, and concludes that this can be accomplished by considerations at the indicator level. Indicator scores are calculated based on distance to a threshold for when green growth is achieved, obtaining a maximum score if the threshold is met or surpassed. This limits the impact of outliers and the compensability between the indicators.

[2] When possible, the imputation is done with linear interpolation. If data is only available for one year the survey mean, private consumption growth rate, and distribution of the observations within the survey are used for imputation (The World Bank, 2022a).

Yet, discussions arise on how to determine such threshold values, which is highly dependent on the specific indicator (Sironen et al., 2015). A promising method is presented by Rockström et al. (2009) who finds that average annual carbon productivity increases should be 5 per cent, to achieve the Paris Agreement target. Meanwhile, other thresholds are straightforward, for instance poverty eliminations is key for sustainable development due to which the threshold value is 0. This also implies that some thresholds will be lower targets (carbon productivity increases should be above 5 per cent) and some upper targets (poverty should not surpass 0). For further discussion on the chosen threshold values see Section 3.3.

Based on Acosta et al. (2019) the normalization calculations using min-max standardization and threshold values can be presented by the equation:

$$x^i_{norm} = a + (\frac{x_i - X_{min}}{X_{max} - X_{min}}) \times (b - a) \tag{3.1}$$

where a is the lower bound and b the upper bound. The lower bound for the indicators is set to 1[3]. The upper bound is set for 100, making the index ranging from 1 to 100. The expression within the large parenthesis corresponds to the general min-max normalization method.

The method of including the thresholds into the indicator normalization requires adjusting equation 3.1 based on (1) whether the indicator has a positive or negative impact on green growth, and (2) whether any countries score above/below the indicator threshold (respectively for upper and lower targets). Based on this, five different cases are identified. Table 14 in Appendix A.1 showcase equation 3.1 fitted to each of these cases. The essential changes are, that the min-max normalization equation shifts based on whether the scale is positive or negative and the equation must cap values surpassing the threshold.

Weighting

Taking outset in the discussion on weighting methods presented in Section 2.2, the equal weighting method is applied. Because no strong theoretical arguments have been found in the literature on why some indicators should be more important to green growth than others, even the expert assessment in Acosta et al., 2019 choose

[3]Since experts involved in the development of the index in Acosta et al. (2019) argued it is better than applying 0 as it is more encouraging towards performance improvement.

to apply equal weighting. It is out of scope to assess other weighting procedures, but future needs in this realm is commented on in Section 5.2.

Aggregation

In order for composite indexes to comply with strong sustainability notions it is important to ensure non-compensability between indicators (Nardo et al., 2008; Sironen et al., 2015). Using the arithmetic mean for CI aggregation (as found many places in the literature) implies full compensability between the indicators, such that high carbon emissions can be compensated for instance through high economic growth rates (Munda, 2005; Munda et al., 2008; Petkovová et al., 2020). This goes directly against the theoretical understanding of strong sustainability.

Non-compensatory multi-criteria methods have therefore been argued the only way to measure sustainable development and green growth (Nardo et al., 2008). This aggregation method relies on pairwise comparisons of countries through an outranking matrix and then ranking countries in a complete pre-order through permutations. For the measure used in this thesis, it causes two challenges. First, it relies solely on the ranking between countries, not showing if any of these countries actually have green growth. Secondly, the calculation become very comprehensive almost impossible with 27 indicators, 72 countries and 6 time periods.

Appendix A.2 showcase the procedure for the non-compensatory multi-criteria method using an example of five countries on six indicators in the period 2015-2019. Through this it is evident, that to apply this procedure on 72 countries one would need to calculate and compare more than a googol (1 followed by 100 zeroes) permutation scores. Thus, a partial compensatory method might be more applicable.

The multiplicative aggregation using geometric means is a partial compensatory solution in between the fully compensatory arithmetic mean aggregation and the fully non-compensatory multi-criteria method (Sironen et al., 2015; Acosta et al., 2020; Petkovová et al., 2020). By using the geometric mean more weight is put on the poor performance measures, which suppresses the compensation getting us closer to the ideal of strong sustainability (Sironen et al., 2015). The marginal utility of increases in low scores are namely much higher than for high scores, which incentivize to focus on poor performing indicators (Petkovová et al., 2020). It can be expressed mathematically as

Table 5: Example non-compensatory method - Five of 120 permutations scores

1st rank	2nd rank	3rd rank	4th rank	5th rank	Score
Denmark	Sweden	Ireland	Switzerland	Spain	7.00
Sweden	Denmark	Ireland	Switzerland	Spain	7.00
Sweden	Denmark	Ireland	Spain	Switzerland	6.67
Denmark	Sweden	Switzerland	Spain	Ireland	6.33
Sweden	Denmark	Switzerland	Spain	Ireland	6.33

Source: Author's calculations based on outranking matrix in Table 16, Appendix A.2.

Table 6: Example partial compensatory method - Green growth & dimension scores

Country	Environment	Economic	Social	GG
Switzerland	66.63	84.84	100.00	82.68
Denmark	80.46	89.74	99.87	89.67
Spain	52.01	82.01	99.39	75.12
Ireland	43.87	87.32	99.83	72.59
Sweden	99.83	87.49	99.67	95.48

Source: Author's calculations based on standardized values in Table 17, Appendix A.3

$$CI_r = \prod_{q=1}^{Q} I_{qr} \times w_q \tag{3.2}$$

where I_{qr} is a normalized indicator of the underlying indicators denoted by $q(q = 1, ..., Q)$ for a region $r(r = 1, ..., R)$and w_q is the weight of each indicator.

To showcase why the partial compensatory method is preferred over the non-compensatory method, Table 5 displays five of the highest permutations scores (of the 120) and rankings based on the example in Appendix A.2. In this example the result is to rank countries, either as the first or second permutation in Table 5 as the final ranking is chosen based on maximizing the permutation scores.

For comparative purposes Table 6 displays the green growth scores the five countries in the example would receive when using geometric aggregation, equal weighting, and the normalization procedure explained in Section 3.1.

Evident when comparing these two tables is whereas Ireland performs better than Switzerland and Spain on the non-compensatory multi-criteria approach, this is not the case when using geometric aggregation. This is caused by Ireland's very low score on the environmental dimension, which is a result of their very low score on renewable energy share (displayed in Table 17 in Appendix A.3). This underlines how low values are strongly punished in the geometric aggregation method and how the non-compensatory method lacks the ability to take the absolute differences between countries within indicators into account. In other words, the ranking in the non-compensatory methods does not consider whether Switzerland has a renewable energy share 50 per cent or one per cent higher than Ireland. Finally, only the geometric aggregation method provides an absolute level of green growth for each country.

Therefore, for the aim of this thesis it seems more appropriate to apply the partial compensatory method. Hence, geometric aggregation is applied to obtain a score for each dimension, which are used to compute a final measure of green growth. This is depicted with equal weighting in equations 3.3 to 3.6;

$$GG_r^{environment} = \prod_{q^{env}=1}^{10} I_{q^{env}r} \times \frac{1}{10} \tag{3.3}$$

$$GG_r^{economic} = \prod_{q^{econ}=1}^{8} I_{q^{econ}r} \times \frac{1}{8} \tag{3.4}$$

$$GG_r^{social} = \prod_{q^{soc}=1}^{9} I_{q^{soc}r} \times \frac{1}{9} \tag{3.5}$$

$$GG_r = \prod_{d=1}^{3} I_{dr} \times \frac{1}{3} \tag{3.6}$$

where r are the countries, q the indicators within each dimension as denoted, and d is the different dimension scores.

Comparison to other green growth measures

From now on the measure of green growth obtained from Equation 3.6 will be referred to as the refined GG measure. The analysis in Section 4 will compare this measure to different GG measures both directly and in their analysis results. The first being a green growth measure using arithmetic mean aggregation instead of geometric mean (from now on referred to as GG compensatory). Secondly, a "simple" measure using min-max standardization (without thresholds) and arithmetic mean aggregation is tested (referred to as GG simple). As mentioned above, a measure including the two left out indicators (life expectancy and access to electricity) is included (referred to as GG+2). Finally, to replicate the assessments of prior analysis using questionable measures of green growth, a measure of environmental and resource productivity as in Tawiah et al. (2021) will be applied. The measure simply measures green growth as production-based carbon productivity (referred to as GG CO2). In total, the analysis will use five different GG measures, which will provide strong evidence on differences in the results when using different GG measures.

3.2 Econometric panel data model

In order to reassess prior analysis of determinants on green growth, the same econometric method as in Tawiah et al. (2021) is used; namely the fixed effect model.

Fixed effect model

When using panel-data such as longitudinal cross-country data which is applied here, there is risk of omitted variable bias when running simple regressions. This is due to the potential time-invariant factors causing differences between countries, and country-invariant factors causing time differences. One way to limit the risk of omitted variable bias is using fixed effect model regression. By doing so, it is possible to indirectly control for the unobserved time-invariant factors.

This is done by grouping the unobserved factors into two groups: one varying over time and the other time invariant. If the cross-sectional unit is denoted by i, and the period by t, it can be formally written as

$$y_{it} = \beta_1 x_{it1} + \beta_2 x_{it2} + \ldots + \beta_k x_{itk} + a_i + u_{it} \tag{3.7}$$

where k is the explanatory variables, a_i is the time-invariant unobserved effect and u_{it} is time-variant unobserved effects. In comparison to the simple model, this has two error terms. The objective of including a_i is to control for the possible effect of time-invariant effects (eg. where a country is situated) on green growth without identifying and/or observing them directly. If this does affect green growth, the intercept of the regression would differ between countries, this is allowed for by including a_i. By doing so the fixed effect regression makes it possible to study effects within and not just between countries. A pitfall of the method is that it gets impossible to explicitly control for and assess the impact of time-invariant factors on green growth.

Certain assumptions must be fulfilled for the fixed effect model to produce unbiased estimates. The primary being the strict exogeneity assumption. This requires explanatory variables to be uncorrelated with the time-variant error term, u_{it}. It should be noted that the explanatory variables are allowed to correlate with the time-invariant error term, a_i which is the major difference to the random effects model. The Hausman test indicates that there is correlation between the regressors and the unique errors in the data, such that the fixed effect model is the appropriate choice. Woolridge strict exogeneity test furthermore indicates that the strict exogeneity assumption on the explanatory variables are fulfilled in the data.

The second assumption needed to produce unbiased estimates is that the error terms u_{it} are homoskedastic and serially uncorrelated. The Wald test on the data indicated heteroskedasticity, due to which heteroskedasticity robust standard errors are applied throughout all regressions. Serial correlation is only considered problematic with many time periods, and thus not here where T = 6. Finally, it was tested whether country-invariant time-fixed effects should be included. This indicated a dummy for each panel should be included, to control for confounding factors.

Robustness check

With correlational assessment, the fear of reverse causality is always present. For time-series analysis this can be partially overcome by using lagged explanatory and control variables. This will ensure a clear time-sequence, where the explanatory causes occur before the measured green growth, and in essence causality can only run from the explanatory to the explained variables. Furthermore, this also allows for assessing long-term rather than short-term effects. This is interesting as it will enhance our understanding of how determinants relate to green growth over time.

A final robustness check on the fixed effect results is done by estimating a System Generalized Method of Movement model, which allows controlling for the presence of unobserved country-specific effects, while also controlling for a simultaneity bias caused by endogeneity of the explanatory variable.

3.3 Data handling

The data used is found from various sources, which will be described below after some essential notes on the data handling are clarified. This thesis applies panel data where the 30 years have been divided into six 5-year periods (i.e. 1990-94, 1995-99, 2000-04, 2005-09, 2010-24, and 2015-2019). Each variable has been calculated as the mean over the 5-year periods serving two purposes; 1) it diminishes the issues of missing data, 2) it directly allows for exploring long-term changes in averages rather than simple fluctuating levels from year to year.

The countries, included in the study, are chosen according to the availability of data on green growth indicators. Countries are excluded if they do not have information on all 27 indicators for at least 3 periods. Due to this, 72 countries are included in the analysis, of which 10 are lower-income countries, 19 lower-middle income, 21 upper-middle income, and 22 higher-income countries based on 2019 levels of GNI. The full list of countries can be seen in Table 9. As it cannot be ensured that the countries lacking data is random, the results should only be interpreted as patterns to the 72 countries explored. Further studies on the remaining countries are needed to conclude anything on the generalizability.

Finally, some of the variables have been transformed using the natural logarithm, as will be noted in the presentation of the variables in Table 8. The choice of transforming the variable was based on assessments of histograms to ensure normal distribution and linear scatter plots to ensure linear relations with green growth. This should be kept in mind when reading the results as it affects the interpretation but also limits the potential bias in estimation results.

Green growth indicators and their thresholds

The indicators of green growth are primarily sourced from the World Bank's World Development Indicators, but as evident in Table 7 other sources have been added as there is no database with data available for all 27 indicators. Limitations on the data sources are handled in Section 5.2. For now, it must be stressed although data reliability is always questionable utilizing the widely used international sources increases reliability. Furthermore, the data used ensure compliance in methodology across countries and over time while having the most comprehensive data coverage possible.

Table 7: Green growth indicators - specification, thresholds, and sources

Indicator	Variable	Threshold	Threshold source	Impact on GG	Source
Environmental					
Natural ressource rent	Yearly change in percentage points of GDP	0	NA**	Positive	World Bank*
Level of water stress	Freshwater withdrawal as a proportion of available freshwater resources	25 & 75	Acosta et al. (2019)	Negative	World Bank*
Water productivity	Constant 2015 US$ GDP per cubic meter of total freshwater withdrawal	265.8	Acosta et al. (2019)	Positive	World Bank*
Air pollution PM2.5	Population exposed to levels exceeding WHO guideline (% of total)	0	NA**	Negative	World Bank*
Carbon productivity	GDP (constant LCU) per CO2 emissions (kt) (% change from last year)	5	Rockström et al. (2009)	Positive	World Bank*
Energy Intensity	Energy intensity level of primary energy (MJ/$2011 PPP GDP)	1.092	Acosta et al. (2019)	Negative	World Bank*
Renewable energy consumption	Renewable energy consumption % of total final energy consumption	51.4	Acosta et al. (2019)	Positive	World Bank*
Non-energy material productivity	Non-energy material productivity, GDP per unit of DMC in USD pr kg	5.9	Acosta et al. (2019)	Positive	OECD (2022a)
Total material footprint per capita	Material footprint in tons per capita	5.0	Acosta et al. (2019)	Negative	OECD (2022b)
DALY rate to unsafe water sources	(DALY lost per 100.000 persons)	0	Acosta et al. (2019)	Negative	IHME (2019)
Social					
Primary education completion	Primary completion rate, total (% of relevant age group)	95	O'Neill et al. (2018)	Positive	World Bank*
Poverty gap at 3.2$	Poverty gap at $3.20 a day (2011 PPP) (%)	0	NA**	Negative	World Bank*
Infant mortality	Mortality rate, infant (per 1,000 live births)	4	HICS average	Negative	World Bank*
Labor force participation gender gap	Absolute difference between male and female labor force participation rate (% of male/female population ages 15+) (ILO estimates)	5	NA**	Negative	World Bank*
Employment to population ratio	Employment to population ratio, 15+, total (%) (ILO estimate)	59	UMIC average	Positive	World Bank*
Gini coefficient	Rescaled to be positive scale (100 - gini)	70	O'Neill et al. (2018)	Positive	World Bank*
Mean years of schooling	Mean years of scooling	12	NA**	Positive	UNDP (2019)
School enrollment, tertiary	School enrollment, tertiary (% gross)	79	HICS average	Positive	World Bank*
Unemployment, total	Unemployment, total (% of total labor force) (ILO estimate)	6%	O'Neill et al. (2018)	Negative	World Bank*
Access to electricity***	Access to electricity (% of population)	95	O'Neill et al. (2018)	Positive	World Bank*
Life expectancy at birth***	Life expectancy at birth, total (years)	81	HICS average	Positive	World Bank*
Economic					
Adjusted net savings	Adjusted net savings, excl. particulate emission damage (% of GNI)	32.438	Acosta et al. (2019)	Positive	World Bank*
Age dependency	Age dependency ratio (% of working-age population)	50	MIC average	Negative	World Bank*
GDP pr capita growth	GDP per capita growth (annual %)	2	NA**	Positive	World Bank
GDP per capita	GDP per capita, PPP (constant 2017 international $)	12235	HIC threshold	Positive	World Bank*
Trade openness	Trade Opennes - export plus import as percentage of GDP	50	NA**	Positive	World Bank*
Government debt	Central government debt (% of GDP)	60	EU guidelines	Negative	IMF (2020)
Herfindahl-hirschmann index	Herfindahl-Hirschman index of market concentration	0.15	Competitive market threshold	Negative	WITS (2019)
Green patents	Patent publications in environmental technolgy to total patents (%)	10	HIC average	Positive	OECD (2022a)

Note: *The World Bank (2022b), **no source used, derived by logical line of reasoning, ***only included in the GG+2 measure not in the refined GG measure.

Threshold values were determined for each of the green growth indicators, in order to compute the standardization explained in Section 3.1. The sources of the thresholds can also be seen in Table 7. Some thresholds are taken from Acosta et al. (2019). Others have been developed by research within the field of doughnut economics, which also use the concept of planetary and social boundaries as well thresholds for certain indicators on each of these (O'Neill et al., 2018). Thirdly, for some indicators the thresholds are defined as the higher-income-country average in 2019 (for all HICs in the world). These are indicators such as infant mortality, where the HIC average can be characterized as the unavoidable level. Finally, some indicator thresholds were defined within the concept itself, for instance the HHI index includes a definition for when markets are considered competitive within the index. Due to the scope of this study, the thresholds mainly rely on other studies' development of thresholds or means to obtain most objectivity as possible. Further discussions on the choice of threshold is presented in Section 5.2.

Determinants of green growth

The aim is to reassess previous analyses by Tawiah et al. (2021) and Huang and Quibria (2013) on determinants of green growth using other green growth measures and assessing how the measure applied affects the results. Since many of the determinants explored in Tawiah et al. (2021) are included as indicators in the refined green growth CI, they cannot be explored as determinants. The only determinants possible to explore are (1) the institutional quality and (2) foreign direct investments (FDI). Institutional quality is measured using the World Bank' world governance indicators, which consist of six indicators on institutional quality: Government effectiveness, political stability and absence of violence, regulatory quality, voice and accountability, control of corruption, and rule of law (The World Bank, 2022c). As in Tawiah et al. (2021) a composite index of the indicators was computed using principal component analysis to obtain a measure of institutional quality. The FDI data was available through the World Bank's World Development Indicators (The World Bank, 2022b).

Due to the limited determinants available to reassess from Tawiah et al. (2021) two determinants explored in Huang and Quibria (2013) will also be analyzed: government consumption and investment. Data on both variables were available through Penn World Tables (Feenstra et al., 2015).

Control variables

Since the analysis is a reassessment, the control variables used are the same as in Tawiah et al. (2021): Population, population growth, forest area, and natural resource rent. These are relevant because: It has been found that population influences the environment (Aller et al., 2015). Forest area indicates access to a pool of greener resources, which can affect potentials for green growth. The same applies to natural resource endowments, which are reflected by natural resource rents (Bokpin, 2017; Lopez, 1994). Notably natural resource rents are here measured in absolute terms, whereas it as an indicator in the refined GG measure is calculated as yearly change. Thus, there is no problem with including it as a control variable. It should here be mentioned that the control variables' correlation coefficients will not be presented in the output tables in section 4, since they are not the variables of interest, and their correlation coefficient might be biased (Hünermund & Louw, 2020).

Model specification

Finally, it is time to present the specific regression models that will be carried out in the analysis. For simplicity in the model specification, the control variables are expressed using vector notation, such that

$$\begin{aligned}\boldsymbol{controls_{i,t}} = (&population_{i,t}, populationgrowth_{i,t}, forestarea_{i,t},\\ &naturalresourcerent_{i,t}, Period2_t, Period3_t, Period4_t, Period5_t, Period6_t)\end{aligned} \tag{3.8}$$

$$\boldsymbol{\beta} = (\beta_{p+1}, \beta_{p+2}, \ldots, \beta_v) \tag{3.9}$$

where p is the number of predictor variables and v is the total number of variables included in the regressions apart from green growth. Since period-fixed effects are needed, five dummies are included as controls to indicate if it is period 2, 3, 4, 5, or 6 (using period 1 as the baseline). Applying these notions, it is now possible to write the model specification that will be explored in the analysis as

$$GG_{i,t} = \beta_1 WGI_{i,t} + \beta_2 FDI_{i,t} + \beta_3 GovCon_{i,t} + \beta_4 Invest_{i,t} + \boldsymbol{\beta controls_{i,t}} + a_i + u_{i,t} \tag{3.10}$$

In the analysis variations on this regression model will be carried out. One variation is on the measure of green growth as mentioned in Section 3.1. A second variation is

Table 8: Predictor and control variables - specification and sources

Variable	Measure	Source	Log transformed
Predictor variables			
Insitutional quality	CI from PCA on the six WGI indicators: Government effectiveness, Political Stability and Absence of Violence, Regulatory Quality, Voice and Accountability, Control of Corruption, Rule of Law	The World Bank (2022c)	Yes
Government consumption	Government consumption as share of GDP in constant national 2017 prices	Feenstra et al. (2015)	No
Investments	Investments as a share of GDP in constant national 2017 prices	Feenstra et al. (2015)	No
FDI	Foreign direct investment, net inflows (% of GDP)	The World Bank (2022b)	Yes
Control variables			
Natural resource rent	Total natural resources rents (% of GDP)	The World Bank (2022b)	Yes
Population growth	Population growth (annual %)	The World Bank (2022b)	No
Population	Population, total	The World Bank (2022b)	Yes
Forest area	Forest area (% of land area)	The World Bank (2022b)	No

changing the amount of predictor variables included such that regressions are run for each predictor variable independently. Regressions are also run using only the predictor variables used in Tawiah et al. (2021) (WGI and FDI) and using only the predictor variables used in Huang and Quibria (2013) (Government consumption and investments). This works as a sensitivity analysis of the initial model findings. Finally, regression will be run using only a selection of countries to explore the differences in determinants between higher, lower-, and middle-income countries.

The specification and sources of each variable is found in Table 8. Furthermore, Table 18 in Appendix A.4 includes basic descriptive statistics on each variable, including the different green growth measures that will be explored.

4 Analysis

4.1 The refined green growth measure

The analysis begins with a look at the refined green growth measure through some descriptive statistics. As seen in Table 9 Sweden is the highest scoring country with a green growth mean score of 79.54 in 2015-2019. Consequently no countries score 100 and have achieved green growth. In the lower end, Burundi has the lowest score obtained with their mean score of 17.08 in 2000-2004. This is in line with the two countries respectively having the highest and lowest mean scores across all periods.

On an aggregate level Table 9 shows that on average; the higher the income group the higher the green growth score. Thus, the mean green growth score for the included lower-income countries (LICs) is 30.7 compared to 64.83 for the included higher-income countries (HICs). This tendency is expected since income groups are determined by economic development which also increases social development.

There are, however, differences between the three dimensions. All countries experience the lowest mean score on the environmental dimension. The average for all 72 countries on the environmental dimension is about 41 and 43 points lower than the social and economic dimensions. On a scale from 1-100 this difference in mean scores is quite high. The difference between income groups is also lowest on the environmental dimension. Whereas the difference from LICs to HICs on the social dimension mean is 46.58, the difference on the environmental dimension is only 16.7. This supports previous findings, that the world has come a long way regarding both economic and social development, whereas environmental improvements are lacking.

Table 9: List of countries with mean of green growth and its dimensions

Country / group	Green Growth			Mean of dimensions		
	Mean	Max	Min	Environment	Economic	Social
All	51.01	79.54	17.08	26.98	69.59	67.92
HICs	64.83	79.54	45.54	35.78	88.27	86.03
Croatia	60.42	62.99	58.64	29.82	88.67	78.58
Cyprus	62.67	68.60	56.40	32.67	87.70	84.37
Czech Rep.	68.54	73.41	65.26	38.81	92.51	87.87
Denmark	70.29	77.72	63.65	38.52	93.54	95.21
Estonia	68.84	70.65	67.72	37.74	93.63	90.74
Finland	71.53	72.48	69.42	41.48	91.25	92.50
Greece	54.29	57.42	52.08	24.95	81.73	77.62
Hungary	56.50	59.80	53.03	23.20	90.15	82.88
Ireland	71.62	76.03	67.50	41.06	88.18	86.89
Israel	70.11	72.99	65.32	43.79	85.39	89.82
Italy	68.17	73.22	61.80	46.81	84.28	78.11
Korea, Rep.	63.47	71.52	53.65	30.10	92.66	92.78
Latvia	59.13	68.26	46.80	33.74	72.71	85.98
Lithuania	61.52	67.80	56.93	27.60	93.69	87.81
Poland	66.77	70.49	62.51	36.44	90.36	84.40
Romania	56.99	59.88	52.04	23.88	91.52	82.87
Slovak Rep.	60.93	63.02	58.40	27.02	92.74	81.80
Slovenia	61.48	64.25	59.21	27.01	89.42	92.16
Spain	74.00	79.01	70.14	53.51	89.17	77.25
Sweden	78.03	79.54	76.14	52.30	92.16	95.29
Switzerland	70.11	77.04	62.83	43.03	90.76	88.51
Uruguay	54.41	65.02	45.54	30.25	69.30	78.67
UMICs	50.67	66.37	28.79	25.06	72.84	68.70
Armenia	51.57	57.97	42.90	26.72	69.69	75.91
Azerbaijan	55.90	59.24	47.87	24.75	84.76	81.07
Belarus	54.47	59.20	46.80	20.70	85.83	91.07
Belize	43.30	49.82	36.64	21.42	54.54	64.38
Botswana	40.04	49.20	32.35	22.11	59.45	45.79
Bulgaria	62.14	65.57	57.40	31.17	90.57	81.67

Colombia	54.05	59.78	48.75	27.95	79.93	65.43
Dominican Rep.	59.75	64.16	52.44	35.68	73.21	70.70
Ecuador	52.74	54.91	51.05	21.67	73.27	70.49
Fiji	47.62	52.43	44.56	27.11	62.52	72.50
Guatemala	44.04	49.82	36.40	25.36	53.38	53.48
Guyana	33.89	37.02	28.79	15.06	50.96	56.94
Jamaica	47.92	52.01	39.88	20.25	67.00	68.74
Jordan	50.09	54.51	36.43	31.23	78.20	52.13
Kazakhstan	62.50	66.37	57.30	29.21	89.91	87.04
Malaysia	52.97	60.15	41.81	24.27	83.20	74.27
Mexico	52.89	61.02	44.29	31.34	71.88	66.25
Namibia	40.24	47.27	32.29	21.21	67.36	39.14
Paraguay	46.32	55.58	41.70	26.00	63.91	64.04
Russian Fed.	58.44	60.94	53.10	24.30	91.48	88.40
Serbia	50.04	54.83	43.61	21.96	78.17	74.82
LMICs	44.64	57.14	26.68	24.65	62.08	56.88
Algeria	47.21	53.34	30.80	25.04	82.34	42.66
Benin	35.66	45.81	26.68	22.83	42.70	44.79
Cabo Verde	45.09	52.00	40.71	24.94	58.18	60.02
Cameroon	39.70	47.34	33.42	23.89	48.88	53.42
Cote d'Ivoire	43.45	50.03	36.63	25.73	60.87	47.56
El Salvador	46.60	53.40	38.66	24.29	66.15	64.57
Eswatini	39.20	46.99	34.97	29.89	54.15	30.55
Ghana	49.84	52.21	46.77	23.27	62.06	61.64
Honduras	45.56	48.64	42.53	24.28	51.00	54.86
Kenya	47.82	55.15	43.93	27.96	63.58	57.73
Kyrgyz Rep.	46.48	56.06	39.72	25.76	49.06	81.36
Mongolia	43.57	49.74	36.79	17.59	57.00	82.69
Morocco	47.29	54.95	36.35	28.02	77.03	49.81
Nigeria	44.64	46.92	41.91	23.89	64.06	54.46
Pakistan	46.51	47.87	45.22	31.79	56.29	48.15
Senegal	35.38	43.44	29.42	21.16	50.60	40.69
Tunisia	47.63	57.14	39.48	28.83	69.51	55.42
Ukraine	52.34	53.75	49.46	18.37	88.75	89.73
Vietnam	47.02	51.01	38.45	18.70	76.04	72.90
LICs	30.70	42.90	17.08	19.05	34.77	39.45
Burkina Faso	31.81	36.87	26.80	19.09	41.36	37.56
Burundi	24.98	32.83	17.08	19.22	21.31	37.22
Gambia, The	30.25	32.61	27.70	22.92	32.28	38.21
Guinea	31.20	41.36	25.53	18.58	38.39	38.53
Madagascar	34.26	39.24	29.07	18.24	42.50	46.25
Mali	29.77	34.26	26.36	16.98	36.85	41.32
Mozambique	29.35	30.22	28.20	16.84	31.19	29.93
Niger	26.03	32.37	20.37	17.06	29.12	30.57
Togo	35.19	42.90	28.42	19.38	45.03	49.74
Uganda	34.15	41.84	29.11	22.19	30.76	50.32

To compare how the refined GG measure differs from other measures, graphic correlations are provided in Figure 2. The first graph presents the correlation with the GG CO2 measure from Tawiah et al. (2021). They are slightly negatively correlated, but only weakly as many of the observations are far from the trendline. For instance, the highest scoring observation of GG CO2 has the second lowest refined GG score. In other words, countries score very inconsistently on the two different GG measures and hence they do not measure the same concept.

Correlations with the refined and simple GG measure in Figure 2 are slightly positive, but again the observations are rather scattered. Especially one outlying

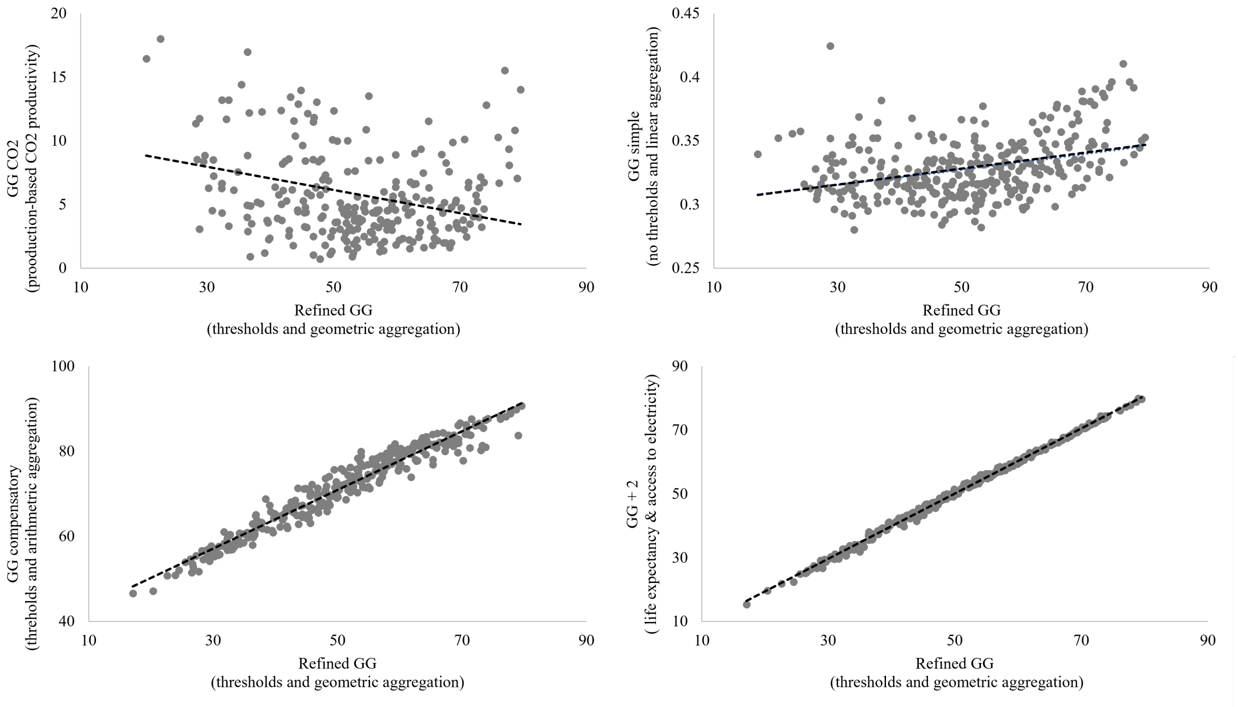

Figure 2: Correlations of different green growth measures

high score on the simple GG measure performs very low on the refined GG measure. This emphasizes how the use of thresholds limits the impact of outliers.

In the left-hand bottom corner of Figure 2 correlations are shown between the refined and the compensatory GG measure. These two measures are highly positively correlated. The general pattern indicates scores are consistently higher on the compensatory GG measure. This is in line with the expectations since the geometric mean puts more weight on the poor performance measures. Theory defends using the less compensatory measure although correlations indicate their similarities. Finally, the correlation of the refined GG and GG+2 measure is highly positive, and almost no differences exist between scores on these measures. Thus, leaving the indicators out, does not seem to have affected the GG score for countries much.

In summary, the developed measure of green growth follows the expected patterns between countries and distinguishes itself from other measures in expected ways. The differences between the green growth measures stress the importance of reaching a common measure. By assessing how applying different measures impacts analytical results, this problem will be illustrated further.

4.2 Determinants of green growth, a reassessment

In order to explore the basic relation between the refined GG measure and the determinants, scatter plots can be found in Figure 3 in Appendix A.5. These indicate positive but rather scattered correlations between all four determinants and refined GG over time within and between countries. The fixed effect models allow for exploring if these relations persists when controlling for confounding factors.

The first regressions applying all predictor variables on the different GG measures are presented in Table 10. The first model using the refined GG measure indicates (as the scatter plots) positive effects of all determinants on green growth within countries, though varying in statistical significance. WGI has a high statistical significance, leading to the interpretation that increasing WGI by 1% will on average increase green growth by 3.6 points.

The effect of WGI persists when using GG CO2 in model 2. For all other determinants, though, using the GG CO2 measure changes the coefficients from model 1. FDI and investments obtain negative coefficients (not statistically significant) and government consumption cease having practical and statistical significance.

Model 3, which uses the simple GG measure, also produce different results than model 1. For instance, WGI changes into negatively affecting green growth, however without statistically nor practically significance. It should be noted that the lower coefficient sizes in model 3 are due to the different GG scales. However, this does not change the conclusion that model 3 produces substantially different results than model 1, emphasizing the impact of the CI design on regression results. This is essential since many analyses reviewed in Section 2.2 use simple CI methods. The results yielded here, questions their green growth measures and hence their findings.

The compensatory GG measure in model 4 provides results that are closer to model 1. Still the coefficient on government consumption change sign and FDI loses its statistical significance. Finally, model 5 with the GG +2 measure yields almost the same results as model 1, but minor differences do exist. For instance, investments are not statistically significant on the 0.1 level anymore. This highlights that even very minor changes in the CI design, matters for regression results.

The within estimate on adjusted coefficient of determinants (R-squared) is increasing with the complexity of the measure. Model 2 with the GG CO2 measure has the by far lowest R-squared, followed by model 3 using the simple GG measure. The

Table 10: Fixed effect regressions - Comparison of green growth measures

VARIABLES	(1) Refined GG	(2) GG CO2	(3) GG simple	(4) GG compen-satory	(5) GG +2
WGI	3.622***	3.887*	-0.003	2.263***	3.676***
	(1.002)	(2.254)	(0.003)	(0.752)	(0.936)
FDI	1.188**	-0.283	0.004*	0.600	0.994**
	(0.472)	(0.288)	(0.002)	(0.468)	(0.469)
Government Consumption	6.687	0.045	0.006	-4.112	7.472
	(7.419)	(5.991)	(0.034)	(6.331)	(7.251)
Investments	10.659*	-2.570	-0.032	9.253*	8.887
	(6.333)	(4.520)	(0.027)	(4.802)	(6.093)
Observations	291	303	291	291	287
Number of countries	72	61	72	72	72
Adjusted R-squared	0.699	0.166	0.454	0.762	0.699
Country & period fixed effect	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES
Number of indicators	27	1	27	27	29
Measured with threshold	YES	NO	NO	YES	YES
Weighting	Equal	NA	Equal	Equal	Equal
Aggregation	Geometric	NA	Arithmetic	Arithmetic	Geometric

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

other three models have quite decent R-squared levels (0.7-0.76), which indicates that the determinants (and controls) explain more of the within country variation on the complex GG measures.

Results in Table 10 illustrates that regression outcomes vary based on what measure of GG is used. This emphasizes how much the measure of green growth matters and that, when using a CI, the index design influences the results. This increases the risk that designs can be changed to obtain desired results, which exemplify why an agreement on measure is needed.

Fixed effect regressions including the determinants individually and pairwise are presented in Table 11. This is to robustness check the findings in model 1 in Table 10 and to explore whether using the refined GG measure changes the conclusions from Tawiah et al. (2021) and Huang and Quibria (2013).

Models 1, 2, and 5 support the results above that WGI and FDI have a positive and statistically significant relation to green growth: Increasing the WGI score by 1

Table 11: Fixed effect regressions with predictor variables individually

VARIABLES	(1) WGI	(2) FDI	(3) GovCon	(4) Invest	(5) WGI & FDI	(6) GovCon & Invest
WGI	3.866***				3.910***	
	(1.008)				(0.974)	
FDI		1.210***			1.469***	
		(0.419)			(0.453)	
Government Consumption			-2.982			4.324
			(7.385)			(8.060)
Investments				13.906***		14.744***
				(5.011)		(5.565)
Observations	291	304	304	304	291	304
Number of countries	72	72	72	72	72	72
Adjusted R-squared	0.689	0.717	0.712	0.720	0.697	0.720
Country & period fixed effect	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

per cent increases green growth score with about 3.5-4 points and increasing FDI with 1 per cent increases green growth with about 1-1.5 points. Hence this differs from the insignificant effects Tawiah et al. (2021) found in their analyses. This might be due to the determinants' stronger relation with the refined GG, which was implied above.

Models 3, 4, and 6 supports the finding in model 1 from Table 10 that investments have a positive relation to green growth. The evidence in these models provides stronger statistically significant results. This indicates that increasing investments with 1 percentage point of GDP will increase the green growth score with 14-15 points on average. This supports the positive but not significant findings by Huang and Quibria (2013). Meanwhile a comparison of the results for government consumption in model 1 in Table 10 and model 3, 4 , and 6 in Table 11 indicate no persistent relation between green growth and government consumption. This might be caused by government consumption being used for both green growth increasing and decreasing activities. This is however different from the findings in Huang and Quibria (2013), who found a positive significant effect.

The countries assessed and the included predictor variables differs from this analysis and the ones in Tawiah et al. (2021) and Huang and Quibria (2013). These

Table 12: Fixed effect regressions with country income groups individually

VARIABLES	(1) HICs	(2) UMICs	(3) LMICs	(4) LICs	(5) MICs & LICs
WGI	15.174*	0.259	2.162	3.592*	3.078***
	(8.788)	(2.473)	(3.806)	(1.668)	(1.038)
FDI	1.103*	0.457	6.156***	3.944	1.170*
	(0.590)	(0.703)	(1.201)	(2.533)	(0.675)
Government Consumption	27.774	26.777	30.374	-48.406***	4.165
	(28.336)	(16.386)	(27.489)	(11.905)	(7.742)
Investments	15.536	27.905**	-7.997	-26.188	5.572
	(13.451)	(12.406)	(13.498)	(14.838)	(6.817)
Observations	94	85	74	38	197
Number of countries	22	21	19	10	50
Adjusted R-squared	0.692	0.747	0.697	0.881	0.711
Country & period fixed effect	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

differences most likely also influence the variations in regression conclusions. However, the results in Table 10 support the conclusion that the chosen GG measure is at least accountable for some of the regression results differences. This once again accentuates the flaws of using many different measures as it hinders aligning findings.

Finally, the regressions for individual country income groups using the refined GG measure are seen in Table 12. Both WGI and FDI have a consistently positive coefficient on GG in all five models, although with varying coefficient sizes and statistical significance. WGI has a very high coefficient for HICs whereas it is low for upper middle-income countries (UMICs) but gain much statistical significance in model 5 where UMICs, lower-middle-inocme countires (LMICs), and LICs are grouped together. Meanwhile, for LMICs it seems that FDI has a high positive and statistically significant impact on green growth. This seem to best support the pollution halo hypothesis oppositely to what was found in Tawiah et al. (2021).

On WGI the differences between developing and developed countries found in Tawiah et al. (2021) are not conclusive, as they find a (non-significant) negative effect in developed countries and a positive (non-significant) effect in developing countries. This discrepancy is different from what is found in this analysis, where a strong positive effect of WGI on green growth is particularly found in HICs.

With respect to government consumption an interesting finding is the large negative statistically significant relation to GG in LICs as seen in model 4. This may explain why inconclusive results are obtained when assessing all 72 countries. This may, however, also be due to the conflicting indicators within the measure where investments in infrastructure development can improve some economic and social indicators, while also damaging environmental indicators.

Investments also have inconsistent effects on green growth in the different income groups. Most notably it has a positive statistically significant effect for UMICs, which may reflect different investment types from e.g. LICs where investments have a large (but not statistically significant) negative impact on green growth.

Overall, the models indicate that determinants of green growth vary across income groups as found in Tawiah et al. (2021). But the way they vary is found to be different, possibly due to the different green growth measures applied. In this study, the differences between country-income-groups are largest with respect to government consumption and investments, whereas coefficients on WGI and FDI only differ in size and statistical significance but not in sign.

4.3 Robustness check on regression results

The results above need a robustness check for misspecification resulting in endogeneity issues. Table 13 present 3 models using S-GMM and 3 models using FE with lags on all explanatory and control variables (and refined GG lagged included as a control). First and foremost, the controls support the previous findings of a positive and statistically significant effect of WGI on green growth. This indicates that improving institutional quality within a country from one period to the next is correlated with increasing green growth on average. The effect is larger in HICs than developing countries, but still noticeable in the latter.

The other results in Table 13 are slightly supportive of the earlier findings, but not as statistically significant nor as large in coefficient sizes. In the S-GMM model the effect of FDI on green growth remains positive, which changes in model 4 and 6. It should be clarified, that this does not necessarily mean endogeneity issues are present. For model 4 to 6, the change of results may also be caused by the fact that the relations are stronger within the period and not between periods. This makes

Table 13: Control regressions: System-GMM and Fixed effect regressions with lags

VARIABLES	(1) S-GMM ALL	(2) S-GMM HICs	(3) S-GMM MICs & LICs	(4) FE Lags ALL	(5) FE Lags HICs	(6) FE Lags MICs & LICs
WGI	8.819**	16.332***	4.371***			
	(3.623)	(5.834)	(1.172)			
FDI	0.982	0.692	1.345			
	(1.064)	(1.157)	(1.562)			
Government Consumption	13.221	12.241	-7.678			
	(24.352)	(32.784)	(13.808)			
Investments	-1.712	-7.047	0.727			
	(10.288)	(24.484)	(8.846)			
WGI_{t-1}				1.950**	7.617	1.772*
				(0.820)	(9.136)	(0.937)
FDI_{t-1}				-0.416	1.087	-1.182**
				(0.561)	(0.783)	(0.563)
Government $Consumption_{t-1}$				12.733	22.619	10.678
				(9.887)	(23.135)	(11.570)
$Investments_{t-1}$				5.101	-5.130	5.686
				(5.948)	(18.250)	(6.211)
Observations	223	75	148	260	85	175
Number of countries	72	22	50	72	22	50
Country & period fixed effect	YES	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES	YES
Adjusted R-squared	NA	NA	NA	0.654	0.626	0.687

Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

sense, since we already work with panels of 5-year averages, and it is plausible that FDI increases six or seven years ago is not reflected in green growth scores today. Especially since the predictor variables included is not expected to have a clear trend over time. Thus, the deviating findings here may reflect differences in long-term and short-term relations of the variables rather than endogeneity issues. Finally, it should be noted the results of the control regressions support that differences in determinants based on the income group of the countries do exist.

Overall analysis findings

To sum up, the analyses indicate differences between the green growth measures, both in their descriptive assessments and in their regression results. In continuation of this, the findings on determinants of green growth indicate that using the refined GG measure change prior analysis results in Tawiah et al. (2021) and Huang and Quibria (2013). The most consistent finding is the indication of a positive statistically significant effect of institutional quality on green growth when assessing patterns of within country changes. Also, FDI has strong indications of a positive relation with green growth. Whereas investment and especially government consumption has more varying and thus inconclusive results.

The inconclusive result might be caused by country differences, since there is strong indication that the patterns of determinants on green growth differ between country-income-groups. Some determinants differ mainly on the size and significance of relations, but other also differ on the sign of the relation. This has also been found in other studies, although the discrepancy between country groups is found different when using the refined GG measure. This implies that using different measures of green growth changes analytical results, imposing a problem for understanding the concept and underlining the need for a streamlined approach.

5 Discussion and conclusion

5.1 Interpretation and implications of results

The overall aim of this thesis has been to explore how green growth has been and can be measured, and in order to enhance the understanding of green growth and its determinants assess how the choice of measure impact analyses. Due to the increasing amount of published empirical articles relying on various definitions and measures of green growth, it has been essential to carry out a study that creates an overview of these and asks the critical questions towards what has been done so far. In this way, the thesis' objective has been to identify challenges presented in the literature and suggest how to move forward. Doing so, the aim has been three-folded.

The first aim is to uncover the current status of the field, explored in Section 2.2. Three overall approaches to measuring green growth were identified: single indicators, data envelopment analyses, and composite indexes. The measures within these approaches differed to the extent that in 30 articles 29 measures were applied. This is quite striking! And this was just the articles identified in this literature review. It cannot be guaranteed that no other relevant articles exist, but the systematic procedure of the review enhances the credibility that the general tendencies are included. The large number of articles covered compared to the size of the literature field also enhances the reliability of the literature analysis results.

The review of the literature has revealed three problems. First and foremost, a lack of consensus in measurement which dilutes the concept and its applicability in the scholarly and public debate. Secondly, a general mismatch between the theoretical understandings of the concept and the empirical measures. Single indicator and DEA methods both lack the needed multidimensionality whereas the composite index method is compensatory. Finally, there is a lack of cross-country longitudinal studies that goes beyond the ranking of countries' performance and instead explore what affects green growth levels. These general patterns are important as they can inform policy makers or researchers working to resolve how to achieve green growth.

The implication of these findings is that researchers should consider alignment with respect to measuring green growth. Many argue that the measure should be adjusted to the local context of the country or region in question (Stepping & Stoever, 2014). The downside of this is that we end up creating completely new measures each time. Furthermore, the findings suggests that a measure of green growth should be based in the theoretical understanding of the concept. Some rightfully argue that SIs and DEA are suited and well-equipped for analyzing certain aspects of green growth. The argument here simply is that the measures should be called what they really are. Analyses on carbon and inclusive green total factor productivity are highly interesting and relevant, but they cannot claim that they examine green growth when they are merely analyzing one dimension of it.

The literature review in this thesis contributes with a detailed overview of studies measuring green growth quantitatively. Šneiderienė et al. (2020) have a review, but the number of articles covered is very limited and many are on the green economy. Other reviews by e.g. Narloch et al. (2016) have a wider scope to uncover general measures of progression towards sustainable development. Consequently, neither of them provides answers to the questions posed in this review.

The second aim has been to uncover how to measure green growth for cross-country longitudinal assessments in a theoretical compliant manner. The theoretical understanding of the concept outlined in Section 2.1 reveal two implications for an empirical measure. 1) It must be multidimensional and include environmental, economic, and social sub-dimensions that do not work in a trade-off. 2) it must state when countries have achieved green growth, and thus be based on the level of green growth in absolute and not just relative terms.

In Section 3.1 it was found that these implications can be incorporated into a composite index measure of green growth. This was done using 27 indicators on the environmental, economic, and social dimensions, which were measured by their distance to the threshold which would imply green growth on each indicator. Furthermore, geometric aggregation limited the compensability. However, applying a fully non-compensatory method was avoided because it did not allow for measuring absolute green growth levels and it was not feasible with so many countries in the study. Interestingly, the findings in the analysis indicated that a fully compensatory measure does not produce very different results than the partial compensatory measure. These findings question the impact and importance of ensuring non-compensatory measurement, which is also what Sironen et al. (2015) finds. But using the partial compensatory method is still defended as it encourages focusing on the poor performing measures.

The refined green growth measure covers 72 countries over the last 30 years. The measure was found descriptively corresponding to theoretical expectations. These findings include that countries score lowest on the environmental dimension, higher income countries generally score higher than other countries, and the difference between higher and lower income countries is smaller on the environmental dimension. This implicates that the refined green growth measure is one step towards developing a measure that allows for the needed empirical cross-country longitudinal assessments. It should be noted, however, that this measure is not perfect nor finished. By further developing previous measures found in Šneiderienė et al. (2020), Jha et al. (2018) and Acosta et al. (2019) the refined measure is part of a learning process that is not yet finished. The specific limitations and needs for further refinements within the measure is presented in Section 5.2.

The thesis contributes to the literature by developing a composite index measure of green growth that is a more theoretical compliant and covering measure than seen in previous studies. It is argued to be more compliant since the measure integrates thresholds for achieving green growth for each indicator and a less compensatory aggregation method. Furthermore, the measure allows for large country and time coverage, which other measures have struggled to accomplish or simply not aimed for. Whereas Acosta et al. (2019) also incorporate thresholds and geometric aggregation, they do not have the same coverage in their measure. One could ask whether this is not just a 30th incomplete measure in the ocean of green growth measures. However, as other measures do not sufficiently ensure both theoretical compliance and coverage, the hope is that the refined measure shown here has taken us one step closer to an agreed measure that can be used for important quantitative assessments.

Finally, the third aim has been to show how the applied measure of green growth affects empirical assessments on determinants of green growth. The interpretation of the findings in Table 10 is clearly that the measure applied affects the regression results. This is a very important finding, as it emphasizes the problem with using too many different measures. The implication is that one can use any measure one wants to get the desired results.

For example, using carbon productivity as a proxy for green growth as in Tawiah et al. (2021) yields completely different results than the refined measure. The refined measure indicates strong correlations between institutional quality (measured by the world governance indicators) and green growth over time within the countries explored. The control regression strengthened these findings, especially among HICs. The findings for developing countries are smaller in coefficient sizes, but LICs also indicated a strong relation between institutional quality and green growth. The specific findings on determinants of green growth are a contribution of the thesis.

Interestingly, the simple composite index yields substantially different regression results than the refined measure. This underlines the need to be careful when computing composite indexes. Including thresholds for each indicator into the measure has a substantial impact on the results. Another reason why this approach is defended, is that it allows for better information on when a country has achieved green growth and follows a stronger sustainability understanding. It also requires choosing appropriate thresholds, but more on this matter below.

5.2 Limitations and future research

The results and contributions outlined above, should be seen in the light of limitations to the current study. The topic chosen in this study is large and ambitious, due to which it is acknowledges that much more is still to be explored to overcome present limitations. In this respect, data limitations serve as the first notable constraint.

The fact that it has been possible to obtain a strongly balanced panel dataset on 72 countries over 30 years is highly positive for the interpretation of the results. Meanwhile, data availability affected both selected indicators and selected countries. Especially the former is unfortunate as this decision should be based solely upon the theoretical understanding of the concept. This is, however, a general problem (Narloch et al., 2016; Acosta et al., 2020; Kim et al., 2014). Data availability on green growth has developed rapidly within the last decade, and hopefully will continue doing so. But for now, as argued in Section 3 the included countries and indicators are interesting and relevant for assessments.

Furthermore, data gathering from different sources possess problems if the sources are not comparable. In this study data sources only vary between variables, which is not conceived problematic. Any source difference will be equal for all observation, and thus not affect the relation between variables. Data limitations still exist when data collection procedures vary between countries. The estimates of poverty from the World Bank serve as an example, where estimates are obtained based on national household surveys, with questions differing from one country to another (The World Bank, 2022a). Meanwhile, the regressions done in the analysis control for both country and period fixed effect, such that if questionnaires always vary between countries or consistently vary over time for all countries, this will be controlled for. Problems with data limitations for the regression have in other words been minimized by taking them into account in the methodology.

Critique has also been made on the quality of the data. For instance, Ates and Derinkuyu (2021) questions the OECD data, as they find some values surprising, such that Greece is the country with most green patents. Generally, uncertainty on the accurateness of data is a necessary evil when working with data analyses. Hence the findings can only argue for correlation among variables in this data, whereas more research is needed to back up the finding to be certain on general causality. The extensive previous theoretical and empirical arguments on institutional quality on green growth outlined in Section 2.3 though support the findings.

Another limitation to the findings is the scope of the thesis, which simply has not allowed for explorations of all the choices involved in computing a composite index. This accounts both for indicator selection, weighting, and the applied thresholds. The focus in this study has been on the normalization and aggregation methods because they are key for introducing a stronger version of sustainability into the measure. Future research should investigate some of the remaining choices, of which the most important aspects to investigate are indicated below.

First, the final indicator selection could be looked more into. This thesis chose to follow indicator selections from previous articles by Šneiderienė et al. (2020), Jha et al. (2018), and Acosta et al. (2019). This served the purpose of utilizing previous knowledge and strengthening the alignment within the literature. Some variables such as age dependency can though be questioned. Although age dependency affects growth prospects (Bloom & Canning, 2008), it is not something governments can change to increase green growth. Also, it is extremely difficult to decide what the age dependency threshold should be to state that it is green growth? The indicators included were though still reflecting very important dimensions of green growth.

As evident from the analysis, including thresholds were important for the refined green growth measure. Meanwhile, the thresholds used have some limitations, as it was out of scope to go into the discussion of each. Some thresholds for example were based on targets from the literature on sustainable development and might therefore reflect the goals and not the process of the transition, which is the focus of green growth. The work by Rockström et al. (2009) on carbon productivity serve as an inspirational way to determine thresholds by looking at what improvements are needed stay within the planetary boundaries. Future research could benefit from performing such analyses on each indicator, to obtain threshold explicitly indicating when growth is green taking into account the country at hand (not every country needs to increase carbon productivity with 5 per cent). Country differences could also be accounted for in the weighting method, which was also called on by Stepping and Stoever (2014). By using geometric aggregation, the refined measure does put more weighting on the poor performing measures for each country, which is an important step towards more accurate weighting in green growth composite indexes.

Keeping the mentioned limitations in mind, the main message is that this is not the final measure of green growth. The findings on determinants should be viewed in this light. Future research should aim to uncover the patterns within determinants of green growth (and its differences between country-income-groups) more carefully which includes assessing in more detail the relationship between institutional quality and green growth, to discover if it can be claimed causal and to understand which dynamics of institutional quality that impacts green growth. The strong relations found here are definitely worth more explorations.

But first and foremost, an agreed-on measure of green growth is the most important area for future research to investigate. There is a serious need for increasing alignment and consensus on the measurement of green growth, to keep the concept relevant to the scholarly and public debate. The ambitions of the concept are high, but before we can measure its occurrence it will remain a hypothesis. As Lord Kelvin (the inventor of the Kelvin temperature scale) put it in 1883: "*... when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind*" (Thomson, 1889, pp. 73-74).

5.3 Concluding remarks

Turning back to the initial research questions, the thesis finds the following. First, green growth has previously been measured by single-indicators, data envelopment analyses, and composite indexes. In total 29 different measures were found among 30 articles. Secondly, a green growth measure must be multidimensional and measure when growth is green. This can be captured in a composite index on three dimensions (economic, social, and environmental), applying thresholds for each indicator and less compensatory aggregations methods that opts for a stronger version of sustainable development. This measure is substantially different from simpler measures. Finally applying this measure of green growth alter findings on determinants, such that institutional quality is found strongly and significantly related to green growth. Meanwhile, differences in determinants based on the country's income level persist. Generally, the thesis provides arguments for why we need increasing alignment in the literature moving towards an agreed upon measure of green growth. The findings and measure developed takes the literature one step closer to a theoretical compliant measure of green growth used for cross-country longitudinal studies. Hopefully more research will take the final step towards a much-needed measure.

References

Abid, M. (2017). Does economic, financial and institutional developments matter for environmental quality? A comparative analysis of EU and MEA countries. *Journal of environmental management*, vol. 188, pp. 183–194.

Acemoglu, D. (2012). *Acemoglu on why nations fail: Econtalk podcast*. Library of Economics and Liberty. Available online: www.econtalk.org/acemoglu-on-why-nations-fail/ 2012 [Accessed April 4, 2022].

Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The environment and directed technical change. *American economic review*, vol. 102, no. 1, pp. 131–66.

Acemoglu, D., Johnson, S., & Robinson, J. A. (2005). Institutions as a fundamental cause of long-run growth. *Handbook of economic growth*, vol. 1, pp. 385–472.

Acosta, L. A., Maharjan, P., Peyriere, H. M., & Mamiit, R. J. (2020). Natural capital protection indicators: Measuring performance in achieving the sustainable development goals for green growth transition. *Environmental and Sustainability Indicators*, vol. 8, pp. 100069.

Acosta, L., Maharjan, P., Peyriere, H., Galotto, L., Mamiit, R., Ho, C., Flores, B., & Anastasia, O. (2019). *Green growth index: Concepts, methods and applications* (tech. rep.). GGGI technical report.

AfDB. (2014). *Transitioning towards green growth a framework for the African Development Bank*. African Development Bank (AfDB).

Aller, C., Ductor, L., & Herrerias, M. J. (2015). The world trade network and the environment. *Energy Economics*, vol. 52, pp. 55–68.

Ates, S. A., & Derinkuyu, K. (2021). Green growth and OECD countries: Measurement of country performances through distance-based analysis (DBA). *Environment, development and sustainability*, vol. 23, no. 10, pp. 15062–15073.

Ateş, S. A. (2015). Development planning in twenty-first century: The case of green growth strategy in South Korea. In *Economic planning and industrial policy in the globalizing economy* (pp. 345–354). Springer.

Ayamba, E. C., Haibo, C., Abdul-Rahaman, A.-R., Serwaa, O. E., & Osei-Agyemang, A. (2020). The impact of foreign direct investment on sustainable development in China. *Environmental Science and Pollution Research*, vol. 27, no. 20, pp. 25625–25637.

Ayamba, E. C., Haibo, C., Ibn Musah, A.-A., Ruth, A., & Osei-Agyemang, A. (2019). An empirical model on the impact of foreign direct investment on China's environmental pollution: Analysis based on simultaneous equations. *Environmental Science and Pollution Research*, vol. 26, no. 16, pp. 16239–16248.

Baniya, B., Giurco, D., & Kelly, S. (2021). Green growth in Nepal and Bangladesh: Empirical analysis and future prospects. *Energy policy*, vol. 149, pp. 112049–.

Barbier, E. B. (2014). Climate change mitigation policies and poverty. *Wiley Interdisciplinary Reviews: Climate Change*, vol. 5, no. 4, pp. 483–491.

Barbier, E. B. (2016). Is green growth relevant for poor economies? *Resource and energy economics*, vol. 45, pp. 178–191.

Barro, R. J., & Sala-i-Martin, X. I. (2003). *Economic growth*. MIT press.

Baumert, N., Kander, A., Jiborn, M., Kulionis, V., & Nielsen, T. (2019). Global outsourcing of carbon emissions 1995–2009: A reassessment. *Environmental science & policy*, vol. 92, pp. 228–236.

Bloom, D. E., & Canning, D. (2008). Global demographic change: Dimensions and economic significance. *Population and development review*, vol. 34, no. Supplement, pp. 17–51.

Bokpin, G. A. (2017). Foreign direct investment and environmental sustainability in Africa: The role of institutions and governance. *Research in International Business and Finance*, vol. 39, pp. 239–247.

Bowen, A. (2012). 'Green' growth,'green'jobs and labor markets. *World bank policy research working paper*, no. 5990.

Brink, P. t., Mazza, L., Badura, T., Kettunen, M., & Withana, S. (2012). Nature and its role in the transition to a green economy. *A TEEB report. Forthcoming www. teebweb. org and www. ieep. eu*,

Brock, W. A., & Taylor, M. S. (2010). The green solow model. *Journal of Economic Growth*, vol. 15, no. 2, pp. 127–153.

Brundtland, G. H. (1987). *Our common future*. Oxford University Press, Oxford, GB.

Cao, Y., Liu, J., Yu, Y., & Wei, G. (2020). Impact of environmental regulation on green growth in China's manufacturing industry–based on the Malmquist-Luenberger index and the system GMM model. *Environmental science and pollution research international*, vol. 27, no. 33, pp. 41928–41945.

Capasso, M., Hansen, T., Heiberg, J., Klitkou, A., & Steen, M. (2019). Green growth–a synthesis of scientific findings. *Technological Forecasting and Social Change*, vol. 146, pp. 390–402.

Chaminade, C. (2020). Innovation for what? Unpacking the role of innovation for weak and strong sustainability. *Journal of Sustainability Research*, vol. 2, no. 1.

Chen, G., Yang, Z., & Chen, S. (2020). Measurement and convergence analysis of inclusive green growth in the Yangtze River Economic Belt cities. *Sustainability (Basel, Switzerland)*, vol. 12, no. 6, pp. 2356–.

Colby, M. E., & Mundial, B. (1989). *The evolution of paradigms of environmental management in development* (vol. 313,). Strategic Planning; Review Department, World Bank Washington, DC.

Debreu, G. (1951). The coefficient of resource utilization. *Econometrica*, vol. 19, no. 3, pp. 273–292.

Dercon, S. (2014). Is green growth good for the poor? *The World Bank Research Observer*, vol. 29, no. 2, pp. 163–185.

Ekins, P. (2000). *Economic growth and environmental sustainability : The prospects for green growth*. Routledge.

Engelmann, J., & Al-Saidi, M. (2019). Business-driven ecological innovations in green growth strategies. In *Innovation for sustainability* (pp. 97–113). Springer.

Engelmann, J., Al-Saidi, M., & Hamhaber, J. (2019). Concretizing green growth and sustainable business models in the water sector of Jordan. *Resources*, vol. 8, no. 2.

Fankhauser, S., Bowen, A., Calel, R., Dechezleprêtre, A., Grover, D., Rydge, J., & Sato, M. (2013). Who will win the green race? In search of environmental competitiveness and innovation. *Global Environmental Change*, vol. 23, no. 5, pp. 902–913.

Fay, M. (2012). *Inclusive green growth: The pathway to sustainable development*. World Bank Publications.

Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, vol. 105, no. 10, pp. 3150–3182.

Fernandes, C. I., Veiga, P. M., Ferreira, J. J., & Hughes, M. (2021). Green growth versus economic growth: Do sustainable technology transfer and innovations lead to an imperfect choice? *Business Strategy and the Environment*, vol. 30, no. 4, pp. 2021–2037.

Georgeson, L., Maslin, M., & Poessinouw, M. (2017). The global green economy: A review of concepts, definitions, measurement methodologies and their interactions. *Geo: Geography and Environment*, vol. 4, no. 1, pp. e00036.

Goodstein, E. (1996). Jobs and the environment: An overview. *Environmental Management*, vol. 20, no. 3, pp. 313–321.

Gu, K., Dong, F., Sun, H., & Zhou, Y. (2021). How economic policy uncertainty processes impact on inclusive green growth in emerging industrialized countries: A case study of China. *Journal of Cleaner Production*, vol. 322, pp. 128963.

Guo, L., Qu, Y., & Tseng, M.-L. (2017). The interaction effects of environmental regulation and technological innovation on regional green growth performance. *Journal of Cleaner Production*, vol. 162, pp. 894–902.

Hallegatte, S., Heal, G., Fay, M., & Treguer, D. (2012). *From growth to green growth-a framework* (tech. rep.). National Bureau of Economic Research.

Hao, L.-N., Umar, M., Khan, Z., & Ali, W. (2021). Green growth and low carbon emission in G7 countries: How critical the network of environmental taxes, renewable energy and human capital is? *Science of The Total Environment*, vol. 752, pp. 141853.

Haug, A. A., & Ucal, M. (2019). The role of trade and FDI for CO2 emissions in Turkey: Nonlinear relationships. *Energy Economics*, vol. 81, pp. 297–307.

Hickel, J., & Kallis, G. (2020). Is green growth possible? *New political economy*, vol. 25, no. 4, pp. 469–486.

Houssini, K., & Geng, Y. (2021). Measuring Morocco's green growth performance. *Environmental science and pollution research international*, vol. 29, no. 1, pp. 1144–1154.

Huang, Y., & Quibria, M. G. (2013). *Green growth: Theory and evidence* (WIDER Working Paper No. no. 2013/056). Helsinki, The United Nations University World Institute for Development Economics Research (UNU-WIDER).

Hünermund, P., & Louw, B. (2020). On the nuisance of control variables in regression analysis. *arXiv preprint arXiv:2005.10314*,

IHME. (2019). *Gbd compare*. Institute for Health Metrics and Evalutation (IHME), University of Washington. Available online: https://vizhub.healthdata.org/gbd-results/ 2019 [Accessed May 24, 2022] Seattle, WA.

IMF. (2020). *Global debt database - central government debt*. International Monetary Fund (IMF). Available online: https://www.imf.org/external/datamapper/CG_DEBT_GDP@GDD/SWE 2020 [Accessed May 24, 2022].

Jackson, T., & Victor, P. A. (2019). Unraveling the claims for (and against) green growth. *Science*, vol. 366, no. 6468, pp. 950–951.

Jacobs, M., et al. (2012). *Green growth: Economic theory and political discourse* (vol. 108,). Citeseer.

Jadoon, I. A., Mumtaz, R., Sheikh, J., Ayub, U., & Tahir, M. (2021). The impact of green growth on financial stability. *Journal of financial regulation and compliance*, vol. 29, no. 5, pp. 533–560.

Jänicke, M. (2012). "Green growth": From a growing eco-industry to economic sustainability. *Energy policy*, vol. 48, pp. 13–21.

Jha, S., Sandhu, S. C., & Wachirapunyanont, R. (2018). *Inclusive green growth index: A new benchmark for quality of growth*. Asian Development Bank Institute.

Kallis, G. (2011). In defence of degrowth. *Ecological economics*, vol. 70, no. 5, pp. 873–880.

Kammen, D. M., & Engel, D. (2009). *Green jobs and the clean energy economy* (vol. 4,). Copenhagen Climate Council Thought Leadership Series.

Kararach, G., Nhamo, G., Mubila, M., Nhamo, S., Nhemachena, C., & Babu, S. (2018). Reflections on the green growth index for developing countries: A focus of selected African countries. *Development Policy Review*, vol. 36, no. S1, pp. O432–O454.

Kaufmann, D., Kraay, A., & Zoido, P. (1999). Governance matters. *Available at SSRN 188568*,

Khan, A., Hussain, J., Bano, S., & Chenggang, Y. (2020). The repercussions of foreign direct investment, renewable energy and health expenditure on environmental decay? An econometric analysis of BRICS countries. *Journal of Environmental Planning and Management*, vol. 63, no. 11, pp. 1965–1986.

Khan, D., & Ulucak, R. (2020). How do environmental technologies affect green growth? evidence from brics economies. *Science of The Total Environment*, vol. 712, pp. 136504.

Kim, S. E., Kim, H., & Chae, Y. (2014). A new approach to measuring green growth: Application to the OECD and Korea. *Futures*, vol. 63, pp. 37–48.

Klein, J., Jochaud, P., Richter, H., Bechmann, R., & Hartmann, S. (2013). Green economy in Sub-Saharan Africa: Lessons from Benin, Ethiopia, Ghana, Namibia and Nigeria.

Leach, M., Raworth, K., & Rockström, J. (2013). Between social and planetary boundaries: Navigating pathways in the safe and just space for humanity.

Lee, C.-M., & Chou, H.-H. (2018). Green growth in Taiwan — an application of the OECD green growth monitoring indicators. *Singapore economic review*, vol. 63, no. 2, pp. 249–274.

Li, M., Zhang, Y., Fan, Z., & Chen, H. (2021). Evaluation and research on the level of inclusive green growth in asia-pacific region. *Sustainability*, vol. 13, no. 13.

Liu, Z., Li, R., Zhang, X. T., Shen, Y., Yang, L., & Zhang, X. (2021). Inclusive green growth and regional disparities: Evidence from China. *Sustainability*, vol. 13, no. 21.

Loiseau, E., Saikku, L., Antikainen, R., Droste, N., Hansjürgens, B., Pitkänen, K., Leskinen, P., Kuikman, P., & Thomsen, M. (2016). Green economy and related concepts: An overview. *Journal of cleaner production*, vol. 139, pp. 361–371.

Lopez, R. (1994). The environment as a factor of production: The effects of economic growth and trade liberalization. *Journal of Environmental Economics and management*, vol. 27, no. 2, pp. 163–184.

Luenberger, D. G. (1992). Benefit functions and duality. *Journal of mathematical economics*, vol. 21, no. 5, pp. 461–481.

Lyytimäki, J., Antikainen, R., Hokkanen, J., Koskela, S., Kurppa, S., Känkänen, R., & Seppälä, J. (2018). Developing key indicators of green growth. *Sustainable Development*, vol. 26, no. 1, pp. 51–64.

Malmquist, S. (1953). Index numbers and indifference surfaces. *Trabajos de estadística*, vol. 4, no. 2, pp. 209–242.

Malthus, T. R. (1798). *An Essay on the Principle of Population*. McMaster University Archive for the History of Economic Thought.

Meadows, D. H., Meadows, D. H., Randers, J., & Behrens III, W. W. (1972). The limits to growth: A report to the club of Rome (1972). *Google Scholar*, vol. 91,

Mensah, C. N., Long, X., Dauda, L., Boamah, K. B., Salman, M., Appiah-Twum, F., & Tachie, A. K. (2019). Technological innovation and green growth in the organization for economic cooperation and development economies. *Journal of Cleaner Production*, vol. 240, pp. 118204.

Michelsen, G., Adomßent, M., Martens, P., & Hauff, M. v. (2016). Sustainable development–background and context. In *Sustainability science* (pp. 5–29). Springer.

Mihci, H., Cagatay, S., & Koska, O. (2005). The impact of environmental stringency on the foreign direct investments of the OECD countries. *Journal of Environmental Assessment Policy and Management*, vol. 7, no. 04, pp. 679–704.

Munda, G. (2005). "Measuring sustainability": A multi-criterion framework. *Environment, Development and Sustainability*, vol. 7, no. 1, pp. 117–134.

Munda, G., et al. (2008). *Social multi-criteria evaluation for a sustainable economy* (vol. 17,). Springer.

Nahman, A., Mahumani, B. K., & de Lange, W. J. (2016). Beyond GDP: Towards a green economy index. *Development Southern Africa*, vol. 33, no. 2, pp. 215–233.

Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Hoffmann, A., & Giovannini, E. (2008). *Handbook on constructing composite indicators: Methodology and user guide* (2nd ed.). OECD publishing.

Narloch, U., Kozluk, T., & Lloyd, A. (2016). *Measuring inclusive green growth at the country level* (GGKP Working Paper). GGKP Research Committee on Measurement & Indicators.

Nguyen, C. P., Nguyen, N. A., Schinckus, C., & Su, T. D. (2018). The ambivalent role of institutions in the CO2 emissions: The case of emerging countries. *International Journal of Energy Economics and Policy*, vol. 8, no. 5, pp. 7.

Nordhaus, W. D. (1974). Resources as a constraint on growth. *The American Economic Review*, vol. 64, no. 2, pp. 22–26.

Nordhaus, W. D. (2007). A review of the review on the economics of climate change. *Journal of Economic Literature*, vol. 45, no. 3, pp. 686–702.

North, D. C., & Thomas, R. P. (1970). An economic theory of the growth of the western world. *The economic history review*, vol. 23, no. 1, pp. 1–17.

OECD. (2011). *Towards green growth: Monitoring progress.*

OECD. (2012). Green growth and developing countries: A summary for policy makers.

OECD. (2017). *Green growth indicators 2017.*

OECD. (2022a). *Green growth indicators*. Available online: https://stats.oecd.org/Index.aspx?DataSetCode=GREEN_GROWTH 2022 [Accessed May 24, 2022].

OECD. (2022b). *Material resources*. Available online: https://stats.oecd.org/Index.aspx?DataSetCode=MATERIAL_RESOURCES 2022 [Accessed May 24, 2022].

O'Neill, D. W., Fanning, A. L., Lamb, W. F., & Steinberger, J. K. (2018). *A good life for all within planetary boundaries*.

Pao, H.-T., & Tsai, C.-M. (2011). Multivariate granger causality between CO2 emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product): Evidence from a panel of BRIC (Brazil, Russian Federation, India, and China) countries. *Energy*, vol. 36, no. 1, pp. 685–693.

Perez, C. (2010). Technological revolutions and techno-economic paradigms. *Cambridge journal of economics*, vol. 34, no. 1, pp. 185–202.

Peters, G. P., Minx, J. C., Weber, C. L., & Edenhofer, O. (2011). Growth in emission transfers via international trade from 1990 to 2008. *Proceedings of the national academy of sciences*, vol. 108, no. 21, pp. 8903–8908.

Petkovová, L., Hartman, D., & Pavelka, T. (2020). Problems of aggregation of sustainable development indicators at the regional level. *Sustainability*, vol. 12, no. 17, pp. 7156.

Pollin, R., Garrett-Peltier, H., Heintz, J., Scharber, H., et al. (2008). *Green recovery: A program to create good jobs & start building a low-carbon economy* (tech. rep.). Political Economy Research Institute, University of Massachusetts at Amherst.

Qu, C., Shao, J., & Cheng, Z. (2020). Can embedding in global value chain drive green growth in China's manufacturing industry? *Journal of Cleaner Production*, vol. 268, pp. 121962.

Ricardo, D. (1817). *On the principles of political economy and taxation.* (1. Ed.).

Rische, M.-C., Röhlig, A. M., & Stoever, J. (2014). *Green, greener, grey: Disentangling different types of green growth* (tech. rep.). HWWI Research Paper.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., et al. (2009). A safe operating space for humanity. *nature*, vol. 461, no. 7263, pp. 472–475.

Rodrik, D., Subramanian, A., & Trebbi, F. (2004). Institutions rule: The primacy of institutions over geography and integration in economic development. *Journal of economic growth*, vol. 9, no. 2, pp. 131–165.

Salahuddin, M., Alam, K., Ozturk, I., & Sohag, K. (2018). The effects of electricity consumption, economic growth, financial development and foreign direct investment on CO2 emissions in Kuwait. *Renewable and Sustainable Energy Reviews*, vol. 81, pp. 2002–2010.

Salman, M., Long, X., Dauda, L., & Mensah, C. N. (2019). The impact of institutional quality on economic growth and carbon emissions: Evidence from Indonesia, South Korea and Thailand. *Journal of Cleaner Production*, vol. 241, pp. 118331.

Saltelli, A. (2007). Composite indicators between analysis and advocacy. *Social indicators research*, vol. 81, no. 1, pp. 65–77.

Sarkodie, S. A., & Adams, S. (2018). Renewable energy, nuclear energy, and environmental pollution: Accounting for political institutional quality in South Africa. *Science of the total environment*, vol. 643, pp. 1590–1601.

Schenau, S. (2017). 15| measuring green growth for environmental economic policies in the Netherlands. *Forum on Natural Capital Accounting for Better Policy Decisions: Taking Stock and Moving Forward*, pp. 131.

Shephard, R. W. (1953). *Cost and production functions* (Repr. of the 1953 ed.). Springer-Verlag.

Sironen, S., Seppälä, J., & Leskinen, P. (2015). Towards more non-compensatory sustainable society index. *Environment, Development and Sustainability*, vol. 17, no. 3, pp. 587–621.

Smith, A. (1776). An inquiry into the nature and causes of the wealth of nations: Volume one. London: printed for W. Strahan; T. Cadell, 1776.

Smulders, S., Toman, M., & Withagen, C. (2014). Growth theory and ‘green growth’. *Oxford review of economic policy*, vol. 30, no. 3, pp. 423–446.

Šneiderienė, A., Viederytė, R., & Abele, L. (2020). Green growth assessment discourse on evaluation indices in the European Union. *Entrepreneurship and Sustainability Issues*, vol. 8, no. 2, pp. 360–369.

Solow, R. M. (1974). The economics of resources or the resources of economics. In *Classic papers in natural resource economics* (pp. 257–276). Springer.

Song, M., Zhu, S., Wang, J., & Zhao, J. (2020). Share green growth: Regional evaluation of green output performance in China. *International Journal of Production Economics*, vol. 219, pp. 152–163.

Steffen, W., Persson, Å., Deutsch, L., Zalasiewicz, J., Williams, M., Richardson, K., Crumley, C., Crutzen, P., Folke, C., Gordon, L., et al. (2011). The anthropocene: From global change to planetary stewardship. *Ambio*, vol. 40, no. 7, pp. 739–761.

Stepping, K. M., & Stoever, J. (2014). Measuring green growth: Why standardisation is (sometimes) not desirable. *Available at SSRN 2685659*,

Stern, D. I., Common, M. S., & Barbier, E. B. (1996). Economic growth and environmental degradation: The environmental kuznets curve and sustainable development. *World development*, vol. 24, no. 7, pp. 1151–1160.

Stern, N. (2007). *The economics of climate change: The stern review*. Cambridge University press.

Stoknes, P. E., & Rockström, J. (2018). Redefining green growth within planetary boundaries. *Energy research & social science*, vol. 44, pp. 41–49.

Sun, Y., Ding, W., Yang, Z., Yang, G., & Du, J. (2020). Measuring China's regional inclusive green growth. *Science of the total environment*, vol. 713, pp. 136367.

Tang, J. (2015). Testing the pollution haven effect: Does the type of FDI matter? *Environmental and resource economics*, vol. 60, no. 4, pp. 549–578.

Tawiah, V., Zakari, A., & Adedoyin, F. F. (2021). Determinants of green growth in developed and developing countries. *Environmental science and pollution research international*, vol. 28, no. 29, pp. 39227–39242.

The World Bank. (2012). *Inclusive green growth: The pathway to sustainable development*. World Bank Publications.

The World Bank. (2022a). *Poverty and inequality platform methodology handbook*. Available online: https://worldbank.github.io/PIP-Methodology/ 2022 [Accessed May 18, 2022].

The World Bank. (2022b). *World development indicators*. Available online: https://databank.worldbank.org/source/world-development-indicators/ 2022 [Accessed May 21, 2022].

The World Bank. (2022c). *World governance indicators*. Available online: https://databank.worldbank.org/source/worldwide-governance-indicators/ 2022 [Accessed May 21, 2022].

Thomson, S. W. (1889). *Nature series - popular lectures and adrsses*.

Toman, M. (2012). Green growth: An exploratory review. *World Bank Policy Research Working Paper*, no. 6067.

Tone, K. (2001). A slacks-based measure of efficiency in data envelopment analysis. *European Journal of Operational Research*, vol. 130, no. 3, pp. 498–509.

UN-DESA. (2012). *A guidebook to the green economy*. United Nations Department of Economics and Social Affairs.

UNDP. (2019). *Human development reports data - mean years of schooling*. United Nations Development Programme (UNDP). Available online: https://hdr.undp.org/en/indicators/103006 2019 [Accessed May 24, 2022].

UN-ESCAP, ADB, & UNEP. (2012). Green growth, resources and resilience: Environmental sustainability in asia and the pacific.

Walter, I., & Ugelow, J. L. (1979). Environmental policies in developing countries. *Ambio*, pp. 102–109.

Wang, X., & Shao, Q. (2019). Non-linear effects of heterogeneous environmental regulations on green growth in g20 countries: Evidence from panel threshold regression. *Science of the Total Environment*, vol. 660, pp. 1346–1354.

Winston, C. (2007). *Government failure versus market failure: Microeconomics policy research and government performance*. Brookings Institution Press.

WITS. (2019). *Hh market concetration index*. World Integrated Solutions (WITS). Available online: https://wits.worldbank.org/CountryProfile/en/country/by-country/startyear/LTST/endyear/LTST/indicator/HH-MKT-CNCNTRTN-NDX 2019 [Accessed May 24, 2022].

Wu, Y., & Zhou, X. (2021). Research on the efficiency of China's fiscal expenditure structure under the goal of inclusive green growth. *Sustainability*, vol. 13, no. 17, pp. 9725.

Yang, Y., Guo, H., Chen, L., Liu, X., Gu, M., & Ke, X. (2019). Regional analysis of the green development level differences in Chinese mineral resource-based cities. *Resources Policy*, vol. 61, pp. 261–272.

Zenghelis, D. (2012). A strategy for restoring confidence and economic growth through green investment and innovation. *Policy Brief*,

Zhang, X., Guo, W., & Bashir, M. B. (2022). Inclusive green growth and development of the high-quality tourism industry in China: The dependence on imports. *Sustainable Production and Consumption*, vol. 29, pp. 57–78.

Zhou, P., Ang, B., & Wang, H. (2012). Energy and CO2 emission performance in electricity generation: A non-radial directional distance function approach. *European Journal of Operational Research*, vol. 221, no. 3, pp. 625–635.

Zhu, H., Duan, L., Guo, Y., & Yu, K. (2016). The effects of FDI, economic growth and energy consumption on carbon emissions in ASEAN-5: Evidence from panel quantile regression. *Economic Modelling*, vol. 58, pp. 237–248.

Zhu, S., & Ye, A. (2018). Does foreign direct investment improve inclusive green growth? empirical evidence from China. *Economies*, vol. 6, no. 3, pp. 44.

A Appendix

A.1 Indicator normalization equations - five cases

Table 14: Indicator normalization formulas, five cases based on scale and thresholds

Case	Impact on GG	Threshold passed	Normalized value	$b = \frac{b_1}{b_2}$	Assume
1	Positive	$X_{max} < X^t$	$x^i_{norm} = a + (\frac{x_i - X_{min}}{X_{max} - X_{min}}) \times (b - a)$	$\frac{X_{max} - X_{min}}{X^t - X_{min}}$	NA
2	Negative	$X^t < X_{min}$	$x^i_{norm} = a + (\frac{x_i - X_{max}}{X_{min} - X_{max}}) \times (b - a)$	$\frac{X_{min} - X_{max}}{X^t - X_{max}}$	NA
3	Positive	$X_{max} \geq X^t$	$x^i_{norm} = a + (\frac{x_i - X_{min}}{X^t - X_{min}}) \times (b - a)$	$\frac{X_{max} - X_{min}}{X^t - X_{min}}$	If $x_i > X^t$ then $x_i = X^t$
4	Negative	$X^t \geq X_{min}$	$x^i_{norm} = a + (\frac{x_i - X_{max}}{X^t - X_{max}}) \times (b - a)$	$\frac{X_{min} - X_{max}}{X^t - X_{max}}$	If $x_i < X^t$ then $x_i = X^t$
5	Negative	$X_{min} < X^t_{min}$ and $X^t_{max} < X_{max}$	$x^i_{norm} = a + (\frac{x_i - X^t_{max}}{X^t_{min} - X^t_{max}}) \times (b - a)$	$\frac{X_{min} - X^t_{max}}{X^t_{min} - X^t_{max}}$	If $x_i > X^t_{max}$ then $x_i = X^t_{max}$ If $x_i < X^t_{min}$ then $x_i = X^t_{min}$

Source: Authors development based on Acosta et al. (2019)

A.2 Example of non-compensatory multi-criteria aggregation method

Table 15 presents the values for six of the 27 indicators (two in each dimension) in the five countries with the highest green growth scores in the final period, i.e. 2015-2019 (calculated based the final revised GG measure). Since equal weighting is assumed, Table 15 corresponds to the impact matrix.

To perform the non-compensatory aggregation, one must apply the C-Y-K-L ranking method. The first step is to compute an outranking matrix, E, which in this example is depicted in Table 16. In this matrix, each element $e_{jk}, j \neq k$ is the result of a pairwise comparison of countries j and k, on all indicators, Q. Shown mathematically as:

Table 15: Example of non-compensatory multi-criteria method; Impact matrix

Country	Renewable Energy Share	Carbon Productivity	Adjusted Net Savings	GDP pr capita growth	Primary Education Completion	Poverty Gap $3.20
Switzerland	24.319	3.567	15.965	0.948	96.466	0.006
Denmark	33.985	4.489	19.379	1.893	101.866	0.174
Spain	16.637	1.346	9.956	2.558	100.222	0.834
Ireland	9.569	10.110	16.143	8.767	98.930	0.228
Sweden	52.522	4.930	17.916	1.422	104.720	0.458

Source: Author's calculations of means for each variable, 2014-2019, based on data from The World Bank (2022b)

Table 16: Example of non-compensatory multi-criteria method; Outranking matrix

	Ireland	Spain	Switzerland	Denmark	Sweden
Ireland	0.00	0.67	0.67	0.33	0.50
Spain	0.33	0.00	0.33	0.17	0.17
Switzerland	0.33	0.67	0.00	0.17	0.17
Denmark	0.67	0.83	0.83	0.00	0.50
Sweden	0.50	0.83	0.83	0.50	0.00

Source: Author's calculations based on impact matrix in Table 15

$$e_{jk} = \sum_{q=1}^{Q}(w_q(Pr_{jk}) + \frac{1}{2}w_q(In_{jk})) \tag{A.1}$$

where $w_q(Pr_{jk})$ and $w_q(In_{jk})$ respectively represent the weights of individual indicators presenting a preference and an indifference. In the used example this means that $e_{12} = 0.67$ because Ireland performs better than Spain on four out of six indicators and equal weighting is applied.

In the final step for the C-Y-K-L ranking, one must look at each possible ranking option (called permutations) and find the one that maximizes the outranking score on individual indicators for each pairwise comparison, summed over all countries. This score can formally be expressed as

$$\theta_s = \sum e_{jk} \tag{A.2}$$

where $s = 1, 2, ..., !M$, with $!M$ defining all possible rankings of alternatives. With five countries $!M = 120$, and each of these permutation scores must be computed as the final ranking, r^* is where

$$\theta_* = max \sum e_{jk} \tag{A.3}$$

A.3 Standardized values for partial compensatory measure example

Table 17: Standardized values using threshold min-max normalization, example

Country	Adjusted Net Savings	Carbon Productivity	Renewable Energy Share	GDP pr capita growth	Primary Education Completion	Poverty Gap $3.20
Switzerland	76.00	93.04	47.72	94.71	100.00	99.99
Denmark	80.96	97.52	66.38	99.46	100.00	99.75
Spain	67.25	82.26	32.89	100.00	100.00	98.79
Ireland	76.25	100.00	19.24	100.00	100.00	99.67
Sweden	78.84	99.66	100.00	97.10	100.00	99.33

Source: Author's calculations based on data from The World Bank (2022b)

A.4 Basic descriptive statistics on variables

Table 18: Basic descriptive statistics on variables

	Mean	Max	Min	Sd	N
Green growth, refined measure	51.01	79.54	17.08	13.61	304
Green growth simple	0.33	0.42	0.28	0.02	304
Green growth compensatory	71.60	90.71	46.61	9.66	304
Green growth plus two indicators	51.46	79.93	15.31	13.87	296
Green growth = CO2 productivity	5.88	58.87	0.72	5.07	360
GG Environmental dimension	26.98	63.86	10.57	8.64	373
GG Economic dimension	69.59	97.60	8.41	23.81	359
GG Social dimension	67.92	99.03	11.08	20.47	373
Institutional quality, WGI	0.15	5.03	-3.49	1.93	360
Foreign Direct Investment	4.41	175.90	-2.76	10.51	423
Government Consumption	0.17	0.43	0.01	0.06	432
Investments	0.23	0.49	0.05	0.07	432
Population (millions)	20.90	207.95	0.19	33.18	432
Population Growth	1.30	5.21	-1.57	1.31	432
Forest Area	31.22	94.46	0.67	20.49	432
Natural Ressource Rent	5.01	37.72	0.00	6.58	428

Note: Based on the 72 countries included in the study and the six five-year periods. Source: Author's calculations, sources on each variable are evdient in Table 7 and 8

A.5 Simple correlations of refined green growth and determinants

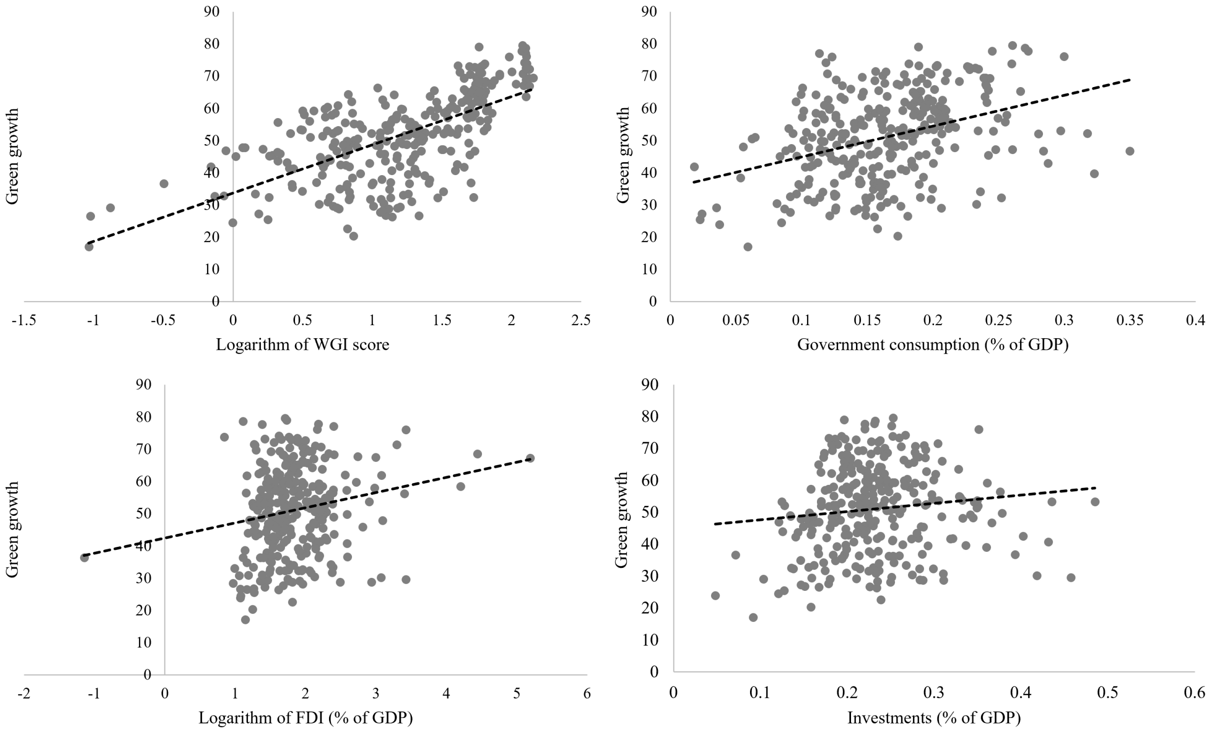

Figure 3: Correlations of green growth and prospective determinants