Partial Order Analysis of the Government Dependence of the Sustainable Development Performance in Germany's Federal States

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1 Introduction

In the year 1992 during the Earth Summit (United Nations Conference on Environment and Development) in Rio de Janeiro the Agenda 21 was established. The Agenda 21 is an action plan with regard to sustainable development that can be executed on local, national, and global level (United Nations 1992). To comply with the requirements of the Agenda 21, the Council of Sustainable Development (Rat für Nachhaltigkeit) was established in 2001 by the German Federal Government followed by the national sustainability strategy in 2002 Federal Ministry for Economic Cooperation and Development (2016). It consists of several goals, quantified by indicators to measure the success of policy implementations and other measures on national and local level (Bundesregierung Deutschland Nationale Nachhaltigkeitsstrategie 2012). To determine meaningful and applicable indicators, the Conference of Environmental Ministers (Umweltministerkonferenz) ordered the Bund/Länder-Arbeitsgemeinschaft Klima, Energie, Mobilität—Nachhaltigkeit (BLAG KliNA—Federal-State working group for climate, energy, mobility, and sustainability) to develop a comprehensive indicator set: the German core sustainability indicators Landesamt für Natur und Verbraucherschutz (2015). This set is divided into four main groups:

1. Climate and energy (A)
2. Nature and countryside (B)

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Table 1 Indicators considered

Indicator number	Description
A2.1	Energy-related carbon dioxide emissions, per inhabitant
A2.2	Fuel-based carbon dioxide emissions generated by traffic, per inhabitant
A3.1	Primary energy consumption, per inhabitant
A4	Share of renewable energy in primary energy consumption
B3	Share of strictly protected nature conservation areas nationwide
B4	Proportion of evidently damaged beech trees (level 2 or higher)
C3.1	Local public passenger transport services, per inhabitant

3. Environment and health (C)
4. Resources and efficiency (D)

Each group consists of 4–9 indicators, which are named after the main group they belong to, for example, "A2 Carbon Dioxide Emissions." Some are divided further into subindicators, for example, "A2.1 Energy related carbon dioxide emissions, per inhabitant" or "A2.2 Fuel-based carbon dioxide emissions generated by traffic, per inhabitant." Overall only seven of the existing 47 indicators were used within the analysis (see Table 1) due to data availability constraints. High indicator values indicate an increasing sustainable development. The selected years for the analysis are 1991 to 2009 as for the considered federal states only this time frame has good data availability.

This chapter aims at answering the following question:

Does a relation between political parties and the sustainable development within Germany's federal states exist?

To answer the question, the introduced seven indicators are analyzed for the federal states Bavaria (BY), Schleswig-Holstein (SH), Baden-Württemberg (BW), Thuringia (TH), Hesse (HN), and Rhineland-Palatinate (RP) for the years 91–09 using Partial Order methodology. The Partial Order methodology can support the analysis of indicator systems as shown in several case studies (Bach et al. 2015; Carlsen and Bruggemann 2013; Bruggemann et al. 2014a).

2 Method

The concept of comparison is the basis of the Partial Order methodology. Given a set of objects, $X = \{a, b, \ldots.\}$, the objects a, b, etc., are mutually compared. A Partial Order is present when the three following axioms are valid.

(I) (Reflexivity): $a \leq a$, for all $a \in X$.
(II) (Transitivity): If $a \leq b$ and $b \leq c$, then $a \leq c$, for all $a, b, c \in X$.
(III) (Antisymmetry): If $a \leq b$ and $b \leq a$, then $a = b$, for all $a, b \in X$.

The $\leq$-relation can be achieved in many different ways. Considering the analyzed objects together with the multiindicator system (MIS) as presented in Table 1, two objects x, $y \in X$ fulfill the $\leq$-relation, if and only if it is valid: $q_j(x) \leq q_j(y)$ for all $j = 1, \ldots, m$. The natural (weak) order among objects for any indicator $q_j (j = 1, \ldots, m)$ is combined to obtain a Partial Order by considering all indicators at the same time. For Partial Orders a total (or complete or linear) order is often not an option. Partial orders can be visualized by Hasse diagrams, which are often useful representations.

Hasse diagram: The Hasse diagram focuses on individual objects and their relation to each other and visualizes them (Bruggemann et al. 2014a; Bruggemann and Patil 2011).

Cover relation: Given $x < y$. If there is no object z, for which is valid: $x < z < y$ then the relation between x and y is called a cover relation. The object y is covering object x.

Set of linear extensions: Any Partial Order can be represented by a set of linear orders (Bruggemann et al. 2014a), called LE, which are extensions of the partial order. Any object $x \in X$ has a certain position within any linear order of LE. The average of all positions over all linear orders of LE is called the average height, hav.

Level: The drawing of the Hasse diagram is organized in that manner that objects $x \in X$ are as far as possible positioned in the same vertical location. The set of objects in the same vertical position is called a level. The concept of levels allows a valuable weak ordering of the objects (Bruggemann and Patil 2011).

Generalized ranking: In strict terms a ranking is understood as a total ordering of the objects of X. Applying Partial Order often only for subsets of X such a total order can be found. Therefore, the wording 'generalized ranking' is used.

Equivalence: If x and y are different objects and $q_j(x) = q_j(y)$ is valid for all $j = 1, \ldots, m$, then the objects x and y can be classified as equivalent and are declared as $x \cong y$ (Carlsen and Bruggemann 2013; Saxl 1995). An equivalent part can be represented by one element. This element is a representative element.

Incomparability: If $q_j(x) \leq q_j(y)$ cannot be established for all $j = 1 \ldots m$, the two elements x and y are "incomparable," denoted as $x \,||\, y$. Incomparability indicates a data conflict: With respect to some indicators x is better than y, but with respect to some other indicators y is better than x.

Discretization: Using various attributes can lead to many incomparabilities caused by minute numerical differences among the attribute values of different objects. To minimize these and preserve the meaningfulness of the results, beside other techniques the formation of intervals can be applied. By dividing the range of highest and lowest value for every attribute into intervals (K value), the amount of incomparabilities can be reduced (Carlsen and Bruggemann 2013; Bruggemann et al. 2014b).

Minimal, maximal elements: Elements x for which no relation $y < x$, $y, x \in X$, can be found are called minimal elements. Elements x for which no relation $x < y$, $y, x \in X$ can be found are called maximal elements.

Similarity: When two sets of attributes are available, based on the same set X of objects, two partial orders arise. The similarity between the two partial orders can

Table 2 Description of similarity terms

Aspect	Relations	Remark
Isotone	$x <_1 y$, $x <_2 y$	
Antitone	$x <_1 y$, $x >_2 y$	and other combinations
Weak isotone	Combinations with one equality, such as $x <_1 y$, $x =_2 y$	
Indifference	All combinations with $x \mid\mid y$, *such as* $x \mid\mid_1 y$, $x <_2 y$	
Identity	$x =_1 y$, $x =_2 y$	

Table 3 Applied modules of PyHasse

Name of module	Application
mHDCl	Standard partial order analysis (Hasse diagram)
discretiz	Building intervals within attributes to improve the comparability of objects
Avranks	Calculating the average ranks (heights)
Similarity	Comparison of two partial orders derived from two MIS

be determined in terms of fractions of isotone, antitone, weak isotone, indifferences, and identities (iso, anti, wiso, indiff, ident). Let $x <_i y$ denote an order relation obtained from the ith MIS. Then the five aspects of similarity (i.e., isotone, ..., ident.) can be explained as presented in Table 2.

Software: The program PyHasse (Bruggemann et al. 2014a) can be used to support the calculation of Partial Order results. Within this chapter, the following modules were applied (Hilckmann 2015) (see Table 3).

3 Results and interpretation

3.1 Comparison of Bavaria and Schleswig Holstein: General remarks

First, the results for the comparison of the federal states Bavaria (BY) and Schleswig-Holstein (SH) are shown. The objects to be compared are years. The indicators characterize each year (of a certain federal state) with respect to the sustainability as far as 7 indicators can be considered as sufficient. Their Hasse diagrams are presented in Fig. 1. BY and SH were chosen as both federal states show different characteristics:

- Bavaria:
  Government: BY was governed by CDU (Christlich Demokratische Union Deutschlands—Christian Democratic Union of Germany) during the period considered 1990. In the year 1990 the FDP (Freie Demokratische Partei—Free Democratic Party) joined the government.

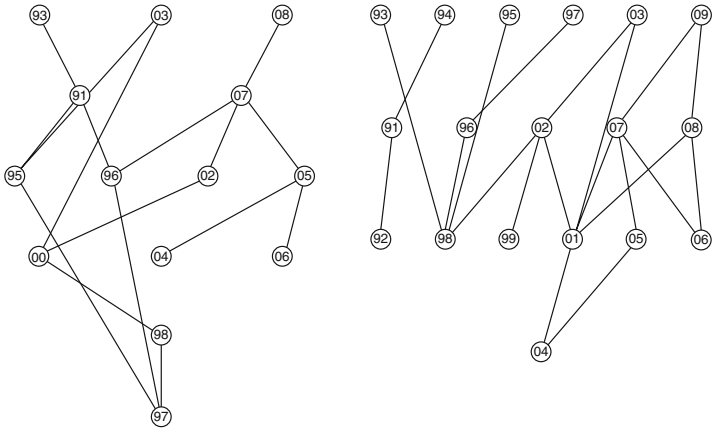

Fig. 1 Hasse diagram of Schleswig-Holstein (*left*) and Bavaria (*right*) for the years 91–09, considering seven indicators. Three equidistant intervals were chosen ($K = 3$). Equivalent classes (SH): {91, 92}, {93, 94} {98, 99}, {00,01}, {08, 09}, Equivalent objects (BY): {99, 00}, PyHasse-Software

Wealth: BY is one of the wealthiest federal state (GDP of 38.429€ per inhabitant and year)

Location: Bavaria is in the south of Germany

- Schleswig-Holstein:
  Government: In SH the SPD (Sozialdemokratische Partei Deutschlands—Social Democratic Party of Germany) governed together with Bündnis 90/Die Grünen (Alliance 90/the Greens) until 2005. After 2005, CDU governed together with SPD (Hilckmann 2015; Landesregierung 1946).
  Location: SH is situated in the north of Germany
  Wealth: SH is one of the poorest (GDP of 27.684€ per inhabitant and year).

The population density is the same in both federal states Statistik Nord (2015); Landesamt für Statistik (2015).

3.2 The Partial Orders of Bavaria and Schleswig Holstein

The Hasse diagrams show the generalized ranking of objects (here: years 91–09) based on the seven indicators considered (e.g., "A2.1 Energy related carbon dioxide emissions, per inhabitant"). Both diagrams are based on a discretization by three equidistant intervals, i.e., $K = 3$.

- Schleswig-Holstein (SH):
  Level: The Hasse diagram of SH has six levels from which the following weak order can be deduced: $97 < \{98, 99\} < \{00, 01, 04, 06\} < \{95, 96, 02, 05\} < \{91, 92, 07\} < \{93, 94, 03, 08, 09\}$

Note, we neglect the set symbols for the singletons.

Cover relation: For example, the years 07 and 08.

Equivalence: Noticeable is the high amount of equivalent objects, which are often consecutive years. Equivalent objects: {91, 92}, {93, 94} {98, 99}, {00, 01}, {08, 09},

Minimal, maximal elements: The year 97 is one of the minimal elements. Thus, it performs worse compared to the other years, e.g., 98 regarding sustainable development. Three maximal representative elements (e.g., 93, 03 and 08) exist; these years perform well regarding their sustainable development. *Incomparability*: Several noncomparable objects occur (e.g., 95 and 96). For them it is hard to say (without checking the data matrix) in which year sustainable development was increasing more, only that they are not comparable with other years and each other, thus indicating a data conflict.

- Bavaria (BY):
  Level: The Hasse diagram of BY has 4 levels. A weak order can be established: $04 < \{92, 98, 99, 00, 01, 05, 06\} < \{91, 96, 02, 07, 08\} < \{93, 94, 95, 97, 03, 09\}$

  Cover relation: For instance, the years 99 and 02.

  Equivalent objects: {99, 00}

  Minimal, maximal elements: The year 2004 is one of the minimal elements. Thus, it performs worse regarding sustainable development compared to other years, e.g., 01. Several maximal elements occur (e.g., 95, 97, 03).

  Incomparability: In comparison to SH many more incomparabilities are found. This finding is in coincidence with the lower number of levels of the Hasse diagram of BY. For example, 93 || 94. For these two years the profiles in terms of modes from 1 to 3 exhibit data conflicts. At least one aspect of sustainability for 93 is better than that of 95, whereas there is another indicator, for which 95 has the better value.

3.3 Average Heights

Based on the Hasse diagrams the comparison of the years and their corresponding sustainable development is limited. Hence it is difficult to establish comparison among federal states on the basis of their temporal development. Thus, calculating the average heights allows for a chronological and thus more adequate comparison (see Fig. 2). The horizontal X-axis displays time while the vertical Y-axis shows the average height of the objects. Thus, we introduce the function hav(t) with t taken from {91, 92, ... , 09} for different federal states, which is a highly aggregated measure for sustainable development. By the functions hav(t) conclusions regarding the sustainable development of the federal states can be made by analyzing the direction of movement of the graph (Fig. 2).

For the years 92, 94, and 99 the direction of the graphs differs. Whereas for SH the graph heads down, it goes up for BY. For those years the sustainable development differs in the federal states. For the other years both graphs behave

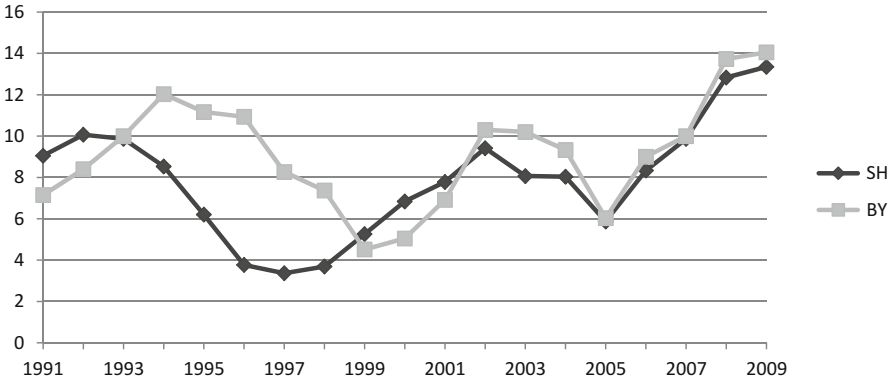

Fig. 2 Average heights of BY and SH for the years 91–09 ($K = 3$)

similar. Starting from the year 04 the development of both federal states is increasing simultaneously. Concluding, the sustainable development of both states is similar considering the chosen time frame and indicators. As the federal states vary in their governance as well as in several other characteristics (e.g., economic background) these results are surprising.

3.4 Similarity Between the Partial Order of SH and BY

When testing the data sets of both federal states regarding their similarity 44 isotone, 4 antitone, 6 wiso, and 288 indifferent relations are identified. As the number of antitone relations only sums up to four a shift in sustainable development hardly takes place, as also indicated in the average heights analysis. The relatively high number of isotone relations points to a similar sustainable development for several indicators. However, as many indifferent objects exist, the sustainable development of both federal states can not be seen as identical.

3.5 Extension to Other Federal States

To make sure that the results of the federal states BY and SH are not artifacts, four additional federal states are analyzed (see Fig. 3). Thereby, federal states are chosen based on a wide variety regarding the considered characteristics: economically strong and weaker regions (e.g., Hesse and Thuringia), high and low population density (e.g., Baden-Württemberg and Thuringia), as well as states of former East Germany (e.g., Thuringia) and former West Germany (e.g., Rhineland-Palatinate) are taken into account.

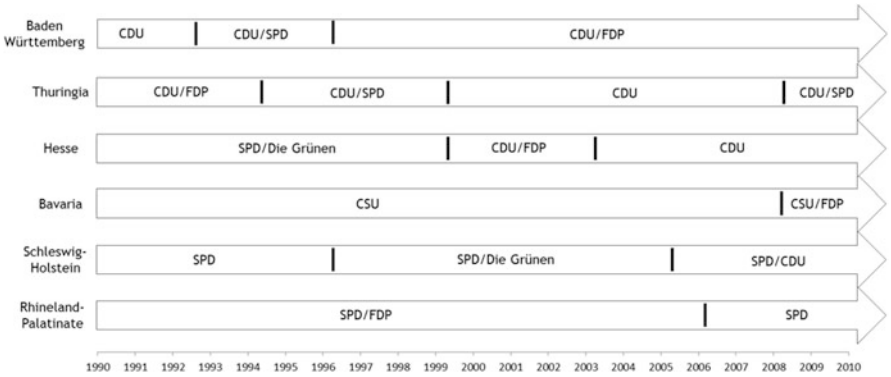

Fig. 3 Overview of governing political parties in the six considered federal states during the years 91–09

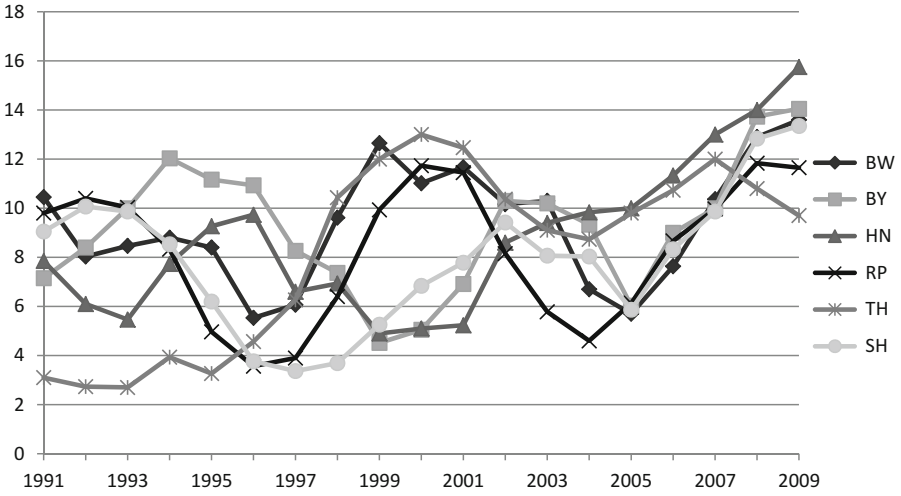

Fig. 4 Average heights of six federal states, $K = 3$

The considered federal states next to Bavaria (BY) and Schleswig-Holstein (SH) are Baden-Württemberg (BW), Thuringia (TH), Hesse (HN), and Rhineland-Palatinate (RP). BW was governed by CDU over the considered time period. For the years 92–96 SPD was supporting the governance. Afterward the FDP joined. In TH the CDU formed the government over the considered time frame. First supported by FDP (90–94) later by SPD (94–99 as well as 09). In HN a more drastic change occurred. First it was governed by SPD and Bündnis 90/Die Grünen (91–99) and then by CDU and FDP until 03 when CDU governed it by themselves. RP was governed by SPD over the considered period of time, joined by FDP from 91 to 06.

The average height analysis of these six states is shown in Fig. 4.

It shows that starting with the year 99, where the change of government (from SPD to CDU) occurs, the sustainable development of HN increases gradually. However, also in the years 93–96 an increase can be observed. For the development of BW (governed by CDU) and RP (governed by SPD) such a trend cannot be detected. The direction of BW's sustainable development changes pretty often. The direction of RP's sustainable development also changes but not as often as BW.

Overall it can be stated, that neither the composition of the government, nor wealth or the geographical location can be identified as a significant paramter for sustainable development. Even though HN and TH have very different gross domestic production, their sustainable development is alike for the most periods of time. Same is true for the federal state BW and TH as well as for TH and RP for the time period 96 to 04. The development of all six federal states is similar but not identical, indicating that some other hitherto not identified characteristics might influence their sustainable development over time.

The main hypothesis of this study, namely, the role of the political parties with regard to sustainable development can be rejected at this point. Reasons for the similar development could be the influence of the federal government, which is not included in the analysis.

4 Conclusion and Outlook

As demonstrated within the chapter, a connection between the sustainable development of federal states and their governing political parties could not be established. This might have methodological reasons like the amount of considered indicators as well as content-related reasons like the influence of Germany's federal government.

Hence, these aspects should be analyzed in more detail. To exclude that the considered indicators and time frames misrepresent the results, a comprehensive assessment of both parameters in several sensitivity analyses should be carried out. If it is confirmed, that neither the amount of indicators nor the considered timeframes lead to a distortion of results, contextual aspects have to be analyzed in more detail. This includes the role of the federal government. As the governing parties and their composition have changed over the last decades, an evaluation similar to the one carried out within this chapter for overall Germany could be established. Furthermore, subsequent changes of sustainable development have to be taken into account as well. As measures to enhance sustainable development will often be visible after considerable time delays, it might happen that successes of one government can only be seen years later when other political parties govern.

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