FROM QUALITY TO QUANTITY: HOW CAN DIGITAL SOVEREIGNTY BE PARSED INTO MEASURABLE COMPONENTS?

Martin Kaloudis[1]

[1] *Mendel University in Brno, Czech Republic*

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ABSTRACT

The use of digital technologies for state-relevant institutions, government organisations and administrations has grown steadily in recent decades. Therefore, the question arises whether the mastery of these technologies has an influence on a state's ability to act and whether state sovereignty is affected. In the European Union, the concept of digital sovereignty of states is being intensively discussed. However, it is unclear what exactly is meant by the term digital sovereignty and how it can be defined. The research gap is the lack of a clear qualitative and quantitative definition of that term, so that the goal of the article is to provide an overview of a qualitative definition. That is the basis for a quantiative model. To achive that goal a hierarchical component model is developed for concretisation. Furthermore, the components are decomposed into subcomponents, each of which is then quantified by suitable metric parameters, which are populated from secondary data sources for states and subjected to selected quantitative analyses. To verify and validate whether the component model and the parameters are suitable and robust for measuring digital sovereignty, a comparative index is formed and compared with existing indices.

KEY WORDS

digital sovereignty, state sovereignty, technology

JEL CODES

N4, N7, O33, O38

1 INTRODUCTION

The social, political and economic relevance of information and communication technology (ICT) is growing, and the associated discussion of digital sovereignty of states is taking place especially in the European Union (EU). The focus is on the question of whether increasing digitalisation influences the sovereignty of states. Various, unspecific and partly contradictory qualitative definitions are used and initiatives are derived whose effectiveness can be described

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qualitatively but not assessed quantitatively (Madiega, 2020). A qualitative uniform understanding does not exist, and there is no possibility of metric classification and comparability or analysis of states about their positioning with digital sovereignty, which describes the research gap. Impulses to make the up to now diversely used term digital sovereignty more accessible from the perspective of the European value system, a model for assessing is needed. This can be used to assess how states can be classified in terms of digital sovereignty and create room for improvement. The aim of the article is to describe the term in a structured, qualitative way, to derive a quantifiable model from it and to prove that the model is suitable for assessing digital sovereignty of states.

2 DATA SOURCES AND METHODS

The qualitative definition of digital sovereignty is derived from historical analysis, through literature review, of the individual terms by deduction and structured through synthesis into a new, composite term. Reference is made to a wide range of literature, which is mainly analysed in an article by the author (Kaloudis, 2021). This analysis is processed in a structured way and a new conceptual proposal for digital sovereignty is derived (cf. 1.1).

The new term is decomposed into qualitative main and sub components based on the structured derivation (cf. 1.2). Then the sub components are quantitatively assessed using metric parameters that are available as secondary data (cf. 1.3).

Secondary data sources on which the analysis is based are:

- World Bank: the World Bank's Open Data database provides a wide range of data, including country-specific data, which is used in this analysis (`www.worldbank.org`),
- OECD (Organisation for Economic Co-operation and Development) statistics: country-specific statistics (`https://stats.oecd.org/`),
- IEA (International Association for the Evaluation of Educational Achievement): network for improving education with data on the educational status of more than 100 countries (`www.iea.nl`),
- GII (Global Innovation Index): index with detailed measurements of 131 countries that rank the degree of innovation of states (`www.globalinnovationindex.org`),
- EUD (EU database): country-oriented database focusing in particular on states of the European Union (`www.ec.europa.eu`),
- PS (Patentscope): patent applications worldwide (`www.patentscope.wipo.int`),
- UND (UN database): database system on UN states maintained by the Department of Economic and Social Affairs (`www.publicadministration.un.org`),
- FS (further studies): selected studies by management consultancies or scientific institutions on special topics (e.g. McKinsey: `www.mckinsey.com`, Cambrian Intelligence: `www.cambrianintelligence.com`, IP Lytics: `www.iplytics.com`, International Institute for Management Development: `www.imd.org`, International Telecommunication Union: `www.itu.int`, Comparitech: `www.comparitech.com`, Leidenranking: Performance from over 1,300 universities worldwide, `www.leidenranking.com`).

The development and evaluation of the model presented in the results closely follows the OECD recommendations for the development of comparative indices. The parameters thus available are analysed and normalised using quantitative methods (OECD, 2020b, p. 13; cf. 1.4). Regression methods are used to evaluate statistical estimators in selected examples (Fahrmeir and Tutz, 2001). Missing data are imputed (cf. 1.4). The weighting of the parameters and their aggregation with suitable procedures is then discussed in various forms (OECD, 2020b; cf. 1.5). Verification and validation of the suggested index is carried out to prove the robustness of the model (Janová et al., 2019; cf. 1.6).

3 RESULTS

3.1 Qualitative Definition of Digital Sovereignty

State sovereignty and economics are closely connected (Kukkola et al., 2019). This is also true in a digital context: discussions about digital sovereignty of a state have arisen due to the criticality of the use of digital technologies and the economic dominance of digital industries of individual countries. The digital dependence on other states that has arisen and the state sovereignty that may be affected as a result, i.e. the influence on the state's desire for autonomy, can basically be countered by two opposing approaches (Pohle and Thiel, 2020; Rhode, 2020).

Through strategic autarky, which attempts through economic and industrial policy to achieve maximum independence in the sense of autarky and thus isolation from other states. Elements that are characteristic of this are strong regulations in the sense of economic promotion of own IT industries such as software, hardware and telecommunication and usage specifications for the industries to be digitised or by building barriers in the sense of protectionism for providers from other states. Examples include the USA, China and Russia.

Through strategic autonomy, which follows the approach of remaining capable of acting at all times in certain administrative and industrial areas that particularly concern state sovereignty (Madiega, 2020). However, this is not achieved through isolation but through active management of a global ecosystem and the use of technologies. The approach is characterised by strategic globalisation. The focus is largely on controllable partnerships. This can take place, for example, through the development of key competencies and key technologies or the use of parallel technologies to reduce dependencies.

Both approaches, i.e. autonomy or autarky, are essential elements of the fundamental (economic) political orientation of a state and are thus closely linked to politics and economics and also historically shaped. By using tools from the social and technology sciences (STS), the complex interdependencies and reciprocal relationships between technological, social and political aspects and actors (multistakeholderism) can be analysed and described (DeNardis et al., 2020). This interdisciplinary approach forms the basis for the analysis of digital sovereignty of a state.

In previous articles by the author, the individual aspects of sovereignty and digitalisation are analysed using methods from STS and an intensive literature search (Kaloudis, 2021, 2022). Selected literature for the aspects of state sovereignty on which the analysis is based include: (Bodin, 1994; Zimmer, 2008, p. 55; Zandonella, 2007; Abbate, 2017; DeNardis et al., 2020; Bublitz, 2014, p. 273; Mohabbat-Kar et al., 2018, p. 189; DeNardis and Raymond, 2013; Cerny, 2010, p. 8; Dahlman, 2009; and Barnett, 2017). For an overview these aspects can be structured as shown in Fig. 1.

The aspects of the term digitalisation are also analysed in the referenced article with the help of the following selected literature: (Kagermann et al., 2011; Tomory, 2016; Mohajan, 2019, p. 383; Juhász et al., 2020, p. 41; Schwab, 2016; Bauernhansl et al., 2014, pp. 14–30; and Wagner et al., 2017). On overview of the aspects is shown in Fig. 2.

From that historically motivated analysis of the understanding of state sovereignty in Europe and synthesis with the emergence of digitalisation, a definition of the composite term digital sovereignty is deducted (Kaloudis, 2021): "(…) A state is digitally sovereign precisely when (1) its sovereignty is preserved in the sense of a Foucauldian approach of 'good governance' based on Europe's democratic and liberal values, i.e. administrative and governmental work must be carried out sovereignly, (2) technological digitization by means of key enabling technologies is defined for the respective state, revised if necessary and generally accepted, and (3) under the aspect of strong data sovereignty, technology sovereignty is also established so that the technologies used by state organisations are understood and can be controlled or replaced at any time if necessary."

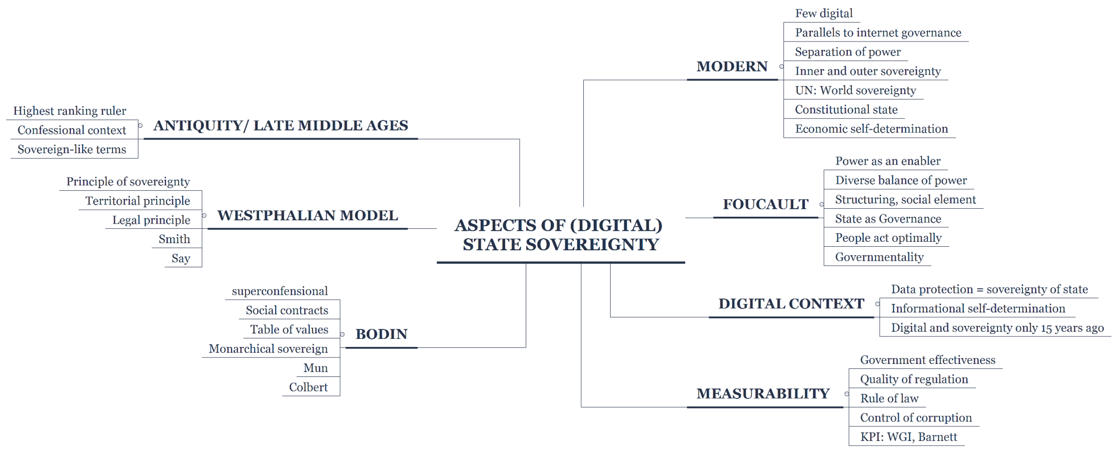

Fig. 1: Literature review: selected, analysed attributes of state sovereignty, adapted from (Kaloudis, 2021)

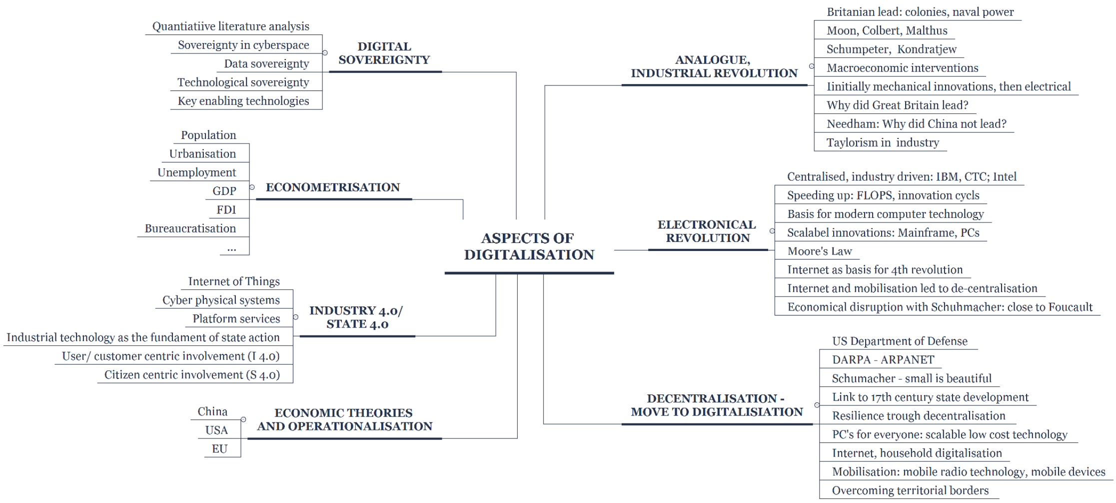

Fig. 2: Literature review: selected, analysed attributes of digitalisation, adapted from (Kaloudis, 2021)

Thus, "good governance", "KETs" and "technological sovereignty" are essential structural elements for digital sovereignty, which will be further defined below.

In order to achieve a common understanding of the variously used term and to generate a basis for further considerations, it is proposed to use the aforementioned definition.

3.2 Component Model

The metric classification of the qualitative definition of digital sovereignty requires a theoretical framework (OECD, 2020b). For the present case, the following hierarchical 3-component model is developed by the author.

The main and sub components are deduced from the definition of the term digital sovereignty in the following structured way.

Main component 1: State sovereignty in the Sense of "good governance"

The classification of state sovereignty in the value context of the EU is relevant because, depending on a state's understanding of sovereignty, it is used to assess how relevant a democratic or (semi-) autocratic state becomes

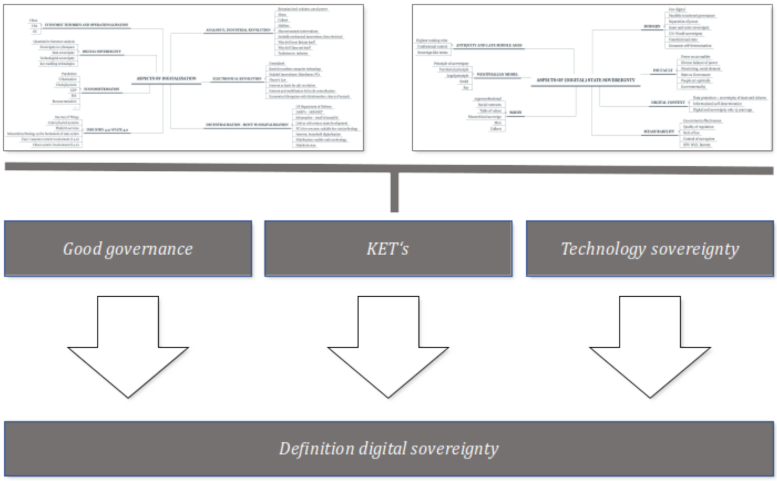

Fig. 3: Conceptualisation, analysis and synthesis digital sovereignty

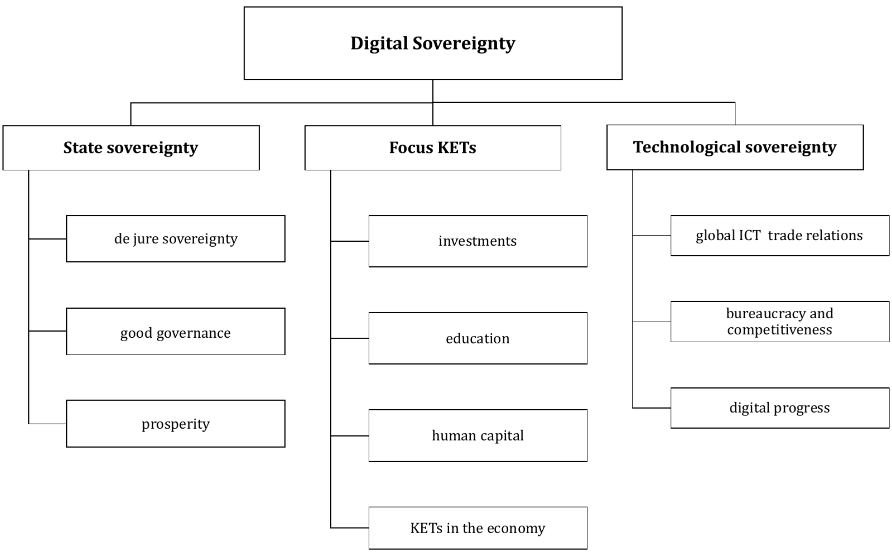

Fig. 4: Component model digital sovereignty

for the quantitative measurement of digital sovereignty.

Sub components of state sovereignty

State sovereignty is guided by elements measuring the quality of governance, through government effectiveness, quality of regulation, rule of law, control of corruption, political stability and participation and freedom of expression. Furthermore, elements of de jure sovereignty are incorporated, and the well-being of a state's citizens is assessed, which is an important indicator of political stability. This is complemented by an assessment of the prosperity of a state, which is directly correlated to "good state sovereignty". This assesses the concept of good governance and "good governmentally".

Main component 2: Focus on key enabling technologies (KETs)

KETs are the focus of the technological consideration of digital sovereignty. Therefore, another main component is a state's assessment

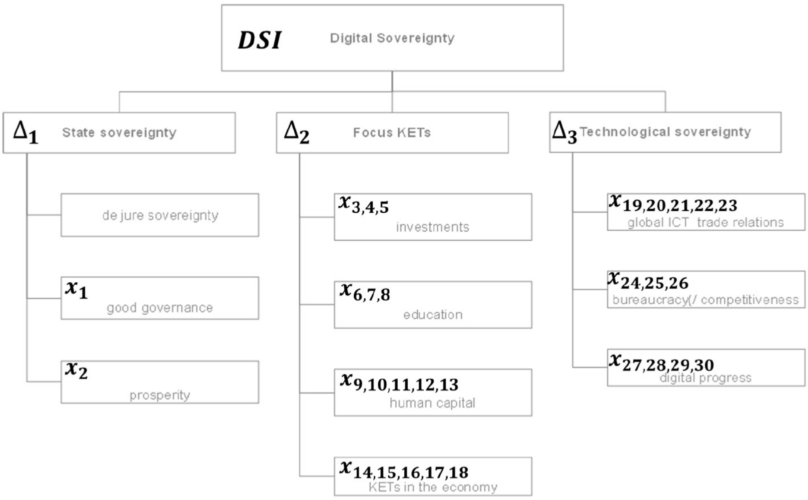

Fig. 5: Classification of parameters in the component model

of how focused key technologies are defined and placed in terms of academic training and economic relevance. Investments, especially in key technologies, also play an important role here.

Sub components KETs

The research, assessment and development of KETs are important influencing factors. These include a state's willingness and ability to develop the (technological) sectors of the economy with and through foreign investment, as well as to promote training of technology assessment specialists through schools and universities and mathematical technical education. Also relevant is a state's ability to mobilise the potential of its citizens in the economy and in the workplace. With the previously mentioned criteria, basic skills emerge to identify which key technologies are relevant for a state and to assess how to deal with them. Another criterion is how successfully countries translate research results into products. However, a uniform understanding of which KETs are really relevant is still lacking among countries (Kaloudis, 2021, p. 7).

Main component 3: Technological sovereignty

Technology understanding and the strategy of increasing strategic autonomy in the sense of technology sovereignty are the focus of the third main component.

Sub components of technological sovereignty

In order to achieve a good understanding of technology, especially with a focus on data sovereignty, i.e., to be able to assess which data are how sensitive and which measures are necessary to keep dependence on third parties at a tolerable level, various indicators can be chosen. The selection is based on the assumption that digital sovereignty in a free, liberal and democratic basic order does not come about through strategic autarky and isolation in the model of autocratic states, but through controllable exchange in an ecosystem of states, i.e., in the sense of global sovereignty. Indicators for this are trade relations with other states with digital services and goods, the evaluation of bureaucratic hurdles to set up a company in a state in order to produce technology with it, the innovative capacity of a state as well as the degree of digitalisation of state institutions or society. Digital competitiveness is also considered, which contributes to remaining "master of technology" relevant to state sovereignty. The sub components will now be assessed with 30 parameters from secondary data, which are described in the following chapter.

3.3 Quantitative Classification and Parameters

Each of those 10 subcomponents can be described by at least one of a total of 30 parameters. For m states, n parameters are collected that describe elements of digital sovereignty of the state. The data is stored in a vector

$$X = X_i = \begin{pmatrix} x_{i1} \\ x_{i2} \\ \vdots \\ x_{ij} \end{pmatrix}, \quad x_{ij} \in \mathbb{R}, \quad i, j \in \mathbb{N}, \tag{1}$$

with $j \in \{1, \dots, m\}$ and $i \in \{1, \dots, n\}$ and n is a number of parameters collected.

After data collection one obtains a $m \times n$ matrix with $k \leq m \cdot n$ coefficients, since not every parameter is complete for every state. X serves as a basis for further multi-criteria analyses and can be examined for further research as a suitable basis for assessing digital sovereignty of a state.

Parameters for main component 1:
Sovereignty in the sense of "good governance"

Sub component: de jure sovereignty

Whether a state is fundamentally sovereign is assessed using "de jure" sovereignty: only states that are recognised in principle are considered. As a prerequisite, it is assumed that a state is a member of the UN, only then is it a state at all. This interpretation is found in common literature (Dahlman, 2009, p. 28). For the purpose of this article, the degree of recognition is the quotient of the number of states that recognise another in comparison to all UN states, standardised to 100 in each case, i.e. a value of 100 means that all 193 UN states have recognised this state (Barnett, 2017, pp. 62–64).

$$\Theta = \text{De jure sovereignty} \tag{2}$$

Sub component: good governance

Through the World Governance Index (Kaufmann and Kraay, 2020) has been collecting data from various sources for almost all states since 1996 and quantifying them in six standardised dimensions: "Participation and Accountability", "Political Stability", "Government Effectiveness", "Regulatory Quality", "Rule of Law" and "Control of Corruption". Thus, this approach corresponds to the quantification of good governance in the faucaldian sense (Kaloudis, 2021). Following Barnett, the World Happiness Index is used as a supplement (Barnett, 2017, p. 21).

$$\Xi = \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 + \beta_6 + \lambda \tag{3}$$

The first parameter is described by the sum of de jure sovereignty and "good governance".

$$x_1 = \Theta + \Xi \tag{4}$$

Sub component: prosperity

The per capita gross domestic product is used to measure the material prosperity of a state.

$$x_2 = \text{GDP}_{\text{per capita}} \tag{5}$$

Parameters for main component 2:
Focus on KETs

Sub component: investments

In addition to the effect that essential digital infrastructures must be available for foreign direct investments, without which they would not be able to operate effectively, these investment activities are a characteristic of the ability of states or their industries to interact with global markets. A distinction is made between net inflows and outflows, but both are seen as a positive feature of investment in general and thus also as potential investments in key enabling technologies:

$$x_3 = \text{FDI}_{\text{inflow}} \tag{6}$$

$$x_4 = \text{FDI}_{\text{outflow}} \tag{7}$$

In addition, the level of investment in startups is used as a parameter to assess a state's ability to also promote new business

$$x_5 = \text{Investment startups} \tag{8}$$

Sub component: education

The qualification of citizens of a state is the basis for (technological) progress (Becker et al., 2011, p. 120; Peters and Jandrić, 2019, p. 14). On the one hand, this pays into the ability of citizens to be digitally sovereign themselves, or to participate as professionals in the digitalisation of the state. Digital capability through education and training assesses a country's ability to produce high-educated citizens. This begins with school education, continues with training and studies, the quality of universities and ends with the number of IT specialists in the labour market.[1] The parameters used are:

$$x_6 = \text{TIMMS} \tag{9}$$

$$x_7 = \text{Assessment in reading, mathematics, and science} \tag{10}$$

$$x_8 = \text{Expenditure on training as a percentage of GDP} \tag{11}$$

Sub component: human capital

The human capital, i.e., the knowledge-based economic power of a country's workforce, is also assessed. The number of employed IT specialists[2] per country represents the amount of ICT know-how that can contribute to the digitalisation of a country. These quantitative data are well recorded for the EU, for other countries only singular sources can be found.

$$x_9 = \text{number of employed IT specialists} \tag{12}$$

In addition, the number of successfully filed patents with an ICT focus is evaluated. It provides an overview of a country's ability to generate new, innovative ideas. Patent submissions are documented worldwide for patent law reasons alone and can be determined. For the present work, the published patents were evaluated in the following categories (included on title page): Cloud, Artificial Intelligence, Quantum, Information Technology and Telecommunication.

$$x_{10} = \text{Number patents} \tag{13}$$

In addition, the quality of universities is included as a key figure. Here, the QS University Ranking is used as a parameter, with the average value of the top three universities.

$$x_{11} = \text{QS university ranking, average score TOP 3} \tag{14}$$

Another question is the extent to which research is transferred to industry. For this purpose, the Leiden Ranking (van Eck, 2021) the indicator for the number of publications in mathematics and computer science in cooperation between universities and industry is used in comparison to all publications with mathematical or information technology content.[3]

$$x_{12} = \frac{\text{Number of publications in Maths \& Computer Science in collaboration with industry}}{\text{Number of publications in Maths \& Computer Science}} \tag{15}$$

The human capital index is used as a complementary factor. The index measures the extent to which a country actually uses the potential of its citizens.

$$x_{13} = \text{Human Capital Index} \tag{16}$$

Sub component: KETs in the economy

As a characteristic of transparency and promotion of data availability for digital processing by an Open Data promoting ecosystem, the index for government support of data use is formed from the characteristics of availability and data accessibility (Lafortune and Ubaldi, 2018; OECD, 2021).

$$x_{14} = \text{Open Data Index} \tag{17}$$

[1] Students reaching the international benchmarks of mathematics achievement.
[2] Persons with ICT education by labour status.
[3] Used parameter calculated independently.

The following parameter is used to assess how key technologies that may be relevant to states are promoted in a state's industries through research and development.

$$x_{15} = \text{Research and development expenses} \quad (18)$$

With a focus on specific KETs[4], it is assessed:

$$x_{16} = \text{Public funding for Quantum} \quad (19)$$

$$x_{17} = \text{Index artificial intelligence} \quad (20)$$

$$x_{18} = \text{Number Blockchain Startups} \quad (21)$$

Parameters for main component 3:
Technological Sovereignty

Sub component: global ITC trade relations

To assess the extent to which states trade in digital goods and services, parameters for imports and exports as well as for restrictions and freedoms in the context of trade in digital goods and services are analysed. The selection of parameters focuses on those that describe the trade relations of ICT services or goods.

$$x_{19} = \text{Amount of exported IT services} \quad (22)$$

$$x_{20} = \text{Share of exported IT services in total exports} \quad (23)$$

$$x_{21} = \text{Amount of imported IT goods} \quad (24)$$

$$x_{22} = \text{Amount of imported IT services} \quad (25)$$

In addition, the Services Trade Restrictiveness Index (STRI), which is based on digital aspects of trade freedom, is calculated by the OECD (OECD, 2020d), STRI, the so-called digital STRI (OECD, 2020a) is used.

$$x_{23} = \text{Digital STRI} \quad (26)$$

Sub component: bureaucracy and competitiveness

To assess a state's bureaucracy, the index for assessing the promotion of business activities and the one for assessing digital competitiveness are used.

$$x_{24} = \text{EDBI} \quad (27)$$

$$x_{25} = \text{WDC} \quad (28)$$

Another criterion for competitiveness in the sense of technological sovereignty is the ability of a state to deal with data protection. The EU's assessment of whether a state has an adequate level of data protection is used to measure this. Based on Article 45 of EU Regulation 2016/679, the EU can define whether a country outside the EU offers an adequate level of data protection. If confirmed, this means that data transfers to the country in question are treated the same as data exchanges within the EU. The rating is digital, i.e., 1 if a country is classified accordingly, otherwise 0. In addition, the point rating from the Comparitech study is used and added to the EU data protection rating.

$$x_{26} = \text{EU-GDPR} + \text{Score Comparitech} \quad (29)$$

Sub component: digital progress

The positioning of a state in the ranking of digital capabilities and digital progress and digital openness is formed by the following individual indices.

$$x_{27} = \text{Internet Access Households} \quad (30)$$

$$x_{28} = \text{SIM Cards to Population} \quad (31)$$

The digitalisation of state organisations, ministries and authorities is assessed with the following indices.

$$x_{29} = \text{Government's online service} \quad (32)$$

$$x_{30} = \text{E-Government Rank (EGDI)} \quad (33)$$

Whether the parameters described above are suitable for quantifying digital sovereignty will be examined in the following chapters.

[4] KPIs for KETs can be added or modified for quantification for later research purposes.

3.4 Quantitative Analysis of the Parameters, Normalisation and Imputation

The data (year 2021 of evaluation) of the parameters collected from the aforementioned secondary sources were normalised[5] to 100 for the following analyses and presentations.

Tab. 1: Number, max, min, mean, 25%, 50%, 75% percentiles of parameters, raw data

X_i	Values	Min	Max	Mean	25% perc.	50% perc.	75% perc.
1	121	65.69	100.00	81.23	74.89	79.65	88.53
2	194	0.00	100.00	9.50	1.15	3.72	11.11
3	185	0.00	100.00	13.82	11.74	11.94	12.86
4	167	0.00	100.00	38.35	36.68	36.70	37.14
5	29	0.00	100.00	4.70	0.03	0.20	0.44
6	55	41.85	100.00	82.15	76.51	85.88	89.16
7	76	1.00	100.00	54.59	27.28	55.49	83.69
8	127	0.00	100.00	42.52	32.29	43.75	55.21
9	37	0.00	100.00	6.67	0.25	0.91	2.64
10	10	0.01	100.00	11.25	0.09	0.24	0.96
11	127	24.00	100.00	46.83	24.00	36.00	68.75
12	59	0.00	100.00	35.15	15.99	29.73	50.98
13	187	0.00	100.00	68.81	55.76	73.96	84.29
14	34	0.00	100.00	60.86	52.85	63.57	74.41
15	126	0.00	100.00	7.68	0.71	2.08	7.76
16	14	3.70	100.00	23.05	3.70	15.93	29.63
17	13	16.00	100.00	42.92	33.75	38.00	44.25
18	9	3.99	100.00	18.73	6.40	8.40	12.29
19	200	0.00	100.00	3.39	0.00	0.08	0.90
20	127	0.00	100.00	8.88	1.94	6.20	11.63
21	170	0.00	100.00	4.12	0.14	0.53	2.47
22	127	0.00	100.00	19.60	8.96	16.42	26.49
23	45	0.00	100.00	68.28	50.36	77.23	86.15
24	127	1.00	100.00	50.61	24.85	51.38	75.62
25	62	23.99	100.00	69.73	54.84	69.11	84.11
26	42	56.25	100.00	89.73	87.50	90.63	93.75
27	199	0.27	100.00	52.88	23.64	57.51	82.02
28	195	5.96	100.00	32.22	25.53	32.56	38.70
29	127	38.97	100.00	70.13	54.93	69.95	85.68
30	187	1.00	100.00	51.37	26.00	51.78	76.52

For the further analysis of the data, various normalisation procedures can be applied for appropriate comparison and imputation procedures, since n individual values x_i for all parameters are not available for each state in the sources. The normalisation and imputation procedures become relevant when a composite index is calculated from the parameters (OECD 2020b).

[5] $x'_j = 100 \cdot \frac{x_j}{\max(x_j)}$

To illustrate arbitrarily selected normalisation and imputation procedures, the following are shown graphically in Fig. 1:

1. Raw data, without imputation, as shown in Tab. 1 shown,
2. Raw data, normalised by mean 0, without imputation,
3. Raw data, imputation with k-nearest-neighbours method (kNN),
4. Raw data normalised by mean 0 and standard deviation 1, kNN imputation.

The graphical representation shows the effect of the normalisation and imputation procedures on the raw data. If the data are used further, then the appropriate selection of the right procedure, e.g. in the context of a sensitivity analysis, becomes very important, since the raw data are optimised for further statistical analyses by the procedure combinations, but at the same time are significantly falsified (OECD 2020b).

In order to identify correlations between the parameters, the coefficient of determination R^2 is used as the explained variance and the p-values, which can be determined by (linear) regression (Montgomery et al., 2012, p. 83). Formal prerequisites for efficient regression estimators are normal distribution of the error terms, linearity, no autocorrelation and homoscedasticity. The raw data shown above fulfil the prerequisites only to a limited extent, are heteroskedastic and not normally distributed. Due to the missing preconditions, the estimators of the regression analysis are indeed satisfactory, but no longer efficient (Fahrmeir et al. 2009, 64ff). Suitable methods of general regression can minimise the negative effects, but this is neglected here due to the practical relevance of the data.

Thus, a pairwise comparison of two parameters X_i and Y_i is carried out. The null hypothesis H_0 is then in each case: The dependent variable Y_i is determined by the independent variable X_i by a linear function

$$y_i = \beta_0 + \beta_1 x_i + \varepsilon \tag{34}$$

and can be explained with a significance level of 5% and a coefficient of determination of

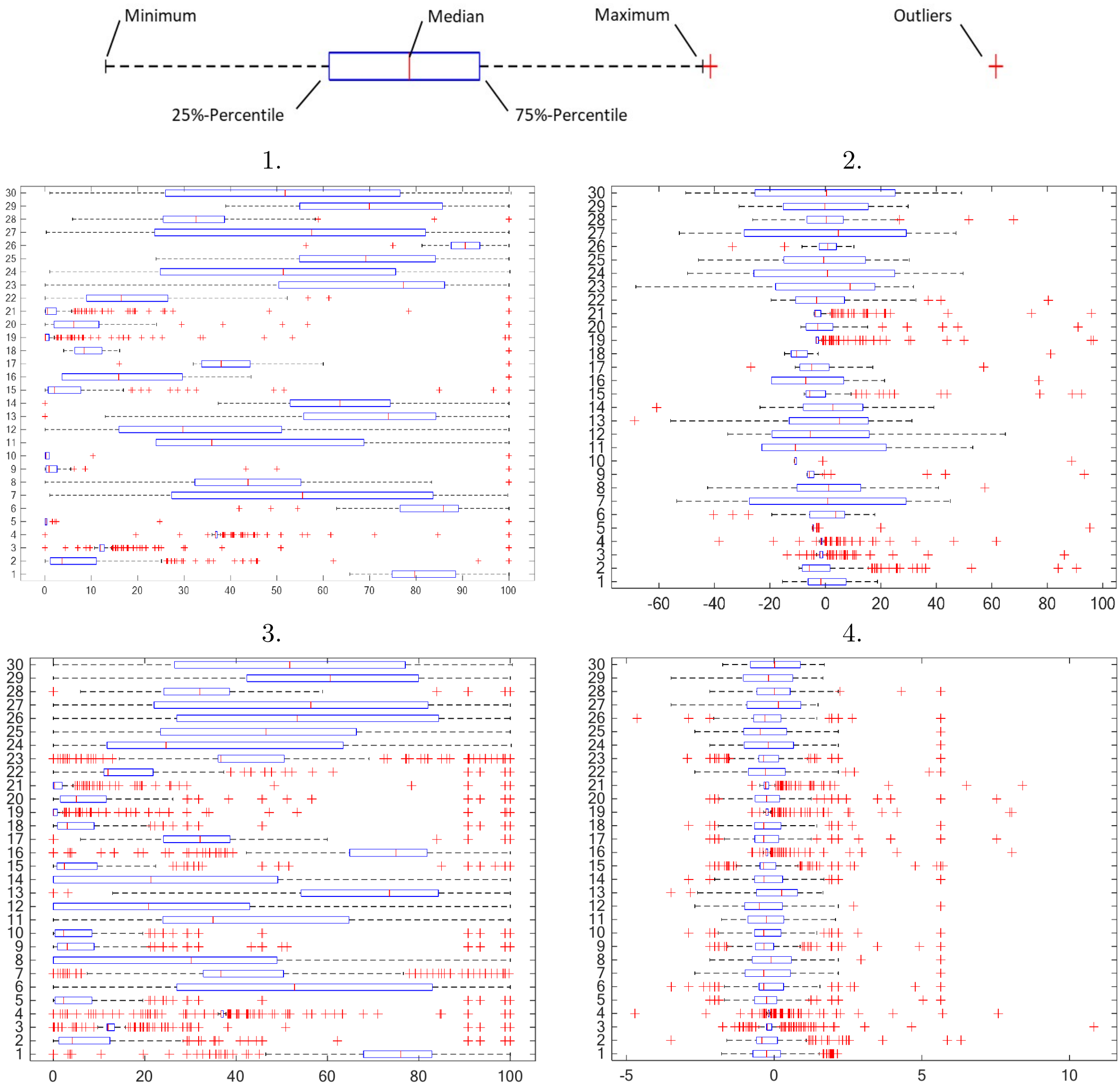

Fig. 6: Normalisation and imputation procedures for raw data

at least 50%. In the following presentation, therefore, only those values are shown for which a coefficient of determination $R^2 \geq 50\%$ and a p-value $< 5\%$ could be determined.

Tab. 2 identifies those parameters that have a high linear correlation, which can also be demonstrated graphically. Since linear regression with two variables is commutative, the matrix is symmetrical. 24 pairs of parameters (5%) can be found whose coefficient of determination $R^2 \geq 50\%$ and $p < 0.05$.

3.5 Weighting and Aggregation

For the present paper, the weighting methods suitable for this application were selected from the possible ones (OECD 2020b, 30). In this case, these are equal weighting (simplicity), Principal Component Analysis (PCA, identifies commonalities of components and corrects for them through weighting) and the Analytic Hierarchy Process (AHP, quantitative support for expert estimators).

Due to the particular relevance of the parameters of main component 1, these are weighted

Tab. 2: Linear regression for X_I and Y_i, outlined in red: $R^2 \geq 0.5$, $p < 0.05$

X_i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	1.00	.66	.04	.05	.01	.26	.33	.16	.14	.17	.37	.34	.54	.00	.01	.01	.00	.06	.11	.06	.09	.20	.49	.16	.58	.21	.54	.17	.50	.67
2	.66	1.00	.06	.04	.01	.21	.32	.06	.03	.10	.35	.38	.23	.00	.01	.08	.04	.17	.07	.08	.12	.22	.30	.14	.56	.12	.35	.10	.41	.32
3	.04	.06	1.00	.46	.87	.07	.03	.01	.43	.10	.20	.04	.04	.18	.56	.10	.84	.84	.16	.01	.78	.00	.01	.02	.10	.45	.04	.02	.13	.07
4	.05	.04	.46	1.00	.37	.06	.04	.00	.12	.08	.15	.09	.02	.02	.17	.14	.29	.53	.01	.08	.47	.00	.00	.00	.07	.11	.04	.02	.09	.05
5	.01	.01	.87	.37	1.00	.07	.00	.01	.32	.02	.09	.03	.00	.44	.66	.03	.96	.92	.14	.01	.69	.03	.00	.00	.12	.76	.06	.00	.04	.01
6	.26	.21	.07	.06	.07	1.00	.49	.10	.09	.02	.15	.25	.50	.02	.02	.06	.14	.00	.07	.01	.08	.09	.13	.08	.14	.02	.30	.01	.17	.54
7	.33	.32	.03	.04	.00	.49	1.00	.15	.06	.09	.20	.29	.40	.09	.00	.03	.06	.04	.14	.04	.10	.07	.14	.17	.42	.00	.22	.02	.25	.44
8	.16	.06	.01	.00	.01	.10	.15	1.00	.00	.05	.07	.11	.05	.03	.00	.01	.05	.01	.01	.02	.01	.10	.11	.03	.08	.12	.02	.00	.05	.06
9	.14	.03	.43	.12	.32	.09	.06	.00	1.00	.77	.14	.01	.22	.25	.81	.05	.21	.00	.23	.00	.57	.07	.50	.00	.02	.78	.36	.01	.04	.05
10	.17	.10	.10	.08	.02	.02	.09	.05	.77	1.00	.12	.01	.11	.88	.34	.00	.08	.01	.01	.01	.33	.15	.45	.03	.02	.80	.07	.00	.37	.02
11	.37	.35	.20	.15	.09	.15	.20	.07	.14	.12	1.00	.28	.34	.02	.26	.01	.42	.21	.24	.02	.37	.04	.00	.09	.39	.05	.34	.08	.58	.45
12	.34	.38	.04	.09	.03	.25	.29	.11	.01	.01	.28	1.00	.20	.00	.00	.00	.16	.48	.12	.10	.08	.29	.25	.05	.43	.04	.19	.01	.15	.21
13	.54	.23	.04	.02	.00	.50	.40	.05	.22	.11	.34	.20	1.00	.00	.02	.02	.04	.04	.06	.03	.07	.04	.32	.14	.24	.28	.62	.28	.51	.77
14	.00	.00	.18	.02	.44	.02	.09	.03	.25	.88	.02	.00	.00	1.00	.11	.13	.56	.80	.00	.02	.08	.00	.02	.02	.00	.01	.00	.02	.00	.00
15	.01	.01	.56	.17	.66	.02	.00	.00	.81	.34	.26	.00	.02	.11	1.00	.09	.44	.30	.32	.00	.63	.00	.18	.00	.00	.58	.01	.00	.14	.05
16	.01	.08	.10	.14	.03	.06	.03	.01	.05	.00	.01	.00	.02	.13	.09	1.00	.01	.01	.30	.01	.66	.00	.05	.47	.16	.09	.04	.00	.00	.07
17	.00	.04	.84	.29	.96	.14	.06	.05	.21	.08	.42	.16	.04	.56	.44	.01	1.00	.83	.09	.07	.78	.03	.00	.02	.16	.71	.01	.03	.02	.02
18	.06	.17	.84	.53	.92	.00	.04	.01	.00	.01	.21	.48	.04	.80	.30	.01	.83	1.00	.05	.06	.51	.02	.11	.01	.24	.01	.02	.01	.14	.07
19	.11	.07	.16	.01	.14	.07	.14	.01	.23	.01	.24	.12	.06	.00	.32	.30	.09	.05	1.00	.38	.31	.03	.00	.01	.07	.04	.04	.00	.14	.09
20	.06	.08	.01	.08	.01	.01	.04	.02	.00	.01	.02	.10	.03	.02	.00	.01	.07	.06	.38	1.00	.00	.21	.02	.03	.01	.03	.03	.00	.03	.05
21	.09	.12	.78	.47	.69	.08	.10	.01	.57	.33	.37	.08	.07	.08	.63	.66	.78	.51	.31	.00	1.00	.00	.01	.02	.17	.44	.08	.02	.20	.13
22	.20	.22	.00	.00	.03	.09	.07	.10	.07	.15	.04	.29	.04	.00	.00	.00	.03	.02	.03	.21	.00	1.00	.12	.03	.09	.07	.07	.00	.05	.10
23	.49	.30	.01	.00	.00	.13	.14	.11	.50	.45	.00	.25	.32	.02	.18	.05	.00	.11	.00	.02	.01	.12	1.00	.07	.23	.37	.28	.00	.08	.34
24	.16	.14	.02	.00	.00	.08	.17	.03	.00	.03	.09	.05	.14	.02	.00	.47	.02	.01	.01	.03	.02	.03	.07	1.00	.40	.01	.18	.07	.18	.20
25	.58	.56	.10	.07	.12	.14	.42	.08	.02	.02	.39	.43	.24	.00	.00	.16	.16	.24	.07	.01	.17	.09	.23	.40	1.00	.01	.44	.12	.38	.50
26	.21	.12	.45	.11	.76	.02	.00	.12	.78	.80	.05	.04	.28	.01	.58	.09	.71	.01	.04	.03	.44	.07	.37	.01	.01	1.00	.17	.01	.00	.14
27	.54	.35	.04	.04	.06	.30	.22	.02	.36	.07	.34	.19	.62	.00	.01	.04	.01	.02	.04	.03	.08	.07	.28	.18	.44	.17	1.00	.29	.46	.76
28	.17	.10	.02	.02	.00	.01	.02	.00	.01	.00	.08	.01	.28	.02	.00	.00	.03	.01	.00	.00	.02	.00	.00	.07	.12	.01	.29	1.00	.18	.39
29	.50	.41	.13	.09	.04	.17	.25	.05	.04	.37	.58	.15	.51	.00	.14	.00	.02	.14	.14	.03	.20	.05	.08	.18	.38	.00	.46	.18	1.00	.72
30	.67	.32	.07	.05	.01	.54	.44	.06	.05	.02	.45	.21	.77	.00	.05	.07	.02	.07	.09	.05	.13	.10	.34	.20	.50	.14	.76	.39	.72	1.00

1 and under the assumption that all other 28 parameters are identically relevant for the index formation, they receive an identical weighting, namely $\gamma_i = \frac{1}{28}$ independent of normalisation and imputation procedures.

The weights in the PCA and AHP procedures are shown as examples in the Tab. 3.

In order to take into account, the fact that only few secondary data are available for some countries in the index calculation, a country-specific weighting factor α is applied in addition to the parameter-specific weightings γ_i. Since the application of imputation procedures in particular leads to a distortion of the results, this weighting factor takes into account that countries with little raw data are devalued. To simplify matters, three country groups are formed: all parameters are fully weighted if more than 20 raw data are available for a country, a weighting of 0.5 is applied if less than 10 data are available, otherwise a three-quarters weighting is applied. Thus applies:

$$\begin{aligned} \alpha &= 1, \quad |X_i| \geq 20, \\ \alpha &= \tfrac{3}{4}, \quad 20 > |X_i| \geq 10, \\ \alpha &= \tfrac{1}{2}, \quad 10 > |X_i| \end{aligned} \tag{35}$$

Tab. 3: left: maximum loadings PCA, weights (MinMax normalisation, kNN imputation), right: weights using the AHP method

X_i	Max loading	Weight	X_i	Weight
3	0.358	0.042	3	0.021
4	0.182	0.021	4	0.021
5	0.565	0.067	5	0.051
6	0.286	0.034	6	0.040
7	0.162	0.019	7	0.040
8	0.212	0.025	8	0.031
9	0.291	0.034	9	0.048
10	0.293	0.035	10	0.040
11	0.273	0.032	11	0.036
12	0.258	0.031	12	0.035
13	0.386	0.046	13	0.032
14	0.256	0.030	14	0.030
15	0.519	0.061	15	0.032
16	0.238	0.028	16	0.048
17	0.248	0.029	17	0.048
18	0.411	0.049	18	0.048
19	0.216	0.026	19	0.025
20	0.322	0.038	20	0.024
21	0.245	0.029	21	0.024
22	0.262	0.031	22	0.024
23	0.173	0.020	23	0.030
24	0.498	0.059	24	0.050
25	0.273	0.032	25	0.050
26	0.164	0.019	26	0.024
27	0.433	0.051	27	0.026
28	0.474	0.056	28	0.031
29	0.162	0.019	29	0.045
30	0.304	0.036	30	0.045

In addition to the weighting of the parameters, the question of how they are aggregated to create a comparative index must be answered. Aggregation functions are additive, multiplicative or other methods of combining the individual indicators into an aggregated index. Depending on the indicators used in terms of compensability, independence and the standardisation method used, aggregation procedures can be excluded (Bjerre et al., 2019; OECD, 2020b). An additive aggregation function is most frequently used, i.e. the summation with γ_i weighted indicators X (OECD, 2020b, p. 109):

$$\text{Indexvalue} = \sum_i \gamma_i x_i \tag{36}$$

In reality, indicators can cancel each other out, i.e., compensate for each other. The weightings that are considered to be the importance of the indicators can thus also cancel each other out, which can lead to several problems (Greco et al., 2019, pp. 75 ff.). However, the above-mentioned disadvantage of the compensability of the indicators can lead to undesired effects. To avoid this as far as possible, geometric methods can be used:

$$\text{Indexvalue} = \prod_i x_i^{\gamma_i} \tag{37}$$

A multiplicative approach can also have compensatory effects, but these are much smaller (OECD, 2020b, p. 32). Combinations between additive and geometric models are also possible and are used for the present purpose.

The index values determined can then be ranked using a ranking procedure in the sense of a “ranking by points”. Non-linear ranking procedures (e.g. according to Condorcet or Borda rules, which carry out pairwise comparisons and lead to a ranking) are not considered in this article (Greco et al., 2019, p. 77).

In order to examine the introduced component model and the parameters for usefulness, a composite index is formed with the help of the weighting and aggregation procedures outlined above, which is used as the basis for the robustness analysis. It is important to mention that there is no golden rule on how to weight and aggregate, and in the further development of indices there are numerous known examples that the procedures can also change in the evolution of indices.

A digital sovereignty index (DSI) for a state can thus be formed as follows:

$$\begin{gathered}
\text{DSI} = \alpha\,(x_1 x_2) \sum_{i=3}^{30} \gamma_i x_i, \\
\sum_{i=3}^{30} \gamma_i = 1, \quad 0 \le \gamma_i \le 1, \quad \gamma_{1,2} = \frac{1}{2}, \\
X = X_n = \begin{pmatrix} x_{n1} \\ x_{n2} \\ \vdots \\ x_{30m} \end{pmatrix}, \\
x_{nm} \in \mathbb{R}, \quad n, m \in \mathbb{N}.
\end{gathered} \tag{38}$$

3.6 Verification, Validation and Robustness

Depending on the use of different normalisation, imputation, weighting and aggregation procedures, different index values or the resulting rankings of the states are produced, as shown in the Fig. 7.

An analysis of variance can identify the best combination of methods. For the data used here, this is simply normalised raw data, mean imputation and equal weighting. In addition to an optimal result through the analysis of variance, this is to be understood in a particularly positive way, as the data thus remain largely unbiased and their weighting is simple.

To validate the index for digital sovereignty, it is compared with other existing indices. In addition to an Economic Forum Index (EFI), the following indices are used for comparison (Miller et al., 2021) as well as sustainable indices in the sense of economically, socially and ecologically relevant indices (Hampel et al., 2016): Food Safety Index (FSI), Better Life Index (BLI), Economic Freedom Index (EFI), Happy Planet Index (HPI), Environmental Performance Index (EPI). In addition and separately, the Digital Dependence Index (DDI), which measures the digital dependence of countries, is compared (Mayer and Lu, 2022).

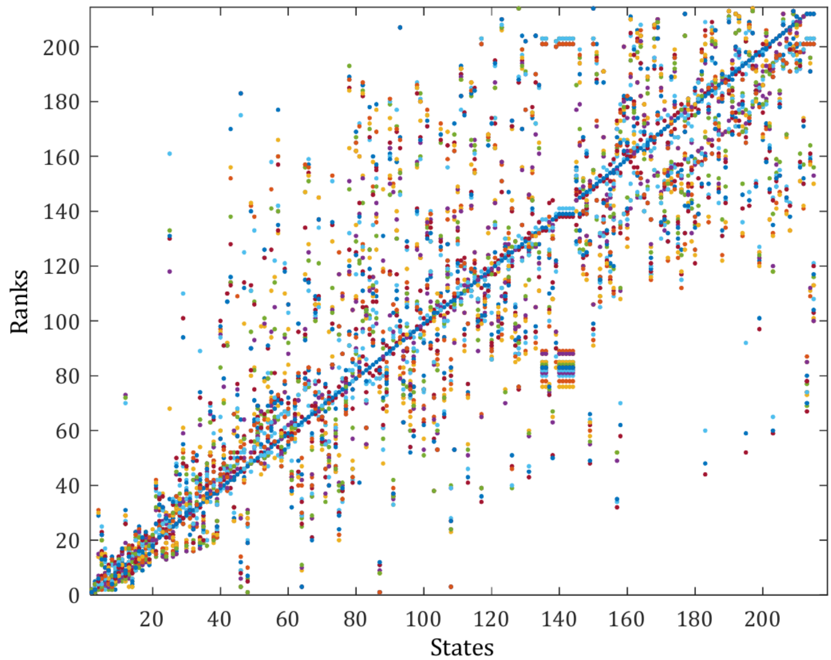

Fig. 7: All states, ranks: sorted by rank, mean imputation, additional ranks of other permutations

Tab. 4: Sum and mean variance calculation

	Raw			MinMax		
	PCA	**AHP**	**equal**	**PCA**	**AHP**	**equal**
Sum	25,059.50	25,907.50	24,969.25	62,177.00	63,138.50	62,821.00
Mean	117.10	121.06	116.68	290.55	295.04	293.56
Rank sum	2	3	1	7	9	8
Rank mean	2	3	1	7	9	8
	MN = 0			**MN = 0, StD = 1**		
	PCA	**AHP**	**equal**	**PCA**	**AHP**	**equal**
Sum	40,583.50	49,113.50	47,897.00	97,503.00	110,100.00	100,745.00
Mean	189.64	229.50	223.82	455.62	514.49	470.77
Rank sum	4	6	5	10	12	11
Rank mean	4	6	5	10	12	11

Focusing on the DSI, it becomes graphically clear that there are linear relationships to the FSI and BLI indices, but not to the other indices. The FSI describes the affordability, availability and quality of food security for 113 countries on the basis of 58 individual indices. The FSI's individual indices largely do not overlap with the parameters of the DSI, and both indices show a high correlation with $R^2 = 0.86$. With the BLI, the OECD assesses elements of quality of life such as the income situation of households, living conditions, education, environment, governance and also security within the framework of the Better Life Initiative (OECD, 2020c). Extensive overlaps with the DSI can be identified, which are also shown in the regression analysis with $R^2 = 0.77$. When focusing on EU states, the degree of determination remains largely identical ($R^2 = 0.79$). This confirms a linear dependence of the DSI on the BLI.

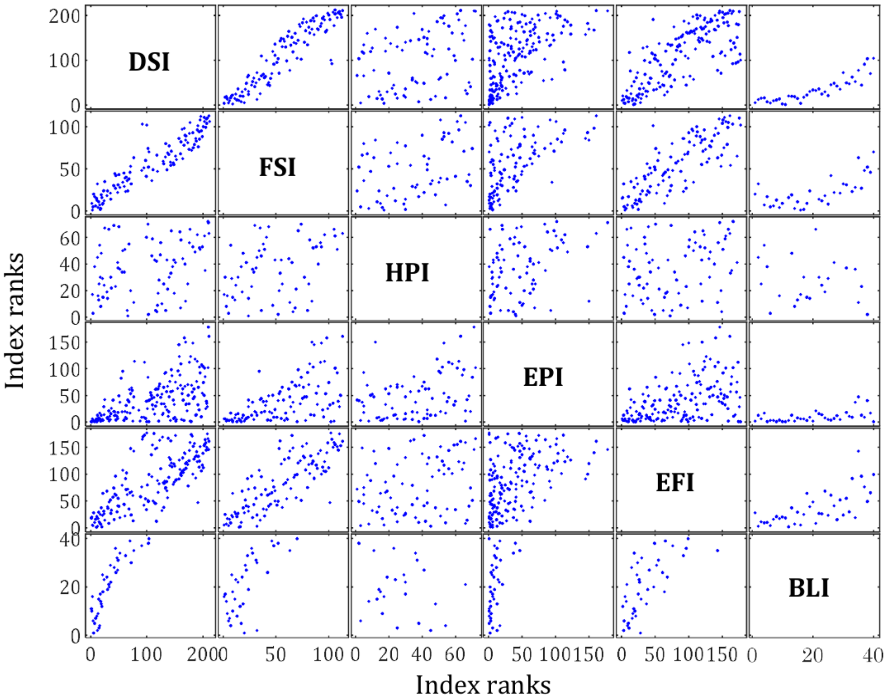

Fig. 8: Scatter plot index comparison ranks, all states

Due to comparable assessment bases, the BLI is suitable in terms of a verification of the selection of the correct parameters for the DSI, but the FSI is suitable as a comparative index for a validation of the correct representation of reality by the DSI.

The Digital Dependence Index (DDI) takes on particular relevance, as it measures the extent to which states act in digital dependence on other states, based on the G20 states as well as Kenya, Israel, Estonia and Singapore. The linear correlation of the ranks of the DSI and DDI is initially not significant ($R^2 = 0.16$). Because some of the main components or sub-indices are similar, it is advisable to analyse them. If there are significant correlations, a significant part of the DSI can be validated. Since the DDI focuses on digital dependencies and does not measure digital sovereignty as a whole, it is recommended not to compare the indices as a whole, but only their sub-indices.

Tab. 5: Coefficient of determination DDI and DSI (main components)

	Δ_2	Δ_3	$\Delta_2 + \Delta_3$	DSI
DDI	0.72	0.26	0.62	0.16

Special attention is thus paid to the main component Δ_2 (KET) with a coefficient of determination of 72%, which also affects the sum of main components 2 and 3 of the DSI.

The main component Δ_3 (technological sovereignty) only has a coefficient of determination of 26%, which can, however, be significantly increased to 56.7% by excluding outliers.

Due to the significance of the regression results, the DSI can be validated by the DDI for two of the three main components.

The verification of the DSI by the BLI and the validation of selected main components of the DDI and in sum with the FSI show that the component model proposed in this article as well as the selection of the 30 parameters seem suitable to measure digital sovereignty.

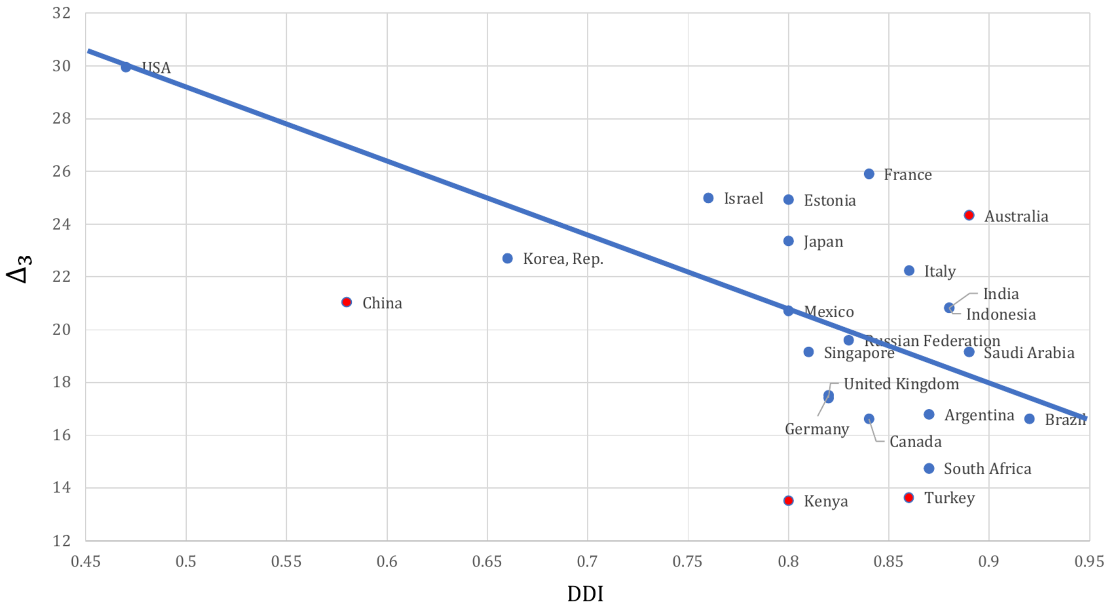

Fig. 9: Regression analysis DDI and Δ_3 without outliers (red)

4 CONCLUSIONS

Digital sovereignty of states is a new concept that has been widely discussed, influencing political and economic actions and creating a proxy discussion on whether dependence on other states' resources affects one's own state sovereignty. There is also no uniform, scientific definition. Although the individual terms "digital" and "sovereignty" as well as elements of digital sovereignty are described in a variety of scientific ways, a synthesis and a common understanding that forms the basis for joint action do not exist. A first qualitative proposal was published by the author in November 2021 and is ready for scientific discourse. The proposal is based on a historical analysis of the individual terms, which was brought together by means of synthesis. The proposal is derived from the understanding of sovereignty of European states and presupposes a free, liberal, democratic basic order. With this proposal, isolationism, autarky and autocracy are considered to prevent digital sovereignty, even if (semi-) autocratic states partly exhibit a high degree of digital sovereignty through protectionism. To concretise the qualitative definition, a hierarchical component model was derived in this article that consists of 3 main components and 10 subcomponents. The subcomponents can each be determined metrically with at least one of a total of 30 parameters from secondary data. The data are subject to different scales and have to be normalised for further consideration. Missing data can be estimated by suitable imputation procedures if necessary. However, normalisation and imputation significantly change the raw data, which must be taken into account in further analyses.

The coefficient of determination can be used to identify linear correleations between the parameters. Redundancies are evident in the evaluation of digital sovereignty with the 30 recommended parameters, since more than 20 pairwise comparisons of the parameters have a coefficient of determination of $\geq 50\%$, but it is suggested by the author that no parameter be completely replaced by the others to prevent information loss. Thus, all parameters should be considered in further analyses. Through the 30 parameters, a metric basis for the assessment of digital sovereignty can be created for each state.

Through equal weightening and a mix of additve and geometric aggregation a composite index is suggested and a basis for verification and validation and the calculated index can be verified and described as valid, because as good correlations can be found with the Better Life Index, which has similar parameters. Various methods are used to validate the model and the index formation. In addition to a visual plausibility check, it can be shown that it, or its main components, have significant correlations with existing indices such as the Food Safety Index and the Digital Dependency Index. It thus maps well the reality, which is formulated as a basis through the definition of the new term with this and an author's previous work, but which can be derived from the previously mentioned indices.

This article can therefore fill the research gap of developing a model that makes digital sovereignty measurable. This can be the basis for quantitatively measuring the digital sovereignty of states and identifying levers with which it can be strengthened. In addition, the effectiveness of the levers can be assessed through simulations, as the effects on digital sovereignty can be measured by changing individual parameters. Therefore, the model can serve as a decision support system for political or economic decision makers who want to strengthen the digital sovereignty of states.

5 REFERENCES

Abbate, J. 2017. What and Where is the Internet? (Re)defining Internet Histories. *Internet Histories*, 1 (1–2), 8–14. DOI: 10.1080/24701475.2017.1305836.

Barnett, M. A. 2017. *Quantifying Sovereignty: A New Way to Examine an Essential Concept* [online]. Master's thesis. Harvard Extension School. Available at: https://dash.harvard.edu/handle/1/33825923. [Accessed 2020, April 12].

Bauernhansl, T., ten Hompel, M. and Vogel-Heuser, B. (eds.). 2014. *Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung, Technologien, Migration*. Wiesbaden, Springer Vieweg.

Becker, S. O., Hornung, E. and Woessmann, L. 2011. Education and Catch-up in the Industrial Revolution. *American Economic Journal: Macroeconomics*, 3 (3), 92–126. DOI: 10.1257/mac.3.3.92.

Bjerre, L., Römer, F. and Zobel, M. 2019. The Sensitivity of Country Ranks to Index Construction and Aggregation Choice: The Case of Immigration Policy. *Policy Studies Journal*, 47 (3), 647–685. DOI: 10.1111/psj.12304.

Bodin, J. 1994. *Über den Staat: Nachdruck*. Stuttgart: Reclam.

Bublitz, H. 2014. Macht. In Kammler, C., Parr, R., Schneider, U. J. and Reinhardt-Becker, E. (eds.). *Foucault-Handbuch*, Chapter 20, 237–277. J. B. Metzler, Stuttgart. DOI: 10.1007/978-3-476-01378-1_38.

Cerny, P. G. 2010. The Competition State Today: From Raison d'État to Raison du Monde. *Policy Studies*, 31 (1), 5–21. DOI: 10.1080/01442870903052801.

Dahlman, C. T. 2009. Sovereignty. In Gallaher, C., Dahlman, C. T., Gilmartin, M., Mountz, A. and Shirlow, P. (eds.). *Key Concepts in Political Geography*, Chapter 2, 28. DOI: 10.4135/9781446279496.

DeNardis, L., Cogburn, D. L., Levinson, N. S. and Musiani, F. (eds.). 2020. *Researching Internet Governance: Methods, Frameworks, Futures.* Cambridge (MA): MIT Press.

DeNardis, L. and Raymond, M. 2013. Thinking Clearly About Multistakeholder Internet Governance. In *GigaNet: Global Internet Governance Academic Network, Annual Symposium 2013*. DOI: 10.2139/ssrn.2354377.

Fahrmeir, L., Kneib, T. and Lang, S. 2009. *Regression: Modelle, Methoden und Anwendungen*. 2nd ed. Berlin, Heidelberg: Springer.

Fahrmeir, L. and Tutz, G. 2001. *Multivariate Statistical Modelling Based on Generalized Linear Models.* 2nd ed. New York, Berlin, Heidelberg: Springer.

Greco, S., Ishizaka, A., Tasiou, M. and Torrisi, G. 2019. On the Methodological Framework of Composite Indices: A Review of the Issues of Weighting, Aggregation, and Robustness. *Social Indicators Research*, 141 (1), 61–94. DOI: 10.1007/s11205-017-1832-9.

Hampel, D., Issever Grochová, L., Janová, J., Kabát, L. and Střelec, L. 2016. Sustainable Development in the EU. In Huber, P., Nerudová, D., Rozmahel, P. (eds.). *Competitiveness, Social Inclusion and Sustainability in a Diverse European Union: Perspectives from Old and New Member States*, Part I, 47–73. Cham, Springer.

Janová, J., Hampel, D. and Nerudová, D. 2019. Design and Validation of a Tax Sustainability Index. *European Journal of Operational Research*, 278 (3), 916–926. DOI: 10.1016/j.ejor.2019.05.003.

Juhász, R., Squicciarini, M. P. and Voigtländer, N. 2020. *Technology Adoption and Productivity Growth: Evidence from Industrialization in France*. NBER Working Paper. DOI: 10.3386/w27503.

Kagermann, H., Lukas, W.-D. and Wahlster, W. 2011. Industrie 4.0: Mit dem Internet der Dinge auf dem Weg zur 4. industriellen Revolution. *VDI Nachrichten*, 13, 2.

Kaloudis, M. 2021. Digital Sovereignty – European Union's Action Plan Needs a Common Understanding to Succeed. *History Compass*, 19 (12). DOI: 10.1111/hic3.12698.

Kaloudis, M. 2022. Sovereignty in the Digital Age – How Can We Measure Digital Sovereignty and Support the EU's Action Plan? *New Global Studies*, 16 (3), 275–299. DOI: 10.1515/ngs-2021-0015.

Kaufmann, D. and Kraay, A. 2020. *World Governance Index* [online]. Available at: `https://info.worldbank.org/governance/wgi/`. [Accessed 2020, December 20].

Kukkola, J., Ristolainen, M. and Nikkarila, J.-P. (eds.). 2019. *GAME PLAYER: Facing the Structural Transformation of Cyberspace*. Puolustusvoimien tutkimuslaitos, Julkaisuja 11.

Lafortune, G. and Ubaldi, B. 2018. *OECD 2017 OURdata Index: Methodology and Results*. OECD Working Papers on Public Governance No. 30. DOI: 10.1787/2807d3c8-en.

Madiega, T. 2020. *Digital Sovereignty for Europe* [online]. EPRS Ideas Paper. Available at: `https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/651992/EPRS_BRI(2020)651992_EN.pdf`. [Accessed 2022, August 23].

Mayer, M. and Lu, Y.-C. 2022. *Digital Autonomy? Measuring the Global Digital Dependence Structure* [online]. Policy Commons Report. Available at: `https://policycommons.net/artifacts/3184149/digital-autonomy-measuring-the-global-digital-dependence-structure/3982752/fragments/`.

Miller, T., Kim, A. B. and Roberts, J. M. 2021. *2021 Index of Economic Freedom*. Washington, The Heritage Foundation.

Mohabbat-Kar, R., Thapa, B. E. P., Parycek, P. (eds.). 2018. *(Un)Berechenbar? Algorithmen und Automatisierung in Staat und Gesellschaft*. Berlin: Kompetenzzentrum Öffentliche IT.

Mohajan, H. 2019. The First Industrial Revolution: Creation of a New Global Human Era. *Journal of Social Sciences and Humanities*, 5 (4), 377–387.

Montgomery, D. C., Peck, E. A. and Vining, G. G. 2012. *Introduction to Linear Regression Analysis*. 5th ed. Hoboken, NJ: Wiley.

OECD. 2020a. *Digital STRI* [online]. Available at: `https://stats.oecd.org/Index.aspx?DataSetCode=STRI_DIGITAL`. [Accessed 2021, February 4].

OECD. 2020b. *Handbook on Constructing Composite Indicators 2020* [online]. Available at: `https://www.oecd.org/els/soc/handbookonconstructingcompositeindicatorsmethodologyanduserguide.htm`. [Accessed 2021, July 27].

OECD. 2020c. *How's Life?* [online]. Available at: `https://www.oecd-ilibrary.org/content/publication/9870c393-en`.

OECD. 2020d. *Services Trade in the Global Economy* [online]. Available at: `https://www.oecd.org/trade/topics/services-trade/`. [Accessed 2021, January 4].

OECD. 2021. *Government at a Glance 2021* [online]. Available at: `https://www.oecd-ilibrary.org/governance/government-at-a-glance-2021_1c258f55-en`.

Peters, M. A. and Jandrić, P. 2019. Education and Technological Unemployment in the Fourth Industrial Revolution. In Redding, G., Drew, A. and Crump, S. (eds.). *The Oxford Handbook of Higher Education Systems and University Management*, Chapter 24. Oxford University Press.

Pohle, J. and Thiel, T. 2020. Digital Sovereignty. *Internet Policy Review*, 9 (4). DOI: 10.14763/2020.4.1532.

Rhode, B. (ed.). 2020. The Digital Great Game. *Strategic Comments*, 26 (7), iv–vi. DOI: 10.1080/13567888.2020.1846453.

Schwab, K. 2016. *Die Vierte Industrielle Revolution*. München: Pantheon Verlag.

Tomory, L. 2016. Technology in the British Industrial Revolution. *History Compass*, 14 (4), 152–167. DOI: 10.1111/hic3.12306.

van Eck, N. J. 2021. *CWTS Leiden Ranking 2021*. Methodology. Leiden University. DOI: 10.5281/ZENODO.4889279.

Wagner, T., Herrmann, C. and Thiede, S. 2017. Industry 4.0 Impacts on Lean Production Systems. *Procedia CIRP*, 63, 125–131. DOI: 10.1016/j.procir.2017.02.041.

Zandonella, B. 2007. *Pocket Europa: EU-Begriffe und Länderdaten*. 2nd ed. Bonn: Bundeszentrale für politische Bildung.

Zimmer, M. 2008. *Moderne, Staat und Internationale Politik*. Wiesbaden: VS Verlag für Sozialwissenschaften.

AUTHOR'S ADDRESS

Martin Kaloudis, Department of Informatics, Faculty of Business and Economics, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: Martin@kaloudis.de