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Measuring the asymmetry of German society with the German Social Groups Skewness (SGSD) equation – based on Food-Energy-Water data

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Abstract

UNEP stresses the contribution of the individual consumption decisions to the global problems (i.e., loss of biodiversity, climate change, food and water security). These ecological problems are threatening the core of a sustainable development: the Food-Energy-Water-Nexus. Therefore, it will be analyzed how the different social groups of Germany contribute to the German consumption patterns. Seven social groups are selected and differentiated according to their income levels. For this analysis, the *new* German household expenditure survey (EVS) data sets of 2018 are used. *To make the results comparable and independent of the household size of the social group, the equivalence income and expenditures of the social groups are determined. The equivalence data enables to measure the distribution of the household income and its expenditures for food, energy and water.* Additionally, the empirical skewness is defined to determine the asymmetry of the income and consumption expenditures distribution. The *new* skewness equation is developed to analyze the distribution over the various household groups. *Hence, it is possible to define the social asymmetry of the German society.*

Keywords: FEW-Nexus, disposable income, skewness, equivalence scale, Germany

Introduction

The Food-Energy-Water-Nexus as the core of a sustainable development [1] is currently at the center of the global environmental problems, as the UNEP has summarized [2]. The global drought events [3-5] are influenced by climate change [6], which is driven by the rising CO_2 emissions of the energy system [7]. The resulting rise of the Earth temperature affects the global food and water security [8]. The import of virtual water [9] incorporated in the consumed commodities can intensify the water security problems of the exporting nations [9, 10]. The UNEP stresses the contribution of the consumption decisions of the global consumers to the current global problems [11]. And the FAO added to this analysis the concerns about the global water conditions [12].

In the following, we will analyze the contribution of the German household consumption decisions to the overall unsustainable consumption. Adam Smith described the meaning of consumption as follows: “Consumption is the sole end and purpose of all production; and the interest of the producer ought to be attended to only so far as it may be necessary for promoting that of the consumer [13].” Hence, the production of goods and services is dependent on the level of consumption as the aggregate of all economic activity [14], i.e. on the consumption decisions of the households.

Hence, we analyze the German households and their consumption decisions. For our analysis, the German household expenditure survey (EVS) data sets of 2018 were used, which were published in 2020 by the Germany Federal Statistical Office [15, 16]. The following social groups were selected for the analysis: All employed households, the self-employed households, the employees, the unemployed, the retired and student households.

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Equivalence

The starting indicator of the consumption decisions of the household is the earnt income. To compare the income of the different household groups, we have to reckon out the different household sizes of the social groups. The OECD uses the square root scale, proposing to divide household income by the square root of household size, while considering both the "*size of the household* and the *age of its members* (whether they are adults or children) [16].".

Equivalence Data Basis

The OCED square root scale is used to not only make the disposable income comparable, but also the consumption expenditures of the various German households. Table 1 shows the disposable income of private households according to the different income and social groups. In this context, also the income dispersion inspired by John Rawls is calculated: the ratio between the income of the highest income group to the income of the lowest income group (table 1).

Disposable income

Table 1

Equivalised disposable income of private households in Germany, 2018, in € - Neu
according to the square root method of the OECD

Income groups in €	All employed	Self-employed	Employees	Unemployed	Retired	Students
All households	2915	3597	3038	752	1626	801
< 900	741	655	801	812	792	741
900-1300	1093	1086	1094	1043	1065	1059
1300-1500	1286	1290	1285	1279	1287	1272
1500-2000	1528	1510	1529	1501	1516	1515
2000-2600	1856	1857	1856	1835	1848	1838
2600-3600	2307	2336	2304	2227	2282	2211
3600-5000	2944	2940	2945	2826	2885	2767
5000-18000	4753	6255	4568	5805	4665	4273
Rawls dispersion*	6.4	9.6	5.7	7.1	5.9	5.8

Source: Own calculation based on German Federal Statistical Office, 2020, *Dispersion: Ratio of the disposable income of the highest income IEK-STE 2021

As shown, the self-employed households have the highest dispersion (9.6) between the equalized disposable income of the highest income group and the disposable income of the lowest income group of the self-employed households, followed by the unemployed and all employed households (7.1, 6.4). The dispersion decreases for employees to 6.4, and to 5.9 and 5.8 for the retired and student households respectively. The disposable income increases continuously in every social group until the highest income group of 5,000-18,000 €.

Food

Table 2 shows that the dispersion continues to decline for food consumption. The food consumption needs are thus less strongly influenced by the income level.

The highest spread was found for the unemployed households (2.19), followed by the employees, and retired students (2.08 and 2.00 respectively). The group of the all employed, self-employed and retired households show the least difference between the highest and lowest income group (1.87, 1.71, and 1.65 respectively).

Table 2

Equivalised food consumption of private households in Germany 2018
according to the square root method of the OECD

Income groups in €	All employed	Self-employed	Employees	Unemployed	Retired	Students
	Food expenditures €					
All households	231	248	246	112	154	98
< 900	160	184	144	151	156	120
900-1300	156	163	154	166	165	134
1300-1500	163	175	161	219	177	153
1500-2000	178	217	174	228	190	188
2000-2600	196	225	194	313	209	222
2600-3600	226	250	224	308	230	207
3600-5000	261	283	259	321	245	223
5000-18000	300	313	300	331	257	240
Food dispersion*	1.87	1.71	2.08	2.19	1.65	2.00

Source: German Federal Statistical Office, 2020, *dispersion: Ratio of the food expenditures of the highest income group to the food expenditures of the lowest income group of the social group. Italic red numbers own estimation, IEK-STE 2021

The food needs of the retired households are the least influenced by the income level of all analyzed household groups.

Energy

Table 3 shows the distribution of the energy expenditures.

Table 3

Equivalised energy consumption of private households in Germany 2018
according to the square root method of the OECD

Income groups in €	All employed	Self-employed	Employees	Unemployed	Retired	Students
	Total energy expenditure (car and residence) in €					
All households	179	194	190	77	117	58
< 900	110	40	106	102	107	60
900-1300	122	145	118	122	112	80
1300-1500	129	66	125	144	126	87
1500-2000	144	153	144	157	142	122
2000-2600	160	204	156	196	162	131
2600-3600	181	195	179	208	178	135
3600-5000	207	221	206	244	193	178
5000-18000	225	242	223	235	205	187
Energy dispersion*	1.25	1.24	1.17	3.05	1.75	3.25

Source: German Federal Statistical Office, 2015, 2020, *dispersion: Ratio of the energy expenditures of the highest income group to the energy expenditure of the lowest income group of the social group. Italic red numbers own estimation, IEK-STE2021

The dispersion of the energy expenditures shows a divided picture. The social group of all employed households show a very low spread of the energy consumption expenditures between the highest and the lowest income group (1.25), followed by the self-employed (1.24) and the employees (1.17). The dispersion increases steeply to 3.05 for the unemployed households and is a little lower for the students and retired households (3.25 and 1.75 respectively). In terms of energy consumption, there is a social divide between the employed and the not employed households.

Water$_{virtual}$

The expenditures of the German households driving virtual water consumption is more unevenly distributed than the food consumption.

Equivalised virtual water consumption of private households in Germany 2018, in m3
according to the square root method of the OECD

Income groups Average household seize	All employed persons 2.3	Self-employed 2.4	Employees 2.3	Unemployed 1.6	Retired 1.5	Students 1.5
All households	92	102	97	31	62	36
< 900	52	59	47	38	44	39
900-1300	51	58	50	47	51	49
1300-1500	55	63	54	57	57	55
1500-2000	62	67	61	62	66	67
2000-2600	72	82	71	77	76	77
2600-3600	84	92	83	100	90	88
3600-5000	99	105	99	124	107	95
5000-18000	131	144	130	123	137	113
Water dispersion	2.51	2.43	2.74	3.27	3.12	2.87

Source: Own calculation based on German Federal Statistical Office, 2015, 2020, *Dispersion: Ratio of the water consumption of the highest income group to the water consumption of the lowest income group of the social group. Italic red numbers own IEK-STE 2021

The lowest spread is measured for the groups of the self-employed and of all employed households (2.43,

2.51). The spread increases for the social group of all employees (2.74) and the student households (2.87). The highest spread occurs in the social groups of the unemployed and retired households (3.27, 3.12). In a next step, the three expenditure categories food, energy, $water_{virtual}$ are summarized in the $FEW_{virtual}$-Nexus expenditures.

FEW

Table 4 shows that the category of retired households has the lowest dispersion (1.95), followed by the group of all employed households and the students (2.03 and 2.05 respectively). The dispersion is slightly higher for the group of all employees (2.19) and reaches its highest spread in the groups of the self-employed and unemployed households (2.48, 2.37).

Table 4

Equivalised $FEW_{(incl.virtualwater)}$ expenditures of private households in Germany, 2018, in € according to the square root method of the OECD

Income groups in €	All employed	Self-employed	Employees	Unemployed	Retired	Students
All households	503	544	534	220	333	191
< 900	323	283	298	291	307	219
900-1300	329	366	322	335	328	263
1300-1500	346	304	340	420	360	294
1500-2000	383	437	379	446	398	377
2000-2600	427	512	420	587	448	431
2600-3600	490	536	486	616	499	430
3600-5000	568	609	564	690	546	399
5000-18000	656	699	653	690	600	450
Rawls dispersion*	2.03	2.48	2.19	2.37	1.95	2.05

Source: Own calculation based on German Federal Statistical Office, 2012, 2015, 2020,*Dispersion: Ratio of the FEW-nexus expenditures of the highest income group to the FEW expenditures of the lowest income group of the social group. Italic red numbers own estimation, Italic red numbers own estimation, IEK-STE 2021

FreFrequency distribution - the empirical skewness

In the first step, we analyzed the distribution of the disposable income, the energy expenditures, the food expenditures, the virtual water costs, and the $FEW_{virtual}$-Nexus related household expenditures. The empirical skewness is analyzed in the second step to measure the frequency distribution as suggested by Neal and Rosen and Lüthi [17, 18]. For our analysis, we used logarithmic income data – as the UNDP in the HDI [19] – to avoid that extreme data elements have too much of an influence on the skewness results.

The skewness is a statistical key figure, which describes the asymmetry of a probability distribution. The skewness shows how strong the distribution is inclined to the right or to the left. Any non-symmetric distribution is called skewed [20].

The empirical skewness (ES) of Pearson will be calculated using the following equation [20-22]:

$$ES = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{\ln(x_i) - \bar{x}}{s}\right)^3,$$

s = standard deviation

$\bar{x}$ = arithmetic mean

x_i = observed value

The skewness is a measure for the symmetry of the distribution:

- If the empirical skewness is zero, $ES = 0$, then the distribution is completely symmetric.
- If the empirical skewness is negative (negative skew), $ES < 0$, then the distribution of the analyzed logarithmic data sets is skewed to the left. The median is greater than the arithmetic mean. A negatively skewed (also known as left-skewed) distribution is a type of distribution, in the case of which more values are concentrated on the right side (tail) of the distribution graph while the left tail of the distribution graph is longer.
- If the empirical skewness is positive (positive skew), $ES > 0$, then the distribution of the logarithmic income and expenditures is skewed to the right. The median is smaller than the arithmetic mean. A positively skewed (also known as right-skewed) distribution is a type of distribution in which more values are concentrated on the left side (tail) of the distribution graph while the right tail of the distribution graph is longer.
- In the case of skewness, the mean is unequal to the median.

The skewness values can be interpreted as follows [23]:

- If the skewness is 0, the distribution is symmetric.
- If the skewness is between -0.5 and 0.5, the data are approximately symmetric.
- If the skewness is between -1 and -0.5 or between 0.5 and 1, the data are moderately skewed.
- If the skewness is less than -1 or greater than 1, the data are highly skewed.

We start our analysis of the skewness with the disposable income and then we scrutinize the skewness of the FEW-Nexus related household expenditures.

Disposable income skewness

The analysis of the skewness [23] of the *disposable income* of the seven household types shows that the skewness of the disposable income is not symmetric. The income is not evenly distributed. All skewness results are positive.

Table 5

Skewness of selected economic activities of German households 2018

Household groups	Disposable income	Food	Energy	Water	FEW
All employed	0.22486	0.56454	-0.19577	0.62781	0.43884
Self-employed	0.35269	0.15130	-0.89795	0.69508	0.25993
Employees	0.27487	0.46969	-0.10087	0.52564	0.35353
Unemployed	0.58746	-0.48923	-0.58979	-0.03885	-0.37653
Retired	0.30211	0.00503	-0.53877	0.26786	0.04998
Students	0.16224	-0.30630	-0.39221	-0.46015	-0.29964

Source: Own calculations, 2021 IEK-STE 2021

Table 5 shows that the disposable income is positive fairly symmetrical. For most of the households only the distribution of the disposable income of the unemployed households is positive moderately skewed. The distribution of the *food expenditures* does not give a consistent image. The distribution of the food expenditures of the unemployed and students households are negative fairly skewed. The distribution of the food expenditures of the all employed households are positive moderately skewed, whereas the distribution of the self-employed, employees and retired households are positive fairly skewed.

The distribution of the *energy expenditures* presents a different picture. The distribution of all households are negative skewed. The expenditures of the all employed, employees, retired and student households are fairly skewed, whereas the energy expenditures of the self-employed and unemployed households are moderately skewed. The skewness of the *virtual water consumption* is mainly positive skewed except of the student and unemployed households. Both distributions are negative skewed and fairly symmetrical.

Hence, we can define the skewness of the *food-energy-water$_{virtual}$ expenditures* of the German households. The distribution is fairly skewed for all households. The distribution of the FEW-Nexus expenditures of all employed, self-employed, employees and retired households is positively skewed similar to the disposable income, whereas this expenditures of the unemployed and student households are negative fairly skewed.

Interpretation – the SGSD equation

The previous analysis has shown a differentiated picture of the distribution of the income and of the expenditures of the German social groups. In the following, we will summarize the skewness over the selected social groups with the following *German Social Groups Skewness* (SGSD) equation.

$$f\left(S_{GSG}\right) = \int_{j=1}^{J}\left(\frac{1}{n}\sum_{i=1}^{n}\left(\frac{\left(x_i\right)-\bar{x}}{s}\right)^3\right),$$

j =household groups, i=expenditures, income

Using this equation the social asymmetry of German society can be made visible and comparable.

A symmetric distribution can also be described by the following function:

$$f(x_{symmetric}^{Skewness}) = \int_1^6 \left(-0.0003\cdot x^3 + 0.0039\cdot x^2 - 0.0172\cdot x + 0.0229\right) dx \approx 0$$

The skewness of the disposable income over all analyzed household groups can be described as follows:

$$f(x_{Income}^{Skewness}) = \int_1^6 \left(0.0031\cdot x^4 - 0.05429\cdot x^3 + 0.2837\cdot x^2 - 0.4689\cdot x + 0.4744\right) dx = 1.7713$$

In addition, the skewness of the food, energy, water$_{virtual}$ expenditures can be described by the following four equations:

Food

$$f(x_{Food}^{Skewness}) = \int_1^6 \left(-0.0052\cdot x^4 + 0.0755\cdot x^3 - 0.3747\cdot x^2 + 0.4777\cdot x + 0.506\right) dx = 0.3933$$

Energy

$$f(x_{Energy}^{Skewness}) = \int_1^6 \left(0.0488\cdot x^4 - 0.697\cdot x^3 + 3.4258\cdot x^2 - 6.6681\cdot x + 3.6675\right) dx = -2.6083$$

Water

$$f(x_{Water_{virtual}}^{Skewness}) = \int_1^6 \left(-0.0364\cdot x^4 + 0.5079\cdot x^3 - 2.4473\cdot x^2 + 4.5092\cdot x - 1.9239\right) dx = 1.73229$$

FEW

$$f(x_{FEW_v}^{Skewness}) = \int_1^6 \left(-0.0174\cdot x^4 + 0.2504\cdot x^3 - 1.2219\cdot x^2 + 2.1616\cdot x - 0.7616\right) dx = 0.4605$$

Hence, we measure the skewness deviation over the various German household groups in relation to a symmetric distribution. We measure the area between the symmetric line of zero and the line of the six economic indicators.

In the case of a symmetric distribution, the value is zero. In the given case, however, the energy expenditures show the highest deviation from a symmetric deviation, followed by the disposable income, the water$_{virtual}$ consumption, the FEW-Nexus expenditures and the food expenditures. The data shows that the food expenditures are the least affected by the earnt income and the social position of the household - i.e., people have to eat irrespective of the social position and the income level.

Conclusion

The analysis shows that the German social groups contribute differently to the consumption of the German households. The analysis further shows that the consumption expenditures for food, energy and watervirtual of the German households increase with rising income continuously without a saturation point before the highest income group.

The analysis has also shown that the skewness of the distribution of the FEW-Nexus expenditures of the German households can be summarized through the developed new SGSD equation. The SGSD equation makes it possible to measure the social asymmetry of

society based on its key characteristics and distinctive features: Income and expenditures.

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