Schlör et al. Energy, Sustainability and Society (2016) 6:34
DOI 10.1186/s13705-016-0100-1

Energy, Sustainability and Society

ORIGINAL ARTICLE Open Access

Analysing Gordon's trade-off by adapting Thurow's approach of pure public good to the German energy sector

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Abstract

Background: We analyse Gordon's trade-off by adapting Thurow's approach of pure public good using the example of the German energy sector which is in a transition process to a low-carbon sustainable energy system (Energiewende). The income distribution and the energy expenditures of households are interpreted as public goods. Their distribution is measured with the Atkinson index, which determines how the quality of life, as measured in income and energy expenditures, is distributed among society.

Methods: We use the disaggregated consumption and income for 39.409 million German households. Our socio-economic analysis focuses on six household types.

Results: Our analysis shows that among German households, energy expenditures are more equally distributed than private consumption in general and income. The rather (but by far not completely) equal distribution of energy expenditures confirms Smil's finding that energy is the universal currency (Sen, On Economic Inequality, 1973) for people's welfare and can be seen as an indicator of the basic needs of households irrespective of household income. Nevertheless, low-income households have to spend a higher share of their income on energy to avoid energy poverty. Further price increases could lead to an unequal distribution and rising energy poverty.

Conclusions: The socio-economic conditions of society and its energy sector have to be addressed in a transition processes. Energy poverty constitutes an infringement of the sustainability concept. If society does not take distributional effects into account, the transition process itself could be jeopardized.

Keywords: Gordon's trade-off, Public goods, Atkinson index, Sustainable energy system

Background

Sustainable development is a process in which society and political decision makers have to balance ecological, economic, and social targets. Equal rights and equality in terms of "equivalent living conditions" (Article 74 German constitutional law) are key elements of the social pillar of sustainability.

Gordon's trade-off

Modern societies are confronted with Gordon's[1] trade-off [14], that is to say, their democratic constitutions guarantee all citizens the same political rights and obligations [27]. However, this democratic guarantee of equality is contrasted with economic inequality as the result of economic market forces which produce unequal income, consumption opportunities, and life prospects [14, 29]. Individuals have the same political rights, but their social participation opportunities correlate not only with these rights but also with their individual success in economic processes [7, 14]. Individuals are affected by two institutions—economic market processes and the constitution—which grant different positions in society according to their specific institutional rules.[2] The constitutions of democratic systems grant their citizens rights without any preconditions, whereas their position within the economic market system is based on their success in this system [27]. Economic institutions can "generate substantial disparities among citizens in living standards and material welfare [14]."

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The political institutions of the government are, on the one hand, confronted with and have to manage a socio-economic democratic system that guarantees the same rights to each individual without any preconditions, and on the other hand, with an economic system in which individual success is based mainly on individual performance. Society and its government have to find a way to balance the trade-off between these two principles to avoid political tensions between social groups and households, because of the trade-off between the conflicting principles of society's democratic institutions and those of the economic market system: "At some points along the way, society confronts choices that offer somewhat more equality at the expense of efficiency or somewhat more efficiency at the expense of equality. In the idiom of the economist, a trade-off emerges between equality and efficiency [14]." Political projects such as the German Energiewende can be implemented more easily if social justice is taken into account, i.e. the distribution of the material welfare of society [26].

Hence, we can summarize that Gordon's trade-off is the result of the relations between two competing institutions (the democratic system and the economic market system). This competition is confirmed by Stiglitz, who illustrates that these conflicts arising from the trade-off are not the "result of the forces of nature, of abstract forces. [They are] the result of government policies that shape and direct the forces of technology and markets and broader societal forces [36]." In other words, Gordon's trade-off is politically shapeable by the institutions of society and has to be analysed so that this management process can avoid mismanagement on the basis of flawed data.

The need for such an analysis is also stressed by Acemoglu and Robinson [1], who argue "that economic analysis needs to identify, theoretically and empirically, conditions under which politics and economics run into conflict, and then evaluate policy proposals taking this conflict and the potential backlashes it creates into account [2]." These conflicts could endanger policy conceptions such as the German energy transition [13].

Our analysis tries to reveal societal obstacles in the socio-economic conditions of society which have to be addressed in transition processes and will show the necessity of political discourse concerning Gordon's trade-off, because transition processes are not only technical problems but increasingly also socio-economic problems that have to be solved. No one in society can escape from these unsolved problems. Hence, we will analyse Gordon's trade-off in the context of Thurow's theory of public goods.

Thurow—distribution of public goods

Private and public goods

The idea of public goods was developed in 1954 by Samuelson in his paper "The Pure Theory of Public Expenditure" [23]. He explains the characteristics of a public good: "that each individual's consumption of such a good leads to no subtraction from any other individual's consumption of that good [23]." Public goods "can be enjoyed by everyone and from which no one can be excluded [24]." Hence, we can classify the private and public goods consumed by households [10] and needed for the well-being of households [17] into four major categories [10] (Table 1).

In the case of private goods, the use of such a good by one consumer excludes other consumers from consuming it (i.e. food). In contrast, a dike is a pure public good, because everyone behind it is protected. A club good [11, 28] refers to, for instance, the use of a gym. If the monthly fee is paid, everyone in the gym may use the equipment. A congested road is an impure public good—no one can be excluded from the use of the road, but there will be rivalry in using the road in the case of congestion [17].

Thurow's public good approach

Income distribution The distribution of income was already interpreted as a pure public good by Thurow in 1971 [39], because every individual is confronted with the same distribution of income. No individual can be excluded from the advantages and disadvantages of a given distribution of income, and there is also non-rivalry in the consumption of the advantages and disadvantages [37, 40] of a given distribution of income [39]. Every individual is confronted with the same distribution of income, because as Joseph Stiglitz explains: "Widely unequal societies do not function efficiently and their economies are neither stable nor sustainable … there comes a point when inequality spirals into economic dysfunction for the whole society [37]." Everyone needs a functioning society to sustain their social position [37]. That is to say, the distribution of income is a pure public good [39] which sustains the functioning of society. It functions like a dike to stabilize the socio-economic system.

Energy distribution We will enlarge Thurow's approach of a public good by interpreting not only the income distribution of German households but also the distribution of their energy expenses as a public good, because the

Table 1 Classification of goods

		Exclusion	
		Yes	No
Rivalry	Yes	Pure private good	Impure public good
	No	Club good	Pure public good

Source: D. Brümmerhoff, [10]

participation of all households in the energy system is an important factor in the success of any country's economy. The energy system is a dike for the socio-economic system which needs a competitive infrastructure. We therefore also interpreted the performance of the energy system as a public good for society, because no individual can be excluded from the advantages or disadvantages of the energy system and there is also non-rivalry in the consumption of the advantages or disadvantages of the energy system.

Hence, we will expand Thurow's idea of a pure public good by including household energy consumption as a parameter for the quality of the German energy system. In the following, the distribution of the two public goods—income and energy system—will be analysed with the Atkinson index on the basis of the German household expenditure survey (EVS) database.

Methods

Atkinson index

The index is based on social theories [5] and regards society as "a cooperative project for the mutual [5]" benefit of all members of society.

The Atkinson index is a normative distribution measure. The index is based on a social welfare function, which implies diminishing marginal utility of income [5, 15]. The index thereby assumes additive social welfare, which is the sum of the individual utility of society members. This concept is based on utilitarian individual philosophy [15]. In this philosophy, the welfare of the other members of society is not part of the individual utility function [5]: Each individual simply maximizes his own utility and does not care about the other individuals. The welfare of the individual is measured independently of the income of other individuals [5, 15]. Hence, the level of possible energy consumption is based on the net income, and energy consumption is part of the social welfare function (SWF), as the following definition of the welfare function shows:

$$\begin{aligned} &\mathrm{SWF} = \sum_{i=1}^{n} U(Y(PC(EC)_i),\ \mathrm{Y} = \text{income},\\ &\mathrm{U} = \text{utility level},\ \mathrm{n} = \text{number of households}\\ &\mathrm{EC} = \text{energy consumption},\\ &\mathrm{PC} = \text{total private consumption} \end{aligned} \tag{1}$$

In our theoretical approach (utilitarianism), an "outside observer" has to compare the individual members of society with each other. His instrument is the Atkinson index [15]. The Atkinson index calculates how society can assess the distribution of individual income and consumption expenditures between the different income classes of the social groups.[3] The index defines maximum inequality with 1 and maximum equality with 0 [26] and fulfils six mathematical axioms thus allowing it to measure inequality [26].

The Atkinson index has a specific feature for calculating distribution, namely the epsilon parameter ε [3, 4]. The epsilon parameter of Eq. (1) "defines how sensitively the Atkinson index should interpret inequalities [25]." The value ranges from zero to infinity. If society does not give any consideration to the distribution of income, then the value is zero (low inequality aversion). If society cares only about the lowest income group, then the value moves towards infinity (high inequality aversion).[4] "The larger epsilon is, the more strongly the Atkinson index reacts to inequalities [27]." Epsilon can therefore represent the inequality aversion of society and can be interpreted as the mathematical parameter of Gordon's trade-off.

$$\begin{aligned} \text{Gordon's Trade-off} &= \frac{\text{Social Equity}}{\text{Economic Efficiency}}\\ &= \text{Inequality Aversion}\\ &= \text{Epsilon Parameter of Atkinson Index} \end{aligned} \tag{2}$$

With the determination of the epsilon parameter, Gordon's trade-off becomes measurable by the Atkinson index. Epsilon relates two institutions to each other: the societal trade-off between social equality based on a democratic constitution and market economic efficiency. Researchers, social stakeholders, or legislators can define the social meaning of inequality for socio-economic development and can define Gordon's trade-off by the epsilon parameter. In a political discourse, society can develop a social view of its own understanding of how individuals treat and see each other in society which can also be expressed in the tax system. Epsilon confronts a society with its self-assessment as a just, fair society but also as an efficient market economy [25, 27].

We use the Atkinson index to determine the distributional effect of gross income, net income, private consumption, and energy expenditures [3]. The value of the Atkinson index is Thurow's public good. It defines the distribution of income and energy expenditure and the shape of the dike which prevents economic and social distortions of the socio-economic system.

For our analysis, we use the modified Atkinson index ($\mathrm{AIX_{type}}$) to analyse the inequality of these issues:

$$\begin{aligned} \mathrm{AIX_{type}} &= 1 - \left[\sum_{i=1}^{n} \left(X_{i,type}\overline{X_{\mathrm{type}}}\right)^{1-\varepsilon} f_{i,type}\right]^{\frac{1}{1-\varepsilon}},\ X\\ &= Y^G, Y^N,\ \mathrm{PC},\ E,\ EK,\ EW,\ \text{for } \varepsilon \neq 1. \end{aligned} \tag{3}$$

$$\mathrm{AIX}_{\mathrm{type}} = 1 - \exp\left[\sum_{i=1}^{n} f_{i,type} \log_e X_{i,type} \overline{X_{\mathrm{type}}}\right],\ \mathrm{X} = \mathrm{Y}^G, \mathrm{Y}^N,\ \mathrm{PC},\ E,\ EK,\ EW,\ for\ \varepsilon = 1 \quad (4)$$

$Y^G_{i,\mathrm{type}}$ represents gross income of individuals, $Y^N_{i,type}$ the net income of individuals, $PC_{i,type}$ consumption expenditure, $E_{i,type}$ energy consumption expenditure, $EW_{i,\mathrm{type}}$ residential energy consumption expenditure, $EK_{i,type}$ car energy consumption expenditure in the i^{th} income range (n sum of the income classes) in the household type (singles, singles with child(ren), couples, couples without child(ren), couples with child(ren)), $f_{i,\mathrm{type}}$ is the proportion of the population in the particular household type with income in the i^{th} income range, $\overline{X}_{\mathrm{type}}$ is the mean household value for six income and expenditure issues (Y^G, Y^N, K, E, EK, EW) of the household types, and the epsilon parameter (ε) is the same for all groups.

Database—German household expenditure survey data

The German household expenditure survey (EVS) provides data sets on German economic life and the consumer behaviour of private households [34]. Every 5 years, the Federal Statistical Office questions a selection of German households (0.2% of all German households) about their income, expenditures, assets, consumer goods, and residential situation. The 2008 survey was the tenth survey, following surveys in 1962/63, 1969, 1973, 1978, 1983, 1988, 1993, 1998, 2003 [16, 35]. The EVS for 2008 was published in 2011 [31, 32]. The EVS for 2013 was not published in 2015. The EVS data sets provide an overview of the social conditions and socio-economic development of the population in Germany. The data sets are important not only for German social politics but also for all other socio-economic fields of politics [33].

Private households are the central object of investigation in the framework of the EVS.

Our analysis focuses on the following household types:

1. Single households
2. Single households with child(ren)
3. Couples
4. Couples without child(ren)
5. Couples with child(ren)
6. Other households[5]

In our model, we consider all 39.409 million households which took part in the EVS survey, of which 15.537 million (30.1%) are single households, 1.339 million are single households with child(ren) (2.6%), and 17.381 million are couples (33.7%) living in one household, while 11.441 million of the couples households have no children (22.2%) and 5.940 million of the couples households have child(ren) (11.5%). We also consider the 5.152 million as other households ("sonstige Haushalte").

The following table shows how German households are distributed among social groups and income groups. We analyse nine income classes as Table 2 shows.

The table shows the distribution of the households over the nine income classes. The relatively largest group of all households (25.8%) is the income class € 2600–€ 3600, whereas within the single households, the income class € 900–€ 1300 has the largest relative proportion (22%). Within the single households with child(ren), the largest relative grouping (26.1%) is the income class € 1500–€ 2000, while couples have the biggest share (25.1%) in the income class of € 2600–€ 3600 and couples without children have the highest share (24.9%) in the income group of € 2600–€ 3600. Couples with child(ren) have the biggest share (28.4%) in the income group of € 3600–€ 5000. Nearly one third of the other households (29.3%) belong to the highest income group (€ 5000–€ 18,000).

Our paper measures the distribution of the public goods (income distribution and energy system) with the Atkinson index [3, 4].

In the first step, we analyse the first part of Gordon's trade-off, i.e. the success of the household groups in the economic process, i.e. the income and consumption expenditures of the different household types.

Results

Real distribution

Disposable income of private households according to their social position

Our analysis is focused on five household types (single households, single households with child(ren), couples, couples without child(ren), couples with child(ren)), which are part of the group of all households. We analyse the real distribution of income, of consumption, and of energy expenses. In the first step, we analyse the dispersion of income [12, 18–21, 38], consumption, and energy use. We define dispersion as the ratio of the income, consumption, and energy expenditures of the highest income group to the average household of the social group.

Monthly gross income Couples without children achieved the highest average monthly gross income in 2008 (€ 9222), followed by other households (€ 9152) and couples (€ 9136). Singles and couples with child(ren) achieved nearly the same level of gross income (€ 9083, € 9037), whereas the gross income of singles with children in the highest income group is significantly lower (€ 7990).

The dispersion of the gross income varies significantly between the household types. We can identify three major groups: The highest dispersion is found in the single households group (4.14, 3.43). The second group

Table 2 Distribution of households 2008

Distribution of German households among the different household types and income groups									
	All	Under 900	900–1300	1300–1500	1500–2000	2000–2600	2600–3600	3600–5000	5000–1800
Number of households in 100									
Single	15,537	3246	3411	1499	3170	2011	1286	589	325
Single with child(ren)	1339	40	335	157	350	232	136	58	31
Couples	17,381	119	609	504	1862	2883	4363	3742	3299
Couples sine	11,441	103	547	421	1476	2234	2854	2056	1751
Couples with	5940	16	62	82	386	648	1509	1687	1548
Other households	5152	32	159	112	425	541	1020	1354	1509
Total	39,409	3524	4964	2663	7244	8008	10,148	8132	6954
Proportion of the social group in all households in % of total households									
Single	39.4	92.1	68.7	56.3	43.8	25.1	12.7	7.2	4.7
Single with child(ren)	3.4	1.1	6.7	5.9	4.8	2.9	1.3	0.7	0.4
Couples	44.1	3.4	12.3	18.9	25.7	36.0	43.0	46.0	47.4
Couples sine	29.0	2.9	11.0	15.8	20.4	27.9	28.1	25.3	25.2
Couples with	15.1	0.5	1.2	3.1	5.3	8.1	14.9	20.7	22.3
Other households	13.1	0.9	3.2	4.2	5.9	6.8	10.1	16.7	21.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Distribution of the households among the different social groups									
Single	100	20.9	22.0	9.6	20.4	12.9	8.3	3.8	2.1
Single with child(ren)	100	3.0	25.0	11.7	26.1	17.3	10.2	4.3	2.3
Couples	100	0.7	3.5	2.9	10.7	16.6	25.1	21.5	19.0
Couples sine	100	0.9	4.8	3.7	12.9	19.5	24.9	18.0	15.3
Couples with	100	0.3	1.0	1.4	6.5	10.9	25.4	28.4	26.1
Other households	100	0.6	3.1	2.2	8.2	10.5	19.8	26.3	29.3
Total	100	8.9	12.6	6.8	18.4	20.3	25.8	20.6	17.6

Source: Schlör et al. 2015 [31, 32]

consists of all couples and couples without children (1.97, 2.18). The income dispersion reaches its lowest value in the groups containing couples with child(ren) and other households (1.66, 1.67) (Table 3).

Monthly net income The monthly net income of private households also varies strongly with the social status of the main income recipient, as the following table shows (Table 4).

Couples with children achieved the highest average monthly net income in 2008 (€ 4191), followed by couples (€ 3662), couples without child(ren) (€ 3387), and singles with and without child(ren) (€ 1943, € 1726). The dispersion of the net income varies significantly between the household types. Once again, the first group contains single households where the dispersion decreases from 4.09 to 3.3. The second group contains couples and couples without child(ren) (1.9, 2.1). They have a significantly lower dispersion than the single households. The income dispersion reaches its lowest value in the group containing couples with child(ren) and other households (1.6). The comparison of net and gross income shows that the German income tax system reduces the dispersion in this particular household type.

Expenditure of private households according to their social position

Monthly private consumption Expenditure for private consumption also varies between the different household types, as the following Table 5 shows. The single households spend an average of € 1418 per month, singles with child(ren) € 1740, couples € 2757, couples without child(ren) € 2622, couples with child(ren) € 3017, and other households € 3142. The consumption expenditures increase with rising income without reaching a saturation point. The consumption dispersion is significantly lower than the income dispersion.

The consumption dispersion of singles (2.35) and singles with child(ren) (2.12) is the highest of all households analysed, followed by couples (1.53, 1.62, 1.38) and other households (1.46). Their dispersion is much lower,

Table 3 Gross income 2008

Gross income of private households in Germany 2008 according to their household type						
Net income groups in €	Single	Single with children	Couples	Couples without children	Couples with children	Other households
All households	2193	2327	4644	4230	5441	5475
Under 900	780	798	790	483	*698*	908
900–1300	1275	1186	1250	1242	1326	1274
1300–1500	1747	1545	1608	1611	1592	1607
1500–2000	2285	2051	2044	2037	2070	2069
2000–2600	3022	2841	2738	2696	2882	2832
2600–3600	3953	3740	3833	3742	4004	4007
3600–5000	5463	5376	5475	5415	5548	5526
5000–18,000	9083	7990	9136	9222	9037	9152
Gross income dispersion[a]	4.14	3.43	1.97	2.18	1.66	1.67

Source: Own calculation based on German Federal Statistical Office, 2011,
[a]Income dispersion: Ratio of the gross income of the highest income group to the gross income of the average household of the social group. Italic numbers own estimation

and they have more similar consumption patterns than the single households.

In the following, we analyse the energy expenditures of the households.

Monthly energy consumption The expenditures for energy consumption of the households will be analysed in more detail to obtain a picture of the real distribution of energy consumption in Germany. This includes car energy and residential energy expenditures and total energy expenditures as summarized in Table 6.

Energy expenses for cars Energy expenses for cars include expenses for fuel and lubricants in the six social groups. The single households without and with children spend nearly the same amount (€ 50 and € 67, respectively) on car energy, whereas the couples without child(ren) spend on average € 111 and the couples with child(ren) and couples spend € 150 and € 124, respectively. The other households have on average the highest expenditures on car energy: € 160. With rising income, expenses for car energy increase continuously without reaching a saturation point. The dispersion of energy expenditure between the household types is significantly lower compared to income and overall consumption. In the case of car energy expenditure, it ranges from 1.18 to 1.94.

Residential energy expenditure With respect to expenses for residential energy, all three couple household types have nearly the same expenditures for residential energy (€ 165, € 163, € 169). The single households with child(ren) (€ 119) have insignificantly higher residential energy expenditure than all single households (€ 93). The other households have the highest expenditures for residential energy, with an average of € 201. With rising income, expenses for residential energy increase continuously, reaching a saturation point before the highest income group only in the case of singles with child(ren). In the other

Table 4 Net income of private households in Germany 2008 according to their household type

Income groups in €	Single	Single with child(ren)	Couples	Couples without child(ren)	Couples with child(ren)	Other households
All households	1726	1943	3662	3387	4191	4229
Under 900	705	758	*759*	*816*	*854*	*429*
900–1300	1097	1125	1125	1120	1169	1144
1300–1500	1396	1394	1407	1408	1402	1407
1500–2000	1736	1727	1766	1766	1764	1766
2000–2600	2259	2268	2303	2296	2325	2299
2600–3600	3028	2984	3073	3048	3120	3112
3600–5000	4168	4187	4213	4200	4229	4249
5000–18,000	7067	6351	7015	7119	6898	6966
Net income dispersion[a]	4.09	3.3	1.9	2.1	1.646	1.647

Source: Own calculation based on German Federal Statistical Office, 2011, /=no declaration, the number of cases is too small. Italic numbers are own estimation
[a]Income dispersion: ratio of the net income of the highest available income group to the net income of the average household of the social group

Table 5 Private consumption

Private consumption of private households in Germany 2008 according to their household type						
Income groups in €	Single	Single with child(ren)	Couples	Couples without child(ren)	Couples with child(ren)	Other households
All households	1418	1740	2757	2622	3017	3142
<900	799	1046	1842	1685	1737	1662
900–1300	1086	1146	1250	1237	1360	1176
1300–1500	1291	1339	1491	1493	1480	1364
1500–2000	1509	1630	1722	1725	1711	1672
2000–2600	1818	2003	2133	2128	2151	2068
2600–3600	2156	2604	2558	2551	2571	2580
3600–5000	2551	3273	3150	3172	3123	3269
5000–18,000	3329	3692	4207	4236	4175	4576
Consumption dispersion[a]	2.35	2.12	1.53	1.62	1.38	1.46

Source: Own calculation based on German Federal Statistical Office, 2011./= no declaration, the number of cases is too small
[a]Consumption dispersion: ratio of the consumption of the highest available income group to the consumption of the average household of the social group

household types, the residential energy expenditure increases without reaching a saturation point. Generally, the dispersion in the case of residential energy is lower than that of car energy. All household types show a dispersion between 1.17 and 1.65.

Total energy expenditure When we now sum up the car and residential energy expenditures to calculate the total energy expenditures. We see that couples with child(ren) (€ 319) have nearly the highest energy expenditures followed by the other two couple household types (€ 274, € 289), whereas the two single household types have lower energy expenditures (€ 143, € 186). The other households have the highest energy expenditures: € 361.

With rising income, the total energy expenses increase and reach a saturation point before the highest income group only in the household type singles with child(ren). In the other household types, the total energy expenditures increase without reaching a saturation point before the highest income group.

Hence, the dispersion varies between households. Couple (1.18, 1.28, 1.33) and single households show a slightly higher dispersion (1.55, 1.75), whereas the other households have a dispersion similar to the couple households (1.32).

In the following, we also present the distribution of expenditures for another basic good: food and beverages. The comparison between food and energy enables us to classify the energy distribution results.

Food consumption The expenditures for food and beverages differ among the households. But the dispersion of food expenditures is the lowest of all analysed types of consumption and income (Table 7).

The single households spend on average €182 for food and beverages. These expenditures reach their saturation point at € 222 per month in the highest income class. The food consumption of singles with children increases on average by about € 100 to € 281 per month and reaches its saturation point in the income group of € 3600–5000 (€ 366) before the top income group, which consumes less (€ 357). The social group of couple households consumes on average food and beverage for € 400 a month, and this consumption reaches its highest value in the highest income group with € 486. Couples without children (€ 360, € 432) consume on average and in the top group less than all couples. Food and beverage consumption increases on average in the social group of couples with children to € 478 a month and in the top income group this rises to € 547. The social group of other households has the highest monthly food consumption with on average € 483 and in the top group € 603. The food consumption dispersion for other households (1.25) and single parents (1.27) is the highest of all households analysed, followed by couples (1.2, 1.2, 1.14). Couples with children have food consumption patterns that are more similar than the other households.

Our analysis shows how the household types' heterogeneous levels of success in the economic system may be measured in income and consumption expenditures.

Discussion

In the following, we examine how the real distribution of expenses and income is perceived by the households against the background of differing levels of inequality aversion within society, i.e. how society assesses the distribution of income and expenditures against their normative perception of inequality.

Normative distribution

In the following, we examine how the real distribution of expenses and income is perceived by the households against the background of differing levels of inequality

Table 6 Energy consumption—car, residential, and total

Energy consumption of private households in Germany 2008 according to their social position						
Income groups in €	Single	Single with child(ren)	Couple	Couple without child(ren)	Couple with child(ren)	Other households
Car energy expenditure in €						
All households	50	67	124	111	150	160
<900	15	17	78	63	71	29
900–1300	32	33	44	42	67	38
1300–1500	47	51	63	63	58	39
1500–2000	61	70	75	73	80	72
2000–2600	75	89	97	90	120	99
2600–3600	86	101	126	115	148	140
3600–5000	93	108	151	141	163	179
5000–18,000	97	130	169	161	177	225
Car energy dispersion[a]	1.94	1.94	1.36	1.45	1.18	1.41
Residential energy expenditure in €						
All households	93	119	165	163	169	201
<900	69	86	161	140	170	151
900–1300	81	100	111	112	104	104
1300–1500	89	103	109	107	116	118
1500–2000	96	112	130	132	126	140
2000–2600	106	123	148	150	141	154
2600–3600	127	165	161	164	155	180
3600–5000	133	198	184	188	180	219
5000–18,000	153	158	201	203	198	252
Residential energy dispersion[b]	1.65	1.33	1.22	1.25	1.17	1.25
Total energy expenditure in €						
All households	143	186	289	274	319	361
<900	84	103	239	203	241	180
900–1300	113	133	155	154	171	142
1300–1500	136	154	172	170	174	157
1500–2000	157	182	205	205	206	212
2000–2600	181	212	245	240	261	253
2600–3600	213	266	287	279	303	320
3600–5000	226	306	335	329	343	398
5000–18,000	250	288	370	364	375	477
Total energy dispersion[c]	1.75	1.55	1.28	1.33	1.18	1.32

Source: German Federal Statistical Office, 2010, [a]residential energy dispersion: ratio of the residential energy expenditures of the highest income group to the residential energy expenditure of the average household of the social group
Source: German Federal Statistical Office, 2010, [b]residential energy dispersion: ratio of the residential energy expenditures of the highest income group to the residential energy expenditure of the average household of the social group
Source: Own calculation based on German Federal Statistical Office, 2011, [c]Total energy dispersion: ratio of the total energy expenditures of the highest income group to the total energy expenditure of the average household of the social group

aversion within society, i.e. how society assesses the distribution of income and expenditures against their normative perception of inequality. In our analysis, the epsilon parameter of the Atkinson index ranges from 1 to 2.5, whereas ($\varepsilon = 1$, 1.5) represents a low inequality aversion of society and ($\varepsilon = 2$, 2.5) represents a high inequality aversion of German society.

Singles

In the case of the single households, the net income (0.149–0.299) is more equally distributed than the gross income (0.176–0.356). This illustrates the effectiveness of the German tax system in reducing some of the inequality of the German economic market system.

Table 7 Food consumption

Food and beverage expenditures of private households in Germany 2008 according to their household type						
Net income groups in €	Single	Single with children	Couples	Couples without children	Couples with children	Other households
All households	182	281	400	360	478	483
under 900	148	*193*	317	289	*298*	*287*
900–1300	172	236	276	269	333	266
1300–1500	182	262	289	283	320	313
1500–2000	193	286	328	314	382	331
2000–2600	202	303	359	340	423	369
2600–3600	213	333	396	365	457	446
3600–5000	219	366	435	389	491	514
5000–18,000	222	357	486	433	547	603
Food dispersion[a]	1.22	1.27	1.22	1.20	1.14	1.25

Source: Own calculation based on German Federal Statistical Office, 2011. Italic numbers own estimation
[a]Food consumption dispersion: ratio of the food consumption of the highest income group to the food consumption of the average household of the social group

The consumption patterns of the singles (0.066–0.149) are distributed more equally between the households than the two income types.

In the case of energy consumption, the expenditures on residential energy (0.023–0.053) are nearly equally distributed between the households. On the other hand, the expenditures for car energy are more unequally distributed in this household group than the gross income (0.165–0.388). Residential energy expenditures are of central importance for the households irrespective of their income, whereas individual mobility (cars) is not necessarily required by all households. For the single households, the public transport system is an alternative. This explains why in the single households the car energy values of the Atkinson index are higher than the residential energy. Table 8 shows that "food" is the most equally distributed (0.006–0.018) item of the analysed data sample. As expected, food is the main basic good for single households.

Singles with child(ren)

As in the household groups of all single households, the net income of single households with child(ren) is more equally distributed than the gross income. The data confirms that the German tax system evens out the inequalities of the economic market system to some extent. The gross income of single households with child(ren) is more unequally distributed (0.125–0.258) than the income of the group consisting of all single households. This is also valid for the net income.

We can also see that the distribution of private consumption (0.056–0.121) and of all energy expenditures (0.038–0.087) is more equal in this household type than car energy expenditures (0.106–0.262). Table 9 illustrates that also in this social group food consumption is the most equally distributed consumption issue.

Couples

In the couple group, the gross income (0.138–0.323) is again more unequally distributed than the net income (0.118–0.277) due to the German tax system (Table 10).

This is also valid for the consumption patterns (0.05–0.124) and energy expenditures (0.025–0.067). The residential energy expenditures (0.025–0.034) of this household group are again the most equally distributed issue in this household group. The results also show that car

Table 8 Atkinson index of single households

Atkinson index 2008—singles							
Atkinson epsilon	Gross income	Net income	Private consumption	Energy	Residential energy	Car energy[a]	Food[b]
Singles							
1.0	0.176	0.149	0.066	0.055	0.023	0.165	0.006
1.5	0.247	0.208	0.095	0.079	0.034	0.246	0.010
2.0	0.307	0.257	0.123	0.103	0.044	0.322	0.014
2.5	0.356	0.299	0.149	0.125	0.053	0.388	0.018

Source: Own calculations 2016
[a]Car energy = fuel and lubricants
[b]Food, beverages (non-alcohol and alcohol), and tobacco

Table 9 Atkinson index of single households with child(ren)

Atkinson index 2008—singles with child(ren)							
Atkinson epsilon	Gross income	Net income	Private consumption	Energy	Residential energy	Car energy[a]	Food[b]
Singles with child(ren)							
1.0	0.125	0.098	0.056	0.038	0.018	0.106	0.011
1.5	0.176	0.138	0.080	0.055	0.027	0.158	0.016
2.0	0.220	0.172	0.102	0.071	0.035	0.210	0.021
2.5	0.258	0.202	0.121	0.087	0.043	0.262	0.027

Source: Own calculations 2016
[a]Car energy = fuel and lubricants
[b]Food, beverages (non-alcohol and alcohol), and tobacco

energy expenditures (0.047–0.139) are more unequally distributed than residential energy expenditures but more equally distributed than in the case of single households. Food consumption is distributed in the same way in the couple households (0.011–0.038) as in the single households with children.

Couples without child(ren)

In the case of the gross and net income, we see again that, because of the tax system, the net income (0.124–0.355) is more equally distributed than the gross income (0.150–0.355). We can assert that residential energy (0.017–0.041) is again the most equally distributed good. Private consumption (0.053–0.128) is distributed in a manner similar to car energy (0.057–0.148), and a little more unequally than energy expenditures.

The food consumption of the couple households with children (0.008–0.020) is more equally distributed than that of all couples. Table 11 also documents the basic need character of food consumption, because it is the most equally distributed good of these households.

Couples with child(ren)

The effects of the German tax system as an instrument to reduce income inequality can also be confirmed by the analysis of the gross (0.104–0.267) and net income (0.091–0.227) of couples with children (Table 12).

Private consumption in this household group is relatively equally distributed. But the results show that car energy expenditures are also equally distributed and we can see a clear contrast to the single households, where car energy expenditures are distributed very unequally. We can conclude from this that car energy expenditures are not necessarily an essential good for single households, but for the couples, especially for those with children, they are indispensable. In the households of couples with children, food consumption is also very equally distributed, and the Atkinson index (0.007–0.018) is a good indicator of that.

Other households

The final household type in our analysis is the group containing other households. This household group also confirms the effects of the German tax system, which reduces income inequality between the members of that household type (0.176–0.337 to 0.149–0.326).

Table 13 shows that the inequality assessed by the modified Atkinson index increases with rising epsilon irrespective of which issue is analysed. The energy expenditures (0.048–0.133) of that group are more equally distributed than the overall private consumption (0.065–0.167). The residential energy expenditures (0.024–0.069) are more equally distributed than the car energy expenditures (0.030–0.129). Food consumption is more unequally distributed in the group of all other households than in the

Table 10 Atkinson index of all couples households

Atkinson index 2008—all couples							
Atkinson epsilon	Gross income	Net income	Private consumption	Energy	Residential energy	Car energy[a]	Food[b]
All couples							
1.0	0.138	0.118	0.050	0.025	0.015	0.047	0.011
1.5	0.204	0.174	0.075	0.039	0.022	0.076	0.016
2.0	0.266	0.227	0.100	0.053	0.029	0.106	0.022
2.5	0.323	0.277	0.124	0.067	0.037	0.139	0.038

Source: Own calculations 2016
[a]Car energy = fuel and lubricants
[b]Food, beverages (non-alcohol and alcohol), and tobacco

Table 11 Atkinson index of couples without child(ren)

Atkinson index 2008—couples without child(ren)							
Atkinson epsilon	Gross income	Net income	Private consumption	Energy	Residential energy	Car energy[a]	Food[b]
Couples without child(ren)							
1.0	0.150	0.124	0.053	0.030	0.017	0.057	0.008
1.5	0.221	0.180	0.079	0.044	0.025	0.086	0.012
2.0	0.288	0.231	0.104	0.058	0.033	0.116	0.016
2.5	0.355	0.278	0.128	0.073	0.041	0.148	0.020

Source: Own calculations 2016
[a]Car energy = fuel and lubricants
[b]Food, beverages (non-alcohol and alcohol), and tobacco

other household groups. The values of the Atkinson index (0.025–0.065) are near the values of the residential energy. The other households group, which includes, for example, parents-in-law, children over 18 and groups sharing an apartment, is more heterogeneous than the single and couple households, which explains the higher Atkinson index.

Conclusions

Summary

We can therefore summarize that the household group of couples with child(ren) is the most homogeneous group and that their net income is more equally distributed than their gross income. Private consumption is more equally distributed than both income types, and energy services are distributed almost equally between the household types. However, the single households are the most heterogeneous household group and show a more differentiated distribution picture than the couple households. In both single household types, the German tax system significantly reduces the inequality between households. In the case of epsilon 2.5—representing a high inequality aversion—the German tax system reduces the Atkinson index of single households from 0.356 to 0.299. But also in the single households, private consumption is more equally distributed than income, and energy expenditures are still the most equally distributed expenditure type (0.055–0.125). What is striking in this group is the fact that car energy expenditures are the most unevenly distributed expenditure type. We have seen that energy expenditures are more equally distributed than private consumption and income types. The nearly equal distribution of energy expenditures confirms Smil's assumption that energy is the universal currency [30] for people's welfare and can be seen as an indicator of the basic needs of the households, whereby "basic" means something different in different countries—for Germany basic needs means an energy consumption which offers social participation. These basic energy needs are to a large extent, but not completely, independent of people's income situation.

This means that the lower income groups have to spend a very high percentage of their income on energy services compared to the higher income groups (Table 14). Households with a net income lower than € 900 are divided into two major groups. The singles in this income group spend between 11.9 and 13.6% of their income on energy services. They spend between 3 and 4 basis points more than the average household in this social group and nearly 10 basis points more than the highest income group.

However, we get a different picture in the social group of couples households: the couple households of the income group <€ 900 spend more than 25% of their net income on energy services. Rising energy prices would affect these households directly. In this case, they would

Table 12 Atkinson index of couples with child(ren)

Atkinson index 2008—couples with child(ren)							
Atkinson epsilon	Gross income	Net income	Private consumption	Energy	Residential energy	Food[b]	Car energy[a]
Couples with child(ren)							
1.0	0.104	0.091	0.039	0.016	0.012	0.007	0.025
1.5	0.157	0.137	0.058	0.024	0.017	0.010	0.040
2.0	0.212	0.183	0.078	0.034	0.023	0.014	0.059
2.5	0.267	0.227	0.098	0.045	0.029	0.018	0.080

Source: Own calculations 2016
[a]Car energy = fuel and lubricants
[b]Food, beverages (non-alcohol and alcohol), and tobacco

Table 13 Atkinson index of other households

Atkinson index 2008—other households							
Atkinson epsilon	Gross income	Net income	Private consumption	Energy	Residential energy	Car energy[a]	Food[b]
Other households							
1.0	0.176	0.149	0.065	0.048	0.024	0.094	0.025
1.5	0.202	0.185	0.074	0.099	0.039	0.151	0.038
2.0	0.271	0.254	0.103	0.133	0.053	0.216	0.051
2.5	0.337	0.326	0.133	0.167	0.069	0.286	0.065

Source: Own calculations 2016
[a]Car energy = fuel and lubricants
[b]Food, beverages (non-alcohol and alcohol), and tobacco

have to rearrange the expenditures in their household budgets. They would have to reduce other expenditures to maintain their use of energy services at its current level; otherwise, they would lose access to modern energy services which are "crucial to human well-being and to a country's economic development" as the IEA stated. There is a danger that these households will be confronted with energy poverty, which can be defined as a "condition wherein a household is unable to access energy services [8]" at its accustomed level, and so there is a growing need for energy governance. Energy poverty constitutes an infringement of the sustainability concept: environmental, economic, and social targets have to be balanced in the transition to a low-carbon economy.

Outlook

Our analysis reveals that energy poverty and the socio-economic conditions of society and its energy sector have to be addressed in transition processes to a sustainable society and have to be at the centre of any energy transition process and its political discourse. The analysis of Gordon's trade-off shows that transition processes such as the German Energiewende are not only technical problems but increasingly also socio-economic problems that have to be solved by energy governance [6], and because of Thurow's public good approach, no one in society can escape from the unsolved problems of Gordon's trade-off.

The analysis using the Atkinson index can reveal deeper insights into the self-perception of society and the conception of justice and equality, which are central pillars of a sustainable society. The epsilon parameter thereby enables us to parameterize this perception and conception in measuring the distribution of consumption and income. Our analysis is necessary, because every economic and political reform has distributional effects. If politicians do not consider these effects (energy poverty), they can endanger the total reform of the energy sector (Energiewende), because people will turn away from the goals of the reform [1, 9]. Acceptance of reforms such as the German Energiewende will thus decline.

The transformation of current energy systems into sustainable systems is on the agenda of all European countries (EU climate policy). Therefore, such a transformation could (and probably will) also lead to rising electricity prices, placing an above-average strain on the lowest income groups. Moreover, this regressive effect will appear in all categories of expenditure if prices increase, no matter whether this is caused by political decisions or market forces.

Table 14 Energy consumption of private households in relation to net income* Germany 2008 according to their social position—in %

Income groups in €	Singles	Singles with child(ren)	Couples	Couples without child(ren)	Couples with child(ren)	Other households
All households	8.3	9.6	*7.9*	*8.1*	*7.6*	*8.5*
<900	11.9	13.6	31.5	24.9	28.2	42.0
900–1300	10.3	11.8	13.8	13.8	14.6	12.4
1300–1500	9.7	11.0	12.2	12.1	12.4	11.2
1500–2000	9.0	10.5	11.6	11.6	11.7	12.0
2000–2600	8.0	9.3	10.6	10.5	11.2	11.0
2600–3600	7.0	8.9	9.3	9.2	9.7	10.3
3600–5000	5.4	7.3	8.0	7.8	8.1	9.4
5000–18,000	3.5	4.5	5.3	5.1	5.4	6.8

Source: Own calculation based on German Federal Statistical Office, 2011. Italic numbers: own estimation, limited data basis in this income group
*Total energy dispersion: ratio of the total energy expenditures of the highest income group to the total energy expenditures of the average household of the social group

Our index can also be applied to other countries with respect to energy and other household expenditures, if the respective national statistical office provides the necessary household survey data for the analysis. Our index can then provide decision makers and institutions with information on how (un)equally the costs of transformation processes are distributed between the different income groups. We used energy in our analysis because it is one of the basic needs, and the energy sector is at the centre of the German transformation process: the Energiewende. Energy poverty caused by the Energiewende—as a synonym for a lack of societal participation in the transformation process, at least in highly developed countries—can endanger the whole transformation process. Political strategies to strengthen participation should therefore focus on the regressive effect of high energy prices.

Decision makers and political institutions can decide in a public discourse which categories of expenditures should be analysed and which are more important and relevant to justify political interventions to reduce the inequality caused by rising prices.

The index could also deliver information about the differences in income distribution in EU countries. For this analysis, we need reliable and comparable statistical data for the whole of Europe. However, in our view, two important political obstacles are looming: Firstly, it is difficult enough to find common political ground in domestic policy between the different political actors and interest groups in order to distribute the costs of national transformation policies. Secondly, this challenge is raised to a completely different level if wealth is to be redistributed between EU states (Euro crisis, Greek debt crisis) to a much larger extent than is the case today (EU Regional Fund, Structural Fund etc.).

To summarize, our concept has both a detection (revealing the implicit preferences) and potentially also an orientation function (defining explicit societal preferences with respect to the degree of homogeneity of a society).

Endnotes

[1]Kermit Gordon (1916–1976) was Director of the United States Bureau of the Budget (now the Office of Management and Budget) (December 28, 1962–June 1, 1965) during the administration of Lyndon Johnson, and he was also the president of the Brookings Institution. He oversaw the creation of the first budgets for Johnson's Great Society domestic agenda. Gordon was a member of the Council of Economic Advisors, 1961–1962.

[2]For our analysis, we take up the definition of an institution offered by Rawls. Institutions in Rawls's sense are the constitution, economic and social conditions, freedom of thought, freedom of conscience, economic markets with competition, and private property [22].

[3]Nicholas Barr shows that the Gini coefficient has two disadvantages for measuring inequality, which are avoided by the Atkinson index [5]. The Gini coefficient is not an unambiguous measure because, as Hauser and Barr have shown, different distributions can lead to the same Gini coefficient [13, 52]. Hence, we decided to use the Atkinson index to estimate the distributional effects of increasing energy prices [27].

[4]This analytical view is based on Rawls' theory of justice, where inequality is determined by the "position of the least advantaged members of society. Where epsilon lies between these extremes depends on the importance attached to redistribution towards the bottom [3]."

[5]Other households include, e.g. parents-in-law, children over 18, and groups sharing an apartment.

Authors' contributions
HS initiated the research idea of analyzing Gordon's trade-off and developed the Atkinson model based on EVS data. HS and WF designed and organized all the research for this study. WF reviewed the theory of public goods. JFH had a leading role in the literature review and the analysis of the real distribution of the EVS data. All the authors contributed to the conclusion and the outlook of the study. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

Received: 27 August 2016 Accepted: 14 November 2016
Published online: 05 December 2016

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