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Measuring social welfare, energy and inequality in Germany

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Measuring social welfare, energy and inequality in Germany

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Abstract

The Atkinson index is an inequality measure based on a social welfare function. We will use the Atkinson index as an analytical tool to examine the interactions between economic activity and energy services. The Atkinson index has a specific feature for the calculation of distribution. The index uses the epsilon parameter to explicitly reveal the inequality aversion of society. Epsilon defines how sensitively the Atkinson index should react to income inequalities. The results of applying the Atkinson index could make a significant contribution to science and policy debates on income and energy equity in the context of sustainable development.

Keywords

Income Distribution, Energy, Atkinson Index, Welfare Measurement

Contribution to Applied Energy
I Introduction

Since the earliest times, people have striven to improve their living conditions. The “universal currency” [Smil, 1994] used to measure this improvement is the amount of energy consumed. The abundance of energy is the fundamental determinant for the quality of life. In this paper, we will examine how the quality of life is distributed among the members of society.


Political reforms can be enforced more easily when they are seen to include political measures that contribute to the social justice of society. Social justice is thereby always connected to the distribution of the material welfare of society [Brümmerhoff, 2007, 253]. The political interpretation of the distribution of social welfare confronts society with a structural political problem. On the one hand, the political and social institutions grant the same universal rights and privileges to all citizens. “But its economic institutions rely on market-determined incomes that generate substantial disparities among citizens in living standards and material welfare [Gordon, 1975, vii].” This mixture of the same rights and unequal income generates social tensions between the political principles of society and the economic principles of capitalism.

“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 [Gordon, 1975, vii].” In the following, we want to examine the extent of this trade-off, while determining the dimension of the economic inequality. In addition, we will examine not only the distribution of income and wealth, but also the distribution of the universal currency (energy). Income covers the contribution of the individual to national economic production, while consumption expresses the opportunity for individuals to stake a claim to the goods produced [Brümmerhoff, 2007].

Income forms the basis for consumption decisions by households, which decisively determine our well-being [Sen, 2003, 89]. Or as Pigou said: “The economic welfare of a community consists in the balance of satisfactions from the use of the national dividend (or, as we should say, national product) over the dissatisfactions involved in the making of it [Pigou, 1932].” Hence, the quality of life is determined by income and by consumption [Hicks, 1975].
II Theoretical foundation of the Atkinson index

II.1 Social welfare function (SWF)

The basis for measuring the distribution of income and consumption is the social welfare function, which determines the whole benefit for society by summing up the single benefit for individuals in society. Thereby, we assume that the welfare of society is, in contrast to Aristotle’s “The whole is more than the sum of its parts [Aristotle, 2008]”, not more than the sum of the benefits of its individuals, and the welfare of the other members of society leaves every individual absolutely unaffected [Hauser, 1996, 15]. The distribution of social welfare can be determined with the help of the Atkinson index [Atkinson, 1970, 245].1

II.2 SWF-based inequality measure - the Atkinson index

The Atkinson index is an inequality measure based on the social welfare function [Cowell, 2000b], which defines maximum inequality as 1 and maximum equality as 0 [Sen, 1973, 38]. $Y_i$ is the income of individuals in the ith income range (N ranges altogether), $f_i$ is the proportion of the population with income in the ith range, $\bar{Y}$ is the mean household income [Atkinson, 1970, 257], resulting in the following Atkinson equation [Atkinson, 1983, 57, Atkinson, 1975]:

$$I_\varepsilon = 1 - \left[ \sum_{i=1}^{n} \left( \frac{Y_i}{\bar{Y}} \right)^{1-\varepsilon} f_i \right]^{\frac{1}{1-\varepsilon}}, \text{ if } \varepsilon \neq 1.$$  

$$I_\varepsilon = 1 - \exp \left[ \sum_{i=1}^{n} f_i \log_e \frac{Y_i}{\bar{Y}} \right] \text{, if } \varepsilon = 1.2$$


---

1 Cf. inequality measures such as the Gini coefficient, Dalton’s inequality measure and the Theil measure [Cowell, 2000a].

2 The special case of Atkinson index $\varepsilon = 1$ is also known as the measure of Champernowne [Champernowne, 1974]. It corresponds to the hypothesis of Bernoulli that the marginal utility of the income is inversely proportional to the income level [Lüthi, 1981, 52].
Several authors have shown within the scope of the axiomatic approach that the Atkinson index fulfils six axioms for inequality measures [Lüthi, 1981, 52, Litchfield, 1999, Cowell, 2000b, Seidl, 2001, Cowell, 2000a]. The axiomatic methodology “consists of a rule-based system of thought which enables us to state precisely what we mean by inequality comparison, and thereby what we mean by inequality [Amiel & Cowell, 1999, 8].”

The Atkinson index fulfils

- the Bresciani-Turroni condition (income scale independence) [Diekmann, 1981],
- the criterion of the independence of the population size (principle of population [Dalton, 1920, Amiel & Cowell, 1999, Cowell, 2000a]),
- anonymity condition [Cowell, 2000a, Litchfield, 1999],
- the Pigou-Dalton transfer principle [Dalton, 1920, Pigou, 1912, Amiel & Cowell, 1992, Cowell, 2000a],
- the operationality condition [Lüthi, 1981, 23pp.], and

The Atkinson index fulfils these six axioms and thus allows inequality to be measured [Cowell, 1985].

II.3 Epsilon – Trade-off between equality und efficiency

The Atkinson index has a specific feature for calculating distribution, namely the parameter epsilon $\varepsilon$. Epsilon is the distribution focus of the distribution analysis. “This parameter represents the weight attached by society to inequality in the distribution [Atkinson, 1983, 56].” With the parameter epsilon $\varepsilon$, the size of the welfare difference of additional income can be fixed between a person with a high income and a person with a low income.

Epsilon $\varepsilon$ “is clearly a measure of the degree of inequality-aversion – or the relative sensitivity to transfer at different income levels. As $\varepsilon$ rises, we attach more weight to transfers at the lower end of the distribution and less weight to transfers at the top [Atkinson, 1970, 257].”

The epsilon parameter defines how sensitively the Atkinson index should react to income inequalities. The greater epsilon is, the stronger the Atkinson index reacts to inequalities. Epsilon therefore represents the inequality aversion of society. It ranges
from zero if society is totally indifferent to the distribution of income to infinity if society only considers the position of the lowest income group.3

One can say that epsilon represents the social trade-off between social equality and economic efficiency. With the Atkinson parameter, a normative dimension is therefore incorporated into the inequality analysis, which allows a degree of social aversion to be introduced into the inequality analysis. The advantage of the Atkinson index is that the epsilon parameter can be varied in such a way that the welfare of the lower income groups is weighted strongly or weakly in the welfare measurement.

In the following, we address the question of what the socially acceptable value for epsilon is, representing Gordon’s social trade-off between equality and efficiency. A socially acceptable value for the parameter epsilon can be determined with Okun’s leaky bucket experiment [Okun, 1975, 91-100, Atkinson, 1983, 58, Barr, 1993, 159, Seidl, 2001, Lüthi, 1981].

Okun assumes in his experiment that 20% of American families in 1974 had an average net income of $5,000 and that the top 5% of families had a net income of $45,000. If the top 5% pay additional income tax of 9% ($4,000) to the lowest 5%, and if we take into consideration that the lowest 20% comprises 4 times more people, then every family in the lower income group receives $1,000 [Okun, 1975, 91]. “However, the program has an unsolved technological problem: the money must be carried from the rich to the poor in a leaky bucket. Some of it will simply disappear in transit, so the poor will not receive all the money that is taken from the rich. The average poor family will get less than $1000, while the average rich family gives up $4000 [Okun, 1975, 91].”

Okun assumes that every economic transfer is associated with transaction costs (administrative costs, work effort, savings and investment, socioeconomic leakages) [Okun, 1975, 96-100], which reduce the economic contribution to the poor. From this the question arises as to how high the transaction costs should increase so that the transfers can still be justified by society [Okun, 1975, 92]. This question can be answered with the following formula [Lüthi, 1981]:

\[ \frac{1}{(1-x)} = 2^\epsilon, \ x = \text{transfer share} \]

If one assumes a socially acceptable transaction share of 29.5%, we obtain the following value for epsilon:

3 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 [Atkinson, 1983].”
\[
\frac{1}{1-x} = 2^\epsilon \\
\frac{1}{1-0.295} = 2^\epsilon \\
1.418 = 2^\epsilon \\
\ln(1.418) \div \ln(2) = \epsilon \\
0.5 = \epsilon
\]

If society accepts transaction costs of 50%, then we get an epsilon value of 1. If a transfer loss of 75% is accepted, the epsilon value is 2. However, if society only accepts a transfer loss of 10%, than we get an epsilon value of 0.15. Okun has decided for himself that he “would stop at a leakage of 60 percent” [Okun, 1975, 94] in his example, representing an epsilon value of 1.3.

According to Okun, the question of the socially acceptable epsilon value can be answered from two different perspectives: whether the main focus is on the question of social equality in the sense of Rawls or on economic efficiency in the sense of Milton Friedman [Okun, 1975, 92, Rawls, 1971, 62, Friedman, 1962, 161-166]. He explained in his book “Free to Choose” his view on justice and social equality in the following way: “Life is not fair. It is tempting to believe that government can rectify what nature has spawned [Friedman, 1990].” John Rawls responded to Milton Friedman and his view on natural distribution: “The natural distribution is neither just nor unjust; nor is it unjust that persons are born into society at some particular positions. These are simply facts. What is just or unjust is the way that institutions deal with these facts [Rawls, 1971].” The social institutions can adjust the epsilon parameter based on the two different views of the nature of society and the need for social adjustments of the natural distribution. Milton Friedman would probably choose an epsilon parameter of \( \epsilon < 1 \), whereas John Rawls would probably prefer an epsilon parameter of \( \epsilon > 2 \). Hence, the value of epsilon can be interpreted in the sense of Gordon as the relation of the perceptions of Rawls and Friedman on social equality and economic efficiency:

\[
\epsilon = \frac{\text{equality Rawls}}{\text{efficiency Friedman}} = \frac{\epsilon_{\text{Rawls}}(1,2,3,4,5)}{\epsilon_{\text{Friedman}}(1,2,3,4,5)}.
\]

If society mainly focuses on efficiency and has a very low aversion to inequality, it would choose 5 for Friedman and 1 for Rawls and we would receive an epsilon value
of $\varepsilon < 0.2$. On the other hand, if the main focus of society is on fairness and justice, it would choose 5 for Rawls and 1 for Friedman and the epsilon value would be $\varepsilon > 5$. In this case, society only focuses on the welfare of the lowest income group, whatever the transaction costs may be.

With respect to redistribution between income groups, we have to consider that the marginal social benefit of the lowest income group is higher than that of the highest income group [Lüthi, 1981]. To achieve consistent social welfare of society, only a small fraction of what is taken from the highest income group has to be given to the lowest income group, as the following example shows.

**Table 1: Gross income of German private households**

<table>
<thead>
<tr>
<th>Income Groups of German Households</th>
<th>Monthly net income range in €</th>
<th>All Households</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>overall</td>
<td>under 900</td>
</tr>
<tr>
<td>Households (1 000)</td>
<td>38110</td>
<td>3041</td>
</tr>
<tr>
<td>Share of income group</td>
<td>100%</td>
<td>8.0%</td>
</tr>
<tr>
<td>of all households in %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross income in €</td>
<td>3561</td>
<td>811</td>
</tr>
</tbody>
</table>

Source: German Federal Statistical Office, 2006, EVS 2003 and own calculation

In our analysis, as Table 1 shows, the highest income group (€ 5000 – 18000) has an average gross income about 10 times higher than that of the lowest income group (under € 900). The gross income in that income group is € 811, whereas in the highest income group the average gross income is € 8729. In this case, the social welfare function remains unchanged if the income of the highest income group is reduced by $10\varepsilon$, i.e. society will not face a social welfare loss through the redistribution [Lüthi, 1981].

The social welfare remains unchanged depending on the value of epsilon,

for $\varepsilon = 0.1$, if we take € 1.3 from the highest income group and give € 1 to the lowest,
for $\varepsilon = 0.5$, if we take € 3.2 and give € 1 to the lowest income group,
for $\varepsilon = 1.0$, if we take € 10 and give € 1 to the lowest income group,
for $\varepsilon = 1.5$, if we take € 32 and give € 1 to the lowest income group,
for $\varepsilon = 2.0$, if we take € 100 and give € 1 to the lowest income group.

If we use the social welfare function on the basis of epsilon 0.1, social welfare remains unchanged if we take € 1.3 from the rich and give € 1 to the poor. Society only accepts redistribution costs of € 0.3. With an epsilon of 2, the social well-being function remains unchanged if we take € 100 from the rich and give € 1 to the poor [Lüthi,
In this case, society would accept € 99 redistribution costs caused by Okun’s leaky bucket.

The acceptable redistribution costs increase from € 0.3 to € 99 due to the increase of epsilon representing the inequality aversion of society. Societies with an epsilon parameter of 2.0 accept higher redistribution costs without causing a reduction of social welfare than 0.1-epsilon societies. Hence, the potential loss of social welfare that a society accepts through redistribution depends on its values and its self-perception, i.e. the relevance equality has for society.

The epsilon parameter of the Atkinson index reveals both the values of society for distributional justice and the willingness of society to accept transfer costs to achieve distributional justice. Epsilon indicates how high the welfare difference can be between the lower and higher income groups from society’s viewpoint. The epsilon parameter represents a connection between the universal equal political rights of the citizens and the efficiency criterion of the economy, and it defines fairness from the perspective of society.

We chose the Atkinson index for our analysis, because the epsilon parameter makes it possible to quantify the trade-off between Milton Friedman and John Rawls and enables us to make justice measurable.

Finally, it has to be pointed out that no objective statistically neutral inequality measures exist. Every measure contains implicit evaluations about a desirable distribution of income. The degree of inequality cannot be measured without taking social judgments into consideration. “Measures such as the Gini coefficient are not purely ‘statistical’ and they embody implicit judgments about the weight to be attached to the inequality at different points on the income scale [Atkinson, 1983, 56].”

If the Gini coefficient indicates a decrease in inequality, then not everyone must agree with that judgment [Hauser, 1996]. Due to the fact that inequality measures contain implicit judgments about a certain distribution, it is sensible to use inequality measures that reveal this judgment explicitly. The Atkinson index reveals its values explicitly because the distribution parameter epsilon can be chosen freely [Atkinson, 1975]. The index makes clear “just what distributional objectives are being incorporated [Atkinson, 1983]” in the distribution analysis. We will carry out our distribution analysis on the basis of the German household expenditure survey data (EVS) of the German Federal Statistical Office [Statistisches Bundesamt (Federal Statistical Office), 2005b, Statistisches Bundesamt (Federal Statistical Office), 2005a].

### III Database – German Household Expenditure Survey data (EVS) 2003

The household expenditure survey data (EVS) of the German Federal Statistical Office provides information on German economic life and the consumer behaviour of
private households in 2003. This database was published in 2008 [Statistisches Bundesamt (Federal Statistical Office), 2008]. These data provide a basis for estimating the effects of economic policy. The EVS is constructed according to the methodological Eurostat recommendations “Household Budget Surveys in the EU. Methodology and recommendations for harmonisation – 2003 [Statistisches Bundesamt (Federal Statistical Office), 2005a, 18].” Every five years, a selection of German households (0.2% of all German households) is questioned as part of a household expenditure survey. The households are questioned about their income, expenditure, assets, consumer goods and residential situation. The 2003 survey was the ninth, following surveys in 1962/63, 1969, 1973, 1978, 1983, 1988, 1993 and 1998. [Statistisches Bundesamt (Federal Statistical Office), 2005b]. The 2008 was published in 2011 but has not yet been fully analysed. We therefore used the 2003 survey data for our analysis.

This survey focuses on collecting income and expenditure data on households [Statistisches Bundesamt (Federal Statistical Office), 2005a]. The Federal Statistical Office thus provides important data for the assessment of the income situation, standard of living and the expenditure behaviour of the whole population and its different social groups [Statistisches Bundesamt (Federal Statistical Office), 2005a, 17]. The EVS supplies detailed data on the distribution of household income. Therefore, the data enable us to estimate the consequences of income changes, tax alterations and changes in consumer prices and social security contributions for the consumption behaviour of households, as well as the consequences for a country’s economic development [Statistisches Bundesamt (Federal Statistical Office), 2005a, 17].

The household is the most important socioeconomic investigation unit in the EVS. To separate a household in the statistical sense and to create an option of grouping multiperson households according to different social issues (e.g. social status, age, household income class, tenants/owners of residential property), the statistical issue of the main income recipient of the household was introduced in 1998. The EVS in 1998 defined the main income recipient as that person in the household who contributes the biggest share to the household income.

The Federal Statistical Office understands a private household to be a group of related or personally linked (not necessarily family-related) persons, who belong together in terms of income and consumption. A household must dispose together of one or several incomes or income shares. An individual living alone also counts as a household unit [Statistisches Bundesamt (Federal Statistical Office), 2005a, 20]. The key statistical issue in EVS is the income and expenditure of private households. In order to cover income and expenditure of the households, the Federal Statistical Office us-

es the market concept. This means that the only expenditure that is registered is expenditure on the market for goods and services [Statistisches Bundesamt (Federal Statistical Office), 2005a, 21, Burghardt, 2000, 141-142, München, 2000].

The most important group for the organization of households within EVS 2003 is the social position of the main income recipient, the age of the main income recipient, household size, household type and the monthly net income. For our analysis, we concentrated on the household net income and household type. The following household groups were analysed:

- All households
- Single woman, single man
- Single parent
- Married couple without children
- Married couple with children

A household’s gross income comprises all income received from employment and self-employment, public and private transfer payments and subleases [Statistisches Bundesamt (Federal Statistical Office), 2005a, 25]. The gross income from employment does not contain the employer’s contributions to the social security system. The net income is calculated by subtracting taxes and contributions to the social security system from the gross income. The expenditure of the households mainly consists of expenditure for private consumption. Based on the statistical data basis of the EVS, we examined the distribution of income and consumption in Germany.

IV Measuring inequality in Germany - results

In the first step, the social welfare function was determined, followed by the Atkinson index.

IV.1 Social welfare function

A starting point for our calculation was the social welfare function and its characteristics (cf. II) (individualistic, non-decreasing, symmetric and additive) which enabled us to aggregate the individual utility level of the households to an aggregated social welfare function:

\[
SWF = \sum_{i=1}^{n} U(y_i)
\]

where \( U(y_i) \) represents the utility level of the ith household, which is defined as follows:

\[
U(y_i) = \frac{1}{1 - \varepsilon} y_i^{1-\varepsilon}
\]
On account of the additivity condition of the social welfare function, the single utility levels of the households can be aggregated to a social welfare function.

$$SWF = \sum_{i=1}^{n} \frac{1}{1-\varepsilon} y_i^{1-\varepsilon}$$

On the basis of the social welfare function, social welfare can be calculated for the whole of society, but we will also define the social welfare of the consumption of society and of the energy consumption (residential energy and car traffic). We thus not only calculate the social welfare for the whole of society, but we also develop a disaggregated welfare picture of society. We will show how different epsilon values affect the distribution results in the energy sector and in the whole of society. This approach allows the effect of the inequality aversion of society to be considered in the energy sector as well. We obtain the following additional sector welfare functions:

Social consumption welfare function:

$$SWF_{PK} = \sum_{i=1}^{n} \frac{1}{1-\varepsilon} PK_i^{1-\varepsilon}$$

Social energy welfare function:

$$SWF_E = \sum_{i=1}^{n} \frac{1}{1-\varepsilon} E_i^{1-\varepsilon}$$

Social residential welfare function:

$$SWF_{EW} = \sum_{i=1}^{n} \frac{1}{1-\varepsilon} EW_i^{1-\varepsilon}$$

Social car traffic energy welfare function:

$$SWF_{EK} = \sum_{i=1}^{n} \frac{1}{1-\varepsilon} EK_i^{1-\varepsilon}$$

On the basis of the described functions, we can define the social welfare for all households depending on the chosen epsilon parameter. The values are not comparable for different values of epsilon; they can only be interpreted as indices [Lüthi, 1981, 47].

For the household group of all households, the indices (Table 2) reveal that under the condition of low aversion to welfare differences (epsilon 0.1), social welfare would increase if all households were to receive the average income. An increase in social welfare through the distribution of the average income would decrease with an epsilon value of 0.5 because the transfer costs would increase with increasing epsilon values. With epsilon parameters of 1.5 and 2.0 and transfer costs of 65-75%, no additional welfare would occur through a redistribution of income.
The analysis also shows that with a low epsilon parameter and low transfer costs, welfare gains occur in the private consumption, energy consumption, residential energy consumption and car energy consumption of all households. However, it also shows that for an epsilon value greater than 1.5, no more welfare gains appear in private consumption. In the area of energy, small welfare losses appear when all households consume the average energy services. This means that in spite of high transfer costs, the social well-being function is not changed by the redistribution. If we take a more differentiated look at the households, a slightly modified picture arises. In the household group of single women, the welfare gains decrease with increasing epsilon when every household is assigned the average consumption. Some welfare losses were detected for single-woman households in the energy sector. Therefore, we can summarize that the social welfare of this group does not increase when

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</tbody>
</table>

Source: Own calculation

Table 2: Social Welfare
the transfer costs rise more than 50%. This development trend also appears within the social group of single men, single-parent households, married couples without children and married couples with children.

The present analysis has shown the influence of the epsilon parameter on social welfare, i.e. how the inequality aversion of society influences the social welfare of that society. In the following, we will examine what influence the inequality aversion of the epsilon parameter has on the distributional effect measured by the Atkinson index.

IV.2 Atkinson index - Inequality of income and consumption by population subgroups

In the following, we will use the Atkinson index to determine the distributional effect of income and energy. For the calculation of the distribution of the gross and net income for the different social groups, we used the modified Atkinson index $A I_g$:

$$A I_g = 1 - \left[ \sum_{i=1}^{n} \left( \frac{Y_{i,g}}{\bar{Y}_g} \right)^{1-\varepsilon} f_{i,g} \right]^{1}, \text{for } \varepsilon \neq 1.$$  

$$A I_g = 1 - \exp \left[ \sum_{i=1}^{n} f_{i,g} \log_\varepsilon \left( \frac{Y_{i,g}}{\bar{Y}_g} \right) \right], \text{for } \varepsilon = 1.$$  

$Y_{i,g}$ represents the income of individuals in the ith income range (n sum of the income classes) in the g social groups (all households, single women, single men, single parent with children, married couple, married couple with children), $f_{i,g}$ is the proportion of the population in the social groups with income in the ith income range, $\bar{Y}_g$ is the mean household income of the social group, and the epsilon parameter for all groups is $\varepsilon$.

For the calculation of the distribution of the private consumption, we also used a modified Atkinson index $A I K_g$:

$$A I K_g = 1 - \left[ \sum_{i=1}^{n} \left( \frac{K_{i,g}}{\bar{K}_g} \right)^{1-\varepsilon_2} f_{i,g} \right]^{1}, \text{for } \varepsilon \neq 1.$$  

$$A I K_g = 1 - \exp \left[ \sum_{i=1}^{n} f_{i,g} \log_\varepsilon \left( \frac{K_{i,g}}{\bar{K}_g} \right) \right], \text{for } \varepsilon = 1.$$
$K_{i,g}$ represents the consumption expenditure of the individuals in the $i$th income range of the social group $g$, $f_{i,g}$ is the proportion of the population in the social group $g$ in the $i$th income range, and $\overline{K}_g$ is the average household consumption.

For the calculation of the distribution of energy consumption $E_{i,g}$ in the various social groups, we used the following modified Atkinson index $AIE_g$:

$$AIE_g = 1 - \left[ \sum_{i=1}^{n} \left( \frac{E_{i,g}}{E_g} \right)^{1-\varepsilon} \right]^{1-\varepsilon}, \text{ for } \varepsilon \neq 1.$$  

$$AIE_g = 1 - \exp \left[ \sum_{i=1}^{n} f_{i,g} \log_e \left( \frac{E_{i,g}}{E_g} \right) \right], \text{ for } \varepsilon = 1.$$

$E_{i,g}$ represents the energy consumption expenditure of the individuals in the $i$th income range of the social group $g$, $f_{i,g}$ is the proportion of the population in the social group $g$ in the $i$th income range, and $\overline{E}_g$ is the average energy household consumption in that social group.

For the calculation of the distribution of the residential energy and car energy used by the various social groups, we used the following modified Atkinson indices $AIEW_g$:

Residential energy:

$$AIEW_g = 1 - \left[ \sum_{i=1}^{n} \left( \frac{EW_{i,g}}{EW_g} \right)^{1-\varepsilon_4} \right]^{1-\varepsilon_4}, \text{ for } \varepsilon_4 \neq 1.$$  

$$AIEW_g = 1 - \exp \left[ \sum_{i=1}^{n} f_{i,g} \log_e \left( \frac{EW_{i,g}}{EW_g} \right) \right], \text{ for } \varepsilon_4 = 1.$$  

$EW_{i,g}$ represents the energy consumption expenditure of the individuals in the $i$th income range of the social group $g$, $f_{i,g}$ is the proportion of the population in the social...
group $g$ in the $i$th income range, and $\overline{EW_g}$ is the average energy household consumption in that social group.

Car energy:

\[
AIEK_g = 1 - \left[ \sum_{i=1}^{n} \left( \frac{EK_{i,g}}{\overline{EK_g}} \right)^{1-\varepsilon} f_{i,g} \right]^{\frac{1}{1-\varepsilon}}, \text{ for } \varepsilon \neq 1.
\]

\[
AIEK_g = 1 - \exp \left[ \sum_{i=1}^{n} f_{i,g} \log \frac{EK_{i,g}}{\overline{EK_g}} \right], \text{ for } \varepsilon = 1.
\]

$EK_{i,g}$ represents the energy consumption expenditure of the individuals in the $i$th income range of the social group $g$, $f_{i,g}$ is the proportion of the population in the social group $g$ in the $i$th income range, and $\overline{EK_g}$ is the average energy household consumption in that social group. The following Table 3 shows the results of our calculations using the various Atkinson indices.
Table 3: Distribution of income and consumption in Germany

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<tr>
<th>epsilon</th>
<th>net income</th>
<th>private consumption</th>
<th>energy</th>
<th>residential energy</th>
<th>car energy*</th>
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</tr>
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*) car energy = fuel and lubricant

Source: Own calculations based on Statistisches Bundesamt 2008

Table 3 shows that the value of the Atkinson index increases when a higher weight is attached to the lower income groups with rising epsilon. This development is inde-
pendent of the chosen household type. However, differences exist between the social groups and research topic: net income, private consumption, energy consumption, residential energy, and car energy.

Net income

In the case of net income, we see for the group of all households that inequality rises significantly from 0.02 to 0.30 by increasing epsilon. The inequality of the distribution of net income rises for single women from a nearly equally distributed income 0.01 by an epsilon value of 0.1 to an Atkinson index of 0.27 by an epsilon value of 2.0. For single men, this ranges from 0.02 to 0.35, while for single parents with children we see a smaller increase from 0.01-0.22 and 0.01 to 0.19 for married couples. The group of married couples with children have the smallest spread of the Atkinson index (0.01-0.15) by raising epsilon.

The increase of the Atkinson index is a little lower for the social group of single women than for the group of single men. The reason for that is that the net income of single women is more equally distributed between the income groups than in the case of single men. Only 3% of households with single women are in the two highest income groups, whereas for single men at least 9% are in these two groups. The values of the households with couples and single parents are below the values of the Atkinson index of the group of all households.

Private consumption

The analysis shows that private consumption is more equally distributed among households irrespective of the chosen social group and the chosen epsilon parameter. The split of the Atkinson index of the various social groups ranges from 0.01 to 0.17 by raising the epsilon parameter from 0.1 to 2.0 for the overall households. In the social group of single men (0.01-0.13) and women (0.01-0.12), consumption is more equally distributed among the households than in the overall households. The households of single parents with children reveal a smaller increase in inequality according to private consumption. The Atkinson Index increases in family households in the range of 0.0 to 0.10 by raising the value of the epsilon parameter. Married couples with and without children experience the smallest increase of the Atkinson index by raising epsilon. From this fact, we can conclude that the level of and the need for consumption by these households is not so much influenced by income but by family necessities, which are largely independent of household income.

Energy consumption

Table 3 also shows that energy consumption is more equally distributed than consumption expenditure in general. In the case of the distribution of energy consumption between the income groups of the social groups, the social groups can be summarized in two major subgroups. The group of all households (0.01-0.12) and households of single men (0.00-0.11) show nearly the same distribution by the rising epsi-
ion parameter. Households of single women (0.00-0.07) and family households (0.00-0.05, 0.00-0.04, 0.00-0.02) have a lower spread of inequality by rising epsilon. It is noteworthy that especially in the households of married couples with children energy consumption is nearly equally distributed between the households. This development is also visible in the distribution of residential energy.

Residential energy is almost equally distributed between the income groups in all social groups. The Atkinson index ranges from 0.00-0.09. In the group of all households we see a small increase of the Atkinson index (0.01-0.08) by rising epsilon. The single men have a similar development of the Atkinson index (0.01-0.08) to that in the group of all households. The other households show a similar picture of the development of the Atkinson index by rising epsilon parameter. Also for the residential energy consumption, we see that this consumption is nearly equally distributed between the households, which can be interpreted such that residential energy is a fundamental good for all households irrespective of the household’s income.

In the case of car energy consumption, we see a slightly different picture: The Atkinson index values are raised. For all households, we see an increase of the index from 0.02 to 0.19. These values are significantly higher than in the case of residential energy consumption. The households of single women and single men show a very similar development, where the spread is greater than in the family households. In the social households of single parents with children, married couples and married couples with children we see almost equally distributed consumption. Car energy consumption is a central necessity for family households and is independent of the household’s income. The family household budget will allocate the necessary money to finance this consumption. Car energy consumption is not such a basic necessity for the households of single men and women. The reason for this might be that most households of single people are found in large towns and cities, where mobility is not concentrated on private transport.

To summarize: Private consumption is more equally distributed than income, and expenditure for energy consumption is more equally distributed than private consumption in general. And residential energy consumption is the most equally distributed consumption of all households. Family households are more evenly distributed than in the other social groups especially in the field of energy consumption.

Table 3 also makes clear that the energy expenditure is distributed almost equally between the households, and that it does not increase very much with increasing income. Energy expenditure thus plays a much more important role for the lower income groups than for the upper income class, and price changes will have a higher impact on their household budget.
V Conclusions

Our analysis has shown that the Atkinson index provides a powerful tool not only to measure the distribution of income but also as a new tool to estimate the distributional dimensions of energy consumption. Our analysis has shown that a distribution analysis based on the Atkinson index can make an important contribution to the social debate about the distributional justice of income and consumption. With the epsilon parameter, the Atkinson index explicitly reveals the inequality aversion of society, and this enables us to define how sensitively the Atkinson index should react to inequalities. This parameter expresses the assessment on the part of society of its own vulnerability. The more acutely society sees its vulnerability through unequal distribution of income and consumption the higher is epsilon. This self-perception of society determines the value of epsilon (0.1-2.0). Every society is affected by this vulnerability [Atkinson, 2011], which could be reduced by a sustainable development of society.

For the purposes of sustainable development [Cranston & Hammond, 2010], epsilon can be interpreted as a sustainable parameter. The transfer of money represented by epsilon can be used to finance sustainable projects, which are not part of the social welfare function.

Epsilon can be extended with a view to sustainable development in such a way that the greater the epsilon value is, the higher the need for financing sustainable development projects is in the view of society. The transfer losses can then be used for sustainable measures and thereby generate intergenerational profits for future generations.

Epsilon can therefore be interpreted as an intergenerational justice factor in the sense of sustainable development. A low epsilon value means that society has a low aversion to inequality both in an intragenerational and an intergenerational sense. The aversion increases with a rising epsilon, and society takes more intra- and intergenerational questions into consideration. The trade-off between equality and efficiency is thereby extended to the area of intergenerational equality.

These distributional effects are of great political interest not only in Germany but also in the European Union and in the OECD as recent studies by these organizations show [OECD, 2011b, OECD, 2011a, European Commission, 2010, European Commission et al., 2009]. Further research on the inequality of energy consumption should be performed for the European Union, OECD countries and for emerging countries, because as the OECD wrote, “there is a widespread concern that economic growth [in the emerging economies] is not being shared fairly [OECD, 2011a].” This concern is also shared by the European Commission as the director of Science, Economy and Society wrote in the Research Policy Report: “There is now compelling scientific evidence that since the mid-1970s socio-economic inequalities have in-
creased significantly in the world including Europe [European Commission, 2010].” If we understand the inequalities of income and consumption better, we can develop adequate policy measures to better handle the wellbeing and the quality of life of these societies [Wilkinson & Pickett, 2010, 31].

VI References


Preprints 2012

01/2012 Schlör, Holger, Fischer, Wolfgang, Hake, Jürgen-Friedrich: Measuring social welfare, energy and inequality in Germany
Systems Analysis and Technology Evaluation at the Research Centre Jülich

Many of the issues at the centre of public attention can only be dealt with by an interdisciplinary energy systems analysis. Technical, economic and ecological subsystems which interact with each other often have to be investigated simultaneously. The group Systems Analysis and Technology Evaluation (STE) takes up this challenge focusing on the long-term supply- and demand-side characteristics of energy systems. It follows, in particular, the idea of a holistic, interdisciplinary approach taking an inter-linkage of technical systems with economics, environment and society into account and thus looking at the security of supply, economic efficiency and environmental protection. This triple strategy is oriented here to societal/political guiding principles such as sustainable development. In these fields, STE analyses the consequences of technical developments and provides scientific aids to decision making for politics and industry. This work is based on the further methodological development of systems analysis tools and their application as well as cooperation between scientists from different institutions.

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