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Socio-metabolic class theory and statistical analysis of German population survey data

An interdisciplinary approach of assessing socio metabolic classes on the German society and the inherent role of different types of capital on carbon emissions.

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Abstract

The Earth's seven billion people consume varying amounts of planetary resources and have varying impacts on the environment. This work explores whether the global concept of Planetary Boundaries can be downscaled to the individual level as well as the research methods and data that can be used for this purpose. I combine the analytical tools offered by the socio-ecological metabolism and class theory and propose a novel social stratification theory to identify the individual resource using hotspots within societies. The theory is tested on the German society and explores data gathered in a representative survey of the German population, including per capita greenhouse gas emissions in the sectors Housing, Transportation and Secondary Consumption. To grasp socio-metabolic profiles of individuals who are responsible for high emissions, I analyzed the data multi-dimensionally using cluster analysis and principle component analysis. Additionally, I have included the economic perspective, as well as interpret the social and cultural factors, that determine resource intensive lifestyles. The results show large disparities and inequalities in emission patterns in the German society. The greenhouse gas emissions in the lowest and highest emission classes differ up to tenfold. Income, education, age, gender and regional differences (FRG vs. GDR) determine different distinct emission profiles. In addition, economic, cultural and social factors influence individual carbon footprints and thus determine class differentiation. I also explore the role of digital technologies regarding resource and energy consumption understood as a cultural asset. Showing inequalities within societies is a step towards downscaling carbon emission reduction targets that are in the foreground to avoid transgressing the planetary boundary climate change. I discuss the results in the context of climate policy implications as well as behavioral changes.

1. Introduction

Environmental, climate, and population pressures accentuate the required quest for global sustainability. Resource depletion, overused or under-provided global commons, major environmental problems and loss and damage to ecosystem services are consequences and pose a threat to human security and social stability (Schellnhuber et al., 2014). The role of humans as influencing factors to natural systems, is undisputed, as humans are seen as geological forces that influence the trajectory of the Earth System (Steffen et al., 2018). This new geological epoch is the Anthropocene (e.g. Steffen et al., 2007). The potential to push components of the Earth system beyond critical states implies further large-scale impacts on human and ecological systems (Lenton et al., 2008). These critical thresholds, referred to as tipping points, or elements at which a tiny perturbation can qualitatively alter the state or development (ibid), might trigger non-linear, abrupt environmental changes within continental-to planetary-scale systems (Rockström et al. 2009). To set preconditions for sustainable development and to evolve a more unified approach for working towards global sustainability, the concept of Planetary Boundaries by Rockström et al. (2009) sets environmental boundaries for a safe operating space for humanity. The nine boundaries are climate change, biosphere integrity, land-system change, freshwater use, biochemical flows, ocean acidification, atmospheric aerosol loading, stratospheric ozone depletion and novel entities (ibid). As stated in the IPCC (2014) report, anthropogenic greenhouse gas emissions are the highest in history and human influence on the climate system is proven; the ocean and atmosphere have warmed, sea level has risen and snow and ice have diminished. The world is likely to warm, also with current mitigation commitments and international pledges, by more than 3°C above the preindustrial levels. Strong changes in the terrestrial system are to be expected. Consequence is the demand for collective human action (Steffen et al., 2018). To address these issues, this thesis focuses on the boundary climate change, that is already transgressed.

The target of keeping global temperature rise below 2° C above pre-industrial levels, while pursuing efforts to limit it to 1.5°C, was agreed by 196 UNFCCC parties in 2015 at the 21st Conference of the Parties (COP) in Paris (UNFCCC, 2015). The reduction of emission is a public good and international agreements are difficult to achieve – multi- and unilateral emission reductions are discussed (e.g. Eisenack & Kähler, 2016). For climate change, especially intergenerational and regional, dimensions are to be emphasized - there is a separation between cause and effect in a spatial and temporal way (Gardiner, 2011), which increases the intricacy of action.

In order to transfer or divide global responsibility and give guidelines to the political arena, especially with regard to inequality (e.g. Oxfam, 2015) and climate justice (for ecological debt see e.g. Roberts & Parks, 2009), recognized concepts such as the Planetary Boundaries should be made accessible for decision-makers. Häyhä et al. (2016) provide an applicable approach for translating the Planetary Boundaries into national-level fair shares to make use of a global concept in smaller entities. With the identification of emission hotspots (IPCC, 2014), national reduction potentials and inequalities between countries can be demonstrated. Emission hotspots can be countries, industries, or a group of individuals that cause an unusually intense bulk of emission.

To get better insights on ongoing processes, today's emissions and emission hotspots need to be considered at different levels: At the national level (also in historical comparison), at the corporate level and at the individual level, which can be traced back to lifestyles. The satisfaction of consumer needs is related to emissions and opens up an analytical level – the individual becomes the focal point. In the Anthropocene, humans are seen as a geological force who can alter states or developments of systems, but also render the possibilities for a sustainable transformation.

On account of this, the individual subject is of interest. Additionally, its inherent human agency that are the choices and action plans made or the appropriate future course of action and how agency is allocated to society and human agents (Otto et al., submitted). The concept of human agency is related to as lifestyle changes (Van Vuuren et al., 2018), changes in the institutional structures or in the rules of the games they play (Farmer et al., 2012). It plays an important role in identifying potential for change and could also be operationalized in social-ecological system models.

Aside from the implementation of concepts like agency, data analysis is necessary to operationalize theoretical approaches. Otto et al. (2015) state that subnational socio-economic datasets are required to assess climate impacts and to overcome the gaps between existent data for natural and social analyses. If data is available, analytical strategies are often concerned with correlations between emissions and (socio-demographic) factors like income (e.g. Oxfam, 2015). One example are publications that try to answer the question, if higher inequality leads to lower emissions (see e.g. Borghesi, 2000) and stating that keeping individuals in poverty is a solution to climate change. In the context of this thesis though, it is rather about understanding the profiles of individuals who are responsible for high emissions and approaching from a multi-dimensional, not only economic perspective, and trying to understand social and cultural factors, that determine lifestyles.

In principle, the thesis uses the analytical power of socio-ecological metabolism approaches for understanding regional, and in this case national, environmental changes or impacts (Singh, 2013). To be more explicit, social metabolism refers to the manner in which human societies organize their growing exchanges of energy and materials with the environment (Fischer-Kowalski, 1997; Martinez-Alier, 2009). It is an approach to connect environmental change to social coevolution. The word *metabolism* comes up in many different research fields, from biology to anthropology, and became more visible with the increase of the discussion about economic growth and the changes in energy and material flows. To that fact, Marina Fischer-Kowalski (1998) did pioneer work to cut across the divide between natural and social science and humanities in pointing out, how the approximation from different research fields can be useful to set up an appropriate framework for society-nature-interaction analysis. The objective of this thesis is the operationalization of the concept with empirical data. Based on the metabolism approach, Otto et al. (submitted) divides societies into classes that are not based, for example, on the labor condition or status, but rather on their metabolic profiles (Martinez-Alier, 2009). This socio-metabolic class theory asserts that an individual's position within a class hierarchy is therefore determined by the metabolic profile. The metabolic profiles can be, however, linked with specific world views, believes, the access to resources, and lifestyles. The human use of energy can be divided into two main categories. The first one refers to the endosomatic use of energy as food, and the second one refers to the exosomatic energy use, that is, energy for cooking and heating, and as power for the artifacts and machines produced by human culture. The exosomatic energy use can be directly linked to carbon emissions and footprints and varies considerable in the human population and can serve as the basis for defining socio-metabolic classes (Otto et al., submitted). A new approach of social stratification can thus be achieved in combination with the identification of emission hotspots.

The French sociologist Pierre Bourdieu also assumes a division of society into classes. He postulates a social space in which he locates the different classes that differ in the endowment with capital types - a distinction is made in social, economic and cultural (and symbolic) capital (Bourdieu, 1986), although the social structure is determined by the distributional structure of capital. These assumptions can also be applied to a socio-ecological context in which the capital types evoke a particular habitus that can be equated with a lifestyle and is thus related to emission profiles. Bourdieu's theory is therefore not used for the extraction of classes but for the subsequent examination of the classes.

To avoid only working theoretically, this thesis applies findings from social science to Earth System Science and attempts to gain scientifically sound knowledge (by statistical analysis) based on existing data from the Federal Environment Agency (UBA). Since the data has not been collected for this research question, only an approximation is possible. The initial assumption is that humans do not have same socio-metabolic profiles and do not use equal shares of natural resources or contribute equal shares of emissions (Otto et al., submitted) - a huge disparity between and also within societies exists, showing new patterns of inequality. The Oxfam report (2015) asserts that the richest ten percent of global population are responsible for almost half of all total lifestyle consumption emissions. The correlation of carbon emissions and income was proofed (e.g. Sommer & Kratena, 2017) but further analysis is needed to capture the determinism of human behavior. Therefore, the research gap is to find a way to grasp the reasons for specific action - to understand what constitutes the realities of the emitters, and how behaviors and lifestyles evolve. To close this gap, my motivation is to better understand social structures and to address inequality and societal and environmental justice. In this context, the following research question arises: *Can individuals be grouped into emission classes and how do these classes differ from each other regarding their economic, social and cultural capital?* To make use of the Planetary Boundary framework, the research objective is to group the German society into socio-metabolic classes and exhibit a multi-dimensional approach to detect common social, cultural and economic properties within these classes and identify emission hotspots. Therefore, the thesis is divided into two parts: First, the theoretical background and second, the application of the gained knowledge on real data, as well as a statistical evaluation. The thesis begins with the introduction of the umbrella framework of Planetary Boundaries (Rockström et al., 2009). The conceptualization of metabolism and socio-metabolic classes, giving a natural perspective, by mainly highlighting the limitations of systems and organisms, ties in with an overview of the discourse about agency and inequality. Class theoretical thoughts follow and are extended with contemporary analytical levels of social stratification (e.g. Savage et al., 2013). For the purpose of this research, the human socio-metabolic classes are analyzed regarding their properties using Pierre Bourdieu's theory of capital.

Thereupon, the focus is on particular groups and classes of emissions are constructed, which is a first operationalization of socio-metabolic class theory on real data. A thorough literature research has been done to create the theoretical foundation of this paper. While creating my theoretical foundation, I drew on literature from various research fields to create a holistic approach. Equipped with these findings, I started my own analysis. The application follows in the second part in cluster analyses, own descriptive statistics and results of the UBA working group. All findings are then discussed, and results of this work are implemented in terms of recommendations for further research on downscaling Planetary Boundaries, environmental action and climate mitigation policies.

2. Literature Review and Theory

2.1. Planetary Boundaries and Downscaling efforts

Humanity, especially since the industrialization, has strong impacts on natural systems (Zalasiewicz et al., 2012). The determination of the epoch Anthropocene, which began in the late 18th century when analysis of polar ice showed the beginning of growing global concentrations of carbon dioxide and methane, demonstrates the importance of social-ecological interactions as humans becoming a geological force (Crutzen, 2002). The fact, that the level of influence between individuals, corporations, societies and countries and hence (negative) impacts on ecological systems vary, point out the necessity of detecting hotspots to specify implementations of ecological responsibilities which can be approached from different perspectives: This thesis gives attention to one possible way to meet the goals of global agreements, like the Sustainable Development Goals (SDGs) or the Paris Agreement, that is, to focus and put responsibility on individuals and with that on countries and their governments, because the focus of action had been to date on states and firms (Paterson & Stripple, 2010).

In the context of this work, the point of reference is the global concept of Planetary Boundaries from Rockström et al. (2009). It provides physical limitations of impacts as thresholds (see e.g. Castellani et al., 2016) and derives also from the observation that the earth has entered an epoch, where changes of the system earth are influenced dominantly through impacts of human activities (Steffen et al. , 2007). The impacts can be of an extend, that is critical and dangerous for human well-being. Based on this, the PBs define a safe operating space for humanity by setting quantified thresholds for nine earth system processes on a global scale, that must not be transgressed in order to prevent potentially dramatic and irreversible changes of the earth system, that negatively affect the existence of humanity (Rockström et al. 2009). Three of nine boundaries (rate of biodiversity loss, climate change and nitrogen cycle) were already transgressed during that time (Steffen et al., 2015). Due to that importance, the updated version of this concept from 2015 shows that two core boundaries are highlighted by Steffen et al. (2015): Climate change and biodiversity integrity. The greenhouse gas Carbon Dioxide functions as a control variable, since it is strongly connected to climate change (see e.g. IPCC, 2013; Le Quéré et al., 2016).

Häyhä et al. (2016) proposes the necessity of downscaling the Planetary Boundaries to national fair shares and developed a framework that addresses the biophysical, socio-economic, and ethical dimensions of bridging across scales. For example, studies include analysis for Sweden (Nykvist et al., 2013), Switzerland (Dao et al., 2015) and the European Union (Hoff et al., 2014). In these attempts, environmental performance is measured from a consumption- or production-based perspective and the authors end up with allocation principles like equal per capita shares or hybrid allocations (considering impacts from the past and future). Equal per capita shares are on one hand useful as directories for own consumption behavior, on the other hand, hotspots of emissions and ensuing implications, like shifting norms, creating (economic) incentives or implementing restrictions, need to be identified to make them useful at all.

Climate justice or responsibility raises the question of who is responsible for climate change and who should bear the burdens (Caney, 2006). Focus lies on the principle, that those who cause the problem are morally responsible for solving it. Caney (2006) also states, that this approximation cannot provide a complete account and gives an indication to a more common but differentiated responsibility.

However, this discussion, which is often conducted between nations or state unions, can also be transmitted to smaller levels - within a state or a society. To avoid the equalization of all individuals within a society, an aggregation in groupings is reasonable. It is important to examine who creates carbon emission hotspots and if these hotspots can be minimized. For example, civil aviation is an increasingly significant contributor to anthropogenic CO_2 emissions (Grote et al., 2014), therewith an analysis of carbon footprints of frequent fliers is appropriate.

Nevertheless, downscaling efforts are worth trying out, to use global concepts on smaller scales and to make scientific findings accessible to the public.

2.2. Human agency and Inequality

Consumption patterns, or behavior in general, differ extremely between individuals: Humans do not use equal shares of natural resources or contribute equal shares of emissions – between societies or individuals exists inequality (Otto et al., submitted). The differences in resource use and emerging emissions define individual profiles that include energy and material flows, which are referred to as socio-metabolic profiles.

The different socio metabolic profiles come to light through a certain kind of lifestyle, which is, exemplarily, connected to an individual lifestyle related footprint (see e.g. Reusswig et al., 2003). A society is not a mere sum of individuals (Durkheim, 1938) and it is meaningful to put different individuals with different lifestyles in groups, to analyze their common characteristics. As humans are dependent on different, predetermined factors, such as access to technology, public infrastructure, geographical location, they act out a certain lifestyle with different environmental impacts. The possibility to choose a lifestyle, is dictated by economic, cultural and explicitly social factors that are not clearly evident and much harder to observe.

The question, what is shaping human behavior and therefore choices of lifestyle, opens the structure-agency debate, which tries to understand what the social world is made of, what is a cause and what is an effect. The relevant difference on which to build is, that structure is the recurrent patterned arrangements which influence or limit the choices and opportunities that are available (Barker, 2005). On the other side, agency is the capacity of individuals to act independently and to make free choices (ibid). The lifestyle a person lives out and the impacts on nature that come along are preset but also chosen consciously. Anthony Giddens is one of the theorists whose ideas are most often invoked when the idea of agent-structure explanation is in play. He demands a theory of the human agent, and an account of the conditions and consequences of action with an interpretation of structure, which is entangled with conditions and consequences. (Parsons & Giddens, 1980). This demand is applicable for questions of sustainability where agency plays a major role regarding impacts and responsibility. Agency, that is allocated to society and human agents (Sztompka, 1994), can be an appropriate analytical level for understanding the social metabolism of today.

A perspective, useful in the context of this work, comes from psychologist Albert Bandura (2000), who describes, that individuals believe in personal efficacy and are producers of experiences and shapers of events. As he depicts in “Toward a Psychology of Human Agency" (2006), social cognitive theory rejects a duality between human agency and social structure, because individuals create social systems themselves and in turn organize and influence lives. Humans are contributors to their life circumstances and not onlookers of their behavior (Bandura, 2006).

In an environmental context, he claims that individuals act on the environment actively, in making decisions consciously and subconsciously. In contrast to the upcoming chapter 2.3.2 and the revolutions in energy regimes, Bandura (2006) depicts, that humans are adaptable and have always taken an active role in their own development or evolution and are responsible for consequences as they are prime players in the coevolution process (ibid). Conclusion is a human responsibility and contribution for respecting the boundaries of the earth system.

Bandura (2006) has also taken up the idea of collective agency which becomes important, if the level of one's agency is limited (due to social, cultural and economic limitations), but becomes powerful as collective action, that creates social and political institutions (see e.g. Otto et al., submitted). The enhancement of the agency debate with regard to various groups or classes is relevant to assigning responsibility and opportunities for action. Otto et al. (submitted) started to think of a conceptualization (table 1), which is different from the commonly used rational choice paradigm, using lifestyle and greenhouse-gas emissions and the degree of agency, to stratify the global population according to their socio-metabolic classes. Socio-metabolic classes are groupings of individuals with same or similar metabolic profiles. The global socio-metabolic underclass is characterized by a very low degree of agency because individuals are mostly occupied with meeting their ends and have low organizational capabilities – institutional changes through e.g. mass protests are hardly expected (Kashwan, 2017). The global socio-metabolic upper classes are characterized by a high level of individual agency having the organizational capabilities to actively exercise their agency and because of their resource incentive life-style, there is a moral obligation to be the agents of a global sustainability transformation (Otto et. al., submitted). It must be added that the authors only used household electricity use, excluding energy used for Transportation and for production of goods. This is therefore only a rough impression, but still striking.

	Percent of global population	Percent of life-style CO_2 emissions	The level of human agency
Socio-metabolic underclass	20%	2.5%	Low
Socio-metabolic energy poor class	30%	7.5%	Low
Socio-metabolic lower class	30%	22%	Moderate level of collective agency
Socio-metabolic middle class	10%	19%	Moderate to high
Socio-metabolic upper class	9.5%	36.5%	Very high
Super rich	0.54%	12.5%	Extremely high

Table 1: Socio-metabolic classes (source: Otto et al. (submitted))

The approach of socio-metabolic classes and the connection to their agency is the basis for the research of this paper. These attempts reveal inequalities which show the necessity to create more accurate views on agents and their environmental impacts. At present, greenhouse gas emission analyses are strongly focused on economic variables. Figure 1 for instance illustrates the connection between per capita carbon footprints and income levels.

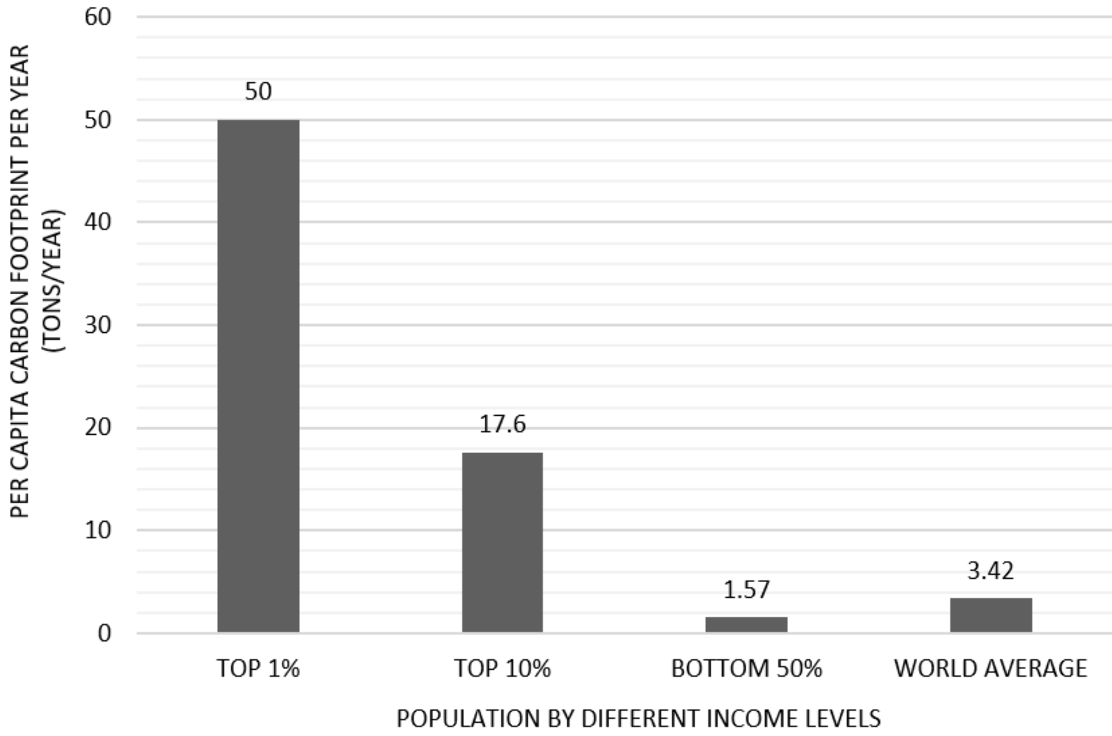


Figure 1: Per capita carbon footprints and income levels (source: Kim, 2018)

Though, that explanatory context is short of detail. The following chapters analyze social, cultural and economic factors determining environmental footprints and also scrutinize consequently the level of agency.

2.3. (Social) Metabolism

2.3.1. Metabolism in Biology

From a biological perspective, Beck (1991) stated that a metabolism embraces the processes of catabolism, anabolism and all the regulatory mechanism that govern these systems. The concept can be transferred to many scales, for example on populations, communities or societies. This debate is carried out in the conflict on holism versus reductionism, which tries to answer the question, if there are self-organizing properties that allow these systems to optimize the utilization of energy and nutrients (Fischer-Kowalski, 1998).

Marina Fischer-Kowalski describes (1998) that humans do have a metabolism and that they need to (at least) sustain it, or they will simply die. As social animals, humans solve this problem collectively and societies sustain at least the total metabolism of their members. The surplus cannot be used for the production of more cells, so the extension of the concept takes place in recognizing a new form of interaction with the environment, which is no direct exchange, but via the activities of humans as a matter of organization. Humans do have a social metabolism that goes beyond biological requirements. Via activities like breeding, cultivating, constructing and producing, humans create and maintain this social metabolism (Ayres & Simonis, 1994; Fischer-Kowalski, 1998). The proposition that humans, as heterotroph organisms, take material input from the environment but return it in a different form (Fischer-Kowalski, 1998), is crucial for the understanding of energy and material flows.

2.3.2. Revolutions in energy and material flows

The magnitude and mode of input/output or material cycles differed a lot in Earth and human history. Lenton et al. (2016) argues in a journey of time, that these revolutions or changes in energy and material flows and the consequences for the internal organization of the respective system, can be shown. The authors focus on the Paleolithic and the use of fire, the Neolithic revolution to farming and the Industrial revolution as major steps in human history and make an attempt to quantify the resulting increase in energy input (Lenton et al., 2016).

In foraging societies and before the intentional use of fire, humans lived in uncontrolled solar energy systems (Sieferle, 1997). Paleolithic fire use was therefore the first human revolution in energy input, that sets humans apart from all other species in extending the metabolism outside the body (Lenton et al., 2016). This collective organization marked the turning point in social metabolism (Fischer-Kowalski, 1998).

Around 10.000 years ago the change from pre-agrarian societies to agrarian societies transformed the energy regime, because the so called “Neolithic revolution” stood out with the invention of farming, breeding, and animal husbandry (Lenton et al., 2016) and the transition to a controlled solar energy regime (Sieferle, 1997). Advancements in the way of life were accompanied with contradictory obstacles, because farmers had to work more than humans in pre-agrarian societies, had a less diverse diet, were more prone to diseases and had a lower productivity in calorific return on labor investment (Boserup, 1965 ; Bowles, 2011). Population pressure (Boserup, 1965), climate change or resource scarcity can be explanations why there was anyhow a revolution (Lenton et al., 2016). Considering social metabolism, it is important to notice the change in societal structure: These new forms of living together marked a point of no return (to pre-agrarian societal structures) where societies exercised more pressure on natural systems and had to handle environmental constraints in their occupied spatial unit. Economic growth was only possible through land expansion and increase in area productivity, but had practical limits that needed an increase in population (Lenton et al., 2016). Mobility was limited, cities became a widespread phenomenon and with it local negative feedbacks of metabolism. A sustained material growth was impossible on a per capita basis and made the distribution of wealth a zero-sum game (ibid).

The third major change in energy use and adherent in social metabolism, which is expressed by a worldwide expansion of a new energy regime, came certainly with the Industrial revolution in the 18th and 19th century (Lenton et al., 2016). There is a strong impact until today, especially in countries that catch up on technological progress. Wrigley (2010) calls this revolution a "puzzle", unlike other energy revolutions, the domino effect and the continuation are outstanding.

For this thesis, it is important to see that the key energy transformation of the industrial revolution came with the ability to massively scale-up fossil fuel energy use (Sieferle, 1997; Wrigley, 2010). Within 150 years, global human energy use has increased tenfold (Fischer-Kowalski et al., 2014; Krausmann et al., 2008; Lenton et al., 2016) and the world population went from 1.3 billion to 6 billion (Van Zanden, 2014). Natural resource use and also land-use changes, entailed an increasing socio-ecological metabolism.

I light the concept of metabolism from different research perspectives, to show how the revolution in energy regimes changes the metabolism and how this affects society, nature and the interaction between them. A new digital revolution is also relevant in this context, as digitization and automation continue to impact on energy and material flows.

2.3.3. Metabolism in Sociology

In the context of the Industrial revolution theories from Karl Marx and Friedrich Engels appear, that apply a form of metabolism between men and nature (Marx & Engels, 1867/1961).

Of course, their concept of metabolism is strongly connected to the description of the labor-process (Fischer-Kowalski, 1998), to that fact that natural resources are appropriated to human requirements through labor itself, which then turns to be a use-value, where the labor process disappears. According to Benton (1996), Marx sees the intentional structure of the labor process as a transformative one, which does not consider all types of labor, especially the ones that are closest to nature (for example farm work). The concept of metabolism from Marx and Engels is therefore insufficient and limited, because the theory is incapable conceptualizing ecological conditions (Benton, 1996).

Different to the biological perspective of metabolism, Marx and Engels recognized a material interdependency between organisms and the environment separate from a cellular or biochemical conversion, which is beyond the simple idea of humanity just utilizing nature (Fischer-Kowalski, 1998). Nevertheless, they are not able to include nature or resources in their theoretical approach of capital accumulation, which is based on labor surplus. Martinez-Alier (1987) describes, that the accumulation of capital is only an appropriation of human labor surplus and has nothing to do with the appropriation of the accumulated wealth of nature.

This material approach from the 19th century stands exemplarily for many other approaches from modern sociology which did not refer to society-nature interactions and, with that, natural parameters as causes or consequences of social activities (Fischer-Kowalski, 1998).

2.3.4. A systemic perspective on analogies between nature and society

From 17th to 19th century, contrarily to today, "there was reciprocity in the interests of naturalists and social scholars of the time, and a genuine desire (…) for discovering universal patterns, principles, and laws that applied to all orders of matter organization." (González de Molina & Toledo, 2014, p.44). As described previously, there were attempts in analogy to describe the two systems, nature and society, as biological and social

organisms, that are in general different but structurally similar. Strong criticism of this organicist conception came up from theorist that became later creator of these theories themselves, for example Emil Durkheim, Max Weber and Talcott Parsons (ibid).
Manuel González de Molina and Víctor M. Toledo point out in "The Social Metabolism" (2014) that within the study of society, it was a common assumption in sociology, that social processes could only be explained by social factors themselves. This assumption could only be diminished in the 1970's, when the human exceptionalism paradigm was questioned in upcoming environmental sociology.
Even though Karl Marx' approach was not fulfilling in every sense, he stands out with his use of the metabolism approach as part of his social theoretical construct. Metabolism approaches as analytical tools, appear in recent scientific research in different forms, for example as industrial metabolism or national metabolism. Industrial metabolism describes flows of materials in industrial societies that aim to reconstruct the biophysical base of territories, nationally or globally (González de Molina & Toledo, 2014).
Like mentioned previously in this text, Robert Ayres (1993) depicts, that there is a compelling analogy between biological organisms and industrial activities, or likewise economic systems, because they are cases of self-organizing dissipative systems (Ayres, 1988) in a stable state, far from thermodynamic equilibrium.
Fossil fuels, mineral inputs and thus the outflow of materials changed extremely during Industrialization. From year 1850 to 2000, global CO_2 emissions increased 125-fold (Marland et al., 2008) and with around 80% per weight of the total annual outflow of materials, CO_2 is making the atmosphere the largest waste reservoir of the industrial metabolism (Matthews et al., 2000).
On a national scale (national metabolism), material flow accountings have been performed for some countries, among them is Germany (ibid). In this context it is clear, that metabolisms differ strongly between countries, what depends on many factors (e.g. stage of development), but also within countries.

Lenton et al. (2016) connect the level of income and energy use to stages of development, considering high income countries with an average energy use of 302 GJ cap^{-1} $year^{-1}$ as fully industrial. Figure 2 illustrates material and energy use in and total population by income groups in 2000. Around 15% of global population lived in an industrial energy regime in 2000, 44% (74 GJ cap^{-1} $year^{-1}$) were in a transition phase, but nearly 40% (with 42 GJ cap^{-1} $year^{-1}$) lived under largely agrarian conditions (ibid). The authors see the connection between energy use and human development as highly non-linear, which means, that at low level an increase of energy input has a much larger effect on the improvement of living conditions than at high stage of human development.

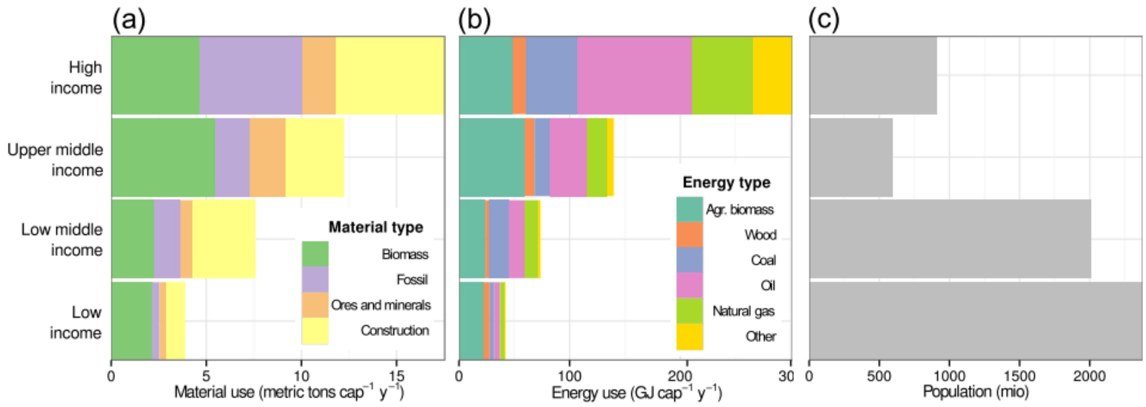


Figure 2: Year 2000 material and energy use and total population by income groups (source: Lenton et al., 2016, adapted from: (a) Steinberger et al., (b) 2010, Krausmann et al., 2008, (c) Worldbank (data.world.org))

Based on research that connects energy consumption (e.g. CO_2 footprints) to economic variables like income, there is a relationship between stage of (economic) development and consumption patterns/energy use (e.g. Sommer & Kratena, 2017). One example is figure three, that is an illustration from the Oxfam (2015) report, that shows, that the richest 10 percent of global population are responsible for almost half of total lifestyle consumption emissions (Oxfam, 2015).

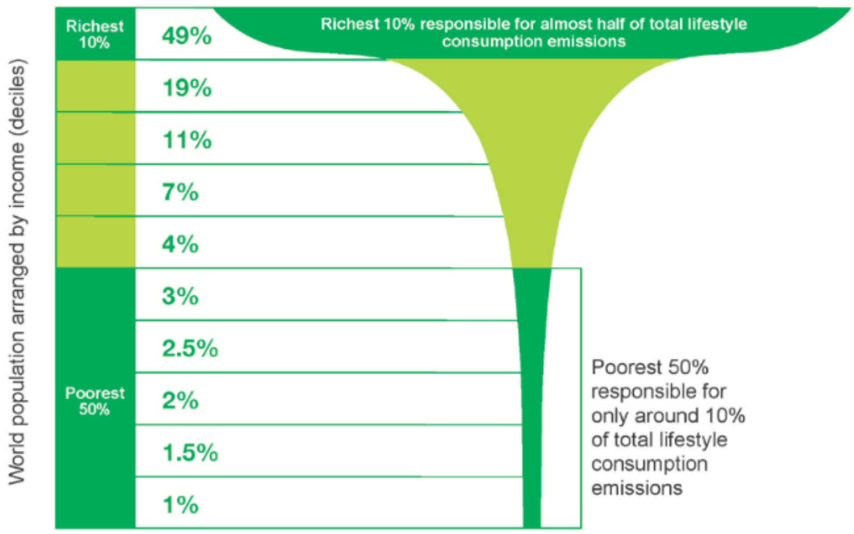


Figure 3: Percentage of CO2 emissions of world population arranged by income (source: Oxfam, 2015)

To conclude the previous chapter: The social metabolism of a country, region or also a person is driven by economic factors and there are “unequal distributions in energy and material use among contemporary humans” (Lenton et al., 2016, p.1).

Thoughts from class and social theory are examined in the next chapter to evaluate possible approaches of social stratification for the German society. A division of society into classes loses more and more its formative power, which is mainly related to the push in individualization of the 21st century (Bühl, 2000). Explanatory attempts by Karl Marx and Max Weber are therefore only conditionally applicable and reach their limits in the sufficient conceptualization of ecological conditions.

2.4. Class Theory

There is a scientific drift, that claim the end of class theory, as a level of analysis for today’s societies. For example, Pahl (1989) argues, that in modern societies class is a ceasing concept and is no useful work for sociology. Holton & Turner (2011) assess, that the class idiom holds more a metaphorical character than any intellectual persuasiveness. The concept of class is therefore accused to be more of a rhetorical, not of a scientific value (Goldthorpe & Marshall, 1992). Additionally, individualism (e.g. Bühl, 2000), globalization (e.g. Goldthorpe, 2002) and digitalization (e.g. Garnham, 2004; Nieminen, 2016) opened the discussion of class conception and the withering away of class practiced by liberal theorists of industrial societies (Goldthorpe & Marshall, 1992). The usefulness of class theory is a debate. Crompton (2015) states, that recent criticism about the end of class theory, have some validity, because developments such as the flexibilization of employment, privatisation and the growth of insecurity make the collective, occupationally based class consciousness, the self-understanding of members of a social class, not very likely. The lack of class consciousness and self-integration in class hierarchies, does not necessarily mean, that class structures do not exist, and prior class theories are worthless. Goldthorpe and Marshall (1992) reveal, that there is a persistence of class-linked inequalities. Today, class structure is deconstructed more accurately (see exemplarily Savage, 2013), which follows Goldthorpe and Marshalls (1992) request to focus on understanding the processes of resistance to change. Social inequalities exist and lead to domination and power structures that oppose certain changes. Therefore, a more accurate understanding of class hierarchy or social stratification eases the identification of hegemony. Since contemporary capitalist societies continue to be fundamentally stratified by systematic inequalities, associated with access to property, jobs and life chances in general (Crompton, 2015), many researchers defend the objective necessity of class relations within capitalism (e.g. O'Neill & Wayne, 2017).

In the 21st century, class and power and their interrelation, are still the most important determinants of the everyday life (Little, 2008). In post-modern societies, class relations, determined by the property system and the basic economic institutions and power relations, that influence careers, opportunities, freedoms, behaviors and choices, are strongly connected and create class structures. It follows that holders of power gain property and holders of property gain power (Little, 2008).

Additionally, structures of discrimination, that are highlighted in the research field of intersectionality, such as race and gender, that, along with class, also matter because they are foundations for systems of inequality and power (Andersen & Hill Collins, 2013).

These thoughts open a discussion, to approach the classification of societies regarding carbon emission hotspots, from a very different perspective. The exposing of in-depth discriminatory mechanisms, which are different from the previous explanatory power of class theory, that is mainly regarding occupation and assets, are of interest. Ongoing debates of intersectionality with race, class and gender as categories of analysis, are helpful to perceive aspects of domination and subordination (ibid).

As the extent of this thesis is limited, the focus is on class. The existence, but also the consciousness of belonging to a certain class, is crucial for the understanding of environmental impacts in socially stratified societies.

2.4.1. Karl Marx and Max Weber

Western conceptualization of class is strongly connected to the doctrines of Karl Marx and Max Weber (Singh, 2017). Otto et al. (submitted) also point out, that many modern class theories build either on Marxian or Weberian tradition. Popular approaches, especially in the Marxist tradition, are frequently discussed and enhanced (for example Choonara, 2017). Karl Marx divided the capitalist society into two classes: The capitalist class or bourgeoisie and the working class or proletariat (Marx & Engels, 1867/1961). These classes are economically determined through their physical and capital endowment. Capitalists own the means of production, increase wealth through surplus value and capital accumulation and purchase labor power from workers (Radice, 2013). The polarization into two great classes creates a class consciousness whereby the working class unites in collective action to overturn the capitalist order to create a classless society (Ritzer, 2011). For Karl Marx, class division is the most important reason of social conflict.

On the contrary, Max Weber was more aware of the complexity of society (Singh, 2017), and that the central character of capitalism is not the class character. Even though Weber's conception of social structure refers to Marx theory, for him, it is more a combination of three components in social stratification: class, status, and power (Ritzer, 2011). Weber depicts, that class position is determined by a person's relationship to the means of production. Therefore, a class situation exists when three conditions are met (Weber, 1921/1968): "(1) A number of people have in common a specific causal component of their life chances, insofar as (2) this component is represented exclusively by economic interests in the possession of goods and opportunities for income, and (3) is represented under the conditions of the commodity or labor markets. This is "class situation".

Nevertheless, class is only one part of social structure. For Weber, a reduction to only economic factors is not sufficient and a multidimensional analysis is needed – through status and power, where status or "Stand" is closely connected to honor or prestige (Ritzer, 2011). A status situation is therefore a social estimation of honor (Weber, 1921/1968) and status is associated with a style of life, which relates to the consumption of produced goods (Ritzer, 2011).

Hence, money and an entrepreneurial position may lead to status qualifications but are not necessarily status qualifications itself. Also, the lack of property is not in itself a status disqualification, although this may be a reason for it (Weber, 1921/1968).

Thus, in Weber's conception of class, the social component is more on focus, which does not reduce class structure to only capital and physical endowment.

2.4.2. Contemporary analytical levels

Over the past decades, several class theories have been published for different countries, often influenced by Marx' or Weber's way of thinking (see e.g. Dahrendorf, 1959; Giddens, 1973). A topical example of class analysis was published by Mike Savage et al. (2013) from London School of Economics. Within the largest survey of social class ever conducted in the United Kingdom, the researchers include detailed questions asked on social, cultural and economic capital (Savage et al., 2013), which strongly relates to Pierre Bourdieu's work. In deriving seven classes (see table below), the authors emphasize the role of wealth that lead to the existence of classes like an elite, an established middle class, technical experts and a class of new affluent workers. New classes are determined to meet current structures and to find good models to recognize social polarization and class fragmentation. In the 21th century, a division in not only two classes (like the bourgeoisie and working class) is more seminal. For instance, the proletariat in the Marxian sense is therefore obsolete since, for example, (new affluent) workers are still subordinated under the capitalists but are characterized by good economic capital, socialization and level of cultural capital. They also characterize a precariat with a very low level of capital, which is generally described by inequality and insecurity (Standing, 2014). The example from Great Britain shows, that economic capital, is still a sufficient level of analysis if it is combined with social and cultural capital. The seven classes are described in table two and percentages of the population are indicated in two surveys. The term highbrow culture used here is fundamentally complex and is constantly changing, to put it simply, it is connected to intellectuality or high culture that is attended by prestige.

	% GfK	% GBCS	Description
Elite	6	22	Very high economic capital (especially savings), high social capital, very high highbrow cultural capital
Established middle class	25	43	High economic capital, high status of mean contacts, high highbrow and emerging cultural capital
Technical middle class	6	10	High economic capital, very high mean social contacts, but relatively few contacts reported, moderate cultural capital
New affluent workers	15	6	Moderately good economic capital, moderately poor mean score of social contacts, though high range, moderate highbrow but good emerging cultural capital
Traditional working class	14	2	Moderately poor economic capital, though with reasonable house price, few social contacts, low highbrow and emerging cultural capital
Emergent service workers	19	17	Moderately poor economic capital, though with reasonable household income, moderate social contacts, high emerging (but low highbrow) cultural capital
Precariat	15	<1	Poor economic capital, and the lowest scores on every other criterion

Table 2: Summary of social classes by Savage et al., 2013; nationally representative survey (Gfk), BBC's Great British Class Survey (GBCS)

Another common concept of grouping society on the basis of similar characteristics was developed for marketing strategies: The concept of milieus, which was already described by Emil Durkheim (1938) in the 1920th, who saw a milieu as the social environment. One example, developed in and for Germany, is the "Sinus milieu" that assort individuals into milieus, who are similar in their view of life and lifestyle. The sinus institute observes changing values and living environments and arises target group segmentation (Sinus, 2017). In milieu research basic value orientations are included in the analysis as well as everyday attitudes (Flaig & Barth, 2014). The milieu concept is briefly mentioned here, as it will be of importance in the further course of this thesis, especially when it comes to the evaluation of the UBA survey.

2.4.3. Research gaps in class theory and social stratification

Many approaches of class or milieu theory are (still) valid today and hence purposeful to group societies. As Savage et al. (2013) show in the example from the UK, for capitalist, or more specifically Western European societies, an analysis of different aspects of capital is appropriate. However, the resulting groups or classes are at the moment not used to derive recommendations for environmental issues, because they are not applied on practical questions, such as: What are the dimensions of emissions between the classes? The interlinkage between social stratification and human energy and material flows is not sufficiently established. Otto et al. (submitted) also see the necessity for agent classes to be grouped in socio-metabolic classes regarding their emission profiles. A strong connection between classes (and their lifestyles) and resource depletion or greenhouse gas emissions is yet not analyzed in that way.

Climate impact research is mostly concerned with the link between (national) affluence (e.g. Myers & Kent, 2004; Dietz & Rosa, 1997; Davis & Caldeira, 2010), individual income (Ivanova et al., 2017, Druckman & Jackson, 2009; Sommer & Kratena, 2017a ; Aamaas & Peters, 2017) and carbon emissions. Even discussions about the potential consequences for climate targets of achieving poverty eradication appear (see e.g. Hubacek et al., 2017). Eventually, an opening perspective, away from only economic factors, is not sufficiently addressed. In the previous text, the missing class consciousness is stressed out, which becomes relevant in an ecological contexts, when analyzing the own affiliation of individuals to consumption classes (e.g. Rückert-John, 2013). These consumption patterns appear as lifestyles. Reusswig et al. (2003) foregrounds, that consumption is a social process and consumerism a social reality. Belonging to a lifestyle class and the knowledge of this affiliation seem important to change consumer behavior.

2.5. Pierre Bourdieu: Cultural, social and economic capital

The concept of metabolism, and the question of why organisms exploit their environment for overvalue, fits into the current research of Planetary Boundaries and the exceedance of the associated limitations - the social metabolism of today transgresses the safe operating space of the Earth system. Inequality and different levels of agency spread to social layers.

The agency-structure input allows thought-games about what is structurally given and what humans actively influence. This application to an ecological context can be of value in considering natural limitations and options of action.

Hence, these assumptions serve as a starting point or research framework for a social analysis to find out what characterizes individuals with high and low emissions and who has particularly high impacts on the environment and thus, responsibility to an ecological transformation. Groups or classes are created regarding emissions at which individuals are summarized in socio-metabolic classes to identify emission hotspots. Class-theoretical means give a legitimate approach to start analyzing the socio-demographic dimensions and properties of these classes.

To expand the, in climate impact research, frequently applied economic assumptions by social and cultural aspects, I make use of concepts from sociological analysis like Pierre Bourdieu's capital theory, to apply the aforementioned class-theoretical means. Bourdieu worked theoretically and empirically, and his analysis of habitus, field, taste and capital can be executed to analyze ecological behavior, consciousness and consumption patterns. It broadens economic correlations with social and cultural factors to understand lifestyles of different groups, finding hotspots, and to comply with the requested characterization.

2.5.1. Overview

Bourdieu is interested in practice, which is the outcome of the relationship between structure and agency (Ritzer, 2011). Practice can be described as a lifestyle, inherent to certain groups or classes that differ in their influence on, for example, climate change. As socio-metabolic classes, or in other words, groups of lifestyles, that differ through society, are of interest, Bourdieu’s work is especially applicable by accessing the social world epistemologically from praxeology, that asks for the dialectical relations between the objective structures and the structured dispositions (Bourdieu, 2012). Generally, Bourdieu tries to overcome the opposition of the individual and society (Bourdieu, 1990) and looks for the reason of the stability of social structure, to show their mode of action and partially disempower it (Schwingel, 2011). These social structures are interesting to investigate, since they have often become firmly established and difficult to break up and are opposed to a rapid transformation in the ecological sense - status symbols, lifestyles and increased consumerism often avert a sustainable pathway. Practice theorist, like

Bourdieu, analyze, how social beings transform their surrounding world with their motives and intentions, (Ortner, 2006). Therefore, Shove and Spurling (2013) depict, that theories of practice are useful for questions of sustainability especially in consumerism, because increasing levels of energy, material and service consumption are directly connected to the fundamental drivers of environmental change and consumption is still a phenomenon that is only poorly understood (Wilk, 2002). The use of theory of practice, tries to resolve the attempt to explain social phenomena in terms of individual actions, and "is suggested as a way to avoid the pitfalls of the individualist and systemic paradigms that dominated the field of sustainable consumption studies for some decades" (Spaargaren, 2011, p.1). Addtionally, in the change of perspetive, social practice theory is also applied to understand pro-environmental behavior change (see e.g. Hargreaves et al., 2008). Scoones (1999) claims, that the transformation of theory of practice into an ecological context can be meaningful because it connects natural dynamics with social and cultural processes. If humans influence nature actively (e.g. Bandura, 2006), the connection of environmental change and social or cultural processes asks for an analysis of social structures itself, that are directly coupled with questions of sustainability.
For the context of this thesis, Bourdieu's theory is relevant, to understand social structures and he applied his concepts and generated empirical evidence (Ritzer, 2011). Bourdieu uses the concept of habitus and field, that are the forms of existence of the social (Bourdieu & Wacquant, 1996), and as such structured through the access and distribution of capital. Capital can be social, cultural or economic capital, which is used to depart from commonly used economic perspectives and allows a more complex study.

2.5.2. Habitus and Field

Individuals in different socio-metabolic classes have similar lifestyles but different lifestyles between the classes cause unequal emissions. Lifestyles go along with social structures and thus spread over different social strata. It is necessary to understand social structures to respond to detected hotspots. Bourdieu's core concepts for achieving that are habitus and field. Habitus are cognitive or mental structures (Bourdieu, 1989), through which individuals deal with the social world (Ritzer, 2011). Individuals have internalized schemes to live within the social world, dispositions and tendencies are embodied in habitus, which was first acquired by the individual through early childhood socialization

(Swartz, 2002). Habitus is therefore “the product of the internalization of the structures” (Bourdieu, 1989, p. 18) and mirror divisions like age groups, genders and social classes (Ritzer, 2011). Holton (2000) describes habitus as a common sense, that is between structure and action and brings out what makes a human as a social being: The affiliation to a certain class and the influence that one’s got from this affiliation. Habitus can be observed in many activities like the way of eating, speaking or dressing.

However, habitus is adaptive, but it cannot be controlled by the will and is below the level of consciousness and language (Bourdieu, 1984). Habitus suggest doing and thinking and are principles by which individuals make choices and choose strategies. It suggests therefore the lifestyle one chooses - with a certain logic, a logic of practice (Bourdieu, 1980/1990).

Stratification, lifestyle and habitus are strongly connected, in which habitus is taking a mediating position between stratification and lifestyles. Swarts (2002) explains that habitus generates action, not in a social vacuum, but in structured social context. Bourdieu calls it fields. Thus, society is a complex arrangement of many fields, such as the economic field, the artistic field, the religious field, the legal field and the political field. The driving force of habitus is mediated by fields, and the constraints and the opportunities imposed by the fields are mediated through the disposition of habitus. Just as habitus is an inner limitation of action, the fields are external restrictions, with their own rules of play, whose meaningfulness is recognized by all co-players (Bourdieu, 1986; Schwingel, 2011).

Occupants are agents or institutions, constrained by the structure of the field (Ritzer, 2011) – a field is a setting that is a “network of relations among the objective positions within it” (Bourdieu & Wacquant, 1992, p. 97). It is a setting but also an arena (see e.g. Swartz, 2002), so that Bourdieu and Wacquant wrote in 1992, that “the field is also a field of struggles”, which „undergirds and guides the strategies whereby the occupants of these positions seek, individually or collectively, to safeguard or improve their position, and to impose the principle of hierarchization most favorable to their own product” (Bourdieu & Wacquant 1989, p.40). This hierarchy is relevant, as competitive thinking and the constant comparison between individuals is dominating the social relation and leads to a steady improvement in position, that might come at the expense of others (e.g. nature).

The understanding of human practices is strongly connected to habitus, field but also to capital. Habitus as the internalized structures, fields that offer social constraints and opportunities and capital that causes differences in habitus: Capital can be cultural, social, economic and symbolic and habitus are formed with particular types and amounts of capital. The possession of capital is relevant, because dispositions of habitus draw on types of resources to enact practices. Individuals are motivated by these valued resources or forms of capital (Swartz, 2002). The individual positions in the fields, equipped with different capitals, compete with each other and their struggles maintain or change the structures of the fields (Bourdieu, 1998). This possible change is a chance for goals of sustainability.

Lifestyles strengthen self-identity, stability and belonging to a group, which is an anchor in social constellation (Haluza-DeLay, 2008). Different lifestyles occur in different social strata and are determined by the amount and composition of capital forms. The constant comparison and struggle to climb to the top of social hierarchy are expressed in these lifestyles. However, it seems that these lifestyles are opposed to desired environmental behavior. On the one hand, the analysis about habitus and field can serve to find out which habitus causes which impact and how it is composed, on the other hand, it is a chance to break up possible afflicted social structures by giving conscious ecological behavior a better value in the hierarchy.

2.5.3. Capital

Bourdieu (1986) tries to foreground the role of capital and capital accumulation, because it is a force inscribed in subjective or objective structures and the principle underlying the regularities of the social world.

Cultural capital exists in three forms: "in the embodied state, i.e., in the form of long-lasting dispositions of the mind and body. In the objectified state, in the form of cultural goods (pictures, books, instruments, machines, etc.), whose production or consumption presupposes a quantum of embodied cultural capital and in the institutionalized state, meaning as an embodied competence which has been certified by an official agency possessing the authority to legally "warrant" its existence—that is, in the form of educational credentials" (Pierre Bourdieu, 1986, p. 47). The embodied state can be called cultivation and "it implies a labor of inculcation and assimilation, costs time, time which must be invested personally by the investor" (ibid).

Cultural capital is mostly formed by school and family and its foremost characteristics is heritability. As such, it can make a substantial contribution to the intergenerational reproduction of the distribution of individuals across class locations. The reproduction of values and lifestyles (Pelikán et al., 2017) is relevant and the intergenerational context, in terms of the inheritance of an ecological habitus, is crucial. Cultural capital "comprises familiarity with and easy use of cultural forms institutionalized (e.g., through the university) at the apex of society's cultural hierarchy" (Di Maggio, 2005, p. 167).

The second type of capital is called social capital. It consists of valued social relations that can be described as the belonging to a certain group, potential networks or institutionalized relationships of mutual acquaintance and recognition (Bourdieu, 1986). It is the product of an endless effort (ibid).

Thirdly, economic capital which "is immediately and directly convertible into money and may be institutionalized in the forms of property rights" (Bourdieu, 1986, p. 47). Recent research also includes wealth into the definition of economic capital, to apply in latent class analysis, but which is too often neglected (e.g. Waitkus & Groh-Samberg, 2017). The last type of capital is called symbolic capital, that stems from one's honor and prestige (Bourdieu, 1986).

It should be emphasized, that the different forms of capital cannot be seen independently. On one hand, because the amount and composition of all three forms is important and on the other hand, the basis of all capitals is economic capital: Both cultural and social capital can be derived from economic capital because it is at their root (Bourdieu, 1986). Exemplarily, social capital are social obligations or connections, that are under certain conditions convertible into economic capital and can be institutionalized in the forms of a title of nobility (ibid). For the reproduction of capital and positioning in social space, the convertibility is basis of the strategies. If economic capital is the foundation of a social hierarchy, a change in the social position is currently possible, but for many it is more difficult. Though, if the lowest consumption of resources and thus emissions is caused by the simple, precarious milieus (Kleinhückelkotten et al., 2016), an ecological hierarchy works differently. However, this type of hierarchy has not played a role so far.

2.5.4. Social Space and Taste

As previously described, Bourdieu differentiates between three key forms of capital, that are convertible and can be derived (to a certain level) from economic capital. In this regard, analytical approaches connecting income and emissions, can be a first legitimate way to approach questions of climate change impact. Nevertheless, Bourdieu does not only use economic characteristics for his class analysis or his analysis of social stratification. He proposes a model shaped by the distribution of, and relation between key forms of capital, where the "overall volume of capital delineates classes, but these classes are fractioned by the composition of capital" (Bourdieu, 1984, p.114–43). The visualization of that is called social space.

A social space models the distribution of capital and provides a balance sheet of the power relations between social classes (Bourdieu, 1984). Flemmen et al. (2017) explain, that the social space is an objectivation of class divisions, it is continuous, leaving the question of class boundaries open.

The positions in the social space, although the boundaries are blurred, allow classes to associate with a particular lifestyle or taste – with the aesthetic practices. This taste is directly linked to one's habitus because consumption preferences are shaped by the habitus. It is taste, that is realized in lifestyles and its dispositions, that frame the unconscious unity of a class (Bourdieu, 1984). Bourdieu put this more colorfully later in saying that taste is a matchmaker that creates an affinity to other habitus (ibid). The habitus shapes preferences and tastes and aligns individuals in their already affiliated class.

As Ritzer (2011) points out, individuals classify objects and therefore classify themselves. In the fields, games are played that involve self-positioning, which lead to a differentiation of classes through taste. Individuals from different classes have different abilities to play the game, thus the world of culture works itself both hierarchical and hierarchizing. The objects that Bourdieu analyzed decades ago, could be replaced by objects from a context of sustainability; the method of analysis would be the same.

Bourdieu (1990) calls the occurring classes symbolic communities. In his class analysis, the moment of force is distinction – individuals differ and want to be different, which is a conscious act.

To fulfil that, subjects are endowed with categories of perception, classification and taste (Bourdieu, 1998). The lynchpin is thus distinction. Also, Thorstein Veblen (1899/1994) depicts in his theory of conspicuous consumption, that the driving force of all human behavior is the exploration of distinction.

2.6. Application on object of research

2.6.1. Planetary boundaries, downscaling efforts and carbon footprints

The methodological value of the concept of Planetary Boundaries is described in various scientific sources. Exemplarily, Nykvist et al. (2013) allege, that the idea to create boundaries as a safe distance to certain thresholds or tipping points has a scientific grounding and comprehensible visualization and is popular among various stakeholders. The easy access from different perspectives, whether from an institutional or individual, is the special feature. Additionally, the application of best available science (ibid) in quantifying goals to avoid a collapse and the capture of different global environmental stresses (within one framework) are helpful for decision-making processes and political action and can thus be applied in real world politics (Galaz et al., 2012). Examples, that build on the concept, are the UN High-Panel Level on Sustainability, Global Environmental Outlook 5, European Environmental Agency (EEA), the UK Parliamentary Office for Science and Technology, Oxfam International and Planetary Boundaries Initiative (see Galaz et al., 2012). That means, that the concept of Planetary Boundaries operates as a leading framework for this thesis.

Many approaches have been concerned with the quantification of boundaries or guidelines, to keep the anthropological influence on the terrestrial system within acceptable limits. One example from the 1990's is the concept of guard rails (which are the normative stipulation of non-tolerable risks) and tolerable windows by the German Advisory Council on Global Change (2000), in collaboration with the Potsdam Institute for Climate Impact Research (see Biermann, 2012).

Biermann (2012) describes the importance of the Planetary Boundaries as a crucial contribution for global governance and since the boundary climate change is transgressed and most pressing, it replies for an urgent action. Steffen et al. (2015) state, that two variables, atmospheric CO_2 concentration and energy imbalance at top-of-atmosphere, play a central role regarding the Earth system process climate change. Especially, the greenhouse gas CO_2 is in focus, like described in table three, because of its long lifetime in the atmosphere and the connection to very large human emissions, where the zone of uncertainty for the control variable is 350 to 450 ppm CO_2, relative to preindustrial levels (ibid).

Earth-system process	Control variable(s)	Planetary boundary (zone of uncertainty)
Climate change (R2009: same)	Atmospheric CO_2 concentration, ppm	350 ppm CO_2 (350–450 ppm)
	Energy imbalance at top-of-atmosphere, $W\ m^{-2}$	$+1.0\ W\ m^{-2}$ ($+1.0$–$1.5\ W\ m^{-2}$)

Table 3: Planetary boundary for atmospheric CO2 concentration in ppm (source: Steffen et al. 2015)

In this context, a common request for an operationalization and application is to downscale the concept to translate it for the respective context in being spatially more explicit (Nykvist et al., 2013). Hoff and Keppner write (2017, p.10), that after downscaling, the planetary boundaries "serve as benchmarks for the national environmental performance, and enable institutional improvements e.g. of national strategies accordingly".

Global concepts can be downscaled on different levels - on a national, regional, or individual level and can be translated regarding different dimensions. Häyhä et al. (2016) address the biophysical, socio-economic, and ethical dimension. Used tools addressing these dimensions are environmental observations and analytical modelling, production and consumption measures (footprints and territorial approaches) and additionally equity-based allocation principles.

Relevant for this thesis are footprint indicators, that estimate the environmental impact embodied in consumer goods, by accounting natural resources, generated waste and emissions appropriated by humans (Häyhä et al., 2016). They work as an approximation of the national impact on the Planetary Boundaries or, interesting for this thesis, they acknowledge the individual level and operate on the smallest downscaling unit. It started with the ecological footprint by Wackernagel et al. (1999), but different footprints for all boundaries were established over the last years (see table four).

Planetary boundaries	Footprints
Climate change	Carbon Footprint (Wiedmann and Minx, 2008), Ecological Footprint (Wackernagel et al., 1999)
Ocean acidification	Carbon Footprint (Wiedmann and Minx, 2008)
Stratospheric ozone depletion	Chemical Footprint (Sala and Goralczyk, 2013)
Chemical pollution (novel entities)	Chemical Footprint (Sala and Goralczyk, 2013)
Nitrogen cycle	Nitrogen Footprint (Leach et al., 2012), Gray Water Footprint (Hoekstra and Mekonnen, 2012)
Phosphorus cycle	Phosphorus Footprint (Wang et al., 2011), Gray Water Footprint (Hoekstra and Mekonnen, 2012)
Biodiversity loss	Biodiversity Footprint (Lenzen et al., 2012)
Land system change	Land Use Footprint (Weinzettel et al., 2013), Ecological Footprint (Wackernagel et al., 1999)
Fresh water use	Blue and Green Water Footprint (Hoekstra and Mekonnen, 2012)
Atmospheric aerosol loading	PM10 Footprint (Moran et al., 2013)

Table 4: Examples of footprint measures (source: Häyhä et al., 2016, adapted from: Fang, 2015)

In the context of climate change, however, the focus is on carbon emissions and thus carbon footprints. This thesis obtains on Germany and uses carbon footprints, which are actually independent of location, as a successful concept (Häyhä et al., 2016).
The second step, to reach the research objective, is the identification of carbon emission hotspots of groups through summarizing individuals and their footprints in classes.

2.6.2. Theoretical background for research objective

In the previous chapters, the analysis of the usefulness of class theory is extended by a socio-metabolic concept, giving a natural perspective, mainly by highlighting the limitations of systems and organisms. Thereupon, approaches for classes that can be linked to emissions are reviewed. As an analytical level to examine properties within classes Pierre Bourdieu's theory of capital is beneficial. A thorough literature research has been done, to create the theoretical foundation of this thesis, where I drew on literature from various research fields to create a holistic approach. Theories from Karl Marx, Max Weber and the advancement of their theories by, for example, Rolf Dahrendorf and Anthony Giddens are used to give an analytical starting point. Thus, contents from sociology, philosophy and anthropology are conveyed, and discussions about the necessity of class theory, headed by Goldthorpe et al., are pointed out (Andersen & Hill Collins, 2013; Goldthorpe & Marshall, 1992; Holton & Turner, 2011; O'Neill & Wayne, 2017; Pahl, 1989). It follows, that material approaches from the 19th century stand exemplarily for many other approaches from modern sociology, which "just did not refer to natural parameters as causes or consequences of human social activities" and therefore society-nature interactions (Fischer-Kowalski, 1998, p.66). Hence, the excursion into sociology of the last 200 years shows the possibilities and limitations, in using them for dealing with challenges of climate change.

The concept of social metabolism and socio-metabolic classes is discussed in environmental sciences like social ecology, environmental history, industrial ecology or biology in general (e.g. Fischer-Kowalski, 1998, 2011; Fischer-Kowalski et al., 2014; González de Molina & Toledo, 2014; Lenton et al., 2016; Martinez-Alieret al. 2010; Weisz et al., 2001) and gives valuable insights to explain socio-ecological dynamics and environmental conflicts. The excursus to the agency debate opens a psychological perspective (i.e. Bandura, 2006) to give insights into human agency and the role that humans play and can play actively in transformational processes. After an extensive literature research, which has dealt with a very large number of scientific areas, it can be stated that class theory and theories of social stratification are still relevant and used until today (e.g. Savage et al., 2013). In order to do justice to ecological objectives, a reference to natural boundaries is indispensable and thus creates new classes which cannot be defined by only anthropological attributes (e.g. labor condition, gender, race) but by natural ones (e.g. carbon emissions). Hereupon, the (statistical) analysis of these classes refers to Bourdieu's concepts such as habitus, field, capital, social space and taste.

2.6.3. Operationalization

Simply stating, that a person can be assigned to a particular socio-metabolic class is not effectual, hence, two additional levels of analysis need to be applied. On the one hand, a sectoral analysis of the hotspots dividing the total emissions in Housing, Transportation and Secondary Consumption. On the other hand, a recognition of social, cultural and economic factors, that may influence individual consumption and thus emissions. Private or household consumption plays a major role when it comes to resource, especially energy consumption or the based-on emissions. Exemplarily, GHG emissions associated with household consumption in the United States have been estimated to account for over 80% of total U.S. emissions, and of 120% if emissions embodied in imports are taken into account (Jones & Kammen, 2011). In terms of energy consumption, German private households account for 25 % of direct final energy consumption in 2011 (Mayer et al., 2014). For Germany, the private household energy consumption rises (due to more energy required for heating), like, for instance, from 2015 to 2016 by 1.9 % (Statistisches Bundesamt, 2018). Individual consumption patterns and the way of living are of relevance in reducing emissions and, especially on the household level, a high carbon emission reduction potential appears, that could contribute to achieving climate goals (e.g. Dietz et al., 2009). The above mentioned 25 % are seminal but not complete, because they do not take into account the energy required for individual mobility and the production of privately used goods, e.g. like food, clothing, vehicles and equipment. For a comprehensive insight of private emissions, also other aspects of lifestyle should be examined. To meet this, the upcoming data analysis on carbon emissions is split in three sectors: Housing, Transportation and Secondary Consumption.

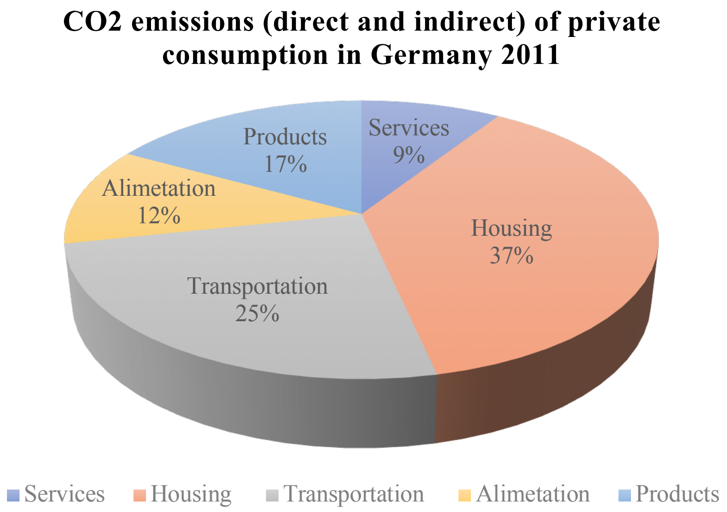


Figure 4: CO_2 emissions of private consumption in Germany 2011 (adapted from: Umweltbundesamt, 2015)

As figure 4 shows, most of the carbon emissions occur in the sector Housing (37%) and Transportation (25%). In this thesis, which is based on data from a UBA survey, Housing includes energy consumption for heating, cooling, cooking, dishwashing, hot water for showers and baths, laundry and drying, lighting and media consumption. Transportation contains energy consumption for everyday and holiday trips and Secondary Consumption includes emissions occurring in food and clothing purchase, which are traced back to standardized data. This approach covers the most important emission sectors: In general, carbon dioxide emissions correspond to fossil resource use (Eisenack et al., 2012) and are the primary cause of global warming (United States Environmental Protection Agency, 2018), which are consequently, strongly connected to heating and electricity in households. Transportation is also a great source of carbon emissions, it follows that the "ownership of large cars, their frequent use, and long-distance holiday travels by car or airplane are the main reasons for high energy consumption and CO_2 emissions" (Kleinhückelkotten et al., 2016, p.28). Recent research supports the focus on these emission sectors in saying that that the greatest energy-saving and CO_2-reduction potentials lie in heating and mobility (Kleinhückelkotten et al., 2016). The third sector, Secondary Consumption, is also worth analyzing. Exemplarily, Poore & Nemecek (2018) support that, in stating, that changes in dietary have transformative potential, and could reduce food's GHG emissions by 49%. The high carbon emissions of individual consumption give therefore reason for a three-sectoral analysis. Within the three sectors, classes are clustered, which correspond to the above-mentioned socio-metabolic classes. These classes are then analyzed for their characteristics, to identify differences between the classes, as the research question demands. In order to take a well-founded analysis path, I used Pierre Bourdieu's capital theory.

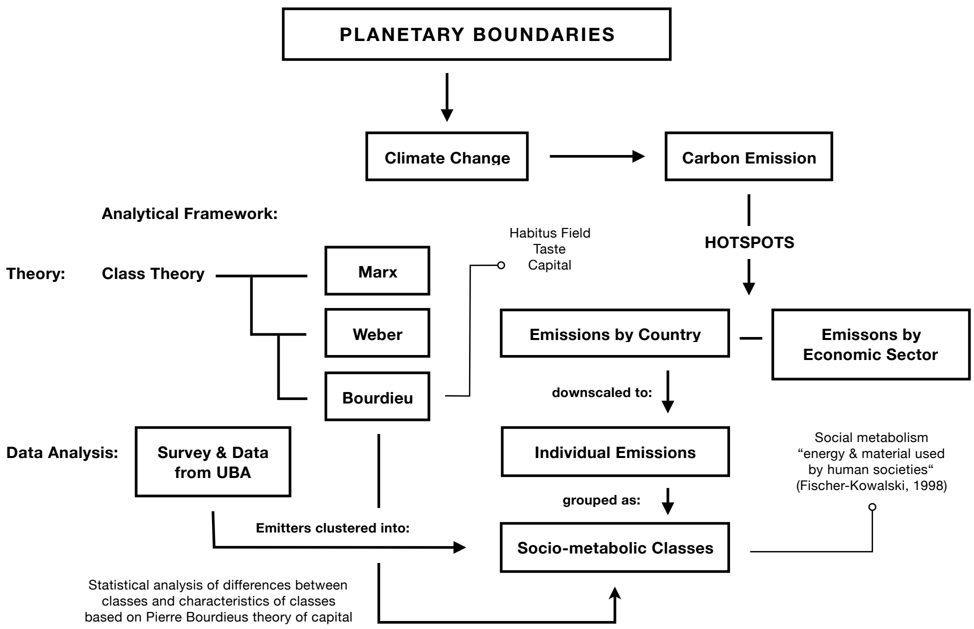


Figure 5: Flowchart of the scientific approach

To summarize Bourdieu's ideas shortly (1986, 1989, 2012; Bourdieu and Wacquant 1992): The habitus are the schemes or the internalized structures to live within the social world - the socialization. Habitus, as learned dispositions, suggests doing and thinking and is composited by different types of capital. Habitus dictates certain tastes and thus preferences for all aspects of culture, like clothing, furniture or cooking and through taste, individuals can be classified in a social space, which then shows the class affiliation. Whereby fields are the social structured context, giving constraints and opportunities which can be intellectual, religious, educational or cultural. For example, an individual living a sustainable and environmental-friendly lifestyle focuses on minimizing any form of resource waste using, for example, mainly public transportation or bicycles, having a vegan or vegetarian diet, avoiding new purchases and instead doing recycling, going on no vacation in long-distance destinations and so on. Habitus is unconsciously derived from life experiences and subsequently embodied in consumption or taste (Woodhall-Melnik & Matheson, 2017), which can be observed in lifestyles and only results from a certain composition and volume of capital, like earning enough money to buy organic food or having the knowledge that flying is harmful to the environment. In Bourdieu's context, it is thus analyzed, how this person was socialized earlier and today and how the internal structures developed. The field, the structuring context, can be, for example, the country in which the person lives and all the structures like the associated government, a membership of a religion (for example, Islam and the related dietary requirements), or cultural relationships, which lead to certain impacts on the environment.

For the question of this thesis, it is necessary to understand what characterizes the individual subject in the socio-metabolic classes, how they are socialized and how is their capital compounded. To illustrate this with an example: If the socio-metabolic class with the highest carbon emissions are characterized by individuals who have a high economic capital (they are rich), there are other possibilities for action, then if this class has a very low economic capital and additionally a low (institutionalized) cultural capital (e.g. low level of education). Understanding the composition, which then generates a taste or lifestyle, is important to find out how hotspots could be avoided (e.g. taxes, awareness training at schools, prohibitions…).

From this perspective, humans distinguish themselves (actively) from each other and thereby mark their class affiliation by means of a certain capital endowment, and thus habitus, if the fields which determine their social world, permit it.

Today, Bourdieu is used for class analysis (e.g. Waitkus & Groh-Samberg, 2017) because his concept allows a more contemporary perspective of structures, that include social and cultural aspects, and eliminate from Marxian attempts to explain societies from labor relations and surplus value.

The exploitation of nature is usually not considered as an analytical level. In the context of social metabolism, Marina Fischer-Kowalski (1998) notes that Bourdieu at least invites humans onto the sociological stage (Fischer-Kowalski, 1998). That supports the assumption of this thesis, that his praxeological attempts are not sufficiently applied and need continuation.

Individual carbon footprints are directly linked to consumption patterns or lifestyles and taste. Different socio-metabolic classes have different patterns of consumption, that are manifested as lifestyles. Exemplarily, Reckendrees (2007) uses Bourdieu's "Distinctions: A Social Critique of the Judgment of Taste" from 1984 in his analysis of changing consumption patterns in Germany from 1952-1998. (Regarding lifestyles and inequality research see e.g. Reusswig et al., 2003; Scholl & Hage, 2004). To answer questions of sustainability, e.g. habits, leisure activities, alimentation, but also a sense of beauty, are relevant to understand today's consumerism and way of life and to detect potentials for a sustainable transformation. These potentials, or level of agency, are directly linked to the three key forms of capital.

The question if high carbon footprints are only connected to affluence or if social and cultural factors play a (major) role, is seminal. For instance, Carfagna et al. (2014) establish the term "eco-habitus" which comes up in terms of ethical or conscious consumption. In applying Bourdieu's concept of habitus, the authors try to negative Holt's (1998) proposition, and deny that high cultural capital consumers are characterized by their cosmopolitanism, idealism, connoisseurship and affinity for the exotic and authentic but by a new consumer repertoire that prefers the local, material, manual to obtain their strategy of distinction (ibid). A new (social-ecological) habitus appears, or could be activated, to lead to transformational processes. The collective strategy of sustainable consumption and distinction is a new lifestyle that is relevant for studies especially in Germany, where a green and healthy lifestyle is currently popular and stands opposite to the resource-intensive consumption of the past. Questions like, what are the carbon footprints of these new consumers and how can they be ranged in social space, are interesting. In this context, it is worth mentioning that Bourdieu's work can only be applied to certain countries, that are similar in terms of culture and development status, like Bourdieu’s subject of study France. The analysis of art taste and music preferences, as Bourdieu did some decades ago, is not directly relevant to environmental issues, but the concept can be easily transformed to more significant indicators regarding climate change. Because of all this, Bourdieu's theory is the theoretical foundation of this thesis. To go into a new research direction, I additionally implement a new form of cultural capital focusing on one hand on emissions and resource consumption, that originate from one’s movement in the digital world (for ICT and GHG see e.g. Andreopoulou, 2013) and on the other hand as a cultural asset itself. The term information and communication technology (ICT) is widely used in the scientific community and is applied in the context of sustainability (e.g. Hilty & Aebischer, 2015). Fettweis & Zimmermann (2008) stated already ten years ago, that ICT systems are the core of today’s knowledge-based society and its growth comes at a price, because these systems are responsible for the same amount of CO_2 emissions as air traveling globally. Research in green informatics (e.g. Coroama & Hilty, 2009) addresses these problems, trying to reduce the energy consumption of ICTs. However, footprint calculators, or measurements of CO_2 emissions in general, do not consider the digital world. Regarding this thesis, I implemented an extension of Bourdieu’s cultural capital with ICT, called informational capital. The used data from UBA does not allow to give any information about the amount of google searches a person has per day, the storage of data that consume energy or the additional carbon emissions occurring due to online shopping. It just gives information of how many computers/smartphones a person owns; how many new computers were bought in the last three years and how much time is spend on the computer in free time daily. The strong limitation of data and the tremendous complexity of the digital refuse an adequate result, but it is a starting point to change perspective to answer questions like: What amount and composition of capital is causing high carbon footprints and what causes low carbon footprints? That could give answers to identify necessary hotspots of emissions and to link it directly to responsible emission groups and their lifestyles.

3. Methods and Data

To make use of the Planetary Boundary framework, it needs to be translated into and collated with targets that are important at decision-making scales (Häyhä et al., 2016). The research objective is to construct socio-metabolic classes, i.e. to group the German society into classes and exhibit a multi-dimensional approach to detect common social, cultural and economic properties within these classes and to identify carbon emission hotspots. The utilization of the knowledge provided by the concept, can only take place if the global impact-reduction targets are translated into applicable levels and are thus applied in the political arena. Creating classes from a metabolic viewpoint is adjuvant because the interpretation of society as a socio-metabolic system is an appropriate unit of analysis (Fischer-Kowalski, 1999). To operationalize the social metabolism, data from UBA is used focusing on carbon emissions. The socio-metabolic classes, created in the context of this thesis, are therefore carbon emission classes.

3.1. Summary of procedures

Identification of the Planetary Boundary "Climate Change", that has been quantified in literature and can be downscaled to certain entities. Legitimation of individual carbon footprint analysis to respond to downscaling effort. For the identification of emission hotspots, possibilities are illuminated to summarize individuals and their footprints in classes: Literature review on class theory and introduction of socio-metabolic classes as level of analysis. Assumptions of class theories, particularly Pierre Bourdieu's work, are not used to create classes directly, but for subsequent (statistical) analysis.

My proposed procedure for answering the research objective is the following:

1. Explanation of data source: Sampled data and information (e.g. footprint calculator) from the German Environment Agency (UBA) contain rich information and cover various areas related to resource use. This data is applicable to the research purpose of this thesis.
2. Drawing on this data, I create clusters that are based on carbon footprints and serve as socio-metabolic classes and analyze the differences between the classes statistically, based on assumptions from Bourdieu's class theory.

3.2. Explanation of procedures

3.2.1. Procedure 1: Survey and Data from the German Environment Agency

The research design of this thesis is to analyze statistically data from a social survey. Generally, surveys are a structured set of data that form a variables-by-case grid (de Vaus, 2002). For that, questionnaires provide a simple and efficient way of constructing a structured data set, whereby individuals are represented as units of analysis. The function of these data sets is to enable the analysis of the characteristics of a set of cases (ibid). As the same type of information is collected about many individuals, passive approaches to identify causes can show covariations but can never explain causal relationships (Marsh, 1982). Relationships between the dependent variable (e.g. carbon footprints) and one or more independent variables (e.g. capital forms) are explored.
Individuals are randomly assigned and cannot be tested on different conditions, which means that survey data is only applicable for comparisons (de Vaus, 2002). Additionally, this passive approach, showing covariations, can only focus on some variables, implying that not all possible influencing factors are included: "Survey analysis attempt to control for other relevant differences between groups by statistically controlling or removing the influence of these variables using a range of multivariate analysis techniques" (de Vaus, 2002. p. 1104).
Criticism comes up regarding social survey research designs. De Vaus summarizes, (2002) that methods of collecting data are subject to sampling problems and flawed data collection and instruments. In addition, discrete variables fail to capture human attitudes and behavior and are only an atomistic way of understanding society (Blumer, 1956). The

main problem is however, that the absence of experimental control variables and time dimension does not allow causal sequence or mechanisms (de Vaus, 2002). Nonetheless, the criticism can be minimized to a certain level if a sufficient survey design was used. The survey, used for this analysis, is described in the following section.

3.2.1.1. The Survey

To substantiate the theoretical input with statistical analysis, sampled data and information (e.g. footprint calculator) from the German Environment Agency (UBA) from 2014 are used. The data contains rich information and covers various areas related to resource use which is applicable to the purpose of this thesis.
The "Representative survey of per capita consumptions of natural resources in Germany (with respect to population segments)" by Kleinhückelkotten, Neitzke and Moser (2016) is based on a study of 1012 individuals throughout Germany and identifies factors affecting individual consumption of resources, mainly energy. The research objective of their study was not a total balancing but to identify "for different fields of activity the most deviant population segments, to determine the kind and the extend of deviations, and to find the relevant drivers" to deduct scopes of action for political decision-makers (Kleinhückelkotten et. al, 2016, p.21). "Based on the compiled data the per capita consumption of land area, energetic and material resources as well as the individual CO_2 emissions have been calculated regarding different fields of activity" (ibid). The fields of activities are listed in figure six.

Fields of activity:
household heating, use of hot water, laundry washing and drying, cooling and freezing, cooking, lighting, use of information and communication devices, everyday mobility, holiday travel, nutrition, clothing, sauna use, and pet keeping.

Figure 6: Fields of activity in the survey "Representative survey of per capita consumptions of natural resources in Germany (with respect to population segments)" (adapted from: Kleinhückelkotten et al., 2016)

The authors place these fields of activity directly in relation to lifestyles or the way of living in general. When it comes to energy use, especially relevant is the used land area, the living space (first residence), area covered by buildings and secondary residence.

Furthermore, the study focuses on milieu studies, that means, not only correlation between particular socio-demographic properties (figure 7) and emissions, but also groupings into six different social milieus (figure 8). This is based on data and answers to questions about their attitudes, using psychological analysis strategies (ibid).

Socio-demographic attributes:
Persons per household, gender, age, educational background, number of income earners, share of income (without) weighting, share of income (weighted by age), residence area (urban–rural), region (North–South, East–West).

Figure 7:Socio-demographic factors analyzed in the survey "Representative survey of per capita consumptions of natural resources in Germany (with respect to population segments)" (adapted from: Kleinhückelkotten et al., 2016)

Social milieus:
Young Milieus, Critical and Creative Milieus, Precarious Milieus, Modern Mainstream, Well-established Milieus, Traditional Milieus.

Figure 8: Milieus analyzed in the survey "Representative survey of per capita consumptions of natural resources in Germany (with respect to population segments)" (adopted from: Kleinhückelkotten et al., 2016)

Additionally, the researchers involved the utilization of and the investment in renewable energies in the survey and the individual willingness to make compensatory payments for CO_2 emissions.

Generally, descriptive statistical methods, correlation analyses, regressions and hierarchical clustering have been carried out for the identification of possible drivers and indicators of energy consumptions and to understand types of consumerism (ibid).

At this point, my work proceeds and continues the analysis, to embed it into theoretical constructs, such as socio-metabolic classes and departs from common analytical strategies. Interestingly, milieu-research is influenced by Pierre Bourdieu's work (Zerger, 2000), not by his class-specific characteristics, but rather by his everyday aesthetics and lifestyles, which are decisive indicators of social affiliation (Klöppel, 2005). The pros and cons of milieu research cannot be discussed at this point. The concept of milieus, as a multivariate type analysis, in the survey executed by sociodimensions, is not effective in answering my research question (e.g. Diaz-Bone, 2003), as more elementary characteristics, that influence the habitus of socio-metabolic classes are, for now, pertinent. Important for this work is a return to the Bourdieu's doctrine to allow easy, but scientifically reinforced access to the characterization of socio-metabolic profiles. Poorly differentiated milieus (Eckert & Jacob, 1994), which were also formulated for marketing research, are not effective. Different to the purpose of this thesis, the survey focuses on total energy consumptions (figure 9) regarding households, educational level, income, region and social milieus.

Total Energy Consumption (kWh/a):
Per capita total energy consumption according to persons per household, per capita total energy consumption according to highest education level attained, per capita total energy consumption according to income, per capita total energy consumption according to region, per capita total energy consumption according to social milieu.

Figure 9: Perspectives on total energy consumption in the survey "Representative survey of per capita consumptions of natural resources in Germany (with respect to population segments)"
(adapted from: Kleinhückelkotten et al., 2016)

3.2.1.2. The Data

Since I used the same data as the UBA report for my analysis, the following paragraph asserts the data ascertainment. The data collection from UBA was generated as follows (Kleinhückelkotten et al., 2016):

The data was compiled in face-to-face interviews through the Gesellschaft für Konsumforschung (GfK) using Computer Assisted Personal Interviews (CAPI). The average enquiry time was 45 minutes and the enquiry period lasted from March to April 2014. UBA restricted the sample to the German speaking resident population from the age of 18 living in private households. All together 1012 persons have been interviewed. The investigation was based on a quota with fixed specifications, at which the quota targets included gender, age criteria and household criteria, as well as the number of households and household size. All quota criteria were crossed with the distribution at federal state level. Overall, the specifications could be met with only minor deviations. With regard to education and income, the following differences can be seen in the sample compared to the data of the Federal Statistical Office: Persons with a university degree and a high net household income (5,000 euros and more net income) are under-, persons with simple and medium educational degrees and medium-income (€ 2,500 to € 3,500) slightly over-represented (Kleinhückelkotten et al., 2016).

If individuals lived in a shared household the fraction to be allotted to the respondent had to be deduced from these data (e.g. home heating). Two methods have been used: First, the equipartition among all members of the household and age-weighted distribution according to the equivalent income concept (ibid).

Eventually, data and information have been collected and combined with information in situ and from literature that can be directly related to individual consumptions of resources and CO_2 emissions of the respondents. The procedure for calculating energy consumption and CO_2 emissions is described in detail in an appendix of the survey (see Kleinhückelkotten & Neitzke, 2016). It also states which of the data and information obtained in the survey were used and where data from the literature was included in the calculations.

3.2.1.3. The footprint calculator

To measure individual footprints (total or in sectors), a footprint calculator was applied and data from questionnaire had determined the area-specific CO_2 values of the respondents. The results were published in the brochure "Representative survey of per capita consumption of natural resources in Germany (by population group)" (Kleinhückelkotten et al., 2016). Necessary to mention is, that the results differ between the published survey and the values used in this thesis, because two calculators were used with different including variables. I am referring in this thesis to the UBA calculator developed by "Klimaktiv" (KlimAktiv CO_2-Rechner, 2018).

Since the CO_2 emission values of the Klimaaktiv CO_2 calculator include more criteria, the results are not identical to the values calculated by the contractor using a different calculator. For my purpose, the data of the respondents were entered into the UBA CO_2 calculator by UBA itself, resulting in total per capita CO_2 values as well as sector specific values (Housing, Transportation, Secondary Consumption, public emissions).

All information, regarding how the CO_2 calculator is composed, are taken from the klimaktiv webpage (http://klimaktiv.CO2 -rechner.de/de_DE/): The CO_2 calculator takes into account the greenhouse gases methane and nitrous oxide, with the corresponding climate impact compared to CO_2 (CO_2 equivalents), as well as the impact caused by air traveling measured as flight equivalents. CO_2 factors, comparative values and general conditions change over the course of time and refer here to the findings, that Klimaktiv determines in cooperation with the ifeu institute and the Öko-Institut. The methodological basis for the calculation of CO_2 emissions is provided by the study "CO_2 Bilanz des Bürgers" (Schächtele & Hertle, 2007). For the UBA calculator the existing German-language calculation tools were compared with one another and optimized to develop a consistent and transparent tool that is available for widespread use.

The direct and indirect greenhouse gas emissions of an average citizen per sector and sub-category (heating and electricity in the area of Housing, air, public transport and motorized mobility, food and other private and public consumption) are calculated and visualized with the average CO_2 emissions in Germany per sector. The emissions of the average citizen are based on data from the transport model TREMOD developed by the ifeu, the publications of the AG Energiebilanzen, the environmental economic accounts of the Federal Statistical Office (Extended Input-Output Model for Energy and Greenhouse Gases) and calculations by KlimAktiv and ifeu.

3.2.2. Procedure 2: Clustering and descriptive statistics

3.2.2.1. Types of Capital

For my analysis, the individual carbon footprints of 1012 persons were clustered in three sectors (Housing, Transportation, Secondary Consumption) into five (socio-metabolic) classes. The selection of five classes is based on the results of the k-means clustering algorithm. Pierre Bourdieu's capital theory is applied to make use of various capital forms (economic, social and cultural capital) to analyze differences between the clusters. (For similar application examples see Prieur et al., 2008; Wolf et al., 2009; Waitkus & Groh-Samberg, 2017). Economic capital consists of income and property measurements. For the ascertainment of social capital, socialization, the kind of living together, belonging to a social group, employment relationships as well as social commitments are encompassed.

Cultural capital is based on education level, more factors are not available due to data limitations. On account of this, I discuss the role of ICTs in terms of energy consumption but more important, relevant to the concept of this paper, as a cultural asset.

The purpose of this method is a more detailed understanding of habitus and lifestyle. Socio-demographic analyses do not adequately capture social and cultural factors that shape human behavior and, moreover, do not observe the interplay of the forms of capital that account for the position of individuals in social space. Additionally, processes of distinction that are the demarcation of groupings to others, can be discussed.

Type of Capital	Variables
Economic Capital	- monthly net income per household - property houses - property cars and type of car - property motorbikes
Social Capital	- Number of individuals in household - Being employed/unemployed - "I prefer living in an environment where I can meet a lot of different people" - Engagement in social and ecological activities - Belonging to a social group (e.g. student, pensioner…)
Cultural Capital	a) Educational achievements (educational degree) b) Informational Capital as ICT - Number of Computers in Household - Number of newly bought computers in last 3 years - Hours spend daily on computer in free time - Number of newly bought smartphones in last 3 years

Table 5: Types of Capital for further analysis (data source: Kleinhückelkotten et al., 2016)

3.2.2.2. Data Imputation

The clustering and statistical analysis was programmed in R. The code can be found in the appendix (A5) of this thesis. Since the data was not complete, a data imputation was performed, to conduct an accurate analysis. Missing of data is usually a nuisance, not the main focal point of inquiry (Schafer & Graham, 2002) and, like in the data at hand, all social science survey research involves some incomplete data (Saunders et al., 2006). To replace the data, instead of ignoring missing values, a data imputation was performed. Assumptions that I made were, that data is missing at random and therefore not missing systemically (Rubin, 1976). Missing data is an unavoidable problem in quantitative data analysis and can be solved by multiple imputation by chained equations, called MICE (Wulff & Ejlskov, 2017). Two general data imputation approaches are maximum likelihood (ML) and multiple imputation (MI) (Schafer & Graham, 2002), whereby MI "has emerged as a flexible alternative to likelihood methods for a wide variety of missing-data problems. MI retains much of the attractiveness of single imputation from a conditional distribution but solves the problem of understating uncertainty" (Schafer & Graham, 2002, p.165).

Multiple Imputation was introduced by Rubin (1987) which estimates a set of likely values of the data that are missing, instead of estimating the best value (Wulff & Ejlskov, 2017). It is a very flexible and easy to handle method. The missing data are filled in *m* times to generate *m* complete data sets, which are then analyzed by using standard procedures, like linear regressions, for completing the data and combining the results from these analyses (Yuan, 2005). Yuan (2005, p.1) explains that this procedure "replaces each missing value with a set of plausible values that represent the uncertainty about the right value to impute". If data is missing at random (MAR) or missing completely at random (MCAR), the standard errors are corrected in an appropriate way and pooled parameter estimates are unbiased (King et al., 2001; cf Wulff & Ejlskov, 2017). The procedure is therefore a valid statistical inference (Yuan, 2005) and can be accepted as a legitimate method to impute missing data.

The MICE algorithm, also called fully conditional specification (FCS), is one of the principled methods regarding multiple imputation. FCS starts from an initial imputation and draws imputations by iterating (low number is sufficient) over the conditional densities on a variable-by-variable basis (Buuren & Groothuis-Oudshoorn, 2011). To avoid problems that appear imputing missing multivariate data and to reduce real life complexities, the columns of the data are specified separately and to fill out the missing data, the chained equations are a concatenation of univariate procedures (ibid). Azur et al. (2011) support the method in stating that the chained equations approach is very diverse in handling different variable types, it is flexible and captures complexities. The method of the MICE algorithm used in this thesis, is predictive mean matching (pmm) based on van Buuren (2012, p.69) developments and calculates the predicted value of target variable Y according to the specified imputation model: "For each missing entry, the method forms a small set of candidate donors (typically with 3, 5 or 10 members) from all complete cases that have predicted values closest to the predicted value for the missing entry. One donor is randomly drawn from the candidates, and the observed value of the donor is taken to replace the missing value. The assumption is the distribution of the missing cell is the same as the observed data of the candidate donors." The R package takes the highest correlation to impute missing data. The implicit model (Little & Rubin, 2014) can be used for discrete and continuous variables and is an example of hot deck methods (Van Buuren, 2012). Values outside the observed data will occur as they are based on observed values, making this procedure realistic. It is an all-around, easy-to-use and versatile method, suiting for large samples (ibid). I used data imputation for missing values, that impede creating my types of capital. Exemplarily, for creating economic capital, only 17 values were missing which shows that the data was overall very complete and data imputation was influencing the results only little.

3.2.2.3. Principle Component Analysis (PCA)

For creating three types of capital, principal component analysis (PCA) was performed, which is a multivariate statistical approach. The idea goes back to Harold Hotelling (1933) and has formal similarity to factor analysis, but renounces causality. Generally, to structure, simplify and illustrate datasets, PCA reduces a large set of variables to a small set, and therefore to a smaller number of highly meaningful linear combinations that contain relevant information, when the feature space may contain too many irrelevant or redundant features. It is a statistical technique for unsupervised dimension reduction (Ding & Xiaofeng, 2004), which facilitates a simplification of complexity without losing trends and patterns (Lever et al., 2017). Regarding Ziegel (1995), the following statistical assumptions were made: Interval-level measurement, random sampling, linearity and normal distributions. PCA is used in different research fields (e.g. Sabatini, 2008).

The method executes a transformation of possibly correlated variables into fewer uncorrelated variables, that are called principal components. These principal components are linear combinations of the original variables, weighted by their contribution to explaining the variance in a particular orthogonal dimension, which act as summaries of features using a limited number of PCs (Lever et al., 2017). By minimizing this distance, the variance of the projected points is maximized. The effect of this maximizing is comparable to multiple linear regression on the projected data against each variable of the original data (ibid). Subsequent PCs are selected similarly but are uncorrelated with all previous PCs. The first principal component accounts for as much of the variability and each succeeding principle component accounts for as much of the remaining variability of the data as possible. Assuming, that information can only be obtained from the data, if the variance along an axis is a maximum, it is necessary to find the direction of maximum variance of the data – a rotation is needed. The PCA loading matrix rotates data such that the projection with greatest variance goes along the first axis. (Lever et al., 2017). If the 1st principal component reaches a high value (percentage), it means that one variable contains most of the information or covariance and thus shows a systemic connection. Large eigenvalues correspond to large variances and the directions of the new rotated axes are called the eigenvectors of the covariance matrix.

In applying PCA on capital forms, exemplarily on economic capital, it can be shown, that a person who has many cars also has a high income. The majority of the information is thus on the factor income. The principal components may then be used as predictor or criterion variables in subsequent analyses (Kellow, 2006) because they account of most of the variances in the observed variables in building a synthetic or artificial variable measuring each dimension. For the purpose of this thesis economic, social and cultural capital and the variables defining these types of capital, can be summarized by PCA to apply them for following statistical tests.

3.2.2.4. Clustering and statistical analysis

Cluster analysis is a multivariate statistical method, by which n objects are clustered into groups based on similarities of the objects measured (Chatfield, 1980). Cluster analysis is an inductive exploration of data (Doreian, 1994) and is a valuable method used for defining groups but also for reducing data (Manly, 1994).

As a common approach for social sciences to create subgroups (Blanche et al., 2006), there are different methods. Two main approaches are hierarchical or non-hierarchical (partitioning) clustering methods (Karson, 1982). In non-hierarchical clustering, which was performed for this thesis, clusters are formed in successive clustering, either by merging or splitting clusters (ibid). Basically, group centers are chosen, and individuals are allocated to the nearest one. Then new centers are at the centers of the individuals in groups and individuals can be moved to a new group if the center is closer than before (Manly, 1994). Objects are being allowed to move in and out of groups during different stages of analysis, they merge and split iteratively, until stability is achieved with a predetermined number of groups (ibid).

Thus, clustering creates groupings where the individuals in one cluster are more similar to each other than to individuals in other clusters. The cluster are the socio-metabolic classes. To fulfil the research objective, I used the k-means clustering algorithm. Regarding the five socio-metabolic classes, individuals in one class (cluster) have similar carbon emissions and thus carbon footprints and differ from individuals in other classes. To scrutinize footprints more precisely in my analysis, I also differentiate between three sectors, Housing, Transportation and Secondary Consumption, to make clear where hotspots exist and to capture excursiveness of human behavior. That means, that the k-means clustering algorithm is applied three times.

A lot of clustering algorithms were developed in the last 50 years, for a variety of research fields, but the centroid-based k-means algorithm is still a valid approach and widely used (Jain, 2010). Hartigan & Wong (1979) explain that the k-means algorithm divides m points (in n dimensions) into k clusters so that the within sum of squares are minimized. MacQueen (1967) stated informally, that the k-means procedure starts with a single random point and adds each new point to the group whose mean the new point is nearest. Then, the mean of that group is adjusted for accounting the new point. At each stage the k-means are the means of the groups they represent. Euclidean distances are used to measure the distances between centers and points. Stability is achieved if no movement of a point from one cluster to another will reduce the within cluster some of squares (variance). At the minimum, all cluster centers are at the mean of their Voronoi sets (the set of data points which are nearest to the cluster center).

For k-means clustering the number of clusters is assumed or known (Doreian, 1994), so that the k clusters are determined in advance and must be fixed, because the squared error would decrease with an increase of k. The plot "within groups sum of squares" (WSS) (see appendix A2) shows the sum of the squared distances between each member of the cluster and the centroid. The "elbow point" is the k after which the WSS decrease is almost constant. Five fitted well to the idea of 5 socio-metabolic classes. Here, I used $k=5$ relating to the theoretical input from (socio-metabolic) class theory. The absence of category information and class labels results in not giving the algorithm any information as to where each of the objects should be placed (Wagstaff et al., 2001). Background knowledge about socio-metabolic classes and the target to have a clear number of clusters was the reason to consider my choice of k=5.

The goal of my statistical analysis is to find out if the classes differ at all and if so, between which classes are differences, with regard to the examination factors (capital forms). Even though there is a large number of techniques for analyzing data, I apply descriptive statistics, that are statistical computations describing either the characteristics of a sample or the relationship among variables in a sample (Babbie, 2010, p. 367). These computations are used to show the central tendency (e.g. mean) and dispersion (e.g. standard deviation) of a single variable or the strength and direction of the relationship between two or more variables and answer relevant questions for the purpose of this thesis. One example, to test if sets of data are significantly different from each other (in comparing means), is the t-test (Babbie, 2010, p. 502). While the t-test is limited to comparing means of two groups, ANOVA (one-way variance analysis) can compare more than two groups, what is relevant for this thesis regarding the multiple clusters.

Barker & Shaw (2015) state, that ANOVA is a special case of regression, just differing in reporting at least two means that are significantly different (ANOVA) instead of only one mean (intercept) to all other means as a sample mean response (regression).

With ANOVA, the idea is, to check if the variance within a group/cluster is smaller than the variance between the clusters. Or whether the clusters are significantly different from each other statistically. The variance between more and smaller clusters is more likely to be significant. ANOVA is a standard method which is applicable in this context. As I used linear models (lm) in my ANOVA executions, the Gauss-Markov assumptions must be met. The following paragraph is a summary of these assumptions all based on Wooldridge (2015):

In a regression model, like $y = \beta_0 + \beta_1 x + u,$ the key assumption for simple regressions is that the expected value of u given any value of x is zero, where u is the unobserved error term (or the disturbance in the relationship) in factors other than x that affect y. Algebraically, in a random sample, the intercept and slope are estimated (as unknown parameters) and need to be chosen to make the sum of squared residuals as small as possible – to reduce the ordinary least squares (OLS). The estimators $\widehat{\beta_0}$ and $\widehat{\beta_1}$ minimize the sum of squares of the differences between the observed dependent variable from the data set and those predicted by the linear function. The statistical approach of OLS uses $\widehat{\beta_0}$ and $\widehat{\beta_1}$ as estimators for the parameter β_0 and β_1 , that are mainly the properties of the distribution.

If, ceteris paribus, x effects y, other (unobserved) factors are ignored. Hence, I need to make restrictions in a concept grounded in probabilities, about the relationship of u to the explanatory variable x. Summing up: A proof is needed, that u is uncorrelated with x, in stating that u = zero expected value.

This task is part of the Gauss-Markov assumptions (and three more), because for executing ANOVA on my clusters, the unbiasedness of OLS must be proofed. Furthermore, I add the assumption of homoscedasticity, meaning that the variance of the error given x is constant, so that the unbiased estimator for σ^2= Var(u). Including that, the variance (not the expected value) of the error term is not correlated with x. Under all these conditions OLS provides minimum-variance mean unbiased estimation and legitimates the procedure for analysis between the clusters.

As shown in figure 10 the following assumptions must be confirmed: Linearity in parameters, random sampling, sample variation in the explanatory variable, zero conditional mean (see description above) and additionally homoscedasticity.

Assumption SLR.1 (Linear in Parameters)

In the population model, the dependent variable, y, is related to the independent variable, x, and the error (or disturbance), u, as

$$y = \beta_0 + \beta_1 x + u,$$

where β_0 and β_1 are the population intercept and slope parameters, respectively.

Assumption SLR.2 (Random Sampling)

We have a random sample of size n, $\{(x_i, y_i): i = 1, 2, \ldots, n\}$, following the population model in Assumption SLR.1.

Assumption SLR.3 (Sample Variation in the Explanatory Variable)

The sample outcomes on x, namely, $\{x_i, i = 1, \ldots, n\}$, are not all the same value.

Assumption SLR.4 (Zero Conditional Mean)

The error u has an expected value of zero given any value of the explanatory variable. In other words,

$$\mathrm{E}(u|x) = 0.$$

Assumption SLR.5 (Homoskedasticity)

The error u has the same variance given any value of the explanatory variable. In other words,

$$\mathrm{Var}(u|x) = \sigma^2.$$

Figure 10: Gauss Markov assumptions for simple regressions (source: Wooldridge, 2015)

Regarding the Gauss-Markov assumption for linear regression, I assume that the following assumptions are valid: Linearity in parameters (not in variable), random sampling and independence of observations, sample variation in the explanatory variable and the zero-conditional mean assumption.
SLR 5 requires the constant variance of the error term or, in other words, the assumption of homoscedasticity. It is not about unbiasedness of $\widehat{\beta_0}$ and $\widehat{\beta_1}$, but about the variance of residuals that should not increase with fitted values of the response variable. That means, that it is necessary to check, if the model is not able to explain patterns in y, that eventually turn up in the residuals. If so, the results of the regression model would thereby be distorted. Tests to analyze heteroscedasticity are Breush-Pagan-Tests or visual interpretations. In my model, I interpret a graphical chart of residuals versus fitted values, that was generated in R (see appendix A4). If homoscedasticity is not obvious a Breush-Pagan test was applied.
After clustering the 1012 respondents into 5 socio-metabolic classes (in three sectors), I examined, if the group means between the clusters are significantly different, regarding the three capital forms. Before doing ANOVA variance tests, the Gauss-Markov assumptions had to be tested, to prove the validity of the method.
ANOVA calculates a parameter called F statistics (F-ratio), which compares the variation among sample means to the variation within groups. The F-Value is therefore the ratio of variance. So, if the variances are equal, the ratio of the variances will be 1. To test if the means differ between the clusters the null-hypothesis, which is $H_0 = u_1 = u_2 = u_3 = \cdots = u_g$, must be rejected. The null hypothesis is rejected if the value of the F ratio is greater than the critical F distribution at $\alpha = 0.05$ (Brown, 2005) .
If the p-value is greater than the significance level (α), there is not enough evidence to reject the null hypothesis (that the population means are all equal). Low p-values are indications of strong evidence against the null hypothesis (in the appendix A4: Pr (>F) is the p-value associated with the F statistic).
If it turns out that the clusters differ in their means, a post hoc test (Bonferroni Holm) was used to determine which clusters are exactly different. The comparison between the clusters was conducted by a pairwise t-test to fulfil this task, using a correction ("Holm") for the Type I error rate (which is rejecting wrongly the null hypothesis) across the pairwise tests. Often a Bonferroni adjustment is used, here I decided to apply the Holm's sequential procedure, because it is a more appropriate method for adjusting familywise error rate inflation (Eichstaedt et al., 2013).

To achieve the research objective, data from the German environmental agency was used to create socio-metabolic classes (regarding individual footprints). The clustering results showed that a division of the German society in emission groupings is reasonable. After that, the classes were analyzed, based on Pierre Bourdieu's capital theory, regarding their cultural, social and economic properties. Differences and similarities were found and the results, that are relevant for the outcome of this thesis, are presented in the next chapter.

4. Results

4.1. Overview of the respondents

The following section gives insights in the data structure (for an overview see also "Numbers of cases in categories" in the appendix A1) and compares it with different sources to assess the explanatory power of the data ascertainment: The survey largely reflects the German society but shows some weaknesses in aspects, that are of importance to this paper.

Around 50% of the individuals representing the German society in the sample are in the age group of older than 50, approximately 15 % represent the young generation of individuals between 18 and 29 and 35% the individuals from 30 to 49. The average age in Germany in 2014, when the survey took place, was 44.3 years (Statistisches Bundesamt, 2017). The focus in the survey is shifted in favor of the older generation.

Concerning the gender ratio it can be said, that by the end of 2014 the gender ratio of 41.362.100 female to 39.835.500 male citizens reflects the ratio of the respondents in the sample, which is almost balanced (Statistisches Bundesamt, 2015). Non-binary gender identities were not taken into account.

Regarding the educational status, respondents with high education (and high income) are underrepresented, as a result, individuals with a low and intermediate education are slightly over-represented (Kleinhückelkotten et al., 2016). Nevertheless, a relationship between education, income and per capita total energy consumption could be found: The higher the level of education or the higher the income, the higher the energy consumption (with a stronger impact of income) (ibid).

After briefly comparing socio-demographic characteristics (age, gender, education), income and wealth are again discussed, as the survey ignores important levels of analysis for this work. The literature review highlights the relevance of income as a parameter for climate change research, on one hand considering the correlation of income and carbon footprints and on the other hand the change of agency with higher income. This thesis is also interested in income as an influencing factor but focuses on economic capital, which includes more relevant factors besides only income, namely wealth. Two main complications arose with the preexisting data: High income individuals are under-represented in the survey and not enough data has been collected to capture (the versatility of) the rich. Inaccuracies thus incurred like, for example, that different high-income classes were grouped in one class (5000 Euro and more) and there is no income differentiation within this class. Furthermore, no special focus was placed on high net worth individuals (HNWI) and ultra-high net worth individuals (UHNWI). HNWIs are defined as those having investable assets of US$1 million or more, excluding primary residence, collectibles, consumables, and consumer durable. Ultra-HNWIs own US$30 million or more in investable assets (Capgemini, 2017). In the survey, there is no focus on wealth, just income, and no closer study between the relationship of income and wealth. (The higher the income, the higher the capital accumulation because of dividends and interest rates). An Oxfam report (2015) revealed, that the richest 10 percent of global population are responsible for almost half of total lifestyle consumption emissions: "The average footprint of someone in the richest 1% could be 175 times that of someone in the poorest 10%" (Oxfam, 2015, p.1), making the analysis of HNWIs and UHNWIs meaningful. As the average net household income in Germany in 2016 was 3132 Euro, excluding households of farmers and self-employed persons and households with a monthly net household income of EUR 18,000 and over (Statistisches Bundesamt, 2016), the focus in the survey is more on individuals with low income and especially not on high income individuals (only 3.5 %). Table 6 compares percentage distribution of income groups in the UBA survey and in data from the Federal Statistical Office. The Federal statistical office estimated that 15.2 % of the German population have a monthly net income between 5.000 and 18.000 Euros. Especially these individuals are of relevance for questions of sustainability. In general, scientists face the challenge of obtaining data about income and wealth (for example even 6.1 % give no information about their income), which is difficult, especially of very wealthy individuals.

UBA Survey	Percent of respondents	Percent of respondents	Statistisches Bundesamt (2014)
< 500 EUR 500 - 1500 EUR	0,6 % 18,2 %	19 %	< 1.300 EUR
1500 - 2500 EUR	32.9 %	31.1 %	1.300 - 2.600 EUR
2500 - 3500 EUR	22.5 %	18.6 %	2.600 - 3.600 EUR
3500 - 5000 EUR	14,4 %	16.1 %	3.600 - 5.000 EUR
> 5000 EUR	3.5 %	15.2 %	5.000 - 18.000 EUR
Don't know No information	1.3 % 6.1 %		

Table 6: Net household income in comparison (Data source: Kleinhückelkotten et al., 2016; Statistisches Bundesamt, 2015)

Still, it seems that the superrich play a major role in terms of energy consumption or lifestyle related carbon emissions. Figure 11 shows estimations from the World Wealth Report (Capgemini, 2017, p.9) that depict, that there are 1.2 million millionaires in Germany: ”Looking at the top four markets of the U.S., Japan, Germany, and China, they continued to account for nearly two-thirds (61.1%) of all HNWIs in 2016. Different (not representative) numbers from the German Institute for Economic Research (DIW) calculated for 2014 an average monthly household net income of 2404 Euro in Germany, at which the HNWIs earn 13.686 Euro on average (Ströing et al., 2016). The differences in income stand out and are also reflected in individual carbon emissions. Both the estimated number of HNWIs and their monthly net income point to shifting the focus to the rich or super-rich to get insights on carbon emission hotspots. Germany, as a prosperous country with a high concentration of millionaires, a wealth inequality that remains at a high level with a Gini coefficient of 0.78 in international comparison (Grabka & Westermeier, 2014), could thus play a significant role in terms of global (individual) carbon emissions.

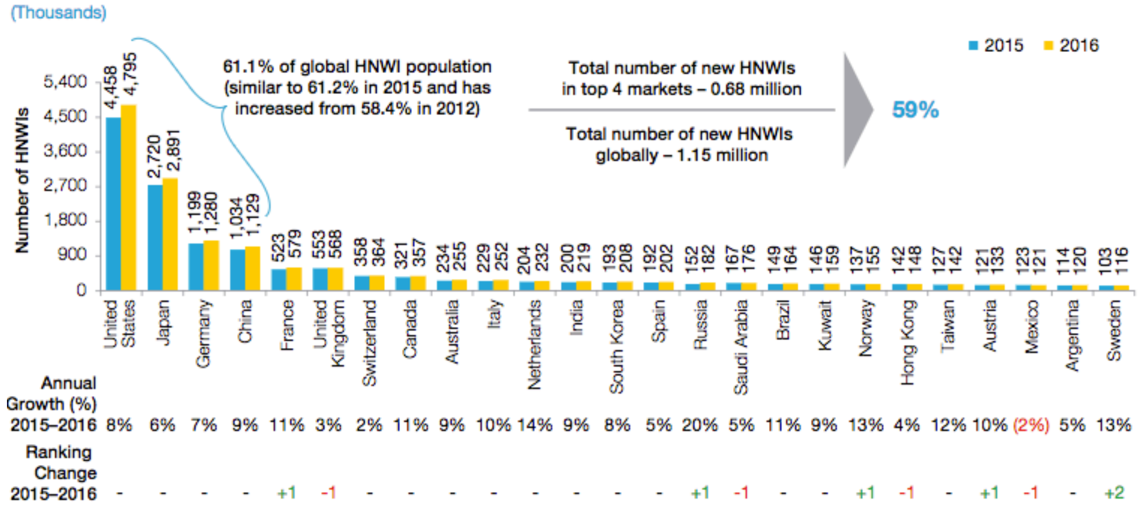
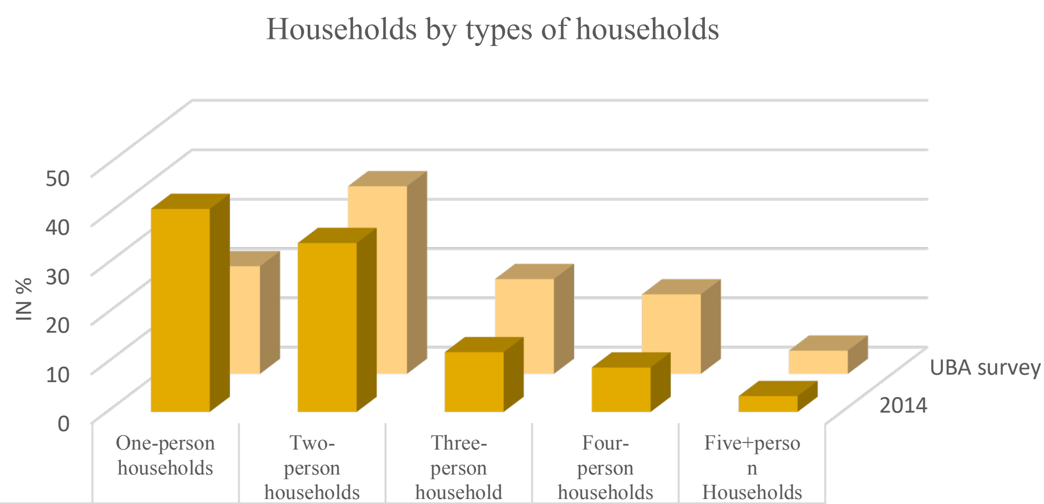


Figure 11: Largest HNWI Populations, 2015–2016 (by market) (source: Capgemini, 2017)

In terms of energy consumption, not only the individual itself, but the households play a key role, in particular the number of individuals living in a household and the size of living space. Figure 12 contrasts types of households in the survey with data from the Federal Statistical Office. The households surveyed by the German Federal Environmental Agency differ from the German average regarding types of households. As the household structures hardly changed between 2014 and 2016 (Statistisches Bundesamt, 2018), the main differences remain, showing that in the survey, one-person households are underrepresented (21,8 % compared to 41,1 %) and three, four and five-person households overrepresented. Again, differences in the data structure are evident.



	One-person households	Two-person households	Three-person household	Four-person households	Five+person Households
2014	41,1	34,2	12,1	9,0	3,2
UBA survey	21,8	38,0	19,2	16,1	4,7

Figure 12: Households by types of households in Germany in 2014
(data source: Statistisches Bundesamt, 2018) in comparison to the UBA survey

4.2. Cluster analysis

To operationalize social metabolic class theory the following cluster analysis is divided in three sectors, Housing, Transportation and Secondary Consumption, in order to be able to conclude by a precise application to a general statement of socio-metabolic classes for the German society. As illustrated above, 37% of the CO_2 emission of private consumption occur in the Housing sector, 25% in Transportation and 29% in Secondary Consumption (alimentation and products) - a division into three sectors takes up the already defined hotspots.

4.2.1. Housing

The k-means algorithm divided the respondents, who represent the German society, into five clusters. The cluster analysis for the sector Housing, includes CO_2 (and CO_2e) emissions, that arise from heating and electricity usage. The plot "within group sum of squares" (see appendix A2) suggests a division of the dataset into five (or six) clusters or classes (elbow point), and five classes were chosen. The exact assignment can be examined in figure 13. The assumption from previous research (e.g. Otto et al., submitted), that emission classes exist, could thus be confirmed.

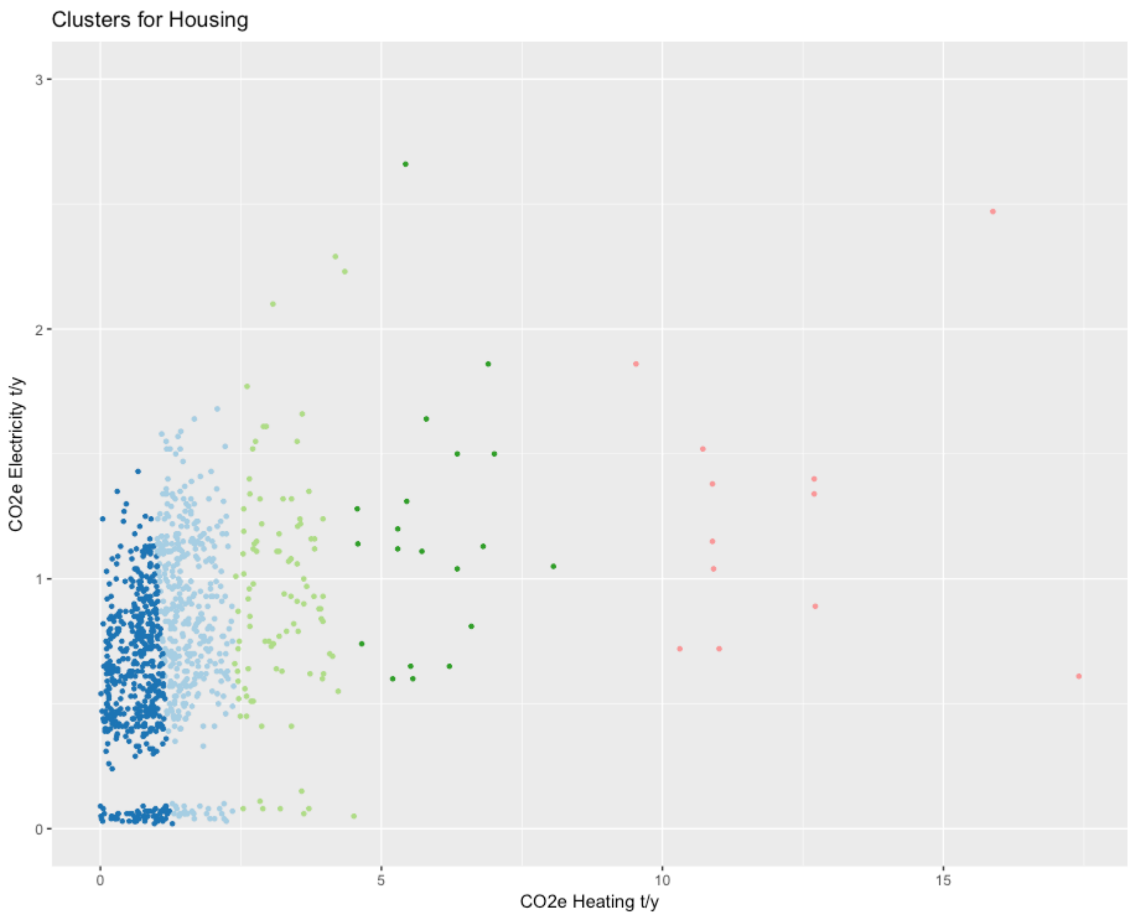


Figure 13: Socio-metabolic classes in the sector Housing (dark blue = class 1, light blue = class 2, light green = class 3, dark green = class 4, red = class 5)

The highest value of carbon emissions in the sector Housing achieved was 17,41 CO_2 e t/y for heating and 2,66 CO_2 e t/y for electricity which shows, that the CO_2 emissions that are caused and can be caused by heating are much higher than by electricity. Energy consumption is directly linked to CO_2 emissions and as heating has the highest share in total per capita energy consumption (Kleinhückelkotten et al., 2016), the differences were to be expected. Especially the energy source (e.g. hard coal, soft coal, fuel oil, natural gas, liquefied gas, electricity, district heating …) is decisive. Second focus is on electricity consumption, as power generation is also directly related to CO_2 emissions. The main uses of electricity are cooling / freezing, cooking, dishwashing, washing and drying clothes, lighting, and differ within the classes. 89 % also stated that they were using normal electricity, while the share of green electricity consumers was just under nine percent (ibid). As individual CO_2 emissions are mainly composed from the above-mentioned sectors, heating and electricity provide a good approximation to CO_2 emissions in the household. Accordingly, the respondents are distributed in the clusters along the x-axis, whereas individual consumption of electricity is generally in a smaller range. In summary, the huge differences in heating consumption determine class differences and increase continuously from class one to five with an extreme jump between four and five.

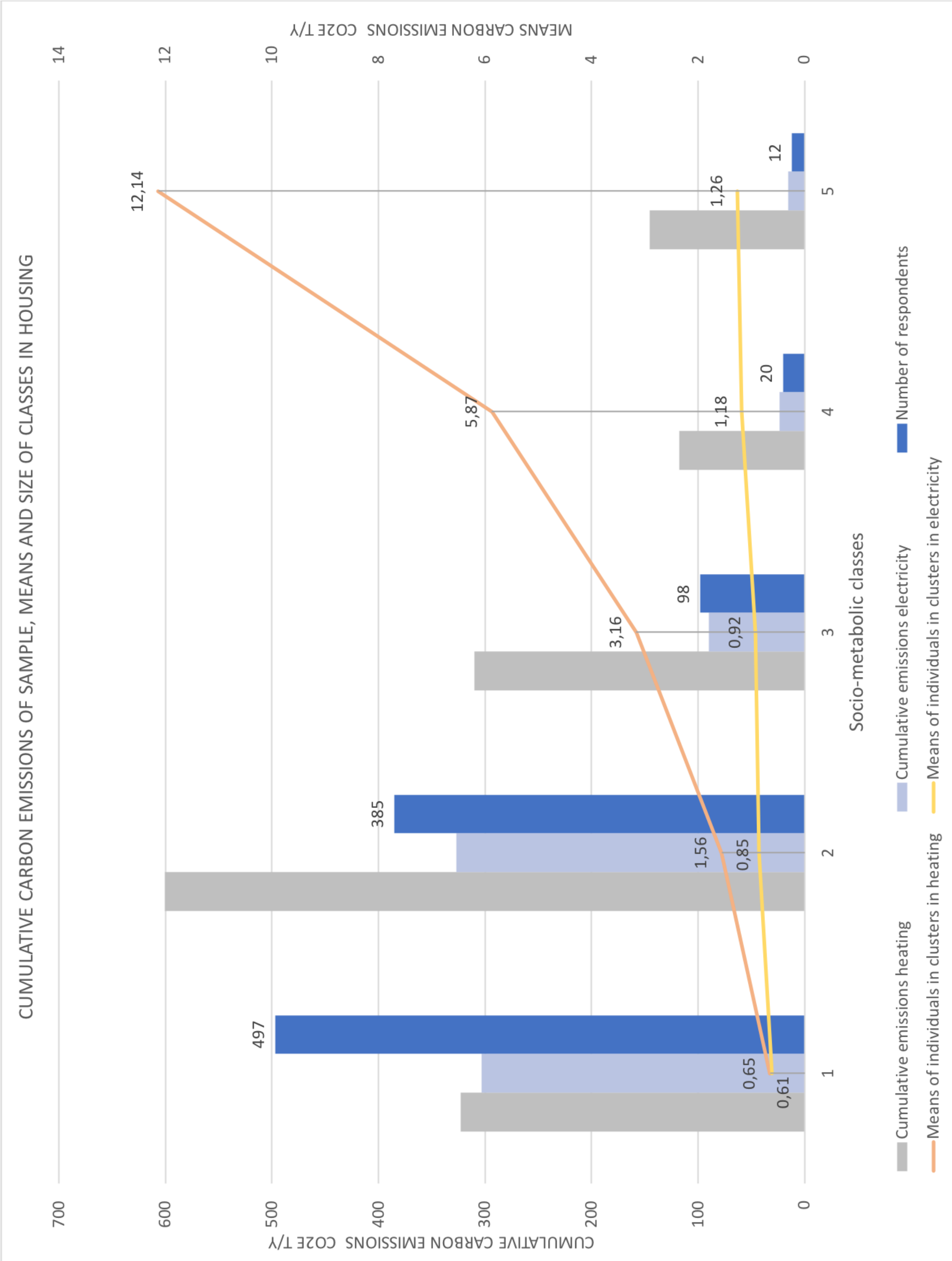


Figure 14: Cumulative carbon emissions, means and size of classes in Housing

Additionally, figure 14 is a visualization of cumulative carbon emissions, means and size of classes in Housing. It shows on one hand the number of individuals that have been assigned to the socio-metabolic classes one to five, the means of carbon emissions within the classes and on the other hand a comparison of the classes regarding their cumulative emissions. The highest emission class, class five, is only represented by 12 individuals meaning 1,1% of the whole dataset but emits around 150 tons of carbon emissions per year only for heating. In contrast, the two lowest classes together account for around 87% of the respondents and emit approximately 920 tons of carbon emissions per year for heating. Figure 14 reflects the different consumption patterns between the socio-metabolic classes accurately: On average, an individual in class five emits around 18 times CO_2 more as a person in class one. For electricity a similar picture emerges, but to a lesser extent. In cumulative terms, emissions are the lowest in the fifth class, but it is striking that the higher the class, the higher the emissions, where respondents in the fifth class emit double as much as respondents in the first socio-metabolic class. The result of this analysis is, that emission classes exist in the German society and most respondents can be assigned to the first, second and third socio-metabolic class, whereas a small number with extremely high emissions stands out. Cluster formations and inequalities in emission patterns can also be explained on the basis of the results of the UBA research group, which are used in addition to my findings (Kleinhückelkotten et al., 2016): The total per capita energy consumption decreases with the number of individuals living in a household. One person in a household has a per capita total energy consumption of approximately 16.000 (kWh/a). If five persons and more live in one household, the per capita energy consumption is only about 12.000 (kWh/a) (ibid). Related to that, the survey also reveals that the living space increases with the number of persons living in a household. The average living space in the survey is 86.8 m^2 (person weighted by age 53.9 m^2, unweighted: 40.7 m^2) (ibid). In Germany, the Federal Statistical Office estimated an average living space per inhabitant in an apartment of 46.5 m^2, which has seen a steady increase since 1999 (Statistisches Bundesamt, n.d.). The estimations fit to the numbers in the survey. From a technical point of view, the size and not the type of Housing is relevant. Interestingly, the size of the place of residence has no discernible systematic influence on the living space (Kleinhückelkotten et al., 2016). It means, that individuals who live in rural areas do not automatically have more living space than in urban areas, making differentiations from that perspective ineffectual. Nevertheless, contrasting rural and urban regions is reasonable regarding lifestyles and consumerism.

Bivariate methods by the UBA working group (Kleinhückelkotten et al., 2016) showed, that independent variables like cooling, cooking, media consumption, purchase of clothes, all-day and holiday mobility influence the total per capita energy consumption. However, results of regression analyses unfold, that individuals who live in urban or rural areas have a similar total per capita energy consumption - although individuals differ in their energy consumption composition, the total consumption is similar (ibid). Table 7 demonstrates that differences in socio-metabolic classes in the Housing sector for heating are not explainable due to place of residence, the emissions in different sizes of the place of residence are approximately the same, and other characteristics of individuals are relevant (see chapter 4.3).

Place of residence	Emissions [kgCO2e/a] per Person (weighted)
City center ＞500.000 citizens	1.816,6
Suburbs ＞500.000 citizens	1.530,7
City center 100.000 - 500.000 citizens	1.656,4
Suburbs 100.000 - 500.000 citizens	1.749,8
Medium-sized town 20.000 - 100.000 citizens	1.528,2
Small town 5.000 - 20.000 citizens	1.770,6
Village < 5.000 citizens	1.618,3

Table 7: Place of residence and carbon emissions for heating (adopted from Kleinhückelkotten et al., 2016)

More important are disparities between former GDR and FRG states- those living in former GDR states consume less energy (ibid). Regarding the answers of the respondents in the survey, the following observations could be made: The living space per person decreases with higher number of roommates, it increases with higher age, households with a person with a university degree have on average 119.4 m^2 available and thus the most living space.

The higher the level of education or also income, the higher the household's living space – explainable by an existing correlation between education and income in Germany (Anger & Geis, 2017).

4.2.2. Transport

For the transport sector, a division of the respondents into five clusters is valid. The partitioning by the k-means algorithm can be considered in figure 15. The clusters separate sharply, with less density in higher emission ranges. The result of the clustering confirms that a division into socio-metabolic classes can also be achieved. There are clear differences in emission patterns between the respondents that make a division into five emission classes in Germany reasonable.

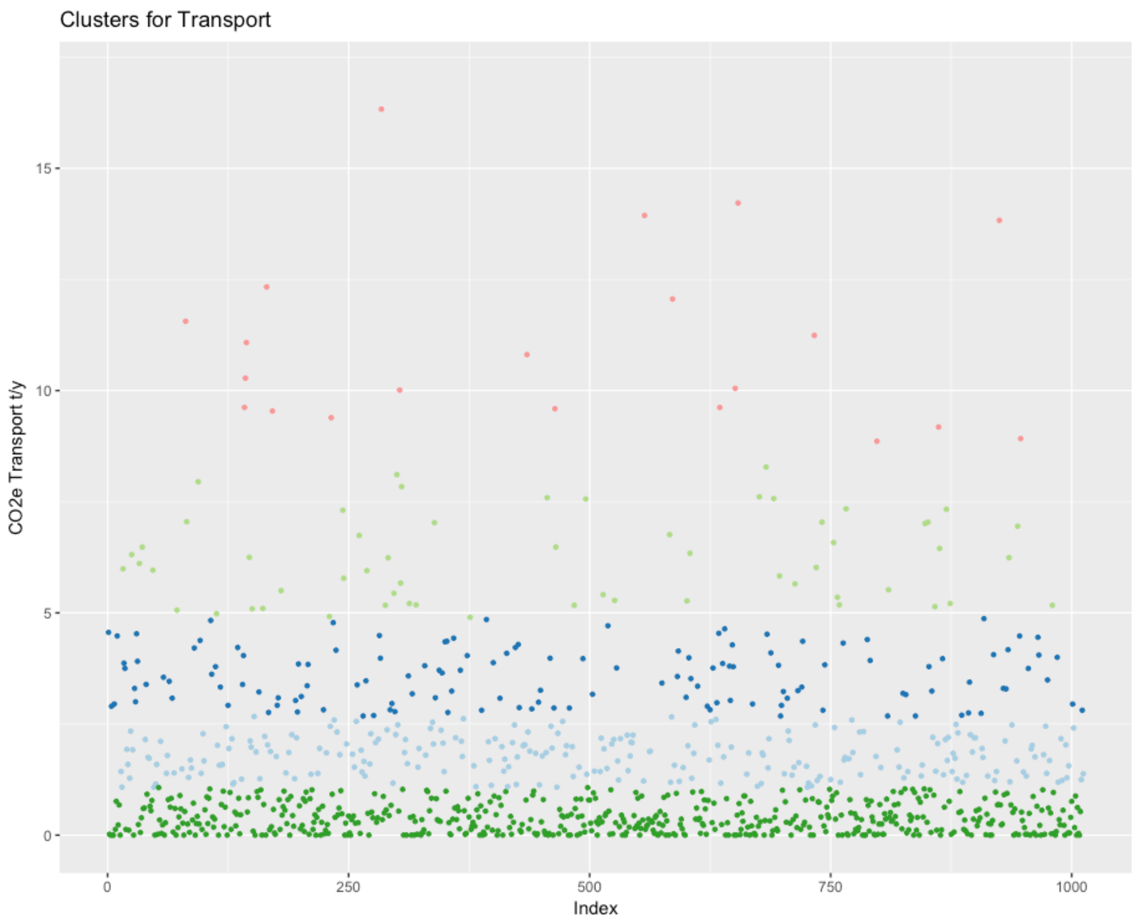


Figure 15: Socio-metabolic classes in the sector transport (dark green = class 1, light blue = class 2, dark blue = class 3, light green = class 4, red = class 5)

Most individual emissions occur between zero to five tons CO_2e per year, extreme emissions even reach values of 16,33. Similar to the sector described before, most of the respondents belong to the first socio-metabolic class (554 individuals) with the lowest emissions, but double as much (21 individuals) appear in the fifth socio- metabolic class. Figure 16 shows the means of carbon emissions in classes, that are similar to the Housing sector, in terms of a constant increase that can be observed from class to class, with a stronger increase in slope between class four and five, where individual emissions are nearly double as high. The results show that some individuals do have very low emissions (the majority) when it comes to Transportation, whereupon others have noticeably high emissions. In the transport sector, cumulatively, the CO_2 output is lower by 554 individuals than by 21, as the gray bars in figure 16 illustrate. The emission differences between the classes in the course of mobility are severe.

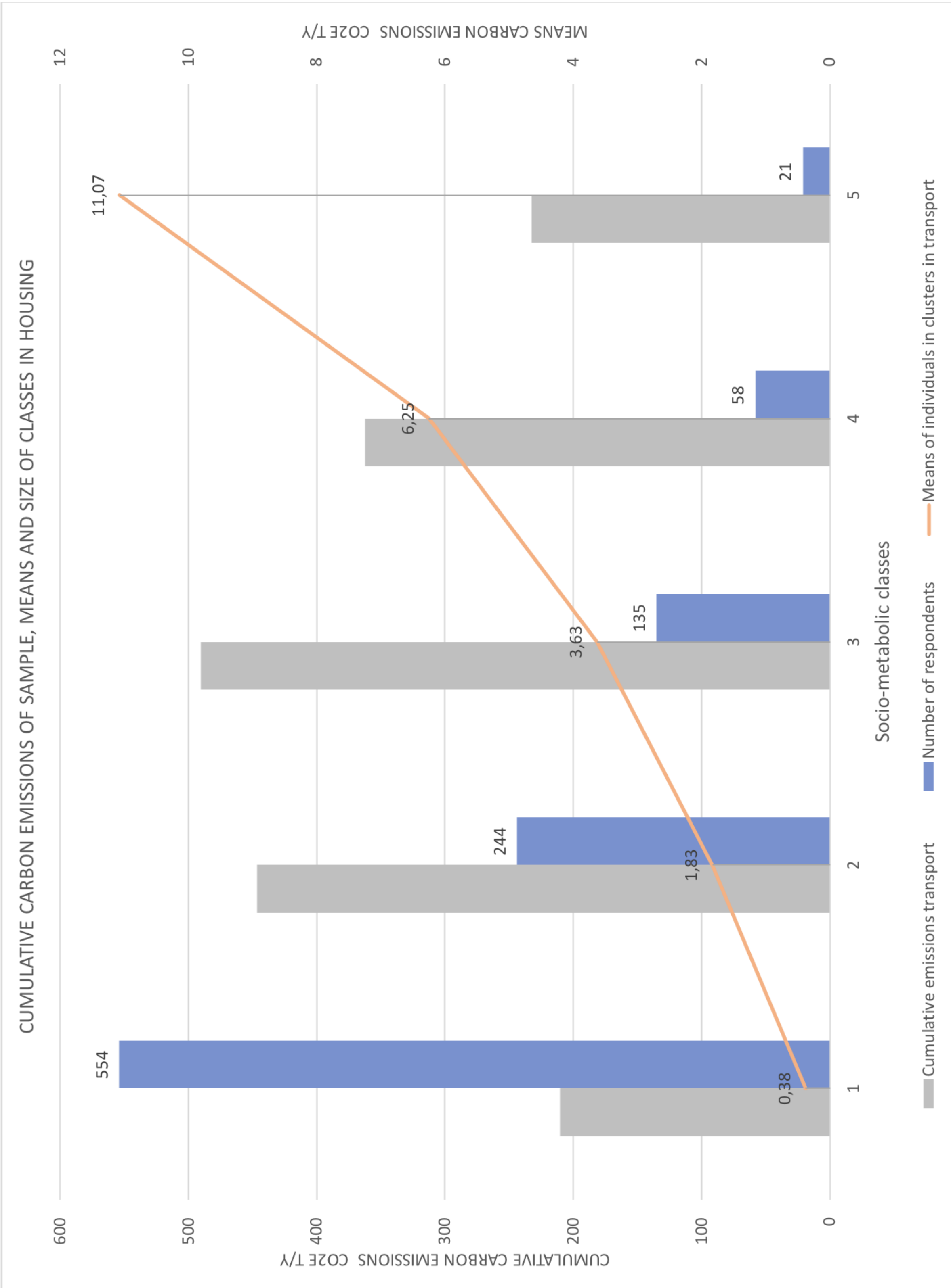


Figure 16: Cumulative carbon emissions, means and size of classes in transport

The results of Kleinhückelkotten et al. (2016) serve for a first understanding of the clustering results:

Main causes for high carbon emissions in the sector are comparatively big cars, frequent use and long holiday trips by car and plane. Car ownership is best comprehended in terms of milieus because the reason why individuals have one or more cars in different sizes depends on many reasons and living conditions. The most and largest cars own individuals of the well-established milieu, which is characterized by middle and high age groups (40-70), high educational levels and income. According to the milieu description by Kleinhückelkotten et al. (2016), also described in the appendix (A1), these individuals are performance and success oriented. A reason for the importance of one or more cars in their life concept are certainly practical reasons (e.g. for older individuals) but also crucial could be the role of status symbols. The modern mainstream and the critically creative milieu also own more, and bigger cars compared to the other milieus. The fewest and smallest cars are in the traditional milieu, the simple, precarious milieu and in the young milieu.

Factors that influence everyday mobility the most are gender, age and income. Similar to ownership and size of cars, the traditional milieu emits the least carbon emissions contrary to the well-established milieu. Regarding everyday mobility, it can be said, that the more individuals living in the household the higher the level of everyday mobility. Additionally, there is no obvious connection between the size of the place of residence and the energy consumption: Distances to work (average of mean: 2,7 km) and to the most frequently used shopping centers (2,4 km) are the same within cities or at the countryside, making no differences in emission patterns, as described in table 8, between rural and urban population. Assessments on public transport have not been made, as the primary concern is the use of cars and the distances covered.

Place of residence	Emissions [kgCO2e/a] per Person
City center ＞500.000 citizens	1.053,5
Suburbs ＞500.000 citizens	1.339,9
City center 100.000 - 500.000 citizens	1.001,2
Suburbs 100.000 - 500.000 citizens	1.163,4
Medium-sized town 20.000 - 100.000 citizens	1.118,4
Small town 5.000 - 20.000 citizens	1.140,3
Village < 5.000 citizens	1.281,8

Table 8: Place of residence and carbon emissions for everyday mobility (adopted from Kleinhückelkotten et al., 2016)

Regional differences play a minor role, but it can be said that the south of Germany is more energy intensive when it comes to mobility, as well as the former FRG compared to the GDR. More meaningful for Transportation are personal characteristics like age and gender because male respondents have higher emissions. An increase can also be observed with regard to age, whereby a decrease takes place from 65 years onwards. The highest emissions cause the age group 30-49. For everyday mobility the factor income is less important, but still shows correlations: Individuals with a net income below 1000 Euro per month are responsible for approximately 950 kgCO_2e/a, individuals who earn 3000 and more are responsible for approximately 2350 kgCO_2e/a (unweighted) (ibid). Here, again, the super-rich are not observed, even though current research depicts that the richest top one percent are responsible for 50 percent of per capita carbon footprints (Kim, 2018).

The same results occur regarding holiday trips: The energy consumption increases with the age until the group of 50 to 65 and decreases from 65 on. There are strong differences between respondents from eastern (former GDR) and western Germany (former FRG): East Germans emit around 168.6 kgCO2e/a, individuals from western Germany 273.5 kgCO2e/a.

In this case there is no difference between male and female respondents. Income also plays a role, rich individuals with 3.000 Euros income and more cause extremely high energy consumption and therefore emissions (1166.2 kgCO_2e/a), in comparison individuals with less than 1000 Euros per month emit only 152.6 kgCO_2e/a (unweighted numbers). The reason is, that persons with higher income travel longer distances for holiday trips.

4.2.3. Secondary Consumption

For the third sector, Secondary Consumption, a cluster analysis was also carried out. The result, visualized in figure 17, is also a division of the respondents into five socio metabolic classes. Secondary Consumption is subdivided into emissions occurring because of purchased food products, whereby other consumption contains the purchase of clothes and keeping of pets.

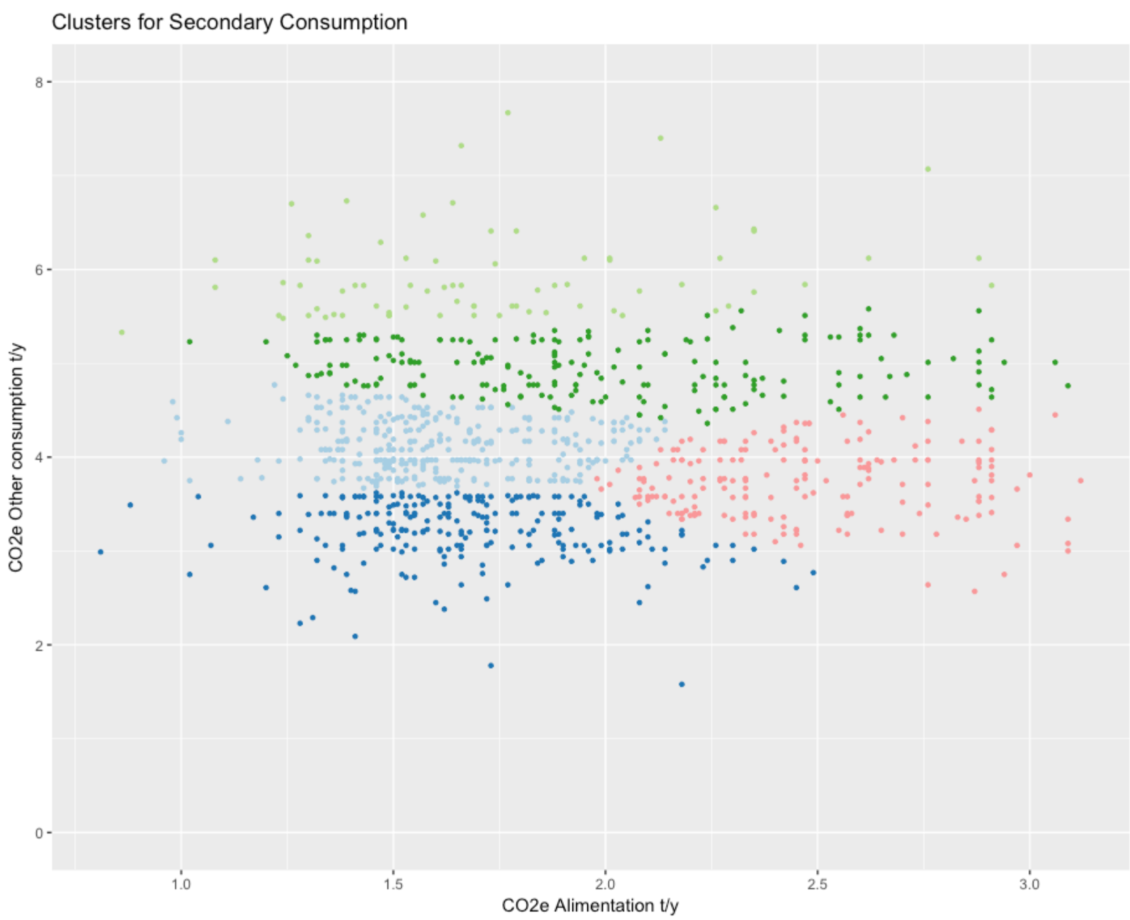


Figure 17 : Socio-metabolic classes in the sector Secondary Consumption (dark blue = class 1, orange = class 2, light blue = class 3, dark green = class 4, light green = class 5)

The lowest value for CO_2 emissions regarding alimentation is 0,81, the highest 3,12 and for other consumption 1,58 and 7,67 CO_2 e t/y. In alimentation the range of carbon emissions is smaller because alimentation is an endosomatic energy use, meaning that the biological system or metabolism of humans cannot differ much between individuals. The purchase of goods, as a consumer behavior that is not necessarily related to natural needs, thus determines the class structure in this sector.

The amount of cluster chosen in advance for the k-means algorithm is between five to eight, still making the decision, choosing five, reasonable. The clusters for Secondary Consumption cannot be as clearly ordered as in the previous sectors. The assignment of the clusters to the classes could therefore only be made subjectively. As figure 17 shows, the order chosen for the socio-metabolic classes follows the rising emissions regarding other consumptions, because alimentation does not show a convenient connection (explained later in this chapter). The term alimentation describes emissions due to nutritional behavior and was chosen for reasons of simplification (equivalent to purchase of food products). Carbon emissions based on alimentation habits occur because of food production and the associated GHG emissions. The calculations are based on self-assessments of respondents and also took into account preferences for products from regional and organic production.

The size of the classes is partitioned, with the class in the middle (class 3) representing one third of the respondents. Generally, the individuals are distributed more equally across the classes than in the previous sectors. Furthermore, socio-metabolic class three has the lowest emissions in alimentation, followed by the first and fifth class. A linear or steady increase from class to class is not observed. Especially for alimentation, one statement of this clustering is that, unlike in Housing and Transportation, not only a number of a few individuals stands out with their extreme carbon emissions – there is less inequality between the classes. Thus, difference in cumulative carbon emissions are not that high between classes. On the other hand, emissions from other consumption are steadily increasing from class one to five. Individuals in the fifth socio-metabolic class all have relatively high CO_2 values regarding other consumption but spread over the whole range in emissions for alimentation. Cumulatively, class five, with only half as much individuals assigned, has about the same carbon emissions output as class one. However, the range, between the number of individuals in classes (e.g. class 1 = 232; class 5 = 128) and differences in means of individual emissions (class 1 = 3,22; class 5 = 5,63) are less crucial as in the sectors before. High emission values by few individuals and also cumulative extremes between the classes are less observable here. Extreme carbon inequality is less noticeable in the sector Secondary Consumption but more in terms of purchase of clothes and keeping of pets than in alimentation. These results show that the connection of alimentation (metabolic needs) and class affiliation is less important than analyses of (redundant) status symbols and lifestyles, whereupon this thesis also aims. Conclusion is, that future research should focus more on consumer goods than on nutritional behavior because dietary changes are hardly to be expected.

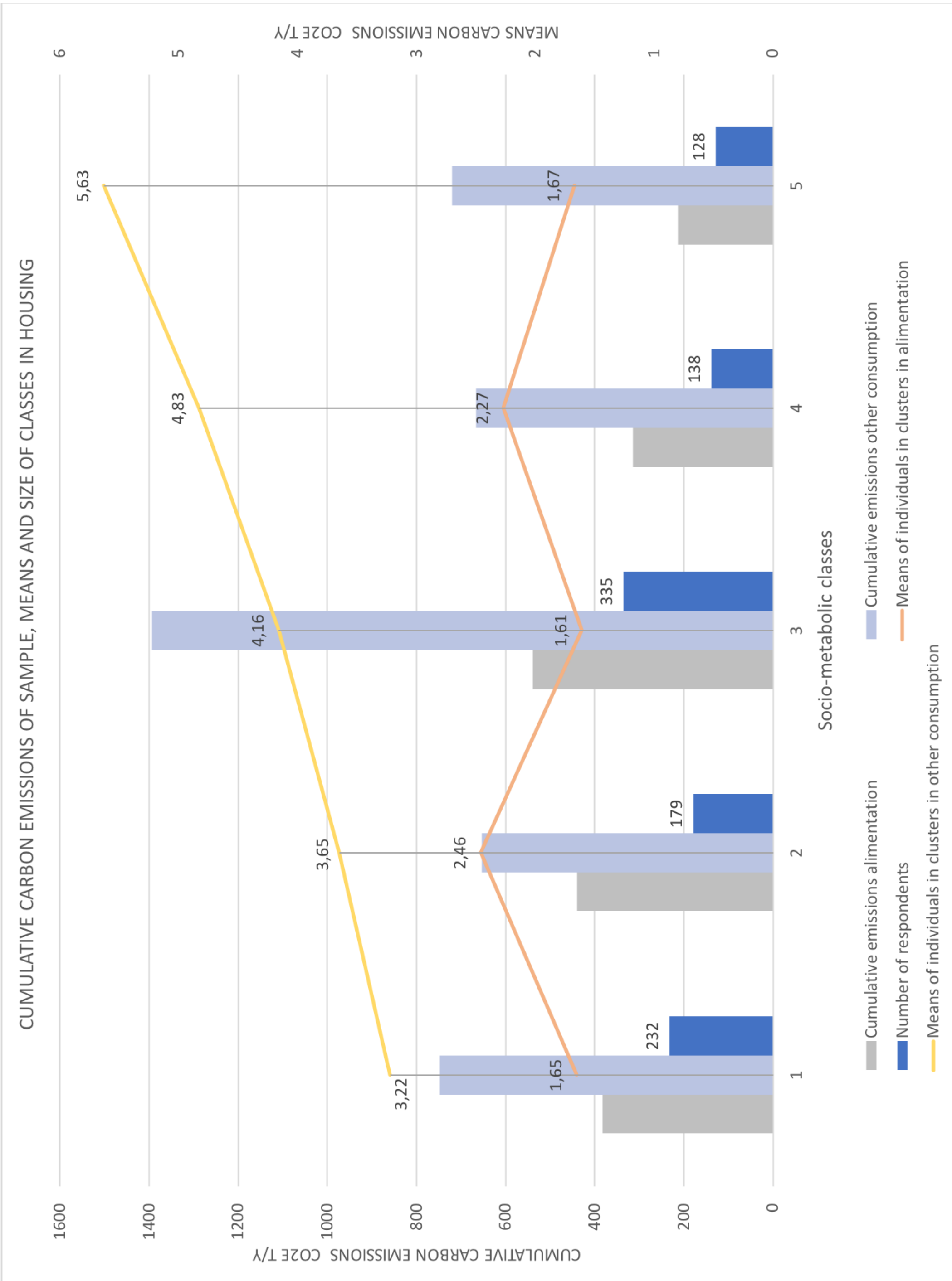


Figure 18: Cumulative carbon emissions, means and size of classes in Secondary Consumption

As in the previous two sectoral inquiries, results of the UBA research group (Kleinhückelkotten et al., 2016) are presented to include socio- demographic analyses: The only significant difference between the previous socio-demographic factors is between the sexes. Regression analyses show that, for example, the place of residence, whether urban or rural, is again not relevant for emissions arising due to alimentation or other consumption. Men have a higher carbon footprint because they consume larger quantities of food, especially more meat. In principle, the eating habits within Germany are very similar across all age groups, income and educational level, place of residence, with a generally high meat consumption. Men tend consume quantitavely more meat products, but regardless of gender, vegetarian or vegan diets are rare.

In contrast to emissions occurring to nutritional behavior, emissions from clothing purchases (part of Secondary Consumption) are greater in women than in men. They also increase with both, the number of persons and the number of household income recipients. Otherwise, high levels of consumption in the 30- to 49-year-olds group occur in comparison with the other age groups. For buying clothes, the inhabitants of the FRG emit more carbon emissions (157,0 kg CO_{2e}/y) in comparison with individuals from former GDR states (126,9 kg CO_{2e} /y). For 8 %, it is important that clothes have ecological labeled goods (ibid).

4.2.4. Intermediate results and further proceeding

The previous chapter gave insights in the data structure and compared different sources to check the validity of the survey by Kleinhückelkotten et al. (2016). Focus was hereby on demographic factors like age, gender, education and income as common approaches for explanatory or descriptive statistics. After checking the legitimacy of the data, cluster analyses were carried out, dividing possible carbon emissions in three hotspots: Housing, Transportation and Secondary Consumption. All sectoral cluster analyses have shown that there are differences or inequalities in emission patterns with regard to carbon emissions in the German society – resulting in a division into five socio-metabolic classes (see figure 19).

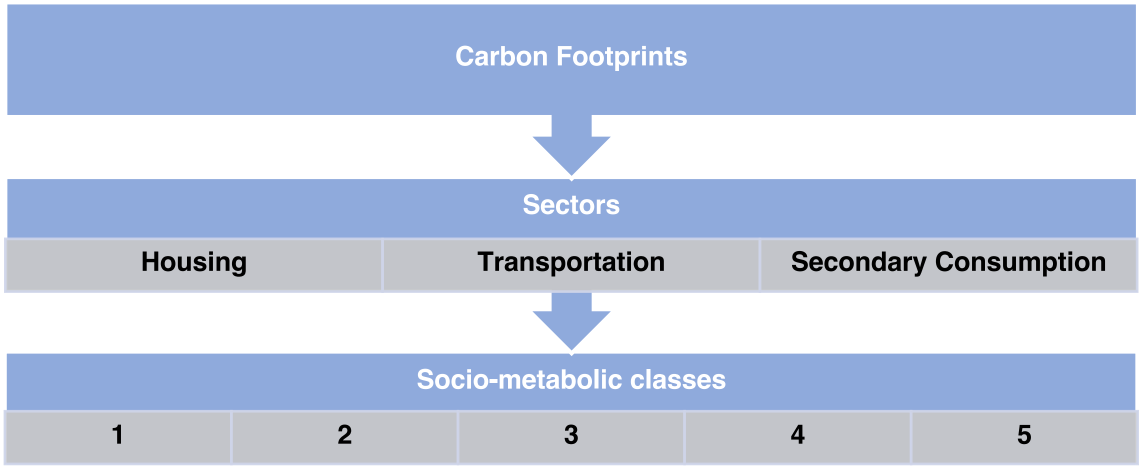


Figure 19: Schema for cluster analysis

To explain occurring carbon emission in the sectors, results (e.g. correlations and regressions) from the survey were taken into account. The findings can be shortly summarized: Income, age and gender determine different emission types and regional differences in consumption have developed with respect to the East-West divide (GRD and FRG), whereby the difference between urban and rural consumption patterns are not significant. Furthermore, it is not relevant if individuals live in cities, suburbs or smaller villages.

These results are a first step to understand lifestyle related emissions. Different to the findings of the UBA working group, I divided the respondents within the sectors into five emission classes. Interesting for me are lifestyles, that can be directly linked to carbon emissions and can be associated with certain emission classes. In order to proceed the results of the federal environment agency, I dissociate myself from the analysis of socio-demographic factors, which was carried out sufficiently and try to understand human behavior, extract their influences from a socio-scientific perspective and in this context, to analyze, how the habitus, that are the expressed lifestyles, are determined. In doing so, the complexity must be taken into account, such as the socialization of a person, the social structure and environment (e.g. education of parents), the cultural environment and norms (e.g. regarding questions of sustainability and responsibility), and of course economic conditions and possibilities. For this reason, the following chapter turns away from traditional approaches (like analyzing socio-demographic relationships) and seeks to discover differences between the clusters through Pierre Bourdieu's theory of capital.

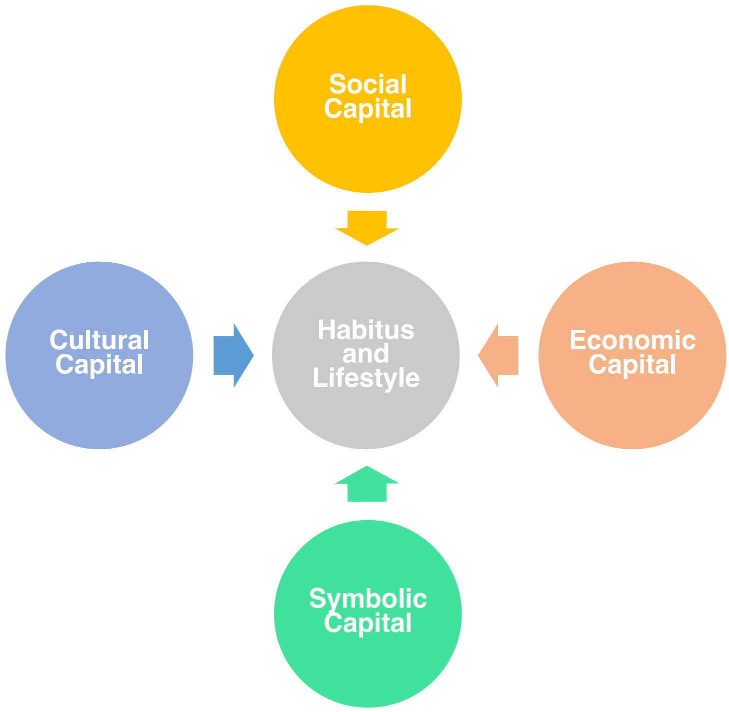


Figure 20: Capital and Lifestyles

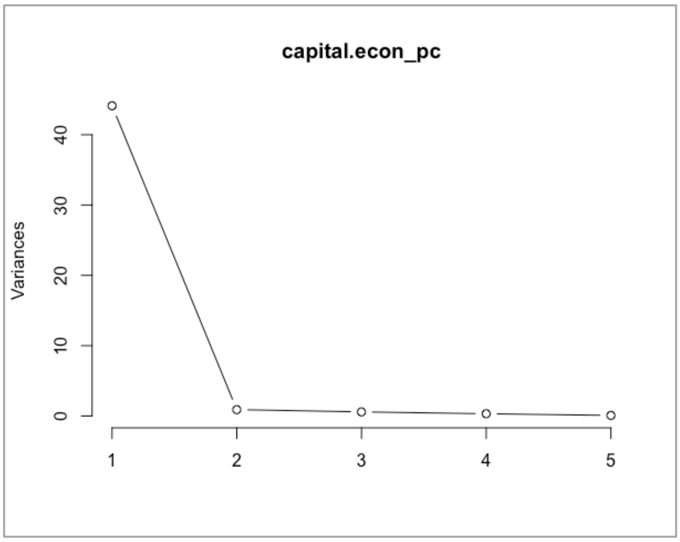
As presented in figure 20, the cultural, social and economic perspective is analyzed, and the clusters or classes are compared in terms of their capital endowment. Symbolic capital (honor, prestige, recognition) cannot be examined, because questions were not included in the survey.

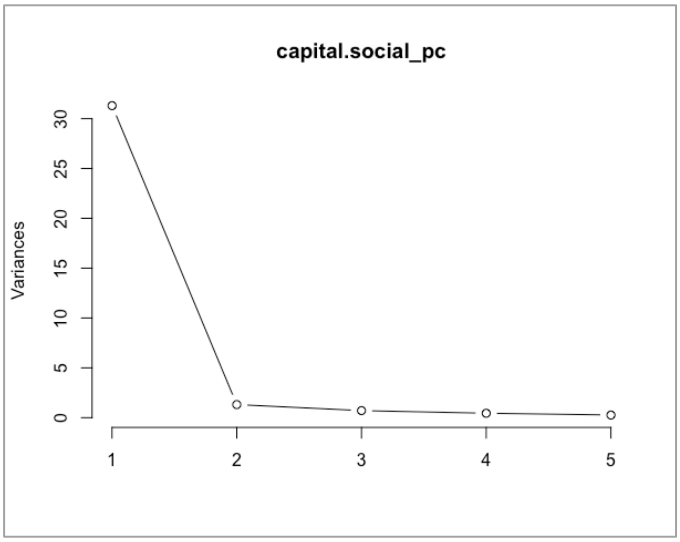
4.3. Descriptive Statistics on cluster: Types of capital and socio-metabolic classes

The application of Bourdieu's three types of capital was used to analyze the differences between the clusters, to answer the question: Do individuals in the classes differ in their economic, social and cultural capital? To summarize this briefly again: Economic capital "is immediately and directly convertible into money and may be institutionalized in the forms of property rights" (Bourdieu, 1986, p. 47) and social capital is the social relations between individuals (e.g. the membership in a group). Generally, cultural capital is complicated to capture and for the purpose of this thesis the respondents were not asked the right questions to do a proper analysis. Therefore, I added results from the survey by Kleinhückelkotten et al. (2016) and used "education" as cultural capital.

Additionally, I established an analysis of ICT as informational capital for the sector Housing to show if clusters differ.

Figure 21 reveals the results of the Principal Component Analysis of all three types of capital which is a multivariate statistical approach for unsupervised dimension reduction The method executes a transformation of possibly correlated variables into fewer uncorrelated variables, that are called principal components. In applying PCA on capital forms, exemplarily on economic capital, it can be shown, that a person who has many cars also has a high income. The majority of the information is thus on the factor income. It is a criterion variable in subsequent analyses because it accounts of most of the variances in the observed variables in building a synthetic or artificial variable measuring each dimension. The reduction of complexity without losing information through PCA, represented in figure 21, indicates the variance explanation power (y-axis) of each of the principal components.





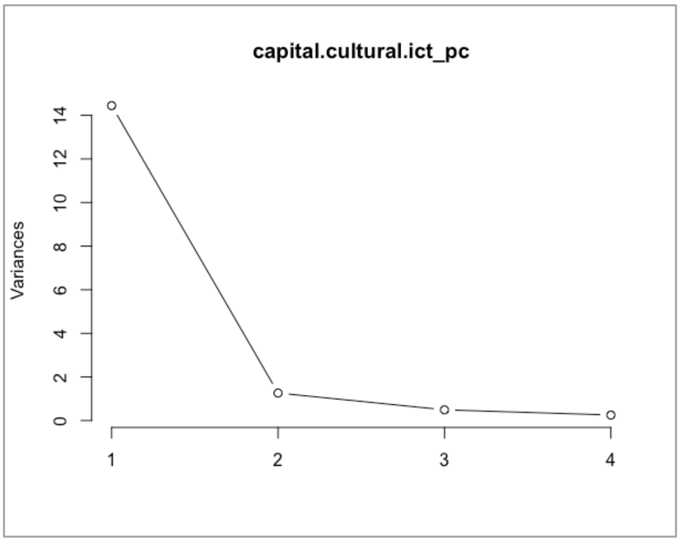


Figure 21: Principal component analysis of all three types of capital

In order to take up the complexity of capital forms (e.g. not using solely income as economic capital), several factors act as influential variables. Some of the factors cause higher variances others not. For economic capital the first principal component (PC1) explains around 45% of the data, which means, that in PC1 most information is included having the highest value in the linear combination. The rotation shows (see appendix A3), that the possession of motorbikes contributes the least difference in variance, contrarily to that, the most comes from income. To say it in other words: For economic capital, the first principal component (monthly net income per household) increases with increasing property houses, property cars and type of car and property motorbikes – the criteria vary together, there is a connection.

It is similar in the case of social capital, where the first principal component explains around 32% of the data where the smallest factor is observed from the status employed/unemployed, and most variance is caused by the belonging to a certain group (e.g. student, pensioner…).

As described in chapter 2.6.3, I implemented a new form of cultural capital focusing on emissions and resource consumption that originate from one's movement in the digital world – called informational capital. Here, also a PCA was performed, showing that the fist principal component explains around 15% of the data with the smallest influence on variance in "how many computers are in the household" and "how many computers and smartphones were recently bought", whereas "how many hours spend daily in free time on the computer" explains most of the covariance. The explanatory power is much smaller than in economic and social capital (variances are described on the y-axis).

In summary it can be said, that the PCA was performed, so that the following comparisons between the clusters is based on one variable for each capital type, that summarizes the covariance for all influencing factors. This reduces complexity without losing relevant information. The capital forms were applied in an ANOVA for all sectors giving the following results:

Analysis of Variance Table

Response Variable	Df = 4 Residuals = 1007	Mean Sq.	F value	Pr (>F)
Housing				
Economic Capital		13.1497	2.3979	0.04862 *
Social Capital		14.5953	12.476	6.563e-10 ***
Cultural Capital as ICT	Df= 4 Residuals= 1001	4.1172	3.2916	0.01083 *
Transportation				
Economic Capital		260.89	57.979	<2.2e-16 ***
Social Capital		1.5659	1.2819	0.2753
Secondary Consumption				
Economic Capital		47.264	8.8372	5.162e-07 ***
Social Capital		32.365	29.443	<2.2e-16 ***
Housing 7 cluster				
Economic capital	Df = 6 Residuals = 1005	12.2903	2.2453	0.03698 *
Housing 5 cluster				
Income	Df = 4 Residuals = 1007	12.4688	2.3236	0.05489

Significant Codes: 0 '***' 0.001 '**' 0.01' '*' 0.05 '.' 0.1 ' ' 1

Figure 22: Results of analysis of variance

The following results are based on analysis of variances (ANOVA) and post-hoc tests like Bonferroni-Holm. For further explanations please see chapter 3.2.2. The analysis of variance is used to determine whether the means of the clusters are all equal. To distinguish between the clusters, the variability between the clusters must be greater than the variability within the clusters. At a significance level $p \leq 0.05$, H_0 should be rejected

and H_1 is supported, meaning that if the null hypothesis is not true, the means are not all equal: There are significant differences between the clusters. The (within-group) mean square, also called error mean square, are the averages of the variances in each cluster. This estimates the variance regardless of whether or not the null hypothesis is true (see appendix A4). The Between-Groups Mean Square (mean square in table) are calculated from the variance between groups and estimates the population variance, if the null hypothesis is true. To compare these two estimates an F-test to of variance is used.
Relevant for my analysis are the p-values if $p \leq 0.05$ and if there are significant differences, a post-hoc test was applied (for all results see appendix A4) to figure out which clusters might be interesting for further analysis.
The results of the analysis of variance show that the clusters within the analyzed sectors almost always differ significantly in their capital forms. In other words, individuals were divided into (five) socio-metabolic classes by cluster analysis and differ in comparison to the other classes. If the habitus or lifestyle of a person is determined or influenced by economic, social and cultural factors, the results are not surprising: The social, cultural and economic are influencing factors for carbon footprints. Pierre Bourdieu's theory can thus be transferred to an ecological context giving better explanations what might influence lifestyles and therefore emission profiles.
With regard to economic capital in the Housing sector, the ANOVA generates a p-value of 0.04862 and thus asserts a significant difference. The post-hoc test Bonferroni Holm, that presents which cluster combinations might be the reason for this difference, shows no directly linked differences. The socio-metabolic classes three and four, are most likely to be the reason. However, the determining significant level cannot be achieved (explainable by the weak significance). The differences regarding the carbon footprints in the Housing sector cannot be securely attributed to economic inequality. A change in the cluster number to seven decreases the p-value (because the higher the amount of cluster the higher the differences between the clusters) but post-hoc tests provides similar results. If just testing the factor income (net monthly household income) on the five socio-metabolic classes (without any other economic determinants) results are not significant which supports the assumption, that wealth or income is not necessarily crucial to electricity and heating consumption or habits, even though the size of living space increases with income. Interestingly, the social capital or (current) social environment is highly significant in the sector Housing. As the PCA showed before, the current social environment, that arise due to the social status (like being a pupil, student, pensioner,

jobless person, housewife/househusband, being in motherhood), is decisive. Additionally, the post hoc test suggests, that the first socio-metabolic class differs from the second, third and fourth and between the third and fourth classes are differences in terms of social capital.

These results depict that the class with the lowest individual carbon footprints differs strongly regarding social factors from all other classes. There is also a different level of capital endowment between class three and four. At this point, further analysis is necessary. It seems that the first class is fundamentally differently socialized than the others and that there is a decisive difference between class three and four, which may be responsible for the increasing carbon emissions. Data from the survey processed in the PCA for ANOVA shows that the membership in a particular group, i.e. the social status, is particularly influential on carbon emissions in the sector Housing. However, the two highest emission classes do not seem to be essentially different - social capital plays a lesser role here. The many significant social differences between the clusters prove that social occurrences between classes exist and are important for understanding environmental impacts. Based on this, a further analysis would be meaningful, which takes up the social environment more precisely to see how these factors affect ecological behavior.

The last form of capital for Housing is cultural capital. Cultural capital in Bourdieu's (1986, p.47) sense exists in three forms: In the embodied state (education), in the objectified state (in the form of cultural goods like pictures, books, instruments, machines, etc.), whose production or consumption presupposes a quantum of embodied cultural capital and in the institutionalized state. Cultural capital is mostly formed by school and family and its foremost characteristics is heritability. The data to perform a sufficient analysis of cultural capital is absent. To avoid the problem, I developed two alternatives: One is to filter out information from the UBA survey (Kleinhückelkotten et al., 2016) on education that fits in with the three sectors in order to meet the Pierre Bourdieu's embodied state of cultural capital.

On the other hand, I have developed a new type of cultural capital as informational capital for Housing in the form of information and communication technology (ICT). The approaches have two advantages: First, there are supposed links between education and the time spent on the computer or surfing online and therefore with CO_2 footprints from an energetic perspective. Second, computer technologies and in particular the internet have grown into new cultural assets, which should get more attention also in the ecological context, thus extending Bourdieu' cultural assets (such as pictures, books, encyclopedias, instruments or machines) by modern technology is reasonable. The idea to use ICT is based on two research directions: what results occur regarding the usage of computers and the digital world with power consumption on site and externally (externally means energy consumption that occur to fulfil digital actions like google searches) and which role does the internet or computers / smartphones play in terms of cultural capital as opinion-forming media.

Socio-demographic attributes	Room heating	Hot water	Laundry washing	Cooling, cooking, dish washing	Electronic media	Lighting	Everyday mobility	Vacation	Nutrition	Clothing	Total
Persons / Household	-	+	-	-	+	--	++	xx	o	+	-
Gender	o	xx	o	x	x	o	xx	o	xx	xx	xx
Age	++	-	--	-	++	++	xx	xx	o	xx	xx
Education	xx	xx	o	o	-	x	+	++	o	+	+

++ / + the energy consumption increases clearly / by trend with increasing value of the independent variable resp. geographical direction
-- / - energy consumption decreases clearly/ by trend with increasing value of the independent variable resp. geographical direction
xx / x energy consumption depends strongly / to a certain extent on the independent variable (bivariate analysis), but there is no distinct trend or such a trend is not possible since there is no ordinal scale or no relationship has been found

Table 9: Effect of socio-demographic factors on per capita energy consumption (adapted from: Kleinhückelkotten et al. (2016))

To answer the first part, Kleinhückelkotten et al. (2016) depict in table nine, that resource consumption increases with education levels. Individuals with a university degree are on the highest level of total energy consumption. Living space occupancy and space consumption are rising with higher education levels (also with income), causing higher emissions in the Housing sector (mainly through heating) and cannot be made up, for example, by the savings made by using more energy-efficient appliances (electricity). The power consumption for personal computer use increases with the number of household members, men spend more time in front of the computer than women, but women watch more television. With age and with educational attainment energy consumption for television decreases whereas energy consumption for using a computer increases. The GDR-FRG comparison results in higher energy consumption for television in the western federal states and for computer use in the former GDR states (ibid). In summary, high energy consumption levels in the sector Housing are correlated with middle and high education.

To answer the second part (ICT as a cultural asset), I analyzed, as before, differences between the five classes regarding cultural capital, in that case based on informational capital or ICT. To determine this new capital type, the following factors were considered: Number of computers in household, number of newly purchased computers in last three years, hours spend daily on computer in free time, number of newly bought smartphones in last three years. Most relevant for variances (PCA) is the factor "how many hours spend daily in free time on the computer" - this is the main reason for differences between clusters. The p-value of 0.01083 * stands for this significant difference: Individuals in the socio-metabolic classes differ in the number of hours spend daily on the computer. That means, suppose that individuals use mainly the internet when they use the computer and the digital world can be seen as cultural capital, the classes differ regarding cultural capital. On how exactly they differ is not clear, because further investigations should be made. It is a first attempt to state, that the analysis of carbon footprint classes and the individuals within the classes regarding their ICT usage is promising, not only from an energetic perspective (media use and carbon footprints) but also from the fact that the internet influences our cultural world (internet as cultural capital).

For the sector Transport, contrasting results were generated. Here, unlike in the sector Housing, economic capital is highly significant, indicating that the socio-metabolic classes are different regarding their economic capital. The post hoc test suggests (for significance levels see appendix A4), that especially the first and second class are different from the other clusters in this regard. There is a divide between the lowest two classes and the upper three classes regarding their economic endowment. Interestingly, the middle class to the fourth and fifth class let arise no striking differences – there is a class separation into two opposing groups, namely the ones that can afford convenient mobility and travelling, and those who do not have the financial possibilities. The provision of economic capital is thus decisive for the mobility or the type of mobility. In the previous text, it was often mentioned that the super-rich have extremely high carbon footprints because of their many, large cars and frequent flying. It can be assumed that in this survey, individuals with extreme wealth are not sufficiently represented. The difference of the socio-metabolic fourth and fifth class, which should actually be present

according to other research results, cannot be proven here. The interpretation of a dichotomy of the German society is thus relativized.
In contrast to economic capital, the classes do not differ significantly from each other in terms of their social capital. Social factors thus play a more subordinate role in terms of choice and intensity of mobility. The results are only approximations - an absolute exclusion of social capital cannot be asserted.
From a cultural perspective, and therefore regarding education, higher education is correlated to higher energy consumption for everyday mobility and holiday trips (Kleinhückelkotten et al., 2016). For everyday mobility individuals with completion of compulsory secondary education (Hauptschulabschluss) only emit around 770 kg CO_2e, in comparison to individuals with a university degree emitting approximately 1.877 kg CO_2e per year. The same results occur for vacation trips: Individuals with a university degree (768,7 kgCO_2e/a) are responsible for CO_2 emissions more than 5 times as individuals with formal education (ibid).
For the sector Secondary Consumption both economic and social capital are significant. Here, it must be pointed out again briefly, that the cluster structure of the classes differs in comparison to the other sectors: There is no linear relation (the higher the class, the higher the emissions) but the first class has low emissions in terms of alimentation and other consumption (for explanation, see the previous text), the second class is characterized by high levels of alimentation and low levels of other consumption, whereas the third class has lower levels of alimentation but is higher in terms of other consumption (see figure 17).
Regarding economic capital many cluster combinations show significant differences especially cluster one and four (with a p-value of 7.3e-06). Economic capital thus determines the purchasing behavior of food products as well as consumer goods such as clothing, which is probably reflected in the number and type of goods. Especially in this regard, an analysis of lifestyles, consumption and luxury is important for climate research. Societal values or norms, that allow a hierarchization through consumption or goods, emerge. The question of how a possible "eco-habitus" (Carfagna et al., 2014) would be socially mature in certain classes seems game-changing.
For social capital a high significance results, but not all possible combinations differ, like exemplarily the second and third socio-metabolic class. As the sector Secondary Consumption stands for consumerism in general (e.g. what individuals eat, how many clothes they buy), the economic environment and the social environment or socialization

are affecting purchase behavior. Although individuals in the classes have shown differences in social capital, there is no clear connection or interpretation of social status and emissions. Here, however, research about milieus can be consulted.
For the third capital form, there is no clear message for education as cultural capital. Analyses revealed, for example, that the degree of education has impacts on the consumption of organic products or seasonal products (which does not necessarily have to be linked to carbon emissions). Regression analyzes unfold that the level of education is not decisive for food consumption, but rather gender, for example, dietary wise, which affects the amount and consumption of meat (Kleinhückelkotten et al., 2016). For the sector Secondary Consumption, differences in the classes are therefore not attributable to the level of education (cultural capital) but more to economic and social factors.

5. Discussion

5.1 Planetary Boundaries and Class Theory

The attempt to quantify complex earth system processes was undertaken by Johann Rockström et al. in the concept of PB (2009). Biermann (2012) describes it as crucial contribution for goals of governance in which a provision of "applicable approach for translating the planetary boundaries into national-level fair shares of the Earth's safe operating space" is needed (Häyhä et al., 2016, p.1). Results from downscaling can thus serve as bench marks or guiding values. Yet, an absolute correctness or "truth" of these numbers should be discarded: it is only an attempt to apply highly complex processes to complex structures. Biermann (2012) critics that the concept of PB is normatively neutral but its operationalization is not - it is a social construct, and further research is vitally important. A similar picture emerges with footprint calculators, that were developed to estimate individual emission patters. They are also indicative and limited in their explanatory power, for example, because the complete life cycle of products is not included but are useful for rough assumptions.
O'Neill et al. (2018) depict that it is likely to meet basic, physical needs and the elimination of extreme poverty at a sustainable global level, e.g. nutrition, sanitation,

access to electricity, without transgressing the planetary boundaries. On the other hand, it is difficult to achieve more qualitative goals such as high life satisfaction because it would require a level of resource use that exceeds the sustainable level by a multiple. These more "qualitative goals", which can be associated with lifestyles, are therefore to be questioned, especially the resource use by certain groups, e.g. the super-rich since they are not possible to achieve for mankind within the planetary boundaries.

Transgressing the safe and just operating space should be beyond question and behaviors that cause unnecessarily high emissions need to be focused on and reduced, to allow more individuals to reach a certain standard of living.

One possible approach to apprehend the limitations of the planet, is the social metabolism, the thinking in cycles and understanding of transformations within systems. The social metabolism uses empirical information about biophysical variables and focuses on the important role of nature. Natural systems coevolve with human interventions and exert pressure upon societies to keep on changing (Fischer-Kowalski, 2011). The Earth system is materially closed and energetically open and based on that, a reinvention of our food, water, and energy systems is needed (Foley, 2017). It can therefore be argued, that the planetary boundaries serve only as guardrails and the compliance of the boundaries can fail or failed already, as long as humanity is the center of the Earth system without reinvention of systems.

For my thesis, the initial point of research is, that there are large differences in consumption among and within countries and in this regard carbon emissions.

The authors Brand & Wissen (2017) developed recently a concept of the imperial way of life, which states that the vast majority of individuals in Germany live resource intensive at the expense of nature and the workforce of other regions of the world. For them, it seems plausible, just as in this thesis, to broaden the critique of the capitalist mode of production by a critique of consumption norms and way of life. Unlike the results of this thesis, the authors suggest that a common across-classes way of life would exist in the capitalist centers. With regard to previous research, this concept should be rejected, since in particular ecologically and socially destructive consumption, like driving a SUV, is only possible for certain social groups. Even though, the average prosperity level in Germany is certainly higher compared to other also industrialized countries, a division of society into socio-metabolic classes, that is, classes that differ in terms of resource use and emissions, is important, as it accurately reflects these different lifestyles, rejects the simplification of social structures and confirms the concomitant inequality in Germany -

an across classes way of life in Germany is, contrarily to the assumptions of Brand and Wissen (2017), based on the results of this thesis, questionable.

In contrast it seems meaningful to me, to uncouple the imperial way of life, that the authors refer to, from a geographically defined reference level (e.g. the study of a universal lifestyle in Germany) and to investigate, if there exists an imperial lifestyle globally. Thus, there is no general type of lifestyle in the global north / developed countries, even though all Germans use a certain infrastructure that is resource intensive or live within economic and political systems that cause harm to other countries, but an imperial lifestyle in the sense of being oppressive or dominant worldwide, so that one social class, e.g. the super-rich or the elite, lives and exploits the Earth system at the expense of others. Of course, there is still a northward bias, both regarding lifestyles and CO_2 emissions, but capitalist structures have enabled the imperial lifestyle in many countries. To put it in a nutshell: it is about the dominance of the privileged over the underprivileged, a unification of a country or region does not allow enough concrete potential for change – resource incentive lifestyles that spread over the world need to be questioned in general. Dividing the German society into classes and defining hotspots is thus contributing to a social ecological transformation.

5.2. Socio-metabolic classes and capital

The discussion of my results is divided in two parts. Based on the research question, firstly on the sectors and the understanding of the socio-metabolic classes and secondly on the analysis of classes according to forms of capital.

The idea of dividing the German society into five socio-metabolic classes was found to be valuable on the basis of the cluster analysis. Based on these results, sectors as well as groups of individuals can be identified as hotspots due to their emission values. Sectoral, it is the transport sector and emissions related to heating, with high levels generated by the fifth socio-metabolic class.

As visualized in the above text, there is a clear separation of socio-metabolic classes in the Housing sector in those who live very economically and those who have an extremely high electricity and heating consumption. Heating is more CO_2 intensive than electricity, which is, among others, certainly due to climatic conditions in Germany and in other, warmer countries a different image of the clusters could occur. The classes differ in all three types of capital, meaning social, cultural and economic factors determine their class affiliation and the differences regarding the carbon footprints in the Housing sector cannot be securely attributed to economic inequality. Interestingly, the cluster analysis results that the fifth socio-metabolic represents only 1.1 % of the respondents. The majority of the population is in the lower three classes, mostly in the first socio-metabolic class (first and second class add up to 87 % of total respondents). That fits in with the assumption, like for example in the Oxfam (2012) report, that a small number of individuals are responsible for very high emissions and their emission patterns are different from the rest of society. The results show, and discussed more detailed later, that not only economic or educational conditions make these differences. In Germany the per capita living space increases with income (Kleinhückelkotten et al., 2016) and respondents prefer to live on their own (41.1%) or in two-person households (34%) (Statistisches Bundesamt, 2018). In conclusion, the German population prefers to live with less individuals, and as soon as it is financially possible, much living space is claimed. Of course, this is ineffective from an energetic perspective. Individuals on lower incomes often live more climate-friendly because they have incentives to save money and avoid unnecessary heating and electricity costs. On the other hand, authors like Hubacek et al. (2017) discuss possible outcomes for achieving climate goals associated with reducing poverty: If the purchasing power parity increases to 2.97$ globally, meaning a reduction of extreme poverty, the required mitigation rate to compensate further emission would raise by 27%. This mode of thought should be rejected, and the focus should be on those who cause extremely high emissions. Large houses, or especially large inner-city apartments are popular with higher education (energy consumption also rises with educational level) which are status symbols and convey a specific lifestyle. Also, the image of the home as a retreat seems to be in the German culture formative. To eliminate these needs with political means or incentives is, in my opinion, difficult to achieve. Carbon dioxide emissions and reduction potential are more likely to emerge through top-down policy implications, such as the coal phase-out, or the switch to renewable energies in general, and more efficient technologies like insulation or energy-efficient home appliances. The implementation of the coal phase-out is a political task, interesting for the scientific community is, to do more research on approaches such as life cycle assessment (LCA), which examines the potential environmental impact of the entire product life cycle, to find out whether there are total reduction potentials

In the Transport sector, the socio-metabolic upper class is twice as large as in the Housing sector, but still very small. Here, too, it stands out that a certain group of individuals is extremely different in their mobility behavior while the majority has a low carbon footprint. These findings are in line with the statements described above (see Sablowski, 2018), that there is no overarching lifestyle and individuals are very contrasting in the German society. While a majority of the population uses public transport and travels little, others live very resource intensive lifestyles.
This is explainable in two ways: On the one hand, about financial restrictions, because many cannot afford a big car or vacation (here, for example, it is important to find out prospectively what role low cost airlines take) or individuals are too busy satisfying their basic needs, have a low level of agency and do not have time to travel. Income is correlated to carbon emissions in the Transport sector (Kleinhückelkotten et al., 2016) and also results from my analysis show that economic capital is significantly responsible for the class differences, whereas social capital is not. That economic factors are mainly responsible for class differences and social factors are not is unexpected, because travel and cars are status symbols, not only for the rich, that appear regardless of the economic situation and are influenced by social and cultural factors. Research on social milieus confirms this assumption. Examples are students backpacking around the world (i.e. Cohen, 2011) or young individuals from simple economic situations with leased sports cars (e.g. Graves-Brown, 1997). The results in this thesis are hence contradictory to intuitive or own observations and it is possible to assume that the data does not provide sufficient information regarding social and cultural relationships. The application of Pierre Bourdieu's various forms of capital is again important to understand why these symbols are relevant in terms of distinction and to be supposedly socially accepted.
Also decisive in the Transport sector are age and gender. The highest emissions in Transportation are caused by the age group 30-49, which would be consistent with the above assumptions, that many individuals that age have a fixed income (Finke et al., 2017) and are cosmopolitan (see Merkel, 2017) but also try to establish themselves socially via status symbols. In the context of carbon footprint measurements, I state, that analyses which differentiate in male and female respondents are outdated because it addresses the reduction of emissions where societal structures are most firmly anchored and where there is the least potential for change. Again, I would like to point out the outdated binary gender models in natural sciences. Nevertheless, I would like to mention

a few interpretations: The analysis by Kleinhückelkotten et al. (2016) showed that men have a higher footprint in the Transport sector than women. Explanations can be the pay gap , i.e. men have higher incomes than women (Finke et al., 2017) and higher income means higher footprints, more men than women fly in their professions (for business travel see e.g. Ciobanu et al., 2016), and cars or motorcycles may be symbols of masculinity, which is deeply rooted in German culture i.e. women were not allowed to drive without permission until 1958. Mobility has a high value in the German liberal society and is associated with freedom. Here, from my point of view, it will be most difficult to get individual behavioral changes for sustainable goals because individuals act antagonistic and are unwilling to give up their freedom or pay more if others do not participate – a high level of distrust is present.

In the course of a sustainable transformation, values and norms play an important role and freedom should get a different interpretation: Freedom is to move freely, which is only possible with better public infrastructure, that is affordable. The automotive industry is a leading economic sector in Germany, and individuals, like in the US, tend to be car lovers. CO_2 emissions from driving in Germany are among the 2nd highest - Germany's Transportation sector remains the nation's second largest source of greenhouse gas emissions, and trends show that it is likely to become the first (Eckert, 2018). The Planetary Boundaries do not allow, at the current technological level, that all individuals have a car and travel with it on a daily basis, especially in the industrialized nations with a high population density. A change of internal structures is fundamental, but renunciation does not limit freedom and a collective attitude should move to the front.

Finally, I would like to assess the result that carbon emissions from everyday mobility are the same in rural and urban areas, as the distances of daily routines are similar. This fact must be further deciphered, in terms of how many individuals on average drive in rural and urban areas (vs. public Transportation) or, in general, how many individuals live in rural and urban areas to get a clearer view on CO_2 emissions. With regard to infrastructure, driving habits and emissions are likely to be different in other countries.

For the last sector Secondary Consumption, the biggest class is, unlike in the other sectors, the first socio-metabolic class which dissolves the previous split regarding the lower and higher classes. In principle, carbon emissions increase with increasing class levels in terms of other consumption, while in the nutrition segment, the curve drops in the third class. The fourth and fifth socio-metabolic class has high CO_2 emissions in other consumption but spread over the whole range of possible emissions regarding alimentation. CO_2 emissions from nutrition are therefore not class specific. That implies, for example, in the fifth class, individuals with a wide variety of dietary habits can be found. Poore and Nemecek (2018) provide in their paper "Reducing food's environmental impacts through producers and consumers" new evidence for the importance of dietary change to meet environmental targets. For Germany, Kleinhückelkotten et al. (2016) state, that eating habits are all over the same regarding regions or milieus. In the field of nutrition, the reduction of meat consumption has therefore the highest priority. The high consumption of meat is culturally very deeply anchored and widespread in all social milieus. Regression analyses unfold that the level of education, or cultural capital, is not decisive for food consumption. This result is unexpected and raises the question of the role of environmental education and strengthens the fact, that a high level of environmental knowledge and consciousness does not influence the decision-making process for a sustainable lifestyle (Kleinhückelkotten et al., 2016). The knowledge of one's own impact is less relevant and personal pleasure is preferential. On the other hand, there is a connection between higher level of education and the purchasing behavior of organic products (Neligan & Eyerund, 2017), which has a positive effect on the environment and must therefore be considered apart from CO_2 emissions. A fundamental cultural change would take much more time than is available in the face of climate change. Therefore, the climate impact of meat production should be consistently reduced through appropriate agricultural policies, even if this would increase the price of meat and meat products.

Though, differences in clusters and thus classes occur mainly because of other consumption, meaning consumerism, e.g. buying clothes, in general. Respondents in the age of 30-49 have the highest consumption, which again could be attributed to a secured income and the importance of status symbols or consumer goods for social hierarchization. Here, too, a gender-specific analysis by Kleinhückelkotten et al. (2016) took place and the results are that men eat more than women, and, above all, more meat and women buy more clothes. They confirm clichés or stereotypical assumptions, but they do not yield any goal-oriented implications - consumer behavior should be analyzed in terms of capital, to understand why these differences exist. The role of material objects within societies and buying patterns are deeply rooted in social and cultural structures, to maintain a distinction. Exemplarily, Hélène Cherrier (2009, p.187) wrote, regarding branded clothes, that „the material object helps differentiate the trendy individuals from the non-trendy. This principle is linked to what Bourdieu calls situational objects (Bourdieu, 1984; Bourdieu and Johnson, 1993). Entry to the ‘trendy’ reference group depends upon one's access and one's knowledge of the “cool” goods, their social and cultural values, and how one uses them.” This could be an opportunity to establish green labels or recycled products in social structures. Results of descriptive statistics in this thesis prove that social, cultural and also economic factors determine consumerism. How these factors might influence ecological behavior can be exemplarily investigated from a historical perspective: Those living in the former German Democratic Republic consume less energy and individuals in the former FRG have higher levels of consumption (Kleinhückelkotten et al., 2016) - there is a social, cultural imprint (maybe also economic imprint regarding income disparity). One possible explanation is that the free market economy in the FRG endorsed habits of intensive or mass consumption (see Reckendrees, 2007), whereas the planned economy in the former GDR forced the opposite. Although the GDR no longer exists, individuals in the new former GDR states are more frugal. These are established norms and values. Is that intrinsic, which is questionable after an alternation of generations, or are these different values relating to consumption and limits of consumption that are passed on intergenerational? Nevertheless, to answer questions of sustainability, these circumstances play a role for initiating a socio-ecological transformation, and further research should detach from socio-demographic variables or think further about the results, in order to understand habitus and lifestyles, because consumers seek their identity through consumption, appearance and social performance (Sennett, 1977). Individuals “accept social expectations and conform to the visible cultural categories created by the media, fashion, and advertising authorities“ (Cherrier, 2009, p.187). As already mentioned in the first pages, there is a new high cultural capital consumer repertoire that privileges the local, material, and manual, while maintaining a strategy of distinction, especially by the rich (Carfagna et al., 2014). These are not individual but collective strategies of consumption. The example of an “eco-habitus” (ibid) offers a possibility to address especially the higher socio-metabolic classes. It is a chance for sustainable collective action: A distinction based on (ecological) values, which may also go along with "green-washing" (yourself) could ultimately be effective.

Especially if the affected class has a high degree of agency and thus functions as a social role model. At this point, it would also be important to focus on urban and rural lifestyles, although according to the data, the per capita energy consumption and CO_2 emissions are not primarily divergent.

5.3. Digitization

Footprint calculators focus mainly on how much individuals fly, how they live and what they eat. In addition, a second layer is necessary: Sustainable evaluation mechanisms need to open up to the modern age and include energy consumption and emission hotspots in terms of digitization. In the circle of growth, there is an economic imperative to use certain technologies at which the use is strongly connected to resource consumption (see e.g. Ayres & Warr, 2010; Kümmel, 2011; Richters & Siemoneit, 2017). In particular, the progressive automation of logistical processes or the acquisition of labor power by computer technologies, confirm the need to investigate the relationship between technologies and energy consumption. Also, data generation and storage (e.g. big data), communication (e-mail, messengers), connectivity or even progresses in sustainable areas such as sustainable mobility (car-sharing) are accompanied by enormous energy consumption in both, the development and the use of technologies. The question of a supposing added value of certain technologies for humanity tempts to consider a new metabolic stage. The "digital ego" or online personality plays a special role when it comes to individual carbon footprints. Of course, it depends on how individuals use the internet or certain technologies. At the same time, it is difficult to grasp the complexity, as many processes are not comprehensible or observable, for example which server is used where, exemplarily for a google search and how much energy is necessary to do that and which energy was fed. Nonetheless, an approximation is still crucial. In the context of peer-to-peer technologies or technologies like bitcoin that use block chain, the dimensions of energy costs were demonstrated to the public.

"The Bitcoin network can be estimated to consume at least 2.55 gigawatts of electricity currently, and potentially 7.67 gigawatts in the future, making it comparable with countries such as Ireland (3.1 gigawatts) and Austria (8.2 gigawatts)" (de Vries, 2018, p.1).

31.57 US households can be powered for one day by the electricity consumed for a single transaction, resulting in emissions of 457.73 kg of CO_2 per transaction. The annual carbon footprint of Bitcoin is 35,830 kt of CO_2 ("Bitcoin Energy Consumption Index - Digiconomist," n.d.).

It results in a technology versus nature conflict. Will such new technologies be sustainable in the future from Earth System perspective? A total economic analysis that weighs all costs and benefits should be carried out. Are technologies that improve life circumstances justified if they possibly co-create the collapse of the terrestrial system? Do they actually bring the desired progress? These questions should be discussed from a metabolic perspective because boundaries are already transgressed, and biological requirements are exceeded. Technologies and digitization should therefore be examined from an energetic perspective as well as with regard to the influence on society. What role does the Internet play as a cultural asset, as an information source or a place for social gatherings?

In this context, Ignatow & Robinson (2017) call for an entirely new realm for the application of the Bourdieusian framework of capital, field and habitus. Especially with the internet, changes in perception of capital appear. Questions like, are social media friends potentially a source of social capital, come up (Park, 2017) or regarding cultural capital: On one hand a person needs cultural capital to make use of the internet, in other words must have embodied cultural or capital that capital can be borrowed from a proxy like a family member (ibid) and on the other hand, the internet itself is cultural capital which is an asset that contributes to cultural value (Throsby, 1999). "Cultural capital is found in material objects—such as a website—and can also be embodied in a person—the ability to navigate the website" (Park, 2017, p. 70). The capital forms, that Bourdieu developed decades ago, must be modernized but still have their raison d'être. Martin (2003) points out that the diffusion of digital technology has built new pathways of capital and habitus and fields of organized striving. Especially for surveys that capture individuals' footprints, the inclusion of questions about behavior in the digital world is inevitable. The discussion following on that, shows how capital endowment leads to groupings within German society. New socialization opportunities and cultural merits have changed dramatically as a result of online networking.

"Individuals engagements with the digital realm throw into sharp relief new interrelations between economic resources, internalized aptitudes, and social positioning" and

"Bourdieu's ontological stance combining moderate realism and moderate social constructionism has proven to be a solid foundation for empirical sociology as well as for interdisciplinary learning and collaboration" (Ignatow & Robinson, 2017, p. 962).

5.4. Conceptualization

Otto et al. (submitted) started to think of a conceptualization using lifestyle and greenhouse-gas emissions and the degree of agency, to stratify the global population according to their socio-metabolic classes and to reveal inequalities which show the necessity to create more accurate views on agents and their environmental impacts. The results of this thesis demonstrate that an operationalization of this concept, i.e. a classification of the German society into socio-metabolic classes, is justified. Nevertheless, the following obstacles reject a direct application of the globally conceived concept: First, the division in the socio-metabolic underclass, energy poor class, lower class, middle class, upper class and super rich and second, the number of classes chosen. The socio-metabolic underclass or even energy-poor class does not exist in Germany. The basic consumption of energy and resources is in principle much higher. The comparison between Germany and Burundi emphasizes this assumption: In Burundi 7,6 % of the population have access to electricity, in Germany 100% (Worldbank, 2017). Apart from many other factor, only the access to electricity thus influences metabolic profiles of the inhabitants. Furthermore, table ten describes the energy balance and carbon footprint of Burundi compared to Europe: In 2014 the per capita CO_2 emissions were 134 times higher in Europe than in Burundi. The global classes can therefore not be applied directly to all countries, because energy and material flows differ extremely.

Energy Balance

	Total	Burundi per capita	Compared to Europe per capita
Electricity			
Own consumption	303.90 m kWh	27.97 kWh	5,402.93 kWh
Production	230.00 m kWh	21.17 kWh	5,821.08 kWh
Import	90.00 m kWh	8.28 kWh	7.29.98 kWh
Carbon footprint			
CO_2 emissions in 2014	440,040.00 t	0.04 t	5.39 t

Table 10: Energy balance and carbon footprint of Burundi compared to Europe (adapted from: World Data, n.d https://www.worlddata.info/africa/burundi/energy-consumption.ph

In addition, my cluster analyses result in a division in five, not six classes for all sectors and the division can be transferred from the sectoral level to the total CO_2 emissions of Germany. Therefore, I developed a new class division, that distinguishes itself by other names from the globally applicable concept and thus refers only to Germany. Table eleven describes the new class designation, the percentage of German population in the sectors (distribution of individuals in the classes), and cumulative lifestyle CO_2 emissions. The five classes are labeled bottom, lower, medium, higher and top class. The cumulative results, in particular, confirm the expectation of a prevalent inequality in environmental impacts between classes: A small percentage of population is responsible for extreme carbon emissions. As mentioned both in the course of this thesis and in various other publications, income or economic capital plays a crucial role in relation to carbon emissions. This leads to the assumption, that climate justice is only associated with redistribution and that capitalist structures should be questioned fundamentally.

Class No.	Socio-metabolic class	Housing		Transport		Secondary Consumption	
		Percentage of survey respondents	Percentage of lifestyle CO2 emissions	Percentage of survey respondents	Percentage of lifestyle CO2 emissions	Percentage of survey respondents	Percentage of lifestyle CO2 emissions
1	bottom class	49 %	28 %	55 %	12 %	23 %	19 %
2	lower class	38 %	41 %	24 %	25 %	18 %	18 %
3	medium class	10 %	18 %	13 %	28 %	33 %	32 %
4	higher class	2 %	6 %	6 %	21 %	13 %	16 %
5	top class	1 %	7 %	2 %	14 %	13 %	15 %

Table 11: Socio-metabolic classes for Germany in the sectors, percentage of survey respondents and lifestyle CO_2 emissions

Otto et al. (submitted) additionally refer their class theory to the level of agency. Better educational opportunities, basic rights, participation in social changes through democratic processes, prosperity or economic stability suggest that the level of agency is generally higher in Germany than in other countries. Though, individuals are also busy with the satisfaction of their basic needs but not to the same extent. Nevertheless, individuals are more likely to have more opportunities for changes or collective action, such as a sustainable transformation. Other limiting factors, like deadlocked political, economic and social structures (e.g. lobbying, values) are in conflict with these changes. However, I would like to refrain from an exact assignment of the level of agency to the classes because a more detailed investigation is decisive.

The target of this thesis is to make complex social structures accessible for analytical modeling. This can be achieved via socio-metabolic classes, but country-specific. Countries, with similar socio-metabolic stratification can also be composited in regions to upscale the concept of metabolic classes and apply it on global levels. Accordingly, countries are not classified on the basis of e.g. GDP, Gini-coefficient or Human Development Index, but rather classified regarding emissions patterns and energy and material flows – namely by the social metabolism.

5.5. Outlook

To answer the research question, the idea approaching from Pierre Bourdieu's theory is, especially regarding future changes, purposeful. Also, the concept of social metabolism emphasizes the limits of systems and scrutinizes the role of humans, both as a global community and individually. More sophisticated research is consequential. For instance Waitkus & Groh-Samberg (2017) extended wealth in economic capital. Economic capital is therefore, net household income, income from capital, net value of home ownership, net value of assets (financial assets, business assets, tangible assets and further real estate), market values of building loans and insurances. This is a much more accurate view to specially capture "the rich". For cultural capital the authors added four indicators: highest educational level in the household (highest qualification), highest human capital in the household (measured via working experience weighted by the level of required qualification), highest activity level of highbrow cultural practices, highest activity level of popular cultural practices. The UBA data, I executed, was very weak regarding cultural capital. For example, the educational level of parents is particularly relevant but not available.

Therefore, the given data allows only an approximation. PCA was used to reduce the complexity of capital forms without losing information. For future research, in principle, the incorporation of control variables would also be interesting, which are kept constant to avoid an additional influence, such as age or gender, on the dependent variable.

Other theoretical research can also help answering questions of sustainability. Another philosophical perspective on lifestyles and environmental behavior could give the teachings of Michel Foucault, who thought of unconscious motives, basic structure, determinisms and constraints. If individuals who are environmentally conscious do not behave environmentally friendly, the general comprehension of the consciousness-action complex must be questioned. For Foucault, societies develop dynamics that individuals are unaware of – it is a decentralized concept of power where structures dominate individuals (Foucault, 1982). What is agency in that context? Where are the potentials for change? There are cultural currents and dispositions based on power structures. For Foucault, unlike Albert Banduras assumes (2006), the subject is driven by the unconscious and it is not self-determined. Foucaults' thoughts on power could help understanding these contradictory findings of climate change research.

6. Conclusion

This thesis has moved from Planetary Boundaries and downscaling efforts, to human agency and inequality, to social differentiation, in order to develop a socio-metabolic class theory to do justice to sustainability issues. Theoretical ideas about social metabolism, i.e. limitations of systems that coevolve with human interventions, and their feasibility have been proved and operationalized through real data and statistical analysis to be accessible for the implementation in climate change modeling.

In addition, a new approach has been tested that breaks away from traditional analytical methods and picks up on the diversity and complicity of human behavior. Based on the inquiry conducted and showing the shortfalls of existing approaches, this work developed a framework in which individuals and their agency are put in the center of attention.

The research operated here may not have appropriately followed conventional science's precept and it surely has not reached the mark of theoretical excellence and tidiness, but the holistic approach, even though it is incomplete, adds value. The rationale of this work has incoherently been implied in existent literature, but there was no attempt to conceptualize it based on real data.

In order to fulfill a sustainable transformation and to keep the planet within a just and safe operating space, humanity is forced to deal with strategies of mitigation and adaptation. Even though it seems individually rational to leave no fossil resources unused (Eisenack et al., 2012), decarbonization and carbon emission reduction targets are in the foreground to avoid transgressing the planetary boundary "climate change" any further.

For managing complex human-environment relationships, the implications of ecological and social structure for (sustainable) resource management and of microscale human decision making and the role of co-evolutionary processes in the dynamics of socio-ecological systems are of particular importance (Schlüter et al., 2012). Recognizing social stratification and institutions, social networks and norms of the social system improve the comprehension of decision making or differences in agency and can be objectives and intervention opportunities. Therefore, the investigation of lifestyles and the relation to the structure of the social space of capital distribution are worthwhile (Flemmen et al., 2017).

Central to success are theoretical feasibility and the existence of solutions for real-world implementation, e.g. of the SDGs, for linking that scale to the global perspective. Nevertheless, the sub-global scale is explicitly of relevance. For climate justice and to conquer inequalities, societies should overcome the logic of collective inaction. Climate policy implications, as well as individual assessments and possible behavioral changes, can be derived from my results. The initial points are multiple.

Eisenack & Kähler (2016) state that it is not automatically beneficial if all nations commit to emission reductions and adaptation at the same time. By showing inequality and individual emission hotspots, for countries like Germany, which can be credited with high environmental debt but also with options for change, there is no need to temporize action.

Abbreviations

CO_2	Carbon Dioxide
GHG	Greenhouse Gas Emissions
HNWI	High Net Worth Individuals
ICT	Information and Communication Technology
IPCC	The Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
PB	Planetary Boundaries
PCA	Principle Component Analysis
PMM	Predictive Mean Matching
SDG	Sustainable Development Goals
UHNWI	Ultra High Net Worth Individuals
UNCED	United Nations Conference on Environment and Development; Rio Conference; Rio Earth Summit
WSS	Within Groups Sum of Squares

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Appendix

A1) Additional information about survey

Numbers of cases in categories in survey (source: (Kleinhückelkotten et al., 2016)

Category		Number of cases
Households with … person(s)	1	221
	2	385
	3	195
	4	163
	5 or more	48
Sex	male	497
	female	515
Age	18-29 years	157
	30-49	357
	50-65	263
	Over 65	235
Educational degree	Completion of compulsory secondary education	400
	GCSE (Mittlere Reife)	331
	Abitur	209
	University degree	57
	No educational qualification/ still at school	14
Number of people with income in one household	1	322
	2	593
	3	57
	4	26
	5 and more	14
Share of net household income (unweighted)	under 1.000 €	479
	1.000 - 1.999 €	424
	2.000 - 2.999 €	98
	3.000 - 3.999 €	7
	4.000 € and more	4
Share of net household income (age-weightened)	under 1.000 €	186
	1.000 - 1.999 €	601
	2.000 - 2.999 €	183
	3.000 - 3.999 €	38
	4.000 € and more	4
Place of residence	City center >500.000 citizens	134
	Suburbs	37

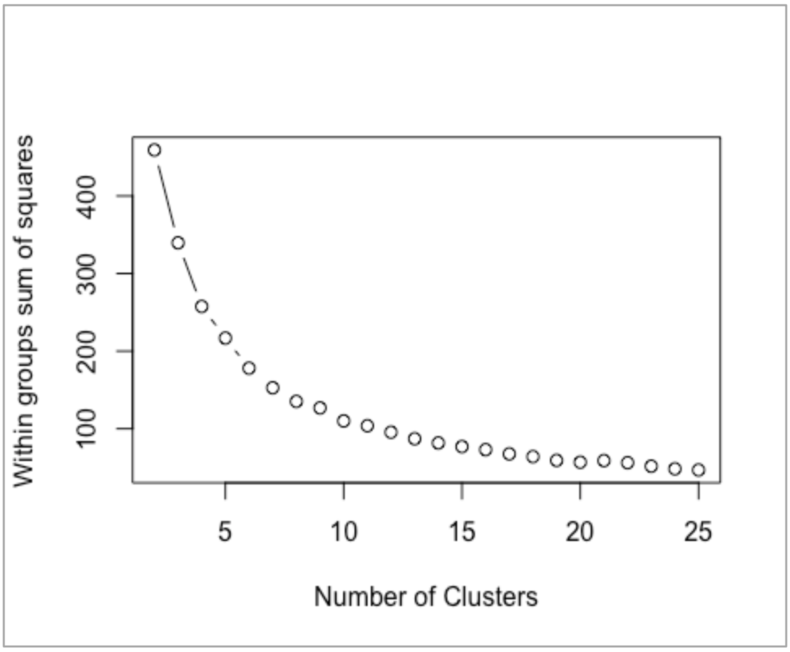
	>500.000 citizens	
	City center 100.000- 500.000 citizens	77
	Suburbs 100.000- 500.000 citizens	77
	Medium-sized town 20.000-100.000	274
	Small town 5.000-20.000	256
	Village < 5.000	157
Region in Germany	North	292
	Central	323
	South	397
	East	164
	West	848

Milieus defined by Kleinhückelkotten et al. (2016)

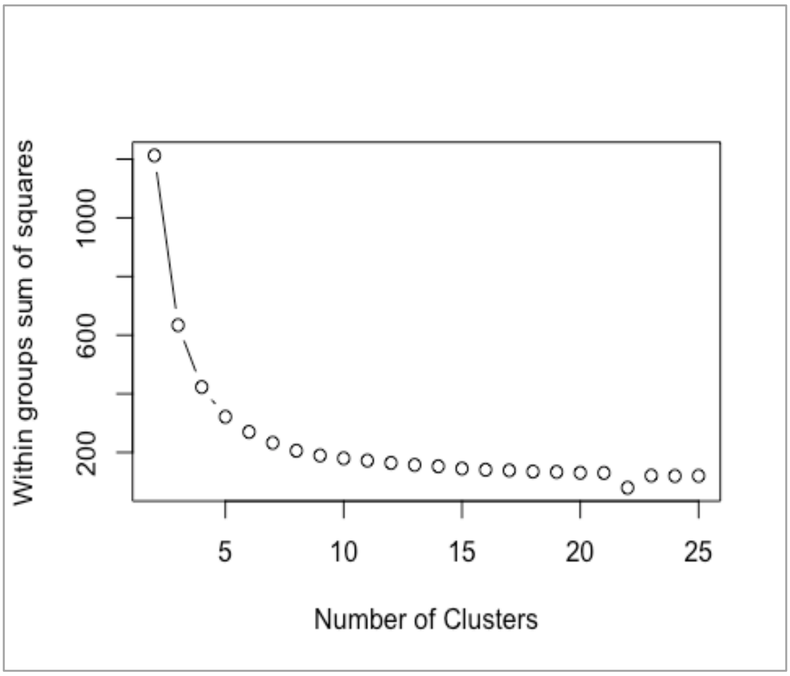
Traditional milieus
Higher and highest age groups (mostly over 70 years old); different educational levels; different incomes; many retired people. Seeking order, security and stability; Desire to preserve the familiar. Life motto: I hope everything stays the way it is.
Well-established Milieu
Middle and higher age groups (40 to 70 years); higher education level; higher income. Performance and success-oriented; Feasibility and economic efficiency as yardsticks. Life motto: Be proud of what you have achieved and enjoy it.
Critical-creative milieus
Different age groups; medium or higher education; wide range of different incomes. Enlightened, cosmopolitan, tolerant and committed; diverse intellectual and cultural interests. Life motto: critically question things; responsible and meaningful life
Modern mainstream
Middle and higher age groups (40 to 70 years); moderate education; middle income. Self-image as the center of society; strong sense of community; oriented to comfort and convenience; pronounced price-performance awareness; increasing fears of social decline. Life motto: To belong, to be integrated.
Simple, precarious milieus
All ages; low formal formation; low income. Participation in consumption and social life severely limited. Life motto: make ends meet, do not attract attention.
Young milieu
Youngest age group (under 30 years); mostly still in education and often dependent on parents. 'Digital Natives', grew up with new technologies; Perception of the future as uncertain and not really plannable; Family important. Life motto: find your place.

A2) Cluster analyses

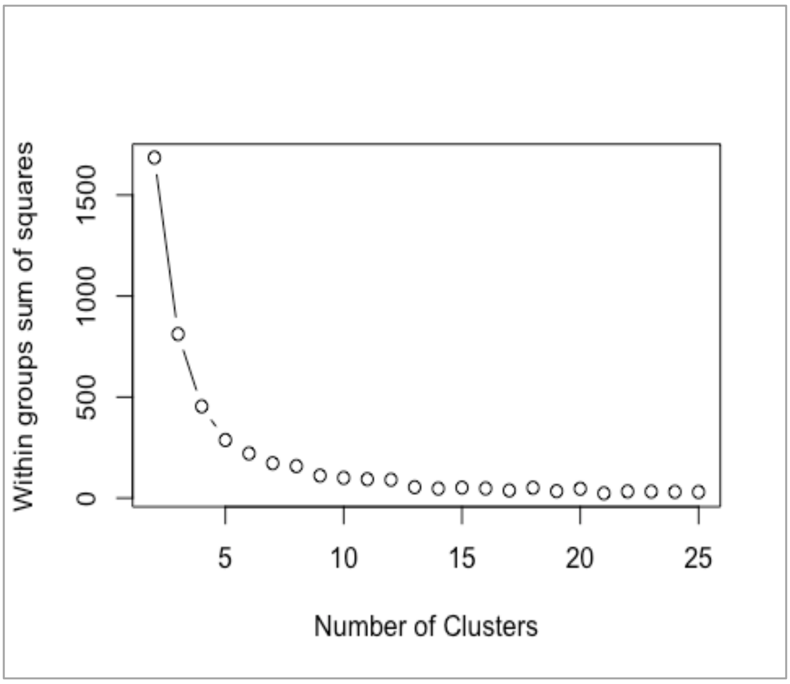
Within groups sum of squares Housing



Within groups sum of squares Transport

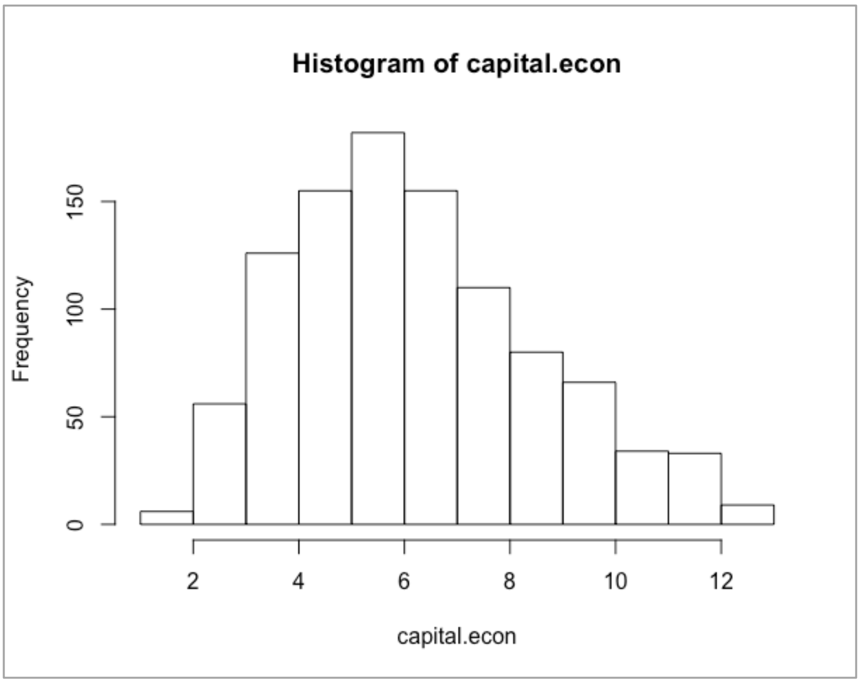


Within groups sum of squares Secondary Consumption



A3) Principle Component Analyses

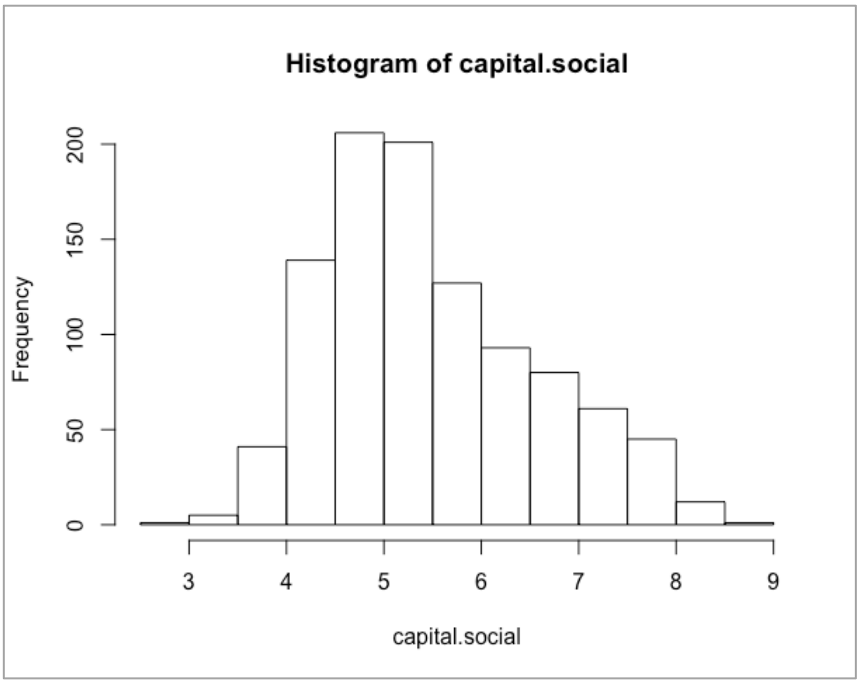
Histogram for economic capital



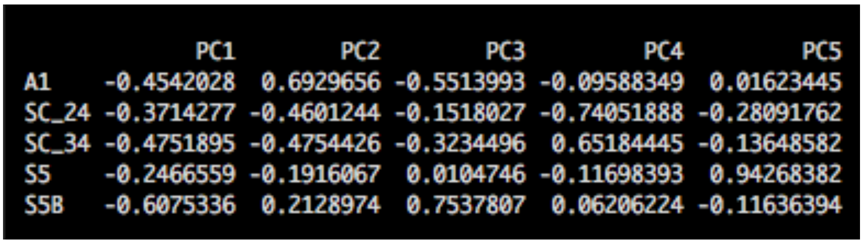
Rotation for economic capital

	PC1	PC2	PC3	PC4	PC5
A3	-0.22703473	-0.688083973	0.67287391	0.14886599	0.008677650
F1_01	-0.16519993	0.080363851	0.23763358	-0.95370169	-0.015296828
F1_02	-0.01339698	-0.007748519	-0.02099823	-0.01959532	0.999467648
F3	-0.30629802	-0.621076941	-0.69979451	-0.17321254	-0.027018883
S11	-0.90948681	0.366449849	0.02485378	0.19469319	-0.005010637

Histogram for social capital

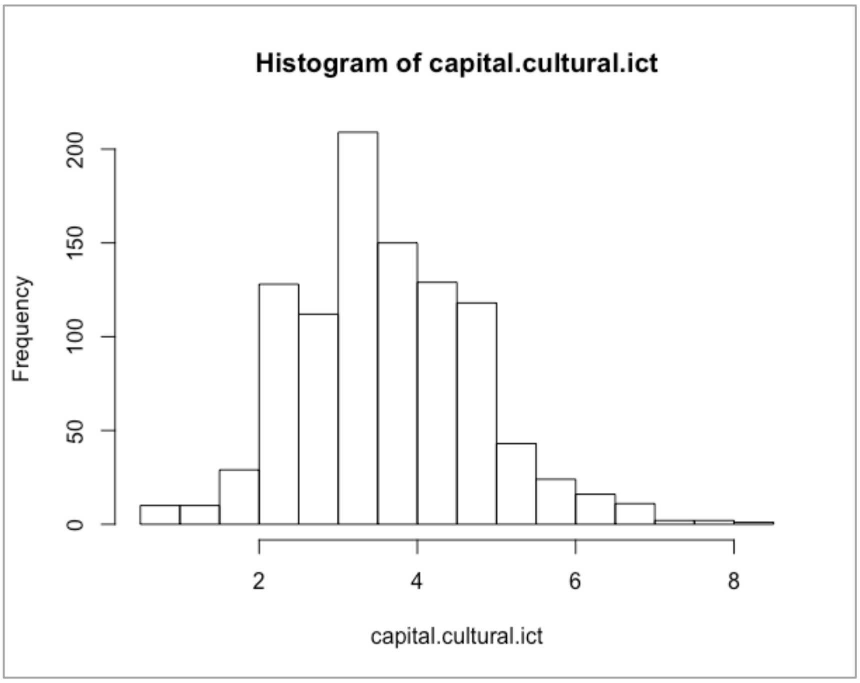


Rotation for social capital



	PC1	PC2	PC3	PC4	PC5
A1	-0.4542028	0.6929656	-0.5513993	-0.09588349	0.01623445
SC_24	-0.3714277	-0.4601244	-0.1518027	-0.74051888	-0.28091762
SC_34	-0.4751895	-0.4754426	-0.3234496	0.65184445	-0.13648582
S5	-0.2466559	-0.1916067	0.0104746	-0.11698393	0.94268382
S5B	-0.6075336	0.2128974	0.7537807	0.06206224	-0.11636394

Histogram for cultural capital / ICT



Rotation for cultural capital

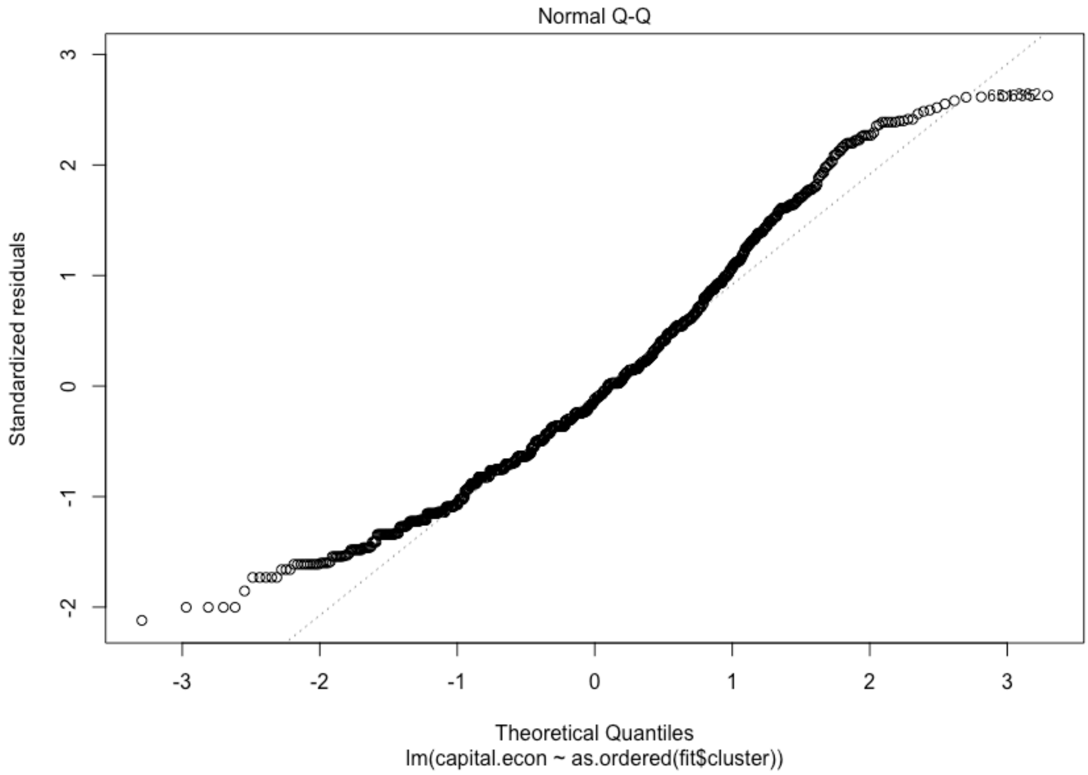
	PC1	PC2	PC3	PC4
D24_num	-0.4478794	0.6128837	-0.55328903	-0.34299975
D25_num	-0.2470322	0.3426431	0.01771877	0.90623222
D26	-0.7855570	-0.6157085	-0.05840534	0.01980213
D30_num	-0.3482519	0.3575923	0.83075033	-0.24637820

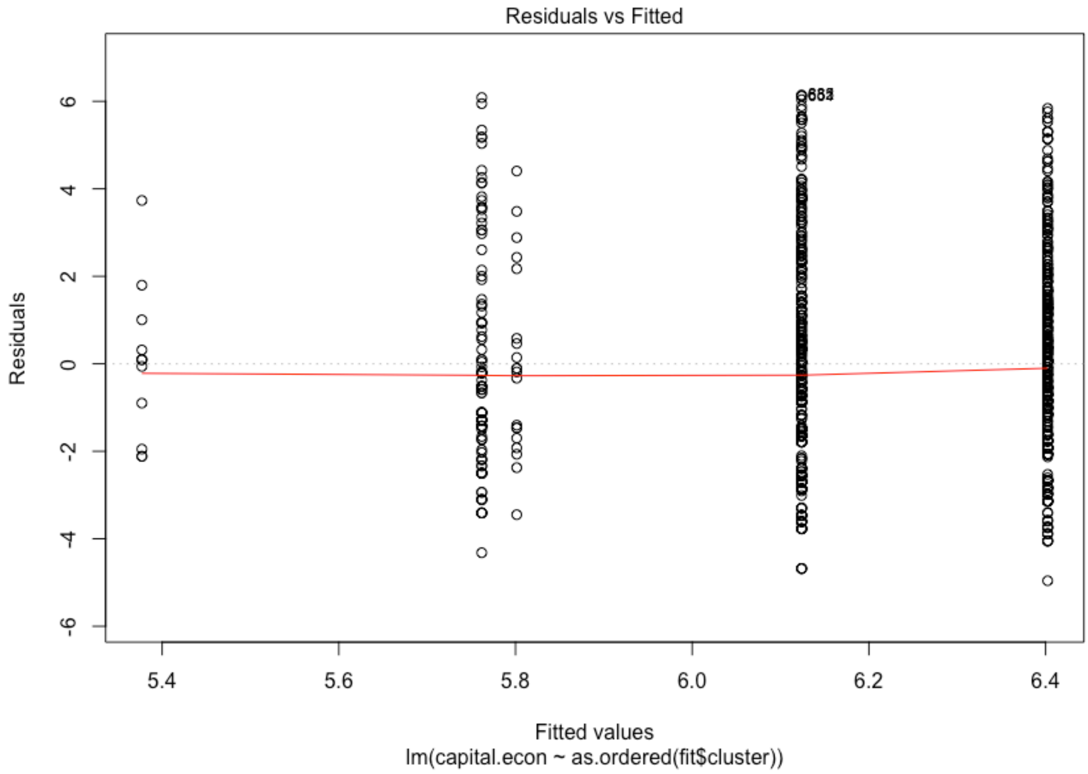
A4) Statistical analyses of clusters

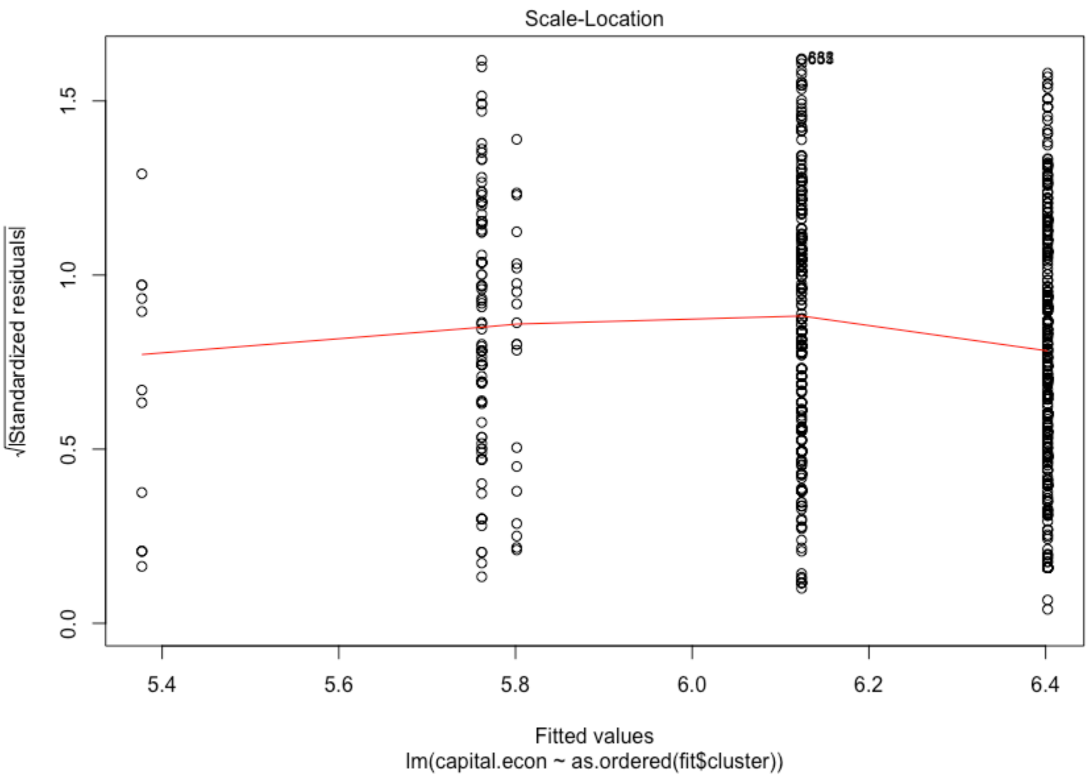
Normal Q-Q Plot: Shows if residuals are normally distributed.
Residuals versus fitted plot shows if residuals have non-linear patterns.
Scale-Location plot (Spread-Location plot): Do residuals are spread equally along the ranges of predictors? Assumption of equal variance (homoscedasticity).

Housing

Economic capital




Residuals vs Fitted
Residuals
Fitted values
lm(capital.econ ~ as.ordered(fit$cluster))


Scale-Location
√|Standardized residuals|
Fitted values
lm(capital.econ ~ as.ordered(fit$cluster))

```
Analysis of Variance Table

Response: capital.econ
                          Df Sum Sq Mean Sq F value  Pr(>F)  
as.ordered(fit$cluster)    4   52.6 13.1497  2.3979 0.04862 *
Residuals               1007 5522.2  5.4838                  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
	Pairwise comparisons using t tests with pooled SD 

data:  capital.econ and as.ordered(fit$cluster) 

  1    2    3    4   
2 1.00 -    -    -   
3 1.00 1.00 -    -   
4 1.00 0.13 1.00 -   
5 1.00 1.00 1.00 0.72

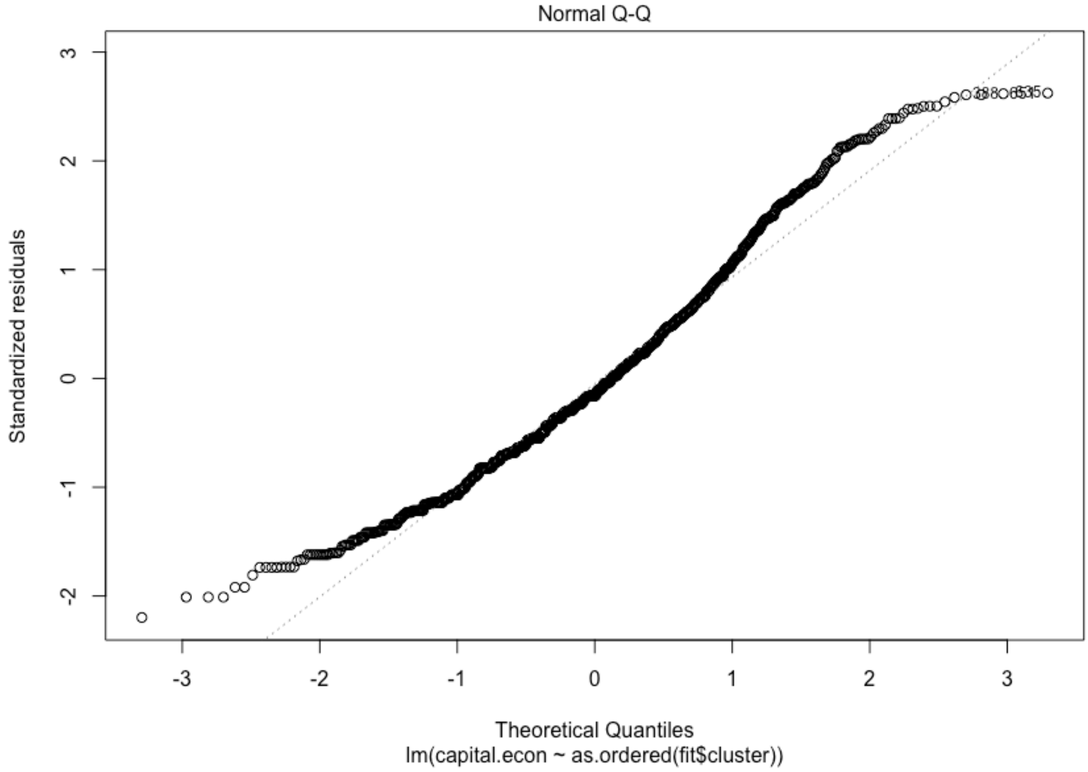
P value adjustment method: holm 
```

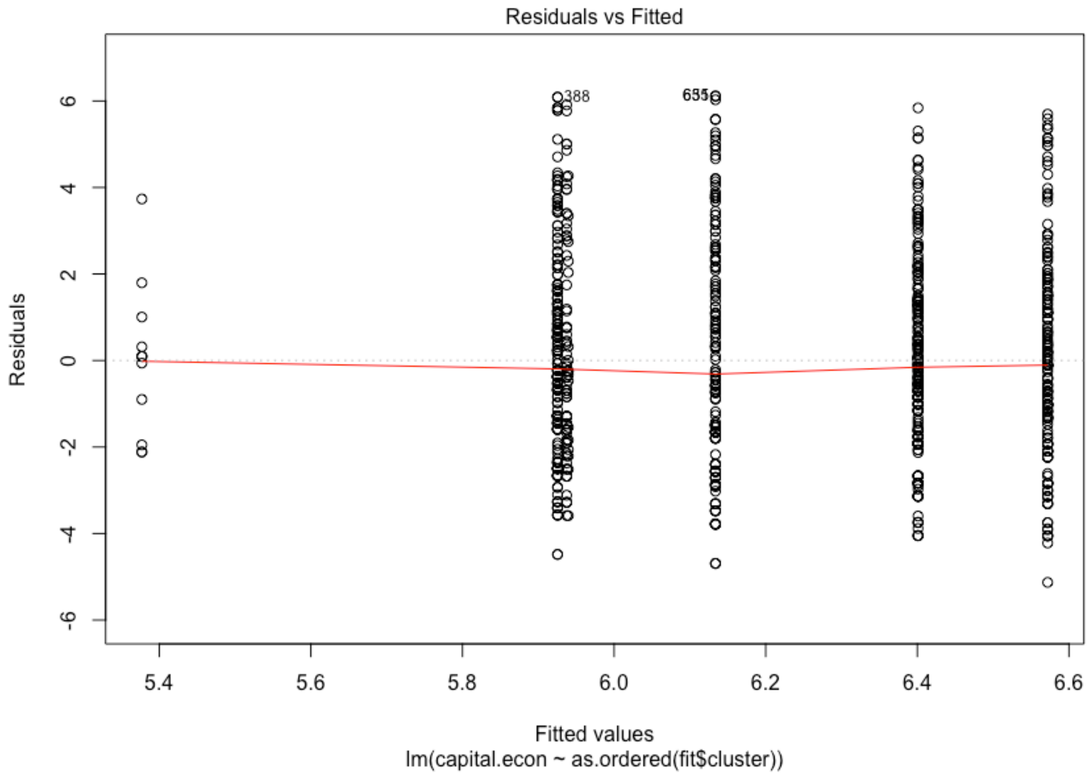
Income:

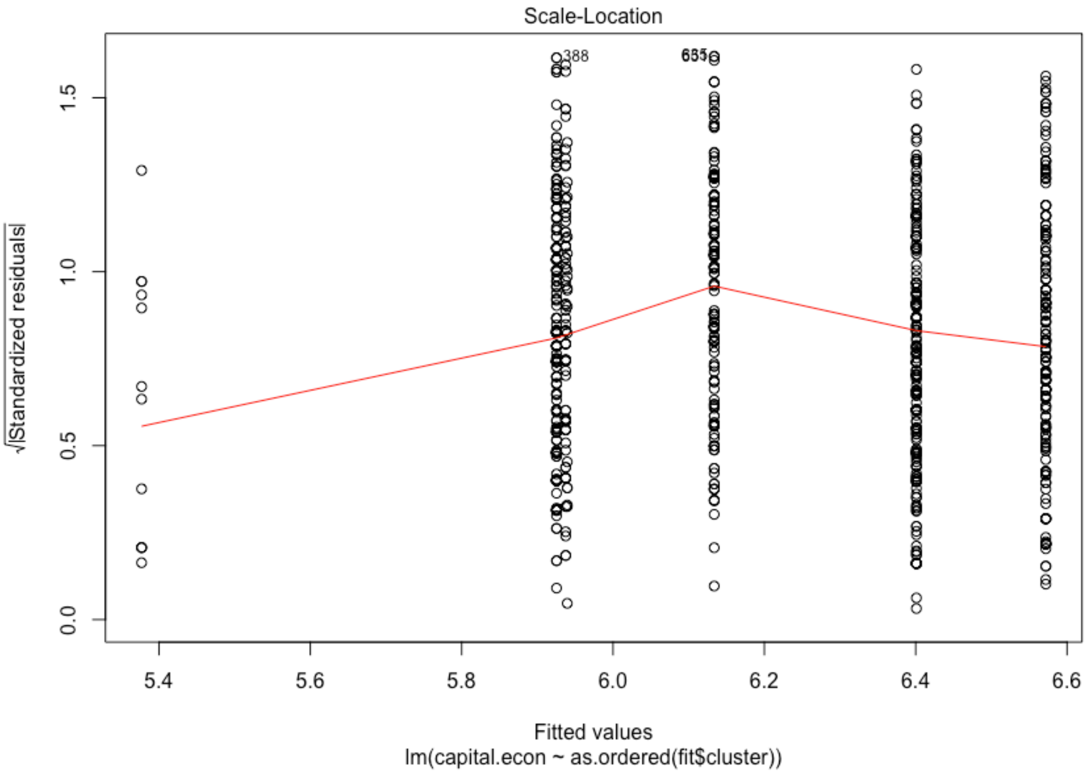
```
Analysis of Variance Table

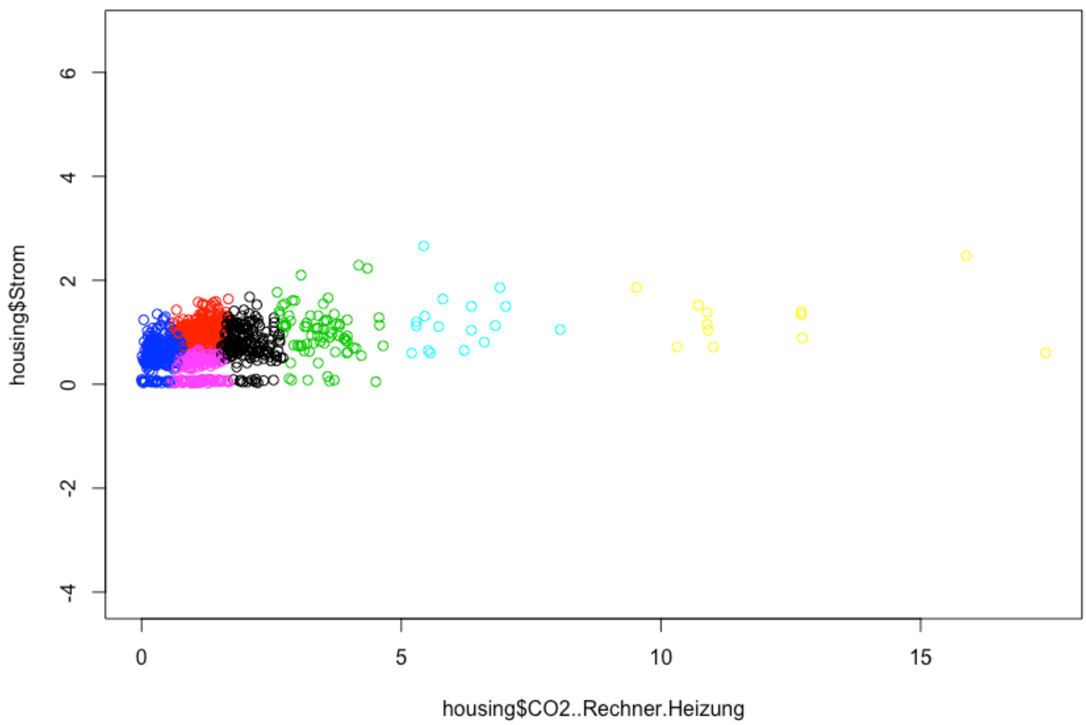
Response: income
                          Df Sum Sq Mean Sq F value  Pr(>F)  
as.ordered(fit.cluster)    4   49.9 12.4688  2.3236 0.05489 .
Residuals               1007 5403.6  5.3661                  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

7 Cluster


Normal Q-Q
Standardized residuals
Theoretical Quantiles
lm(capital.econ ~ as.ordered(fit$cluster))
388
635


Residuals vs Fitted
Residuals
Fitted values
lm(capital.econ ~ as.ordered(fit$cluster))
388


Scale-Location
388
655
√|Standardized residuals|
0.0
0.5
1.0
1.5
5.4
5.6
5.8
6.0
6.2
6.4
6.6
Fitted values
lm(capital.econ ~ as.ordered(fit$cluster))


housing$Strom
-4
-2
0
2
4
6
0
5
10
15
housing$CO2..Rechner.Heizung

```
Analysis of Variance Table

Response: capital.econ
                         Df Sum Sq Mean Sq F value  Pr(>F)
as.ordered(fit$cluster)    6   73.7 12.2903  2.2453 0.03698 *
Residuals               1005 5501.1  5.4737
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

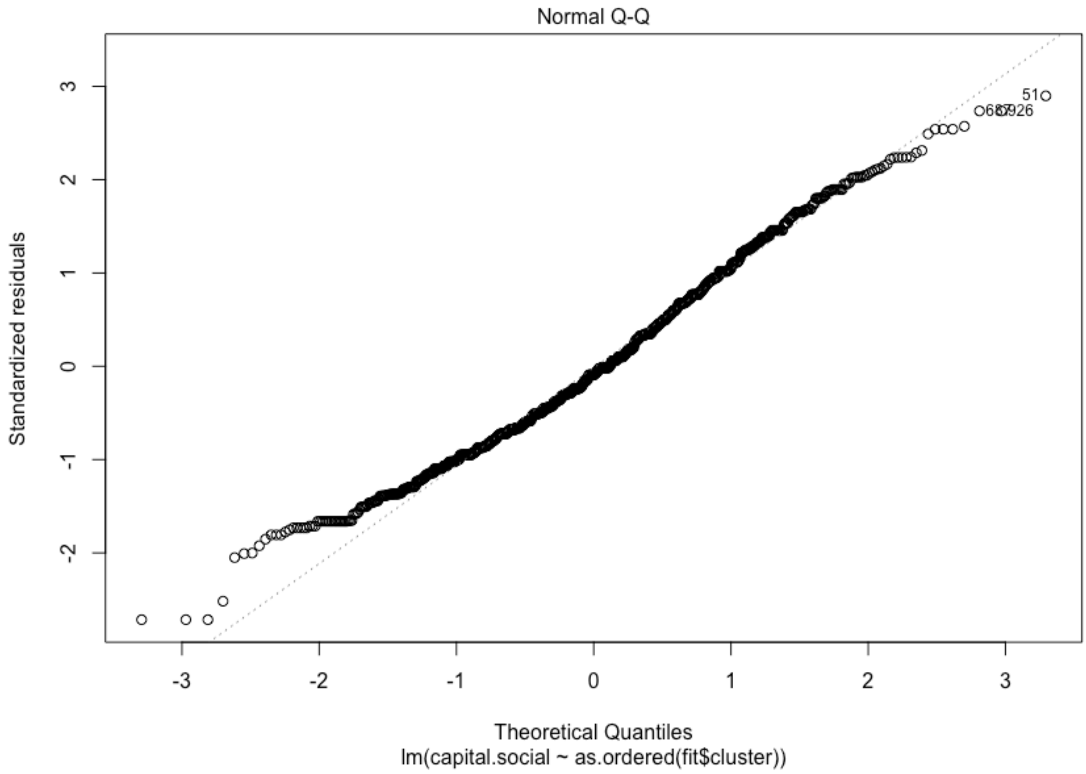
```
        Pairwise comparisons using t tests with pooled SD

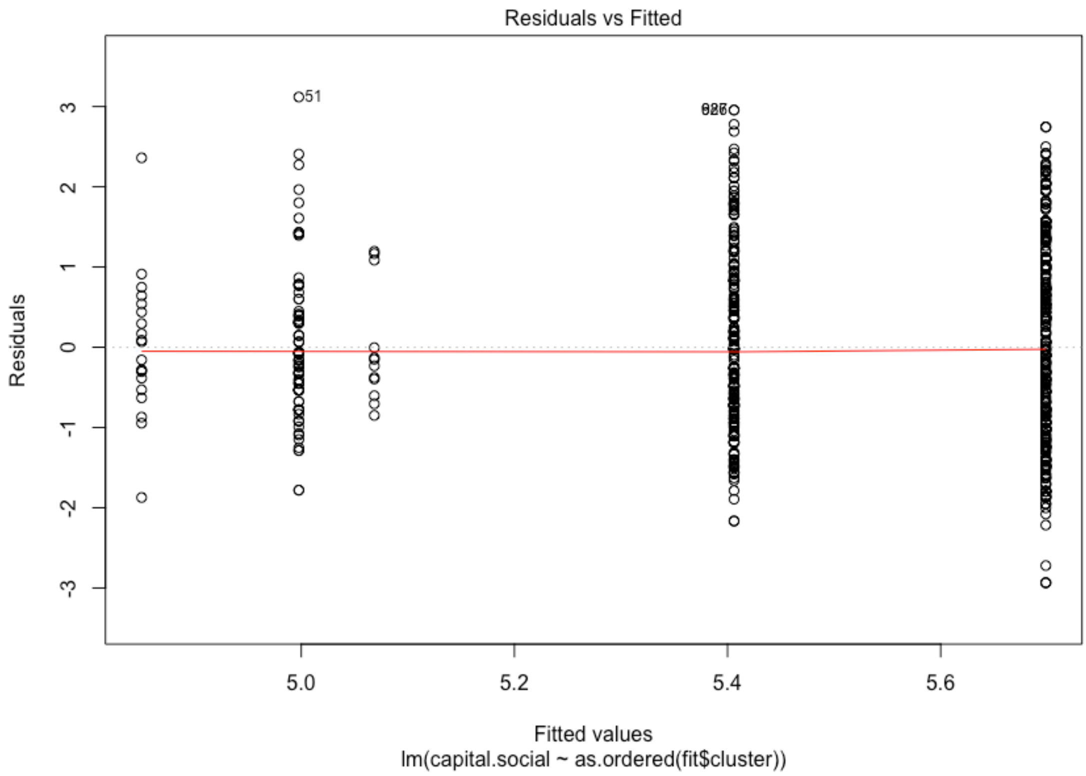
data:  capital.econ and as.ordered(fit$cluster)

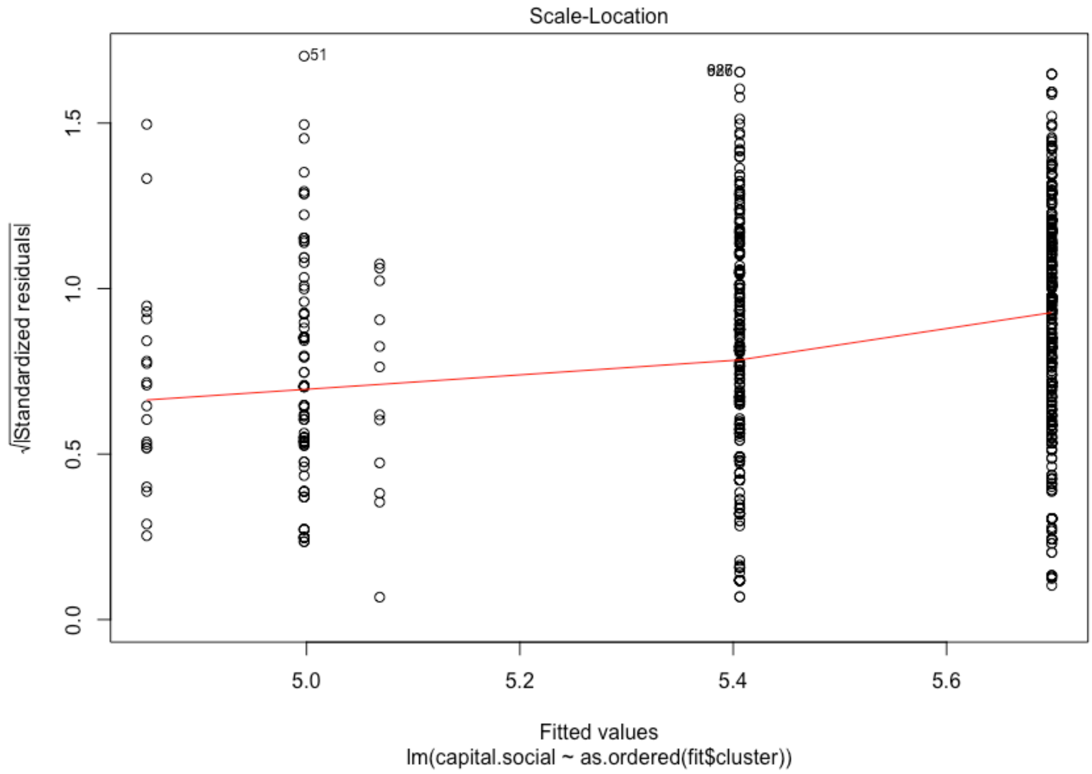
  1     2     3     4     5     6
2 1.000 -     -     -     -     -
3 1.000 1.000 -     -     -     -
4 1.000 0.436 1.000 -     -     -
5 1.000 1.000 1.000 1.000 -     -
6 1.000 0.065 0.804 1.000 1.000 -
7 1.000 1.000 1.000 1.000 1.000 1.000

P value adjustment method: holm
```

Social capital








```
Analysis of Variance Table

Response: capital.social
                          Df  Sum Sq Mean Sq F value    Pr(>F)
as.ordered(fit$cluster)    4   58.38 14.5953  12.476 6.563e-10 ***
Residuals               1007 1178.02  1.1698
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

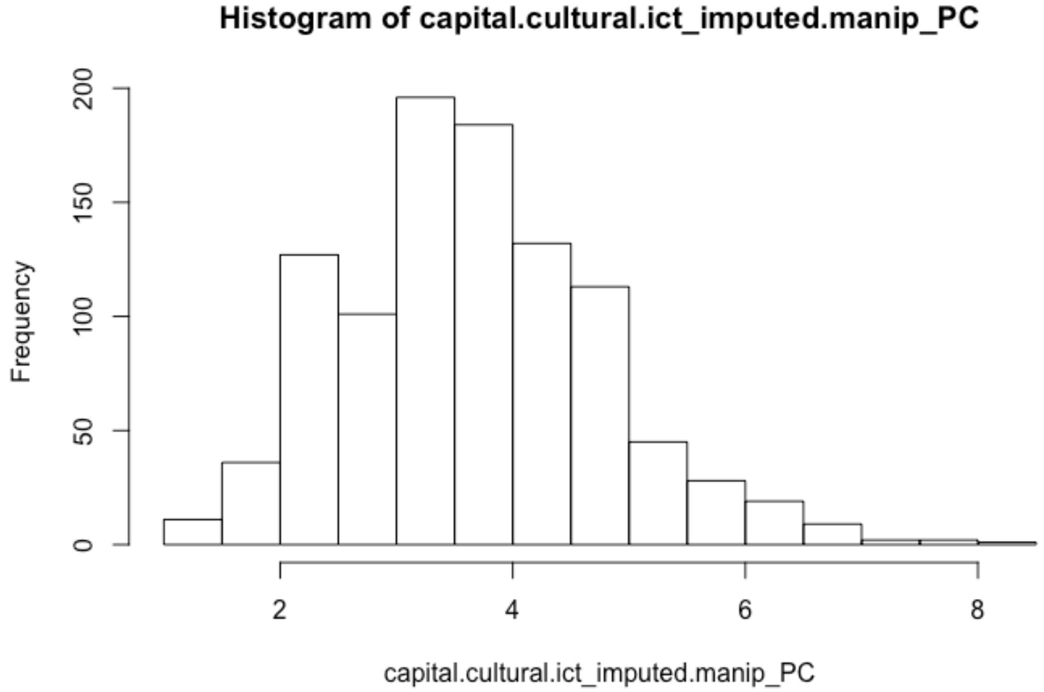
```
        Pairwise comparisons using t tests with pooled SD

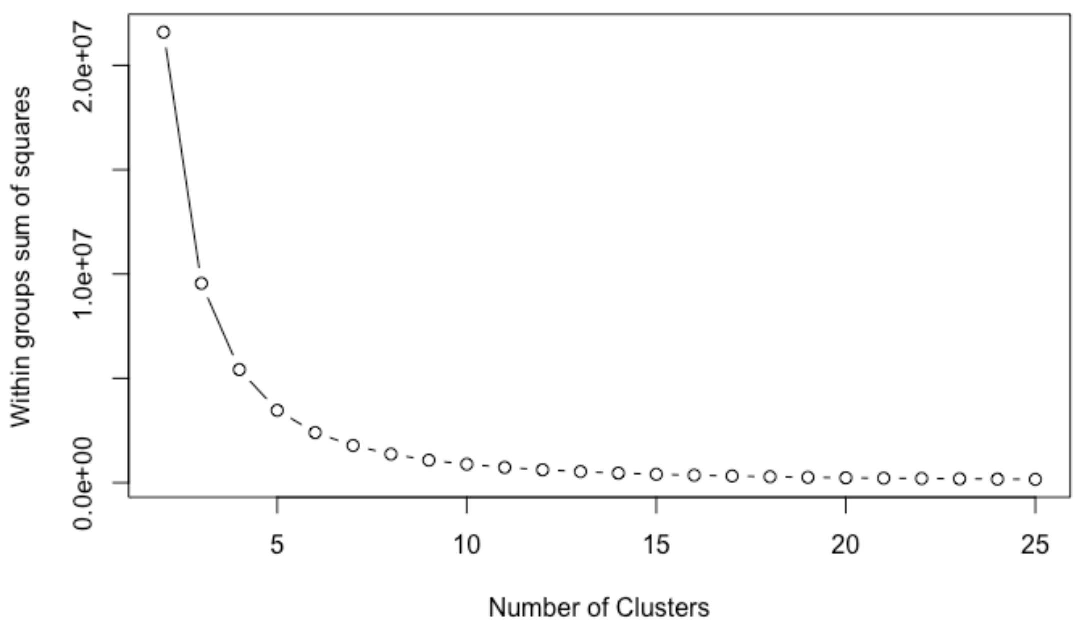
data:  capital.social and as.ordered(fit$cluster)

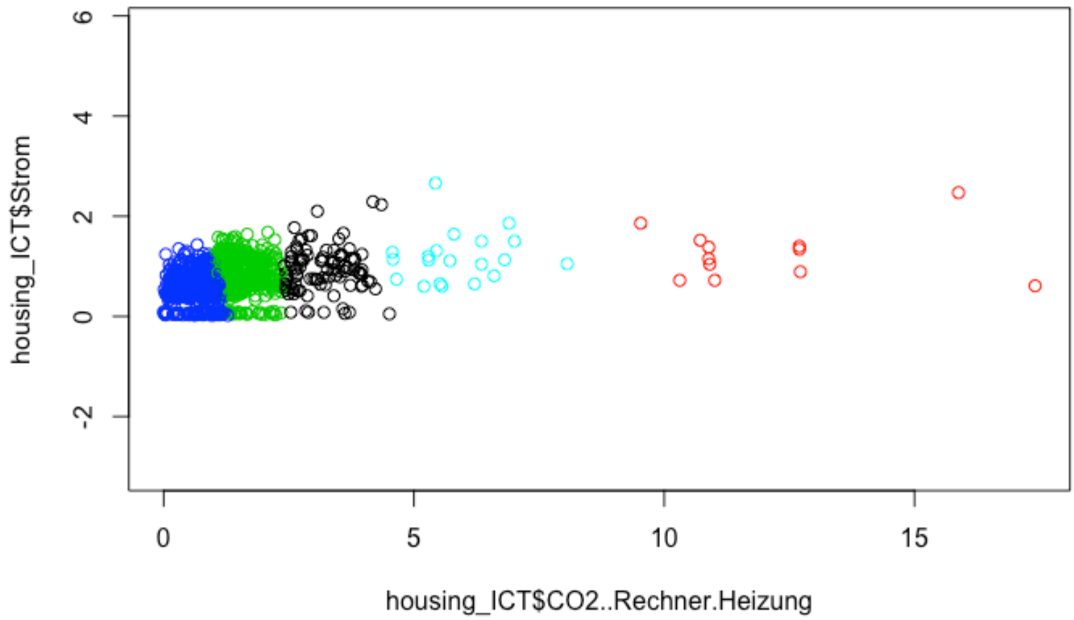
  1       2       3       4
2 0.00485 -       -       -
3 1.00000 6.2e-08 -       -
4 1.00000 0.23208 1.00000 -
5 0.15147 0.00065 0.00614 1.00000

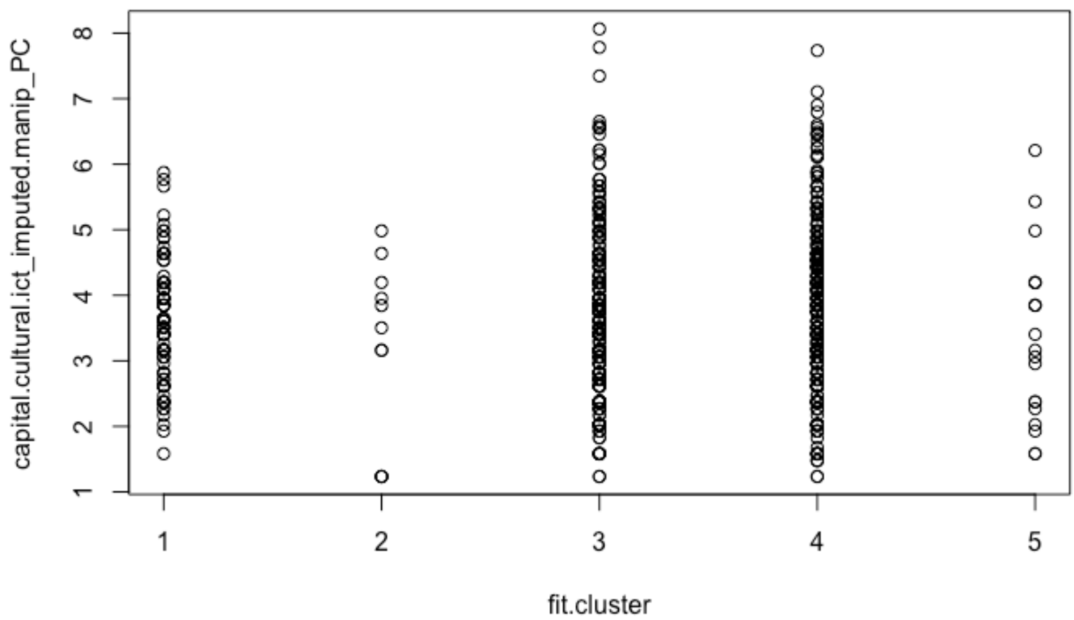
P value adjustment method: holm
```

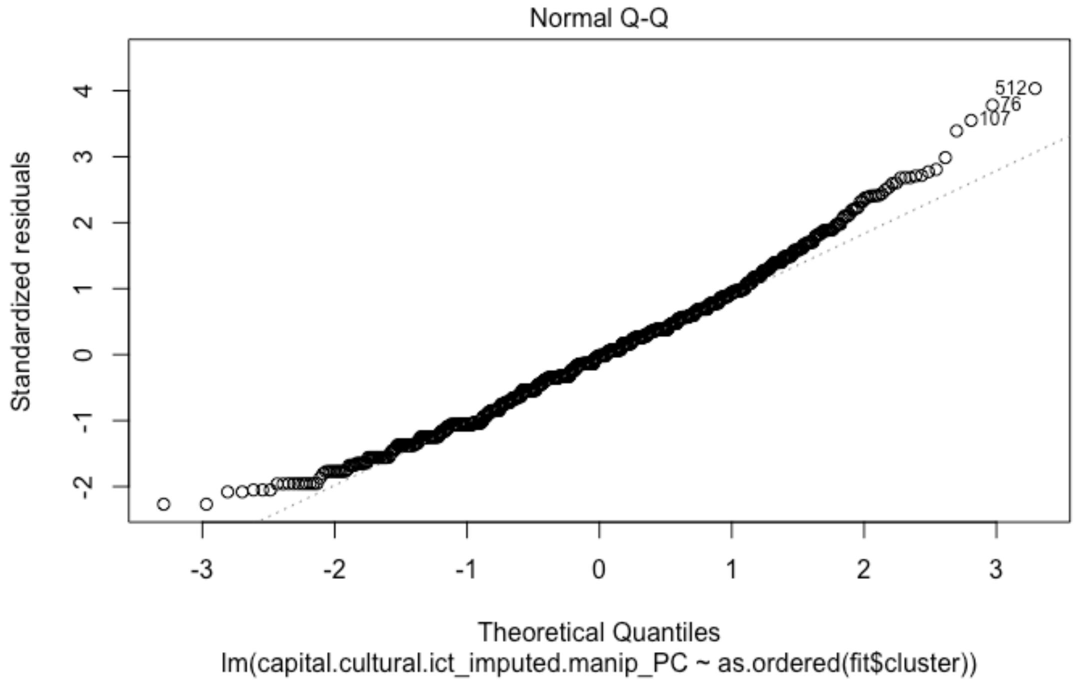
Cultural capital






housing_ICT$Strom
housing_ICT$CO2..Rechner.Heizung
-2
0
2
4
6
0
5
10
15


capital.cultural.ict_imputed.manip_PC
fit.cluster
1
2
3
4
5
6
7
8
1
2
3
4
5




```
Analysis of Variance Table

Response: capital.cultural.ict_imputed.manip_PC
                         Df  Sum Sq Mean Sq F value  Pr(>F)
as.ordered(fit$cluster)    4   16.47  4.1172  3.2916 0.01083 *
Residuals               1001 1252.07  1.2508
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
        Pairwise comparisons using t tests with pooled SD

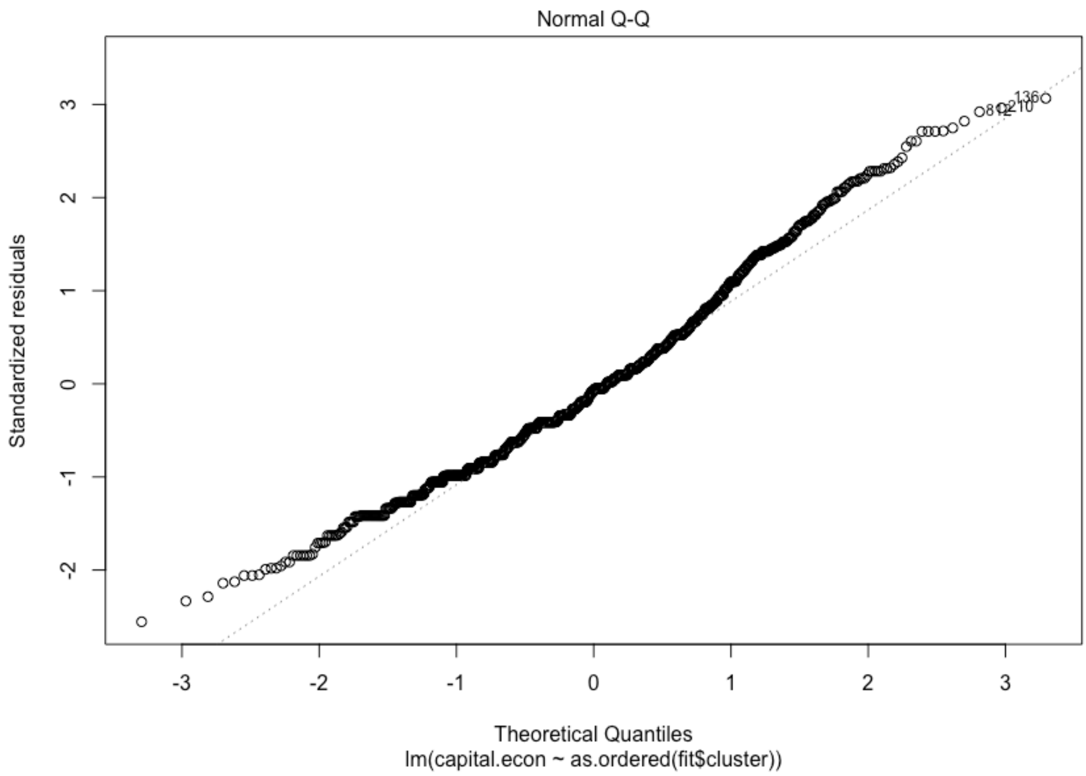
data:  capital.cultural.ict_imputed.manip_PC and as.ordered(fit$cluster)

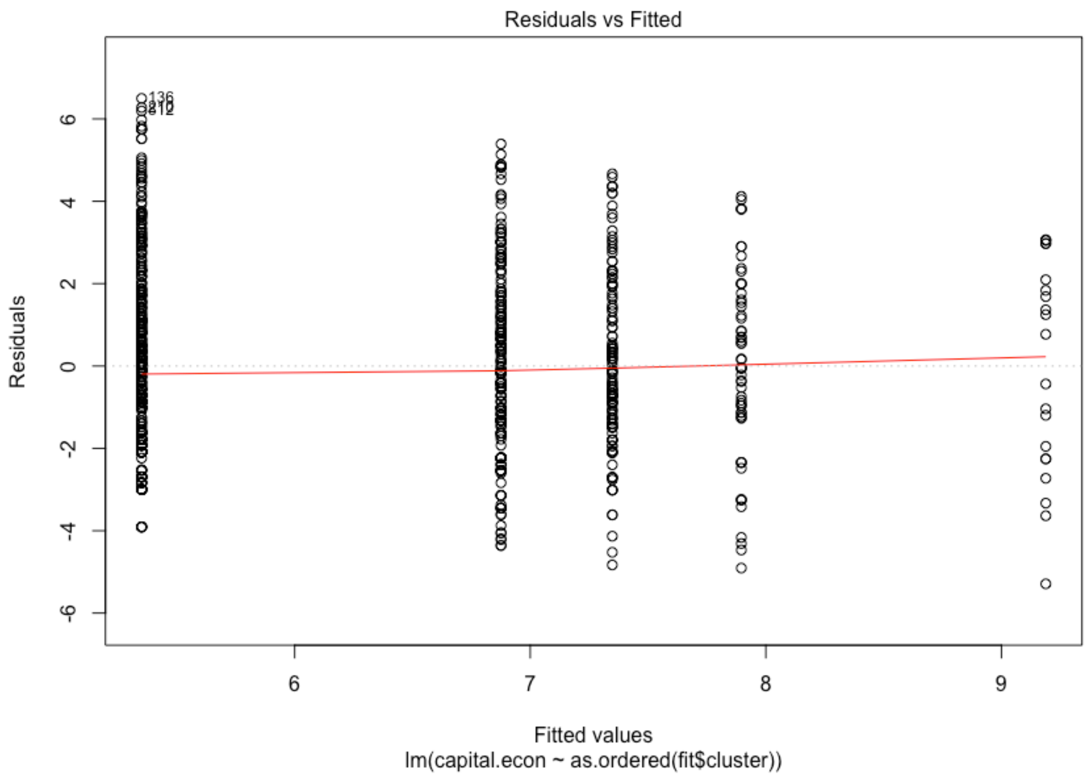
  1     2     3     4
2 0.804 -     -     -
3 1.000 0.804 -     -
4 0.804 0.219 0.061 -
5 1.000 1.000 1.000 0.804

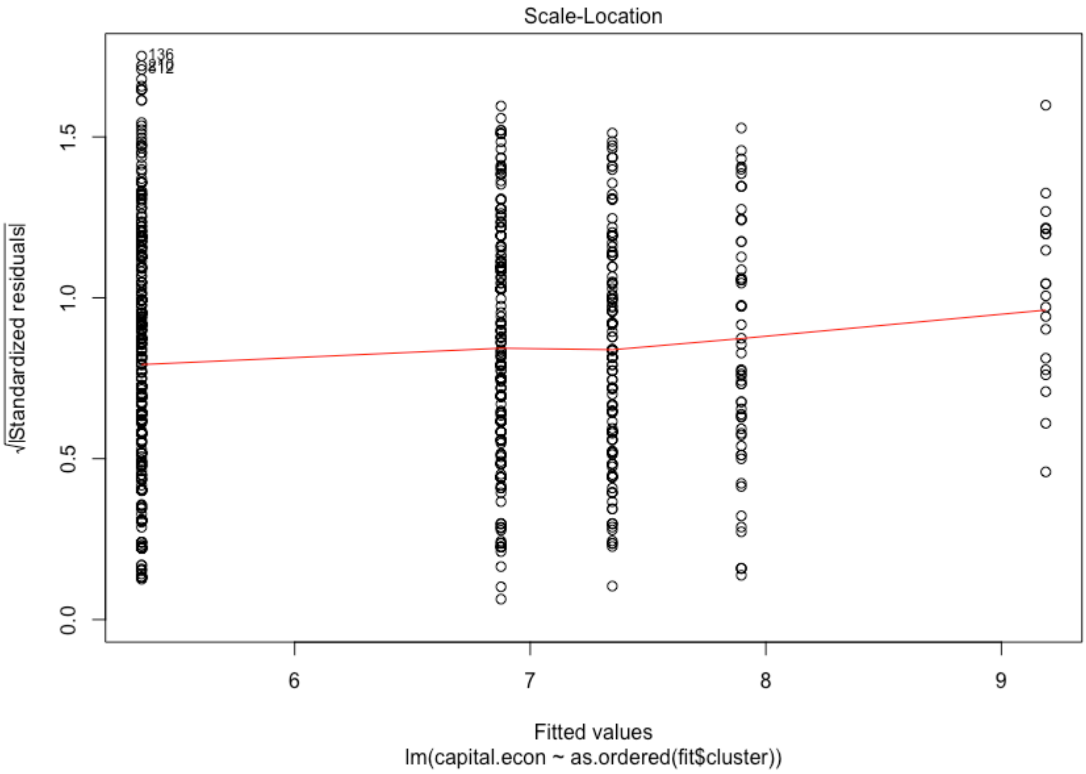
P value adjustment method: holm
```

Transport

Economic capital








```
Analysis of Variance Table

Response: capital.econ
                          Df Sum Sq Mean Sq F value    Pr(>F)
as.ordered(fit$cluster)    4 1043.6  260.89  57.979 < 2.2e-16 ***
Residuals               1007 4531.3    4.50
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
        Pairwise comparisons using t tests with pooled SD

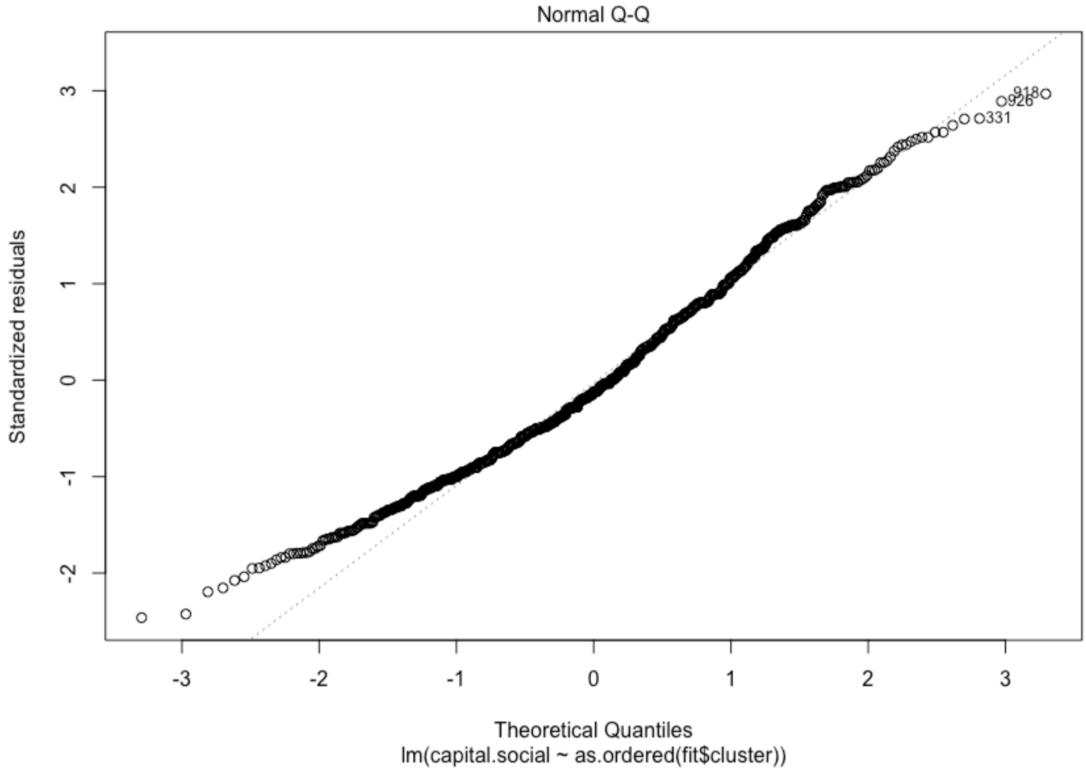
data:  capital.econ and as.ordered(fit$cluster)

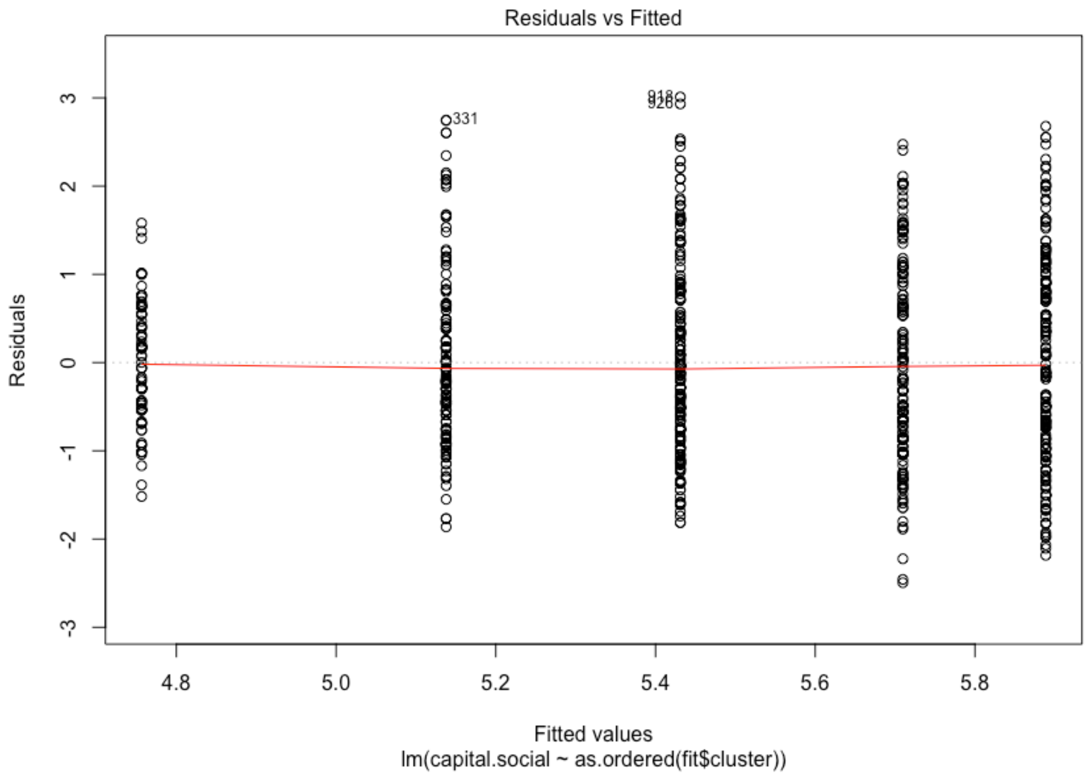
  1       2       3      4
2 < 2e-16 -       -      -
3 < 2e-16 0.0763  -      -
4 8.2e-15 1.1e-05 0.0011 -
5 < 2e-16 0.0041  0.1004 0.0508

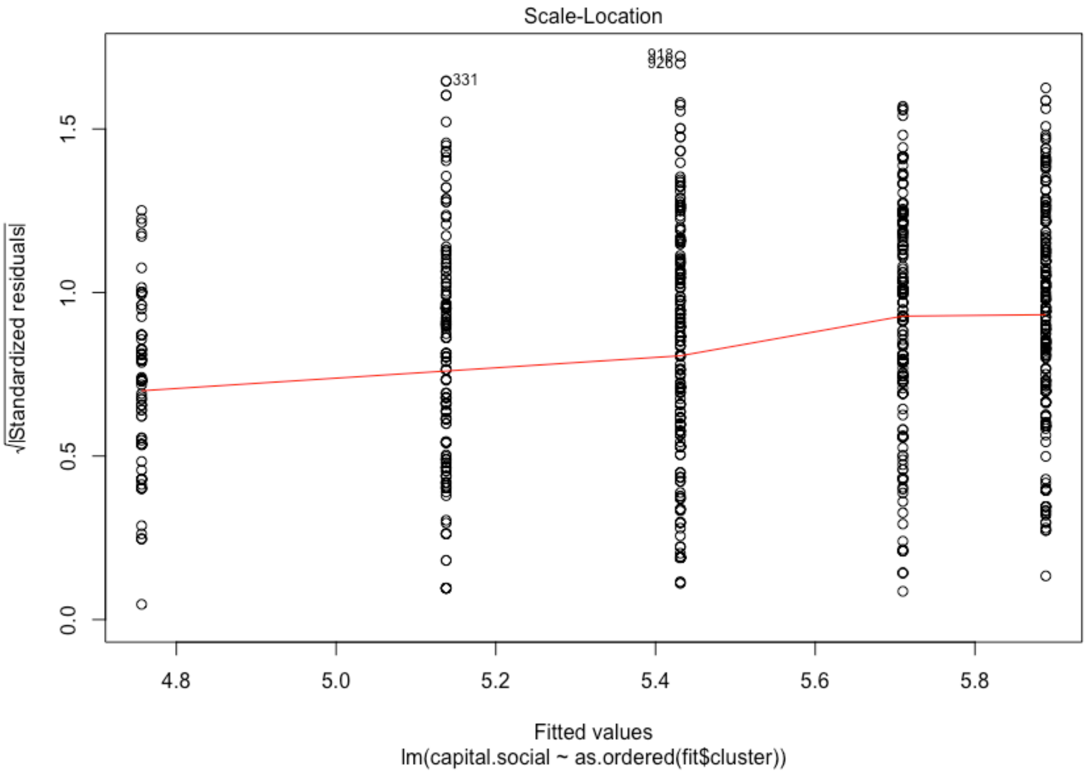
P value adjustment method: holm
```

```
[1] "mean:  5.35048653342854    sd:  2.06448737334034"
[1] "mean:  6.87593540199651    sd:  2.18779394222176"
[1] "mean:  7.34834814995954    sd:  2.07447944945443"
[1] "mean:  9.1883178746496    sd:  2.614878480207 7"
[1] "mean:  7.89597614669994    sd:  2.28573440454377"
```

Social capital





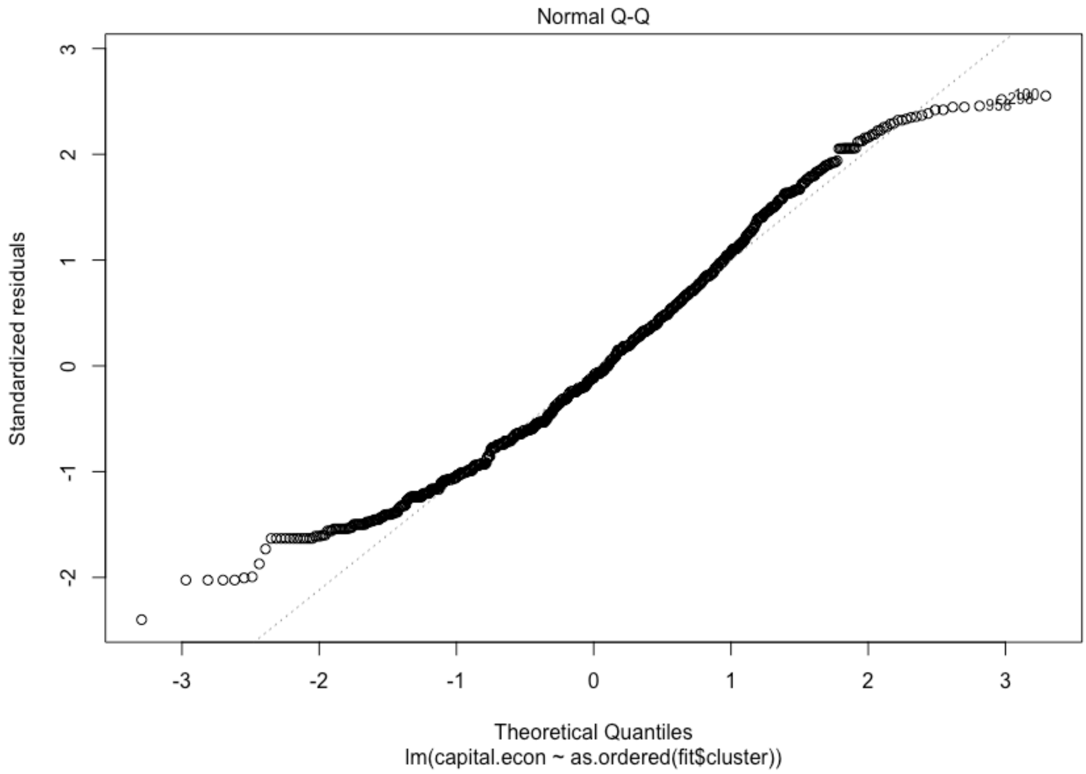


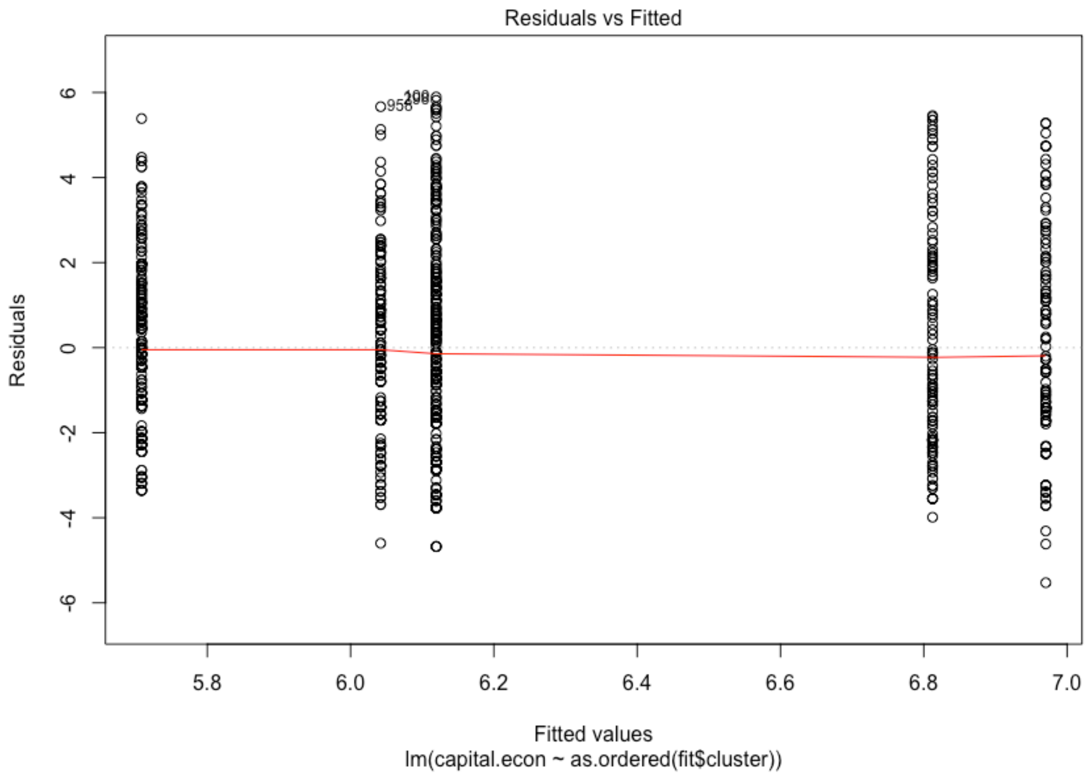

```
Analysis of Variance Table

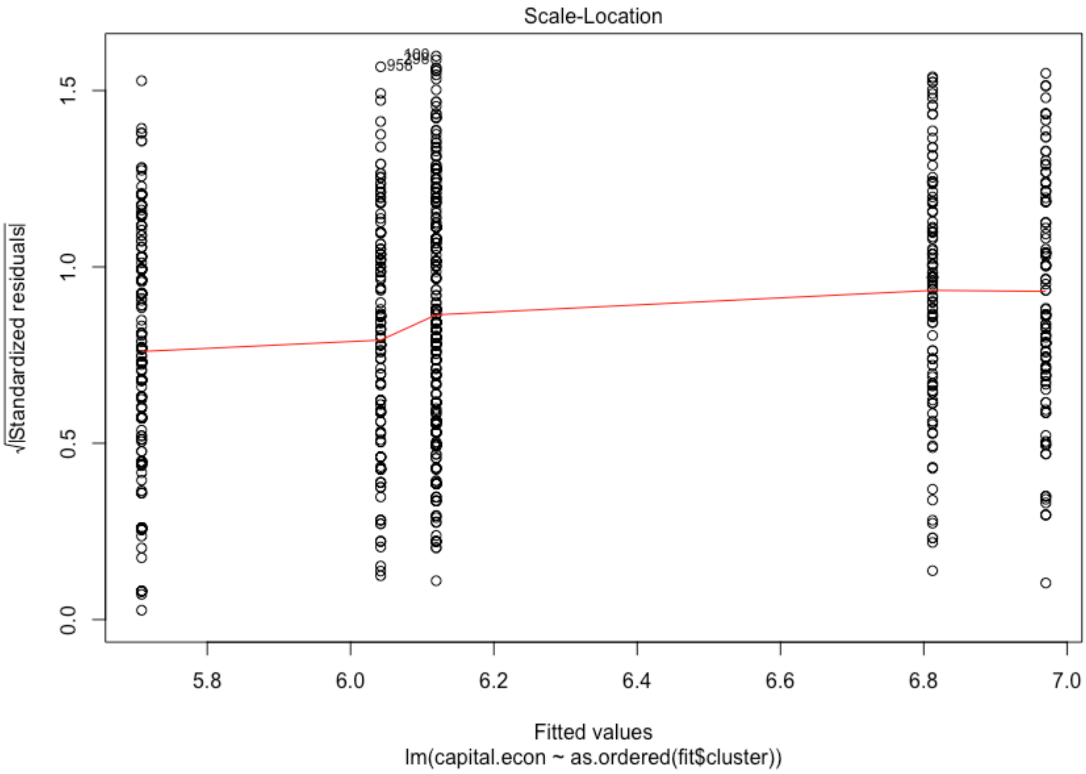
Response: capital.social
                          Df  Sum Sq Mean Sq F value Pr(>F)
as.ordered(fit$cluster)    4    6.26  1.5659  1.2819 0.2753
Residuals               1007 1230.14  1.2216
```

Secondary Consumption

Economic capital








```
Analysis of Variance Table

Response: capital.econ
                          Df Sum Sq Mean Sq F value    Pr(>F)
as.ordered(fit$cluster)    4  189.1  47.264  8.8372 5.162e-07 ***
Residuals               1007 5385.8   5.348
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

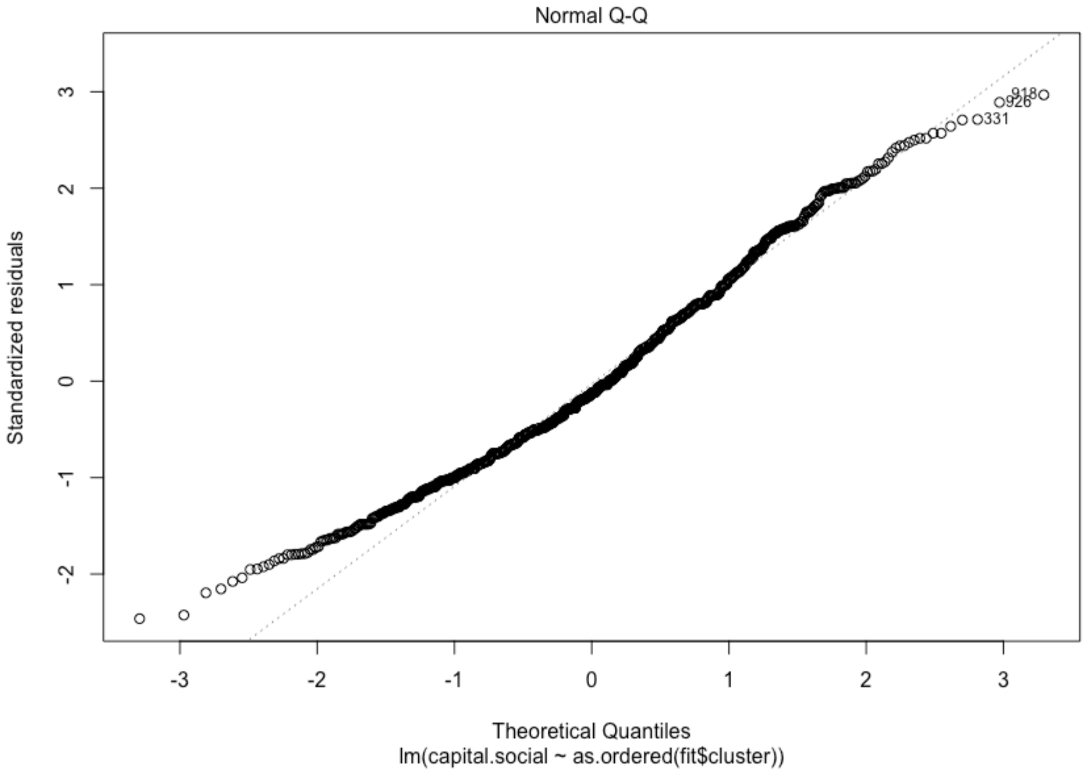
```
        Pairwise comparisons using t tests with pooled SD

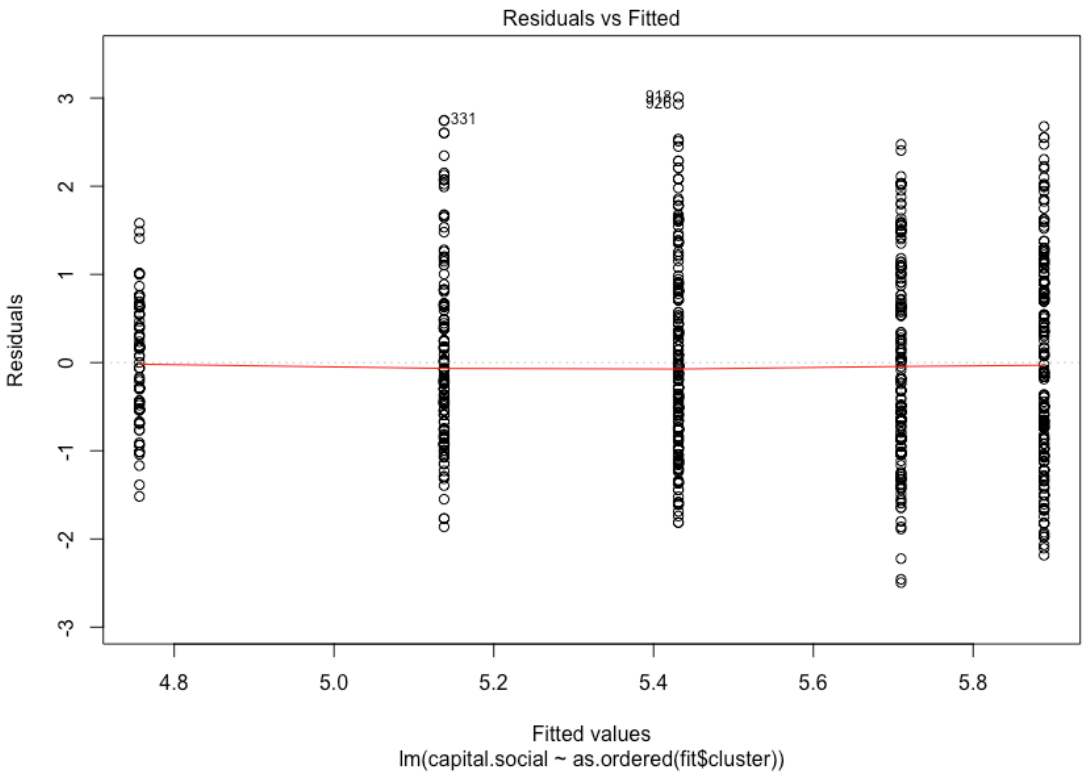
data:  capital.econ and as.ordered(fit$cluster)

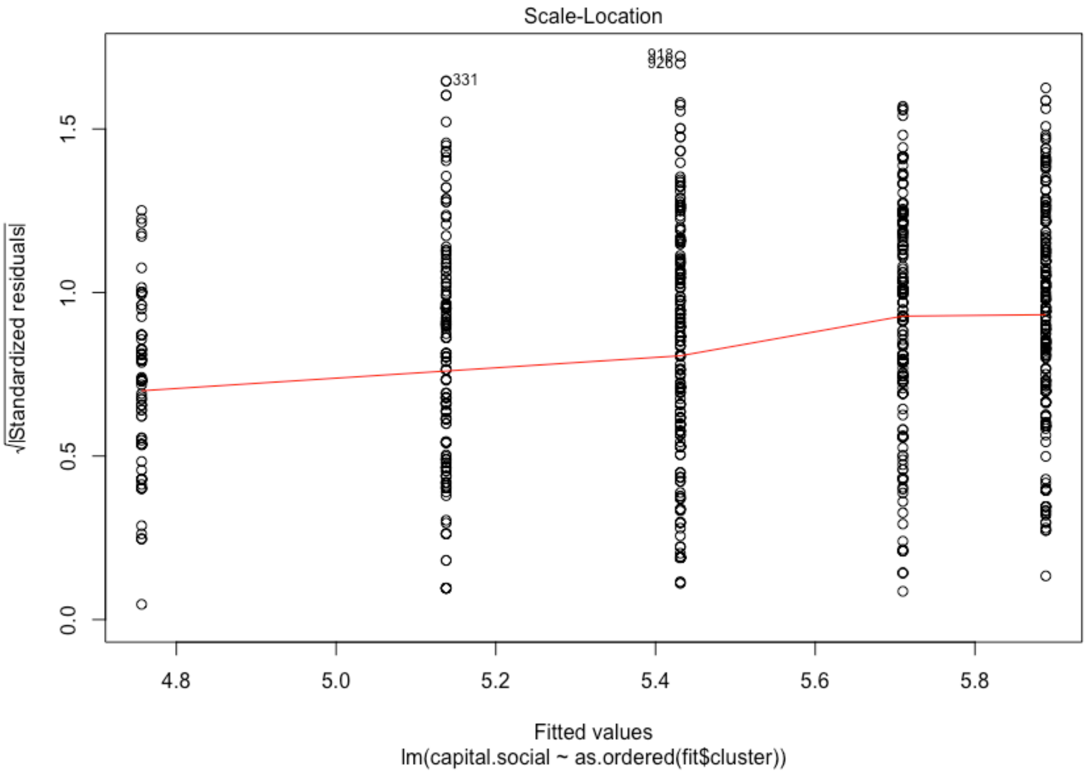
  1       2       3       4
2 0.14652 -       -       -
3 0.02178 0.00012 -       -
4 0.00298 7.3e-06 1.00000 -
5 1.00000 0.44675 0.02178 0.00379

P value adjustment method: holm
```

Social capital








```
Analysis of Variance Table

Response: capital.social
                          Df  Sum Sq Mean Sq F value    Pr(>F)    
as.ordered(fit$cluster)    4  129.46  32.365  29.443 < 2.2e-16 ***
Residuals               1007 1106.94   1.099                      
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
        Pairwise comparisons using t tests with pooled SD 

data:  capital.social and as.ordered(fit$cluster) 

  1       2       3       4      
2 2.9e-05 -       -       -      
3 0.00029 < 2e-16 -       -      
4 0.00034 1.00000 4.7e-15 -      
5 1.00000 1.5e-09 8.1e-05 1.5e-06

P value adjustment method: holm
```

A5) R- Code

```
---
title: "ClusterAnalyse"
output:
  html_document: default
  word_document: default
  pdf_document: default

---

```{r setup, include=FALSE}
chooseCRANmirror(graphics=FALSE, ind=1)
knitr::opts_chunk$set(root.dir =
"/Users/toni/Documents/Master/PIK/05_Data/Pro Kopf
Ressourcenverbrauch/Clustering_R", echo = TRUE)
library(haven)
library("lattice")
library("survival")
library("Formula")
library("ggplot2")
library("Hmisc")
library("cluster")
set.seed(123)
```
Cluster analysis and descriptive statistics
```{r}
install.packages("mice")
library("mice")
data <-
read_sav("UBA_AufbereiteterDatensatz_inklCO2_150418_MOSER.sav")
# capital.econ
# Data Imputation
capital.econ_raw <- data[, (colnames(data)%in%c("S11", "A3", "F1_01",
"F1_02", "F3"))]
prep <- mice(capital.econ_raw, method = "pmm")
capital.econ_imputed <- complete(prep, 1)
# PCA capital_econ
capital.econ_pc <- prcomp(capital.econ_imputed,
                          center = F,
                          scale = F)
plot(capital.econ_pc, type ="l")
# rotation
capital.econ_pc$rotation
capital.econ <- capital.econ_pc$x[,1] * (-1)
hist(capital.econ)
```
capital.social

the plot

```{r}


# Data Imputation
capital.social_raw <- data[, (colnames(data)%in%c( "A1", "SC_24",
"SC_34", "S5", "S5B"))]
prep <- mice(capital.social_raw, method = "pmm")
capital.social_imputed <- complete(prep, 1)
```
```

````
# PCA capital.social
capital.social_pc <- prcomp(capital.social_imputed,
                         center = F,
                         scale = F)
# the plot
plot(capital.social_pc, type ="l")
# rotation
capital.social_pc$rotation
capital.social <- capital.social_pc$x[,1] * (-1)
hist(capital.social)
```
# capital.cultural
```{r}
# Information and Communication Technology
# Data imputation
capital.cultural.ict_raw <- data[, (colnames(data)%in%c( "D24_num",
"D25_num", "D26", "D30_num" ))]
prep <- mice(capital.cultural.ict_raw, method = "pmm")
capital.cultural.ict_imputed <- complete(prep, 1)
# Data manpipulation: create subset without five outliers
drop <- which(capital.cultural.ict_imputed$D26 == 98)
capital.cultural.ict_imputed.manip <- capital.cultural.ict_imputed[-
drop, ]
capital.cultural.ict_imputed.manip2 <-
capital.cultural.ict_imputed.manip[-661, ]
# PCA capital_cultural.ict
capital.cultural.ict_pc <- prcomp(capital.cultural.ict_imputed.manip2,
                         center = F,
                         scale = F)
# the plot
plot(capital.cultural.ict_pc, type ="l")
# rotation
capital.cultural.ict_pc$rotation
capital.cultural.ict_imputed.manip_PC <- capital.cultural.ict_pc$x[,1]
* (-1)
hist(capital.cultural.ict)
```
----------------------------------------------
## K means clustering
```{r, echo=FALSE}
data.co2 <- read.table("CO2-Werte-fuer-Personen_aus-CO2-Rechner_2017-
01-13.csv", header = T, sep = ";", dec = ",")
# data imputation all sectors data Co2.
prep <- mice(data.co2[,-9], method = "pmm")
data.co2_imputed <- complete(prep)

```


##  Housing
# Clustering
```{r}
# Create data housing and cluster housing
library(survival)
housing <- data.co2_imputed[,
(colnames(data.co2_imputed)%in%c("CO2..Rechner.Heizung", "Strom"))]
summary(housing)
wss <- list()
for (i in 2:25) wss[i] <- sum(kmeans(housing,
                                        centers=i)$withinss)
# plot suggests 5 or 6 clusters
plot(2:25,unlist(wss), type="b", xlab="Number of Clusters",
     ylab="Within groups sum of squares")
````

````
# plot of the data
kmeans_5_h <- kmeans(housing, centers = 5, iter.max = 50)
plot(housing$CO2..Rechner.Heizung, housing$Strom, col =
kmeans_5_h$cluster, asp = 1)

#ggplot

ggplot(data.co2_imputed, aes(housing$CO2..Rechner.Heizung,
housing$Strom, color = as.factor(kmeans_5_h$cluster))) +
geom_point(shape=20) + ylim(0,3)
kmeans_5_h.plot <- ggplot(data.co2_imputed,
aes(housing$CO2..Rechner.Heizung, housing$Strom, color =
as.factor(kmeans_5_h$cluster))) + geom_point(shape=20) + ylim(0,3)
print(kmeans_5_h.plot + scale_colour_brewer(palette = "Paired") +
labs(x = "CO2e Heating t/y", y = "CO2e Electricity t/y", title =
"Clusters for Housing", colour = "Classes"))
# the cluster assignments
kmeans_5_h$size
kmeans_5_h$cluster
kmeans_5_h$centers
```
## Descriptive Statistics on Housing
# Are there significant differences in means of captial forms
# Economic Capital
```{r}
library(stats)
summary(capital.econ)
# Mean of Clusters in Housing
fit <- kmeans(housing, 5)
housing_clusteroverview <- data.frame(housing, fit$cluster)
aggregate(housing,by=list(fit$cluster),FUN=mean)
aggregate(capital.econ,by=list(fit$cluster),FUN=mean)
housing_capecon_clusteroverview <- data.frame(capital.econ ,
fit$cluster)
plot(capital.econ ~ fit.cluster, data=
housing_capecon_clusteroverview)
#Anova Analysis
analysis_anova_capital.econ_h <- lm(capital.econ ~
as.ordered(fit$cluster) , data = housing_capecon_clusteroverview)
anova(analysis_anova_capital.econ_h)
# post hoc test because Ho is rejected
pairwise.t.test(capital.econ, as.ordered(fit$cluster),
p.adjust="holm",
pool.sd = T)
# Check assumption normality
plot(analysis_anova_capital.econ_h, which=2)
sresids <- rstandard(analysis_anova_capital.econ_h)
hist(sresids)
# Look for heteroskedasticity
par(mfrow = c(2,2))
plot(analysis_anova_capital.econ_h)

```


# Are there significant differences in means of captial forms
# Social Capital
```{r}
fit <- kmeans(housing, 5)
housing_clusteroverview <- data.frame(housing, fit$cluster)
aggregate(housing,by=list(fit$cluster),FUN=mean)
summary(capital.social)
````

```
aggregate(capital.social, by=list(fit$cluster),FUN=mean)
housing_capsocial_clusteroverview <- data.frame(capital.social ,
fit$cluster)
plot(capital.social ~ fit.cluster, data=
housing_capsocial_clusteroverview)
#Anova Analysis
analysis_anova_capital.social_h <- lm(capital.social ~
as.ordered(fit$cluster) , data = housing_capsocial_clusteroverview)
anova(analysis_anova_capital.social_h)
# post hoc test
pairwise.t.test(capital.social, as.ordered(fit$cluster),
p.adjust="holm", pool.sd = T)
# Check assumption normality
View(analysis_anova_capital.social_h)
plot(analysis_anova_capital.social_h, which=2)
sresids7 <- rstandard(analysis_anova_capital.social_h)
hist(sresids7)
#heteroscedacity
par(mfrow = c(2,2))
plot(analysis_anova_capital.social_h)
```
Are there significant differences in means of captial forms
Cultural Capital ICT
```{r}
# drop
drop <- c(drop,which(is.na(data.co2_imputed[,7])))
data.co2_imputed.manip <- data.co2_imputed[-drop,]
data.co2_imputed <- data.co2_imputed[-
which(is.na(data.co2_imputed[,7])),]
dim(data.co2_imputed.manip)
```
```{r}
# ICT
# check if means capital.cultural.ict are significantly different?
# New Clusters without outliers
library(survival)
# create data without outliers
dim(data.co2_imputed.manip)
# application new data on Housing without outliers
housing_ICT <- data.co2_imputed.manip[,
(colnames(data.co2_imputed)%in%c("CO2..Rechner.Heizung", "Strom"))]
summary(housing_ICT)
# looking for k
wss2 <- list()
for (i in 2:25) wss2[i] <- sum(kmeans(data.co2_imputed.manip,
                                      centers=i)$withinss)
# plot suggests 5 or 6 clusters
plot(2:25,unlist(wss2), type="b", xlab="Number of Clusters",
     ylab="Within groups sum of squares")
# plot of the clusters
kmeans_5_h_ICT <- kmeans(housing_ICT, centers = 5, iter.max = 50)
plot(housing_ICT$CO2..Rechner.Heizung, housing_ICT$Strom, col =
kmeans_5_h_ICT$cluster, asp = 1)
# mean of cluster in housing_ICT
fit <- kmeans_5_h_ICT
housing_capcultural.ict_clusteroverview <- data.frame(housing_ICT,
fit$cluster)
aggregate(housing_ICT,by=list(fit$cluster),FUN=mean)
aggregate(capital.cultural.ict_imputed.manip2,by=list(fit$cluster),
FUN
= mean)
housing_capcultural.ict_clusteroverview <-
data.frame(capital.cultural.ict_imputed.manip_PC, fit$cluster)
```

````
plot(capital.cultural.ict_imputed.manip_PC ~ fit.cluster, data=
housing_capcultural.ict_clusteroverview)
#Anova Analysis
analysis_anova_capital.cultural.ict_h <-
lm(capital.cultural.ict_imputed.manip_PC ~ as.ordered(fit$cluster))
anova(analysis_anova_capital.cultural.ict_h)
# post hoc test
pairwise.t.test(capital.cultural.ict_imputed.manip_PC,
as.ordered(fit$cluster), p.adjust="holm", pool.sd = T)
# Check assumption normality
View(analysis_anova_capital.cultural.ict_h)
plot(analysis_anova_capital.cultural.ict_h, which=2)
sresids6 <- rstandard(analysis_anova_capital.cultural.ict_h)
hist(capital.cultural.ict_imputed.manip_PC)
```
# 7 Cluster
```{r}
# Change amount of cluster to 7 to see if I get a significant
difference
  # plot of the data
kmeans_7_h <- kmeans(housing, centers = 7, iter.max = 50)
plot(housing$CO2..Rechner.Heizung, housing$Strom, col =
kmeans_7_h$cluster, asp = 1)
fit <- kmeans_7_h
# data.frame df contains CO2..Rechner.. and Strom for cluster ==1
for(i in 1:7){
df <- housing[which(fit$cluster==i),]
# function just caluclates mean and standard deviation of df
print(sapply(df, function(cl) list(means=mean(cl,na.rm=TRUE),
sds=sd(cl,na.rm=TRUE))))
}
housing_clusteroverview_7 <- data.frame(housing, fit$cluster)
# cluster assignments
kmeans_7_h$size
kmeans_7_h$cluster
kmeans_7_h$centers
# Mean of Clusters in Housing
aggregate(housing,by=list(fit$cluster),FUN=mean)
# Median of Clusters in Housing
aggregate(housing,by=list(fit$cluster),FUN=median)
# Are there significant differences in mean in captial forms
# capital_econ
summary(capital.econ)
aggregate(capital.econ,by=list(fit$cluster),FUN=mean)
housing_capecon_clusteroverview <- data.frame(capital.econ,
fit$cluster)
plot(capital.econ ~ fit.cluster, data=
housing_capecon_clusteroverview)
#Anova Analysis
analysis_anova_capital.econ <- lm(formula = capital.econ ~
as.ordered(fit$cluster) , data = housing_capecon_clusteroverview)
anova(analysis_anova_capital.econ)
#post hoc test
pairwise.t.test(capital.econ, as.ordered(fit$cluster),
p.adjust="holm",
pool.sd = T)
# Check assumption normality
View(analysis_anova_capital.econ)
plot(analysis_anova_capital.econ, which=2)
sresids2 <- rstandard(analysis_anova_capital.econ)
hist(sresids2)
#heteroscedacity
par(mfrow = c(2,2))
plot(analysis_anova_capital.econ)
````

````
```
# income on 5 cluster
```{r}
# check if means of net income instead of economic capital are
significantly different?
fit <- kmeans(housing, 5)
housing_clusteroverview <- data.frame(housing, fit$cluster)
aggregate(housing,by=list(fit$cluster),FUN=mean)
income <- capital.econ_imputed[["S11"]]
summary(income)
aggregate(income,by=list(fit$cluster),FUN=mean)
housing_income_clusteroverview <- data.frame(income, fit$cluster)
# Anova Analysis
analysis_anova_income <- lm(income ~ as.ordered(fit.cluster), data=
housing_income_clusteroverview)
anova(analysis_anova_income)
# Check assumption normality
plot(analysis_anova_income, which=2)
sresids9 <- rstandard(analysis_anova_income)
hist(sresids9)
#heteroscedacity
par(mfrow = c(2,2))
plot(analysis_anova_income)

```


## Transport

```{r}
# Create data Transport
transport <- data.co2_imputed[,
(colnames(data.co2_imputed)%in%c("Mobilit..t", "RespID"))]
summary(transport)
wss <- list()
for (i in 2:25) wss[i] <- sum(kmeans(transport,
# plot suggests 5 or 6 clusters
centers=i)$withinss)
plot(2:25,unlist(wss), type="b", xlab="Number of Clusters",
     ylab="Within groups sum of squares")
# plot of the data
kmeans_5_t <- kmeans(transport, centers = 5, iter.max = 50)
plot(transport, col = kmeans_5_t$cluster, asp = 40)
ggplot(data.co2_imputed, aes(x=1:1012, transport, color =
as.factor(kmeans_5_t$cluster))) + geom_point(shape=20) + ylim(0,17)
kmeans_5_t.plot <- ggplot(data.co2_imputed, aes(x=1:1012, transport,
color = as.factor(kmeans_5_t$cluster))) + geom_point(shape=20) +
ylim(0,17)
print(kmeans_5_t.plot + scale_colour_brewer(palette = "Paired") +
labs(x = "Index", y = "CO2e Transport t/y", title = "Clusters for
Transport", colour = "Classes"))
kmeans_5_t$size
# Mean of Clusters in transport
fit <- kmeans(transport, 5)
transport_clusteroverview <- data.frame(transport, fit$cluster)
aggregate(transport,by=list(fit$cluster),FUN=mean)
kmeans_5_t$cluster
kmeans_5_t$centers
# Median of Clusters in Housing
aggregate(transport,by=list(fit$cluster),FUN=median)
```
````
````

````
## Descriptive Statistics on Transport
# Are there significant differences in means of captial forms
# Economic Capital

```{r}

# Mean of Clusters in Transport
fit <- kmeans(transport, 5)
transport_clusteroverview <- data.frame(transport, fit$cluster)
aggregate(transport,by=list(fit$cluster),FUN=mean)
library(stats)
summary(capital.econ)
aggregate(capital.econ,by=list(fit$cluster),FUN=mean)
transport_capecon_clusteroverview <- data.frame(capital.econ,
fit$cluster)
plot(capital.econ ~ fit.cluster, data=
transport_capecon_clusteroverview)
#Anova Analysis
analysis_anova_capital.econ_t <- lm(capital.econ ~
as.ordered(fit$cluster) , data = transport_capecon_clusteroverview)
anova(analysis_anova_capital.econ_t)
# post hoc test
pairwise.t.test(capital.econ, as.ordered(fit$cluster),
p.adjust="holm",
pool.sd = T)
for(i in 1:5){
df <- capital.econ[fit$cluster==i]
# function just caluclates mean and standard deviation of df
print(paste("mean: ", mean(df),"   sd: ",sd(df)))
}
# Check assumption normality
#View(analysis_anova_capital.econ)
plot(analysis_anova_capital.econ, which=2)
sresids3 <- rstandard(analysis_anova_capital.econ)
hist(sresids3)
# Look for heteroskedasticity
par(mfrow = c(2,2))
plot(analysis_anova_capital.econ_t)
```
# Are there significant differences in means of captial forms
# Social Capital
```{r}
fit <- kmeans(transport, 5)
transport_clusteroverview <- data.frame(transport, fit$cluster)
aggregate(transport,by=list(fit$cluster),FUN=mean)
aggregate(capital.social, by=list(fit$cluster),FUN=mean)
transport_capsocial_clusteroverview <- data.frame(capital.social ,
fit$cluster)
plot(capital.social ~ fit.cluster, data=
transport_capsocial_clusteroverview)
#Anova Analysis
analysis_anova_capital.social_t <- lm(capital.social ~
as.ordered(fit$cluster) , data = transport_capsocial_clusteroverview)
anova(analysis_anova_capital.social_t)
# Check assumption normality
View(analysis_anova_capital.social)
plot(analysis_anova_capital.social, which=2)
sresids5 <- rstandard(analysis_anova_capital.social)
hist(sresids5)
#heteroscedacity
par(mfrow = c(2,2))
plot(analysis_anova_capital.social)

```
````

````
## Secondary Consumption
```{r}
# Create data Secondary Consumption (Food, Other Consumption)
seccon <- data.co2_imputed[,
(colnames(data.co2_imputed)%in%c("Ern..hrung", "Sonstiger.Konsum"))]
summary(seccon)
wss <- list()
for (i in 2:25) wss[i] <- sum(kmeans(seccon,
                                       centers=i)$withinss)
# plot suggests 5 or 6 clusters
plot(2:25,unlist(wss), type="b", xlab="Number of Clusters",
     ylab="Within groups sum of squares")
# plot of the data
kmeans_5_s <- kmeans(seccon, centers = 5, iter.max = 50)
plot(seccon$Ern..hrung, seccon$Sonstiger.Konsum, col =
kmeans_5_s$cluster, asp = 0.)
ggplot(data=data.co2_imputed, aes(seccon$Ern..hrung,
seccon$Sonstiger.Konsum, color = as.factor(kmeans_5_s$cluster))) +
geom_point(shape=20) + ylim(0,8)
kmeans_5_s.plot <- ggplot(data.co2_imputed, aes(seccon$Ern..hrung,
seccon$Sonstiger.Konsum, color = as.factor(kmeans_5_s$cluster))) +
geom_point(shape=20) + ylim(0,8)
print(kmeans_5_s.plot + scale_colour_brewer(palette = "Paired") +
labs(x = "CO2e Alimentation t/y", y = "CO2e Other consumption t/y",
title = "Clusters for Secondary Consumption", colour = "Classes"))
kmeans_5_s$size
# Mean of Clusters in Seccon
fit <- kmeans(seccon, 5)
seccon_clusteroverview <- data.frame(seccon, fit$cluster)
aggregate(seccon,by=list(fit$cluster),FUN=mean)
# cluster assignments
kmeans_5_s$cluster
kmeans_5_s$centers
```
## Descriptive Statistics on Secondary Consumption
# Are there significant differences in means of captial forms
# Economic Capital

```{r}

# Mean of Clusters in Housing
fit <- kmeans(seccon, 5)
seccon_clusteroverview <- data.frame(seccon, fit$cluster)
aggregate(seccon,by=list(fit$cluster),FUN=mean)
library(stats)
summary(capital.econ)
aggregate(capital.econ,by=list(fit$cluster),FUN=mean)
seccon_capecon_clusteroverview <- data.frame(capital.econ,
fit$cluster)
plot(capital.econ ~ fit.cluster, data= seccon_capecon_clusteroverview)
#Anova Analysis
analysis_anova_capital.econ_s <- lm(capital.econ ~
as.ordered(fit$cluster) , data = seccon_capecon_clusteroverview)
anova(analysis_anova_capital.econ_s)
# post hoc test
pairwise.t.test(capital.econ, as.ordered(fit$cluster),
p.adjust="holm",
pool.sd = T)
# Check assumption normality
View(analysis_anova_capital.econ)
plot(analysis_anova_capital.econ, which=2)
sresids4 <- rstandard(analysis_anova_capital.econ)
hist(sresids4)
# Look for heteroskedasticity
````
````

````
par(mfrow = c(2,2))
plot(analysis_anova_capital.econ_s)
```
# Are there significant differences in means of captial forms
# Social Capital

```{r}

fit <- kmeans(seccon, 5)
seccon_clusteroverview <- data.frame(seccon, fit$cluster)
aggregate(seccon,by=list(fit$cluster),FUN=mean)
summary(capital.social)
aggregate(capital.social, by=list(fit$cluster),FUN=mean)
seccon_capsocial_clusteroverview <- data.frame(capital.social ,
fit$cluster)
plot(capital.social ~ fit.cluster, data=
seccon_capsocial_clusteroverview)
# Anova Analysis
analysis_anova_capital.social_s <- lm(capital.social ~
as.ordered(fit$cluster) , data = seccon_capsocial_clusteroverview)
anova(analysis_anova_capital.social_s)
# post hoc test
pairwise.t.test(capital.social, as.ordered(fit$cluster),
p.adjust="holm", pool.sd = T)
# Check assumption normality
View(analysis_anova_capital.social)
plot(analysis_anova_capital.social, which=2)
sresids5 <- rstandard(analysis_anova_capital.social)
hist(sresids5)
#heteroscedacity
par(mfrow = c(2,2))
plot(analysis_anova_capital.social)

```
````
````

Hiermit erkläre ich, dass die Arbeit noch nicht für andere Prüfungen eingereicht wurde, dass sie selbstständig verfasst wurde und dass sämtliche Quellen einschließlich Internetquellen, die unverändert oder abgewandelt wiedergegeben werden, insbesondere Quellen für Texte, Grafiken, Tabellen und Bilder, sind als solche kenntlich gemacht sind. Mir ist bekannt, dass bei Verstößen gegen diese Grundsätze ein Verfahren wegen Täuschungsversuchs bzw. Täuschung eingeleitet wird.

Datum Unterschrift