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Perspectives on low carbon lifestyles

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Abstract

Climate change is one of the most severe problems facing the world today. If extensive measures are not undertaken to reduce greenhouse gas (GHG) emissions within the near future, the natural conditions under which life depends will change for the worse (Pachauri et al, 2014). The transition to a low carbon and sustainable future represents a major transformation of our society that will need to come about within a timeframe of decades. This thesis attempts to make a contribution to the research field of sustainable consumption and thus involves questions related to the demand of energy and resources in society.

In Papers I and II, we examine different factors affecting the variation in GHG emissions between households. Paper I examines the explanatory value of socio-economic, geographic and motivational factors in the same empirical material, while paper II specifically analyzes the importance of materialistic values to individuals' GHG emissions. Results from Paper I show the importance of situational factors (socio-economic and geographical) in relation to motivational (environmental attitudes). Paper II on the other hand indicates that individuals with a materialistic value orientation tend to fly more and hence cause larger GHG emissions, and the theoretical implications of this result is discussed.

In Papers III and IV, we analyze the relationships between individuals' reported levels of well-being and environmentally relevant behaviors. Paper III analyzes respondents' levels of subjective well-being and GHG emissions, and concludes that when relevant factors are controlled for, there is no relationship between subjective well-being and GHG emissions. Paper IV, among other things, use the introduction of a congestion charge scheme to examine the effect on travel satisfaction and finds no strong effects.

In Paper V, we analyze the direct rebound effect in a large sample of Swedish households by following the changes in fuel efficiency and annual driving distances for in the years before and after they change car. Contrary to previous research, the results suggest that, apart from in certain sub-samples, there is no significant rebound effect and the results are discussed.

Keywords: sustainable consumption, climate change, households, GHG emissions, materialistic values, air travel, subjective well-being, satisfaction with travel scale, congestion charge, rebound effect.

List of publications

I. Nässén, Jonas, David Andersson, Jörgen Larsson, and John Holmberg. "Explaining the Variation in Greenhouse Gas Emissions Between Households: Socioeconomic, Motivational, and Physical Factors" *Journal of Industrial Ecology* (2015), Vol 19, Iss. 3, 480-489.
JN, JH, and JL developed the idea, DA collected the data, DA and JN conducted the analysis and JN wrote the paper with contributions from DA, JL and JH.

II. Andersson, David and Jonas Nässén. "Should environmentalists be concerned about materialism? An analysis of attitudes, behaviours and greenhouse gas emissions" *Journal of Environmental Psychology* **In Review** (2015).
DA developed the idea, collected the data, conducted the analysis and wrote the paper with contributions from JN.

III. Andersson, David, Jonas Nässén, Jörgen Larsson, and John Holmberg. "Greenhouse gas emissions and subjective well-being: An analysis of Swedish households" *Ecological Economics* 102 (2014): 75-82.
JH, JL, JN and DA developed the idea, DA collected the data, conducted the analysis and wrote the paper with contributions from JN, JL and JH.

IV. Andersson, David and Jonas Nässén. "The Gothenburg congestion charge scheme: A pre–post analysis of commuting behavior and travel satisfaction" *Journal of Transport Geography* **In Review** (2015).
Idea developed jointly with local officials at the municipality of Gothenburg. DA and JN collected the data and conducted the analysis, DA wrote the paper with contributions from JN.

V. Andersson, David and Jonas Nässén. "Measuring the direct rebound effect in a large longitudinal sample of Swedish car owners" *Energy Policy* **In Review** (2015).
JN developed the idea, DA conducted the analysis, DA and JN wrote the paper.

Relevant publications not in this thesis

I. Holmberg, John, Jörgen Larsson, Jonas Nässén, Sebastian Svenberg, and David Andersson. "Low-carbon transitions and the good life" *Naturvårdsverket*, Report 6495, Stockholm (2012).

II. Nilsson, Andreas, Cecilia Jakobsson Bergstad, Liane Thuvander, David Andersson, Kristin Andersson, and Pär Meiling. Effects of continuous feedback on households' electricity consumption: Potentials and barriers *Applied Energy* 122 (2014): 17-23.

III. Nilsson, Andreas, Cecilia Jakobsson Bergstad and David Andersson. Using feedback to promote electricity conservation: The effect of value priority on motivation and behavioral change *Working paper*.

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David Andersson

Göteborg, February 2016

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1 Introduction

Climate change is one of the most severe problems facing the world today. If extensive measures are not undertaken to reduce greenhouse gas (GHG) emissions within the near future, the natural conditions under which life depends will change for the worse (Pachauri et al 2014). The transition to a low carbon and sustainable future represents a major transformation of our society that will need to come about within a timeframe of decades. In short, GHG emissions can be reduced either by reducing the *scale* of energy and resource use, e.g. through energy efficiency improvements or reduced consumption, or by introducing technologies that reduce the GHG *intensity* of energy and resource use in production.[1]

This thesis attempts to make a contribution to the research field of sustainable consumption and thus involves questions related to the demand of energy and resources in society. The meaning of the term sustainable consumption has however changed over the course of its relatively short history, and in order to provide a theoretical context for the studies in this thesis a brief historical background is needed.

The term sustainable consumption is recent, but the concept has been used at least since the Club of Rome's *Limits to growth* report in 1972. Meadows et al (1972) raised concerns on the effects on resource scarcity and environmental degradation following from the increased affluence and consumption seen in preceding decades. The report received a large interest and together with developed countries' demands for economic development these two issues pervaded much of the international policy agenda at the time (Jackson & Michaelis 2003). Sustainable development was an attempt to solve these issues and can be described as an attempt to find a common understanding on how to justly perceive both the intergenerational problem of present unsustainable resource extraction, and the intragenerational problem of unequal resource distribution between the rich and the poor. It is in this context the Brundtland report (1987) managed to put forward an ethical framework that described the conditions needed for sustainable development that address both the injustices existing today and the requirements of future generations.

Following the establishment of the concept of sustainable development, the term sustainable consumption became used and spread in the international policy community.

[1] A substantial part of the global GHG emissions arise from livestock, land use and forestry (Pachauri et al 2014), but the main options for abatements within these areas also fall within the broad categories of reduced demand and reduced GHG intensity in production.

Steering towards sustainable consumption was necessary in order to find ways to change consumption patterns, and the Rio Earth Summit in 1992 requested "new concepts of wealth and prosperity", hence connecting sustainable consumption to a tradition of critical theories questioning societal goals and consumer culture (Sitarz 1993).

However, the interpretation of the term was contested and over the years a consensus emerged that understood sustainable consumption simply as a change in consumption towards more sustainable products and services (see Jackson & Michaelis 2003). This shift is likely to have been caused by the general political spirit of the time, and was also propelled by the idea that increased resource productivity would refine the industrial metabolism, and allow for economic growth to decouple from environmental degradation (Huber 2004). This idea was extremely influential and formed what is sometimes called the *ecological modernization paradigm,* leading policy makers all over the world to recognize regulations, industrial development and economic growth as important solutions to many environmental and sustainability problems (Spaargaren & Mol 1992). Given this new reasoning, reduced consumption would only harness and delay the decoupling of the economic system from the ecological ditto. This also meant that the social criticism previously embedded in sustainable consumption was largely eliminated (Jackson & Michaelis 2003).

The prospect of decoupling economic growth from environmental impacts has however proven more difficult than foreseen (Giljum et al., 2008; Wiedmann et al., 2008). Across Western countries the scale of the increase in consumption has counteracted the relative decoupling; the gains through improvements in eco-efficiency are counteracted by an ever growing economy.[2] This has led to an increased recognition of the potential importance of issues traditionally related to sustainable consumption, and three issues can be identified.

First, policy makers again gradually turn towards questions related to behavior, lifestyle and consumer culture as they are increasingly being understood as key factors determining how GHG emissions from consumption could be decreased (Atkinson et al 2014). From a Swedish perspective there is also, as we will discuss in Section 2, an increasing awareness of the need

[2] However, the International Energy Agency (IEA, 2015) reported that although the global economy grew by around 3% in 2014, energy-related carbon dioxide (CO_2) emissions stayed flat. Within the coming weeks of the publication of this thesis, new data should be available that will shed further light on the development in the energy sector for 2015.

to reduce GHG emissions from consumption although the Kyoto protocol does not concern emissions embedded in imported products.

Second, as policy makers became aware of the potential for rebound effects, interest in the interaction between technology and human behavior has increased. The importance of behavioral changes and policies is greatly affected by the efficiency of technological development and the size of the so called rebound effect, as large rebound effects would suggest that behavioral changes are necessary to reduce GHG emissions, while small rebound effects suggests that energy efficiency improvements and new technologies ought to be sufficient.

Third, in parallel to the renewed interest in consumer behavior, normative welfare discussions "beyond growth" have been increasingly debated, and governments around the world, in the UN:s "Sustainable Development Goals" and among influential international organizations have shown increased interest in these issues (Stiglitz et al 2010; SDSN 2015; OECD 2012). Although the ecological modernization paradigm and the more broadly defined "growth model" of the present economic system is being increasingly put in question by these new ideas aimed a conceptualizing a low carbon model, it remains to be seen if insights from the sustainable consumption perspective will help deal with the transition to a low carbon sustainable future (Messner 2015). More specifically, the thesis aims to:

(i) Examine different factors affecting the variation in GHG emissions between households (Section 2, Paper I and II).

(ii) Analyze the relationship between individuals' quality of life and their environmentally relevant behaviors (Section 3, Papers III and IV).

(iii) Provide a quantification of the rebound effect among households, i.e. the extent to which improvements in technical energy efficiency drive increasing consumption (Section 4, Paper V).

2 Consumption patterns and greenhouse gas emissions in Swedish households

Emissions scenarios with at least a likely chance of keeping average global warming below the target of 2 degrees will require reductions of global greenhouse gas (GHG) emissions at the scale of 50-65% between 2010 and 2050 (Rogelj et al 2011). Since reductions in developing countries are likely to take time, it is reasonable to assume that rich countries will need to decrease their GHG emissions even more quickly.[3] But what exactly does this entail in terms of responsibilities for GHG emissions, are citizens in Western countries responsible for the emissions from goods and services imported from other countries?

This question illustrates two different accounting approaches that place the responsibilities either on the production or the consumption (Clift & Druckman 2016). Following a territorial accounting perspective (also named "production perspective"), the GHG emissions caused in production should be attributed to the country where the products are produced, so that national policies are aimed at pushing for less GHG intensive energy supply.[4] By instead following a consumption accounting perspective, the reasoning would be that the production was primarily intended to meet the demand by consumers in the importing country, and responsibilities ought to follow so that demand is harnessed and reduce the scale of consumption in order to reduce emissions. There is a clear parallel to proponents of ecological modernizations' focus on low carbon technologies, and the focus on curtailment and need for behavioral change seen in the consumption perspective. Just as both reduced consumption and energy extraction using low carbon techniques will be needed, policy suggestions advancing from both territorial and consumption perspectives are probably going to be needed when

[3] The principle of a 'common but differentiated responsibility' can be seen in several international documents regulating how emission reductions should be divided. The Rio Declaration states: "In view of the different contributions to global environmental degradation, States have common but differentiated responsibilities. The developed countries acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressures their societies place on the global environment and of the technologies and financial resources they command." Similarly, in the Framework Convention on Climate Change; parties should act to protect the climate system "on the basis of equality and in accordance with their common but differentiated responsibilities and respective capabilities."

[4] The Kyoto Protocol use territorial accounting to be able to measure and evaluate different countries' GHG abatement commitments, and this approach has a practical advantage over consumption based accounting as it allows for better monitoring. Also, the perspectives themselves do not necessarily imply a certain division of responsibilities for GHG emission reductions, but an eventual harmonization of something similar to a similar per capita emission space is difficult to argue against.

devising strategies for a more sustainable future, and the following section describes how the development in Sweden indicates the need for legislations aiming at behavioral change.

According to official production accounting, Sweden reduced its GHG emissions by 24 percent between 1990 and 2014 (SEPA 2015a) while, in the same period, GDP increased by nearly 62 percent (Statistics Sweden 2015). This would indicate a substantial decoupling of emissions from economic growth, but the picture looks less promising from a consumption perspective, where international travel and emissions embedded in imported goods are added and emissions from exports are deducted. Although consumption-based accounting of GHG emissions entails larger uncertainties, previous estimates indicate substantially higher emission levels for Sweden than from a territorial accounting (Davis & Caldeira 2010) and that the emissions are not decreasing (see Figure 1 below, SEPA 2015b). Between 1993 and 2013 the share of GHG emissions from imported goods and services consumed in Sweden increased by 50 percent (from 45 to 65 percent of total emissions, SEPA 2015b).

These trends are not covered by the official territorial accounting, and as long as binding GHG emission targets are not in place for developing countries, this "leakage" of production related GHG emissions to developing countries could hardly be seen as a sustainable path towards the future.

As can also be seen in Figure 1, two very GHG intensive consumption categories beef consumption and international air travel have also increased rapidly in the last decades. The total consumption of beef increased by 67 percent between 1993 and 2014 which is an average growth rate of 2.5 percent per year, slightly faster than growth in GDP (Swedish Board of Agriculture 2015). The number of passengers on international flights increased by a massive 194 percent between 1993 and 2014 which is on average 5.3 percent per year (Trafikanalys 2015). GHG emissions from air travel is not entirely covered under the UNFCCC framework and reliable data is missing, but Larsson et al. (2015) estimated that when the effects of high-altitude emission are included, GHG emissions from air travel by Swedish citizens amounted to 1.1 tons CO_2e per person and in 2012, roughly the size of emissions from private automobiles that year. The fast growth rate of both air travel and beef is worrying in itself, and adding to this the technical potential within these areas is relatively small, and there are currently no policies in place to counter these increases.

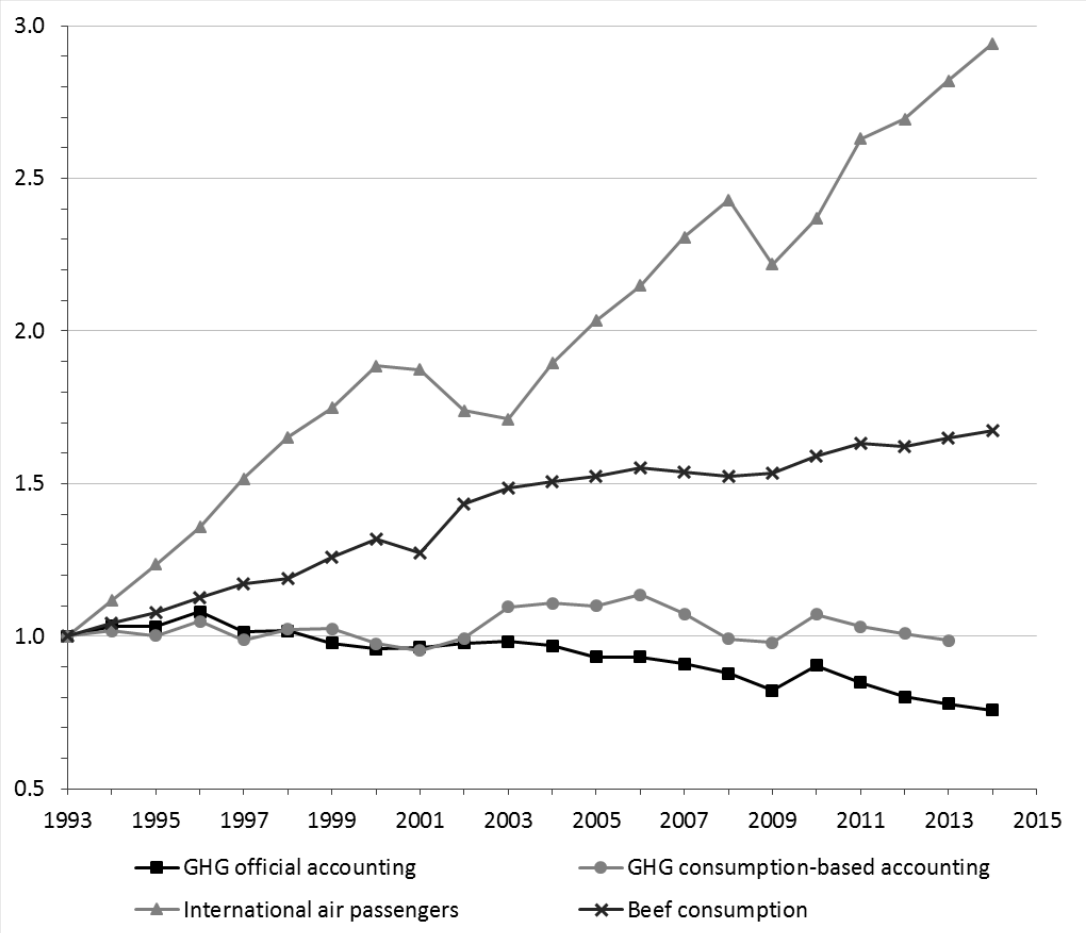

Figure 1: Trends in Swedish GHG emissions according to official accounting and consumption based accounting together with trends in two GHG intensive consumption categories: beef consumption and the number of passengers on international flights from Swedish airports between 1993 (index 1) and 2014. Data sources: SEPA (2015a, 2015b), Trafikanalys (2015), Swedish Department of Agriculture (2015).

Taken together, the increasing amount of GHG emissions being caused outside Swedish boarders and the increase of specific GHG intensive consumption sectors indicate that a successful fulfillment of the two-degree climate target requires action that goes beyond eco-efficiency, by also considering lifestyles and consumption patterns. In recognition of the need to extend policy ambitions beyond national borders the Environmental Goals of Sweden now states the: "The overall goal of environmental policy is to provide the next generation a society in which the major environmental problems in Sweden have been solved. *This should be done without causing increased environmental and health problems outside of Sweden.* The overall goal requires an ambitious environmental policy in Sweden, EU and international contexts." (Swedish Environmental Goals, 2009).

2.1 Measuring households' GHG emissions

In the light of the need for radical cuts in emissions from Swedish households described above, it is of interest to study the reasons behind the considerable variance in current emission levels between individual households. Paper I and II attempt to analyze these differences in a sample of Swedish households. In order to be able to measure households' GHG emissions in a detailed manner, measurement of emissions needs to be fairly thorough. For the survey used for Papers I to III a methodology was developed (see Table 1) and some questions used to estimate GHG emissions were established (for a Swedish version of this survey, see Appendix A).

A pilot survey was distributed to 87 persons in order to test the distribution of answers on different scales and to receive feedback on the formulation of some of the questions. The main survey was sent out in May 2012, to a random sample of 2500 individuals between 20 and 65 years of age, residing in the Västra Götaland Region in the southwest of Sweden. The net response rate amounted to 40.1%, after two mail send-outs, three postcard reminders and a telephone reminder.

Table 1: Indicators used to measure GHG emissions per adult for the different consumption categories, with mean value (M) in CO_2e metric tons and standard deviation (SD) indicated.

Category	Data source(s) and calculation method(s)	*M*	*SD*
Private car transport	Odometer readings from the two most recent vehicle inspections, along with other relevant data such as fuel type, fuel consumption, CO_2 emissions, vehicle brand and model, as obtained from the Swedish Road Registry (2012). In the case of new cars (not inspected in the first three years), the respondents' self-stated annual driving distances were used, combined with vehicle-specific data from SRR. The fuel consumption figures in SRR are based on the NEDC test-cycle scores (all electric equipment turned off, optimal driving conditions), with fuel consumption from regular usage estimated to be 15–40% higher (Patterson, Alexander & Gurr 2011). For this study, a conservative +20% figure was used.	1.7	(1.5)
Public transport	Respondents' self-reported weekly commuting choices and distance to work. Estimates of CO_2 emission intensities from public transport were obtained from the local public transport operator, amounting to 0.031 $kgCO_2$/pkm (0.04 $kgCO_2$/pkm for bus travel, 0.02 $kgCO_2$/pkm for trams and commuter trains).	0.06	(0.16)
Air travel	Respondents' self-reported number of vacation trips taken by air to other European countries in the past 2 years and of inter-continental flight trips in the preceding 5-year period. Average distances were calculated using the distance and frequency to the different destinations in the Nordic countries, Europe, and the rest of the world from the main international airport in the study region. Estimates of average CO_2e aircraft emissions per passenger kilometer were obtained using the Finnish LIPASTO calculation system (2012)A conservative high-altitude factor of 1.7 was used to incorporate the full GWP effect of contrails and induced cloud formation from longer flights (cf. Azar & Johansson 2012).	1.5	(1.4)
Electricity	For 215 of the total of 1,004 respondents, electricity consumption figures obtained from utility company data. For the remaining households in the survey, a model (R^2=0.61) was constructed based on this consumption data in conjunction with survey data on self-reported electricity use, the type of appliances used, and type and size of residence, to estimate their electricity consumption. The European Union electricity mix of 0.305 kg CO_2e/kWh was used to estimate emissions from electricity consumption.	0.9	(0.8)
Space and water heating	GHG emissions were calculated as the product of five factors: residential area, energy performance, heating system efficiency, indoor temperature, emissions factor. For households living in buildings for which a formal energy declaration existed (38% of the sample), some of this data could be obtained directly from the country's national energy declarations registry; for the remaining households data obtained through the questionnaire was used.	1.3	(1.1)
Food	Given the survey's scope, measuring the emissions from all food products was not feasible. The focus was therefore laid on meat consumption, which accounts for a large share of emissions and much of the variation between individuals. Average emissions from food consumption in Sweden are estimated to amount to 1,500 kg CO_2e/cap/yr, of which 800 kg originates from meat consumption (Bryngelsson et al 2013). A multi-item question asking respondents to assess the composition of their diet was therefore used, in conjunction with readily available GHG emission estimates (Röös 2012), to calibrate the 800 kg CO_2e per capita. Emissions from other food types were estimated to be 700 kg CO_2e per capita for all individuals in the sample.	1.5	(0.2)
Other consumption	This category covered clothing, consumer electronics, entertainment, and the like. A model (R^2= 0.88) was constructed using data from the household budget surveys of Statistics Sweden (2008) in conjunction with emissions data from the same agency's annual environmental accounts, to assess the relationship between expenditures on consumption falling into this category and the resulting GHG emissions. The model was then used in conjunction with estimates of each respondent's remaining consumption space as derived from the obtained survey data on income, savings, and other large budget posts.	1.3	(1.0)
Total		8.2	(3.2)

2.2 Paper I: Estimating the importance of different factors to households' GHG emissions

Previous research has established that one of the most important factors determining households' GHG emissions is household income (Gough et al 2011, Kerkhof et al 2009, Chitnis et al 2014, Nässén 2014, Girod & de Haan 2010)). Household size also to some extent determine the households' emissions as living quarters are shared and many other necessities such as transport, household consumption (furniture, household appliances etc.) do not scale (Tukker et al 2010, Gough et al 2011). Gough et al (2011) also found that being employed increased households' GHG emissions when relevant factors were controlled for, mostly because of commuting.

Also, the location of the dwelling affects the overall need for private transport and also differences in living space (Jones and Kammen 2011, Tukker et al 2010). As we will see, Paper I will add to this understanding through the use of an estimate of the centrality of the dwelling (distance to different societal services).

The level of education has also been found to be positively associated with GHG emissions when income differences have been controlled for (Buchs and Schnepf 2013). Gender differences has also been found to generate differences in energy use as men tend to eat more meat than women and drive longer distances (Räty & Carlsson-Kanyama 2010).

Paper I analyzes factors from different areas of research in order to provide an understanding of their relative importance to determining households' GHG emissions.

2.2.1 Objective

Consumption-accounted greenhouse gas emissions vary considerably between households, and research from different traditions have explored different factors that may help explain this variation. Paper I explores the explanatory value of these different variables in the same empirical material, three areas/factors are identified: Previous research on consumption patterns has shown a strong relationship between *socio-economic factors* such as income/expenditures and energy and/or GHG emissions. Research on *urban planning* has naturally focused on infrastructural and spatial variables to explain energy use, and this research has found results suggesting that urban form variables has a large effect on households' energy use. *Social and environmental psychology* on the other hand, has developed models that form interesting foundations for understanding and explaining human behavior, e.g. the roles of norms and values (Aijzen 1991; Schwartz 1992, 2006).

2.2.2 Main Findings

- The results stress the importance of explanatory variables that have to do with circumstances rather than motivations for pro-environmental behaviors.
- Net income was found to be the most important variable to explain GHG emissions, followed by dwelling type and geographical distance to the workplace.
- The results also indicate that social norms related to GHG-intensive activities, for example transport, may have a larger impact on a subject's emission level than pro-environmental attitudes.

2.2.3 Relevance and reflections

The result that income is the single most important variable for explaining variation in households' GHG emissions is in line with previous research (see Clift & Druckman 2016 for a review of this research). The crudeness of estimations on other consumption, where income determines the size of GHG emissions from this sector could however be further studied by analyzing the actual consumption of different income groups. Also, the fact that this study is conducted in a confined geographical area with a certain level of population density, public transport and so on, limits the generalizability of the results regarding the importance of physical structures to GHG emissions.

2.3 Paper II: Do materialists emit more GHG emissions than others?

Paper II continues the examination of factors that may affect households' GHG emissions by specifically analyzing the effect of materialistic values. According to Paper I above, "motivational factors" have a relatively weak effects on GHG relevant behaviors, which indicates that materialistic values are unlikely to affect respondents' GHG emissions, but the actual results suggest a more complex picture.

2.3.1 Objective

The aim of Paper II is to specifically examine the importance of materialistic values (Richins & Dawson 1992) in relation to the climate issue. Some research suggests that societies around the world have grown increasingly materialistic over the course of the last decades (Brown & Kasser 2005, Ger & Belk 1996; Twenge et al 2012; Twenge & Kasser 2013). Yet other research suggests that materialists care less for the environment and that their lifestyles are more resource demanding and hence environmentally damaging (Hurst et al 2013). This paper

attempts to examine if and how materialists differ from others in terms of their GHG emissions and environmental concern.

2.3.2 Main Findings

- GHG emissions differed between respondents scoring relatively low and high on the materialist values scale, and differences in air-travel made up the only significant difference.
- Respondents with materialistic values generally score lower in environmental concern, but in a more thorough analysis, where the dimensionality of the materialist construct was taken into consideration, these results become less clear and the relationship between materialism and environmental concern can be questioned.
- Respondents with materialistic values fly much more than others and also seem to be willing to spend a greater proportion of their income on an attractive living. Surprisingly they are less likely to own a car. This suggest that the status-seeking behavior of Swedish materialists differs from previously studied populations.

2.3.3 Relevance and reflections

The results of Paper II, although weak, suggest that materialists tend to travel by plane more often than others, while they are less likely to own a car. These results raise several questions that are examined at length in the discussion section in Paper II. The surprising results regarding the behavioral linkages to materialistic values, clearly indicates that more research should be conducted in this area. It may also prove fruitful to evaluate values underlying status seeking behaviors more directly (see e.g. the "Aspiration Index" in Kasser 2003).

3 Greenhouse gas emissions vs. quality of life

This section adds to the discussion on how to measure societal development "beyond growth" by measuring individuals' quality of life and comparing these estimates with different environmentally relevant behaviors. As discussed in Section 1, the ecological modernization approach is based on the idea that technological improvements can solve the challenge of increasing GHG emissions, and that lifestyle changes need not be necessary. The reason for the reluctance towards policies aimed at lifestyle changes is likely to also more generally be connected to politicians concern for unemployment and people's unwillingness to change their behavior, and these issues may in themselves constitute an obstacle to bringing about consumption changes. But the limited amount of research that has examined the actual relationship between emissions and quality of life has not come to any clear conclusions (Zidansek 2007, Jackson 2005). Paper III and IV analyze questions related to the relationship between individuals' quality of life and environmentally relevant behaviors. These are described further in Sections 3.2 and 3.3 respectively, but first a brief description of how quality of life can be measured.

3.1 Measuring the good life

The measurement of valuable life circumstances covers many different approaches and anyone interested in trying to understand the relationship between such characteristics and individuals GHG emissions must first decide which indicator to use. Researchers have developed various measures that seek to define the good life in either subjective or objective terms. It is also possible to distinguish between theories that use material conditions and those that also use other non-material indicators to define people's quality of life. Table 2 below summarizes the various options and some of the approaches that can be placed in respective category. In the following we will briefly describe the different theories.

Table 2: Different perspectives on quality of life (from Holmberg et al 2012)

	Objective measures	*Subjective measures*
Narrow material perspective	Income and GDP/GNI	Satisfaction with material assets
Broader quality of life perspective	Standard of living, capabilities	Subjective well-being, Human flourishing

3.1.1 Objective measures

Probably the most widespread measure of welfare is gross domestic product (GDP). GDP measures the economic activity within the nation state and is frequently used at a macro level as an indicator for comparisons of living standards between different countries. This measure is often used presumably because it is supported by the assumption that increased economic productivity functions as a rough indicator of material condition and because it can be measured with a relatively high accuracy.

The theoretical foundation for employing income as an indicator for quality of life can be traced to Paul Samuelson's theory of "revealed preference", where people's actual behaviors are used to describe their likings or preferences (Samuelson 1938). This theoretical advancement allowed economic theory to free itself from some of its utilitarian heritage and the so called "ordinal revolution" was underway (see Robbins (1932) for an overview). Supported by assumptions about rational individuals, it now became possible to argue that consumers' preferences represented a more functional estimate of "utility" than the original Benthamite attempt. This shift also allows the use of objective measures of income to estimate well-being, as higher incomes lead to increased potentials to satisfy different preferences. The assumption is simply that higher incomes give people more options to steer their lives towards whatever gives them more happiness, but it also separates itself from the individual's hedonic appreciation of his/her own life.

There also exist several attempts to find objective indicators that captures a broader qualitative domain of individuals' quality of life. The best known example of this approach may be the capabilities approach (Sen 1985; Nussbaum 2001), which singles out particular skills or capabilities as universally central values in our lives. The capabilities approach takes as its starting point how a combination of external circumstances together with a person's attributes and life situation results in the individual's actual capacity for freedom of action. The theory was highly influential, inspiring the UN to produce the Human Development Index (HDI) which combines objective and subjective factors.

Other prominent systems of indicators aimed at capsuling objective factors necessary for a good life include the Social Progress Index (SPI), which measures the extent to which countries provide for the social and environmental needs of their citizens (Porter 2013) and the Happy Planet Index (HPI) that combines indicators of well-being with the countries' ecological footprints (Abdallah et al 2009).

3.1.2 Subjective measures

There exist many different subjective measures, but arguably the most well-known term is "Subjective well-being" (SWB). SWB includes both affective states (pleasure and discomfort) and satisfaction with life as a whole or with a particular aspect of life and weigh them together (Diener et al. 1999). Subjective well-being therefore implies that happiness is both a state of feeling good overall, and valuing one's life positively (Brülde 2007). This concept has however also been criticized, as research suggest that the two concepts are not always one-dimensional and should be studied separately (Diener et al 2003), however for Paper III and the present Swedish sample the Pearson's r showed strong correlation between the terms (0.77) and was determined as sufficient.

Another subjective well-being construct is the ancient Greek's concept of *Eudaimonia* sometimes understood as "human flourishing" that concerns people's self-perceived success in important areas of life, such as relationships, self-esteem, purpose, and optimism. This has been captured in the Flourishing scale (Diener et al 2009).

Research that attempts to define well-being in subjective terms can be summarized in two different explanatory models (Wilson 1967). The older theory holds that the satisfaction of needs is believed to cause happiness, while psychologists have later come to believe that the degree of fulfilment required to produce satisfaction depends on adaptation or aspiration level, which is influenced by past experience, comparisons with others, personal values, and other factors. In a way, the different domains of the objective indicators may be important determinants of well-being, but lack final value. The relativization of the concept of well-being has strengthened the notion that subjective well-being cannot be reduced to objective factors (Diener et al 1999).

This is important since the choice of measure is of major significance to the links that can be found between quality of life and greenhouse gas emissions. Figure 2 shows the development of relative household expenditures in Sweden between 1995 and 2012, and the corresponding development of Swedish citizens' relative life-satisfaction during this period. If material standard of living measures are used to estimate the degree of quality of life, in principle it postulates a positive correlation between increased quality of life and increased greenhouse gas emissions, while if a subjective measure is selected, the connection depends on people's habituation to a higher standard of living. When analyzing the relationship between quality of life and GHG emissions in a rich country, we therefore believe it makes more sense to rely on subjective well-being.

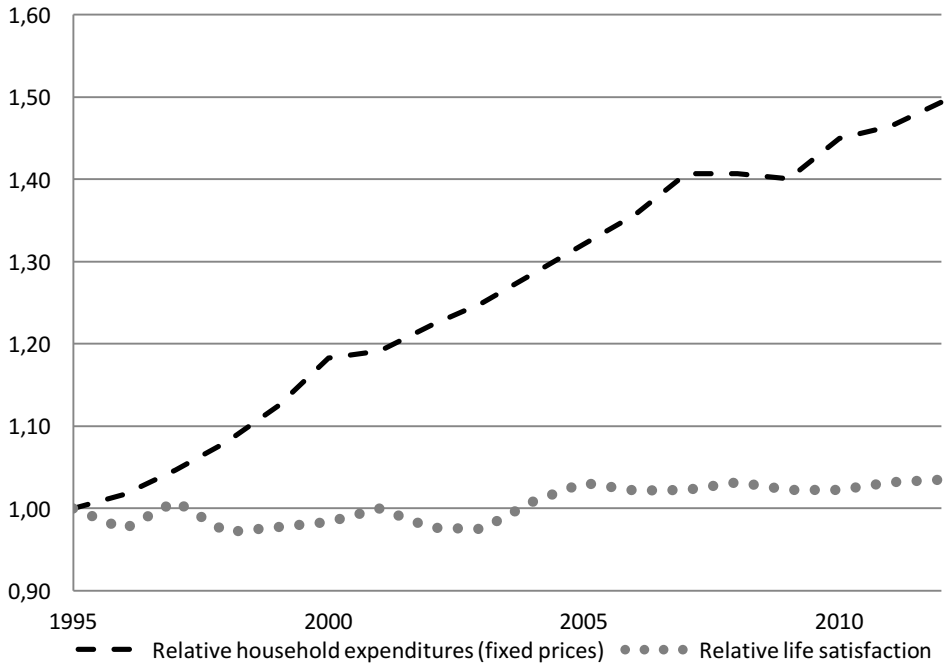

Figure 2: The development of households' expenditures (in fixed prices) and relative life-satisfaction in Sweden between 1995 and 2012. Data on Household expenditures were collected from Statistics Sweden (2015) and data on relative life-satisfaction was collected from the SOM institute (2014) and measured on a 0-10 scale (mean 1995 = 7.51, 2012=7.77).

3.2 Paper III: Low-carbon lifestyles and subjective well-being

Paper III analyzes the relationship between individuals' subjective well-being and GHG emissions from consumption. Previous research that has analyzed the relationship between quality of life indicators and GHG emissions has mainly approached this issue by means of country comparisons (Zidansek 2007; Abdallah et al. 2009; Mazur 2011). Results from these studies suggest a positive but diminishing relationship between the GHG emissions of a country's inhabitants and their subjective well-being (SWB).

3.2.1 Objective

The first aim of Paper III is to analyze the relationship between individuals SWB and their GHG emissions. A second aim of the Paper is to analyze the specific relationship between SWB and certain GHG intensive activities such as air-travel, leisure-driving, share of red meat in diet and dwelling size. A third aim of the study is to examine the hypothesis that lifestyles and values related to the concept of downshifting would imply a double dividend, i.e. that these individuals ought to both have higher SWB and lower GHG emissions than others. Figure 3 below illustrates the results.

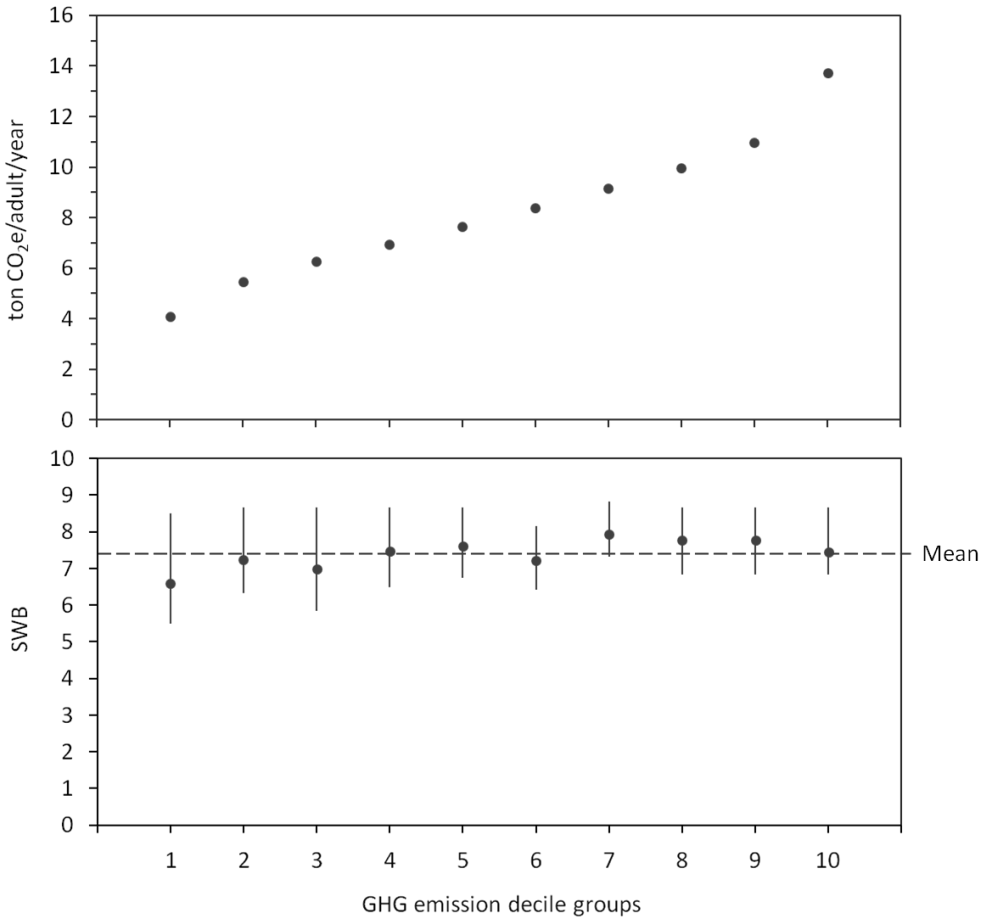

Figure 3: GHG emissions and SWB sorted by GHG emission decile groups. Data from citizens in Western Sweden. The points in the upper diagram represent the average emission levels in ten decile groups (each group represents around 100 households). The lower diagram shows the corresponding average levels of subjective well-being in these decile groups. The vertical lines represent the inner quartile ranges.

3.2.2 Main findings

- There is no strong link between individuals' total GHG emissions and their level of subjective well-being when relevant factors are controlled for.
- A continued analysis of certain specific GHG intensive activities and living conditions and the relationship to SWB showed that the relationships are generally non-significant.
- The double-dividend hypothesis was tested by analyzing households with low GHG emissions and high SWB, to see how they differed from other respondents. A result that stood out from this analysis was that materialist dispositions seem to correlate negatively with SWB and positively with GHG emissions.

3.2.3 Relevance and reflections

Paper III examined the relationship between GHG emissions and subjective well-being in a cross-sectional sample of the Swedish population and found no strong statistical relationships between the two. Does this mean that we could enforce environmental policies that would target specific GHG relevant behaviors without any effect on subjective well-being? No, as pointed out by Kahneman (1999) our results do not exclude the existence of a dynamic effect on SWB of behavioral changes that reduce GHG emissions; a person that is used to going on a winter holiday to the sun and that can no longer afford this because of taxes on air travel is likely to feel at loss. Even behaviors that have become habitual parts of one's lifestyle may be hedonically neutral to us in our everyday life, but changes to such behaviors may still imply negative effects on our subjective well-being.

3.3 Paper IV: Do changes in travel behavior generate changes in well-being?

Paper IV analyze, among other things, how behavioral changes of car usage from implementing economic policies affect individual's satisfaction with his or her daily travel. This study therefore adds to the understanding of how behavioral changes affect peoples' subjective experiences posed in Section 3.2 above.

3.3.1 Objective

In Paper IV we follow the introduction of the congestion charge scheme in Gothenburg in 2013. Congestion charges are directly aimed at changing the travel behavior of individuals and by using the implementation of this scheme as a case study it is possible to learn more about the dynamic effects on well-being from changes in GHG emission relevant behaviors. A survey was conducted including measures of commuting habits, attitudes (toward the congestion charge, the environment, auto-mobility, and public transport, see Appendix B for a Swedish version of the form), and satisfaction with travel, along with socio-demographic and geographical variables. The survey was distributed to a panel of 3,500 car owners just before the implementation of the scheme and again one year later. This approach enables the identification of individual adaptation strategies, and also serves an opportunity to compare how commuting patterns change among "treated" groups (i.e. respondents who cross the cordon regularly) and "non-treated" groups (respondents who do not). On research question is what characterizes the individuals who changed their commuting behavior in response to the introduction of the congestion charge, compared to those who did not and chose to pay the

congestion charge instead? The analysis also considers the role of different socio-demographic variables such as gender, age, education, household income, and the number of adults and children (over and under 18, respectively) in the household.

3.3.2 Main findings

- No change in satisfaction with travel could be observed for any of the studied groups during the period, irrespectively of if they changed their travel behavior or not.
- The respondents' attitudes toward congestion charges grew more positive once the scheme had been introduced and the system was put in place, although a majority of the respondents did not view the congestion charge scheme favorably throughout the study period.
- Geographical and accessibility factors seemed to generate a shift in transport mode, while socio-demographic variables played a smaller role in predicting commuters' adaption strategies. Gender, however, had an impact since women were more likely to change behavior than men.

3.3.3 Relevance and reflections

The results from Paper IV suggests that, taken as a whole, the introduction of the congestion charge scheme and the behavioral changes it entailed for the study participants did not translate into any significant changes in their subjective commuting experience. This finding fits well with the finding that the respondents became more positive towards the congestion charge scheme once it was introduced.

4 Energy efficiency, behavior and the rebound effect

Energy efficiency has been identified as the most important strategy for climate change mitigation (IEA 2010). But as mentioned in the introduction, doubts have also been raised on to what extent energy efficiency can reduce environmental impacts, since efficiency improvements may "rebound" through increasing consumption and take back some of the technological gains. Paper V presented in Section 4.1 analyzes the direct rebound effect among households who change car, and the remaining part of this section provide an introduction to the rebound effect and some suggestions.

It is possible to distinguish between at least three mechanisms behind rebound effects. First of all, new energy efficient technologies reduce the marginal cost of the energy services they provide and may therefore result in increasing energy service demand. For example, a household buying a fuel-efficient car will face lower marginal costs per km and would hence be likely to drive longer distances. This mechanism is often referred to as the *direct rebound effect*. Moreover, energy efficient technologies may save money which can be used for an increase in consumption of other products and services, e.g. money saved on fuel costs are likely to be used on something else, hence generating emissions from this consumption. If a household saves money on better fuel economy and use their savings on a vacation trip the indirect effect of changing to a fuel efficient car might not be good for the environment. This mechanism is often called the *indirect rebound effects*. A third effect is the less tangible *economy-wide rebound effect*. Such macro-effects may take place since reductions in energy demand may result in lower fuel prices, which in turn cause increasing demand by other actors.

While the mechanisms behind potential rebound effects are rather well known, it is the magnitude of these effects which is the crucial point for whether energy efficiency can play its projected role for environmental policy or not. A problem with potentially high rebound effects is that it would make it more difficult to reach policy goals than expected.[5] If the potential for reducing demand by means of technical energy efficiency is lower than expected, lifestyle changes may have to play a more important role. However, another possible conclusion would be that the transition towards long-terms climate targets will require even stronger policy

[5] The rebound effect is not in itself a bad outcome. The case is rather that improved energy efficiency, defined as the ratio of energy to energy service demand (e.g. liter of fuel per km), will tend to *either* reduce energy demand *or* enable increased demand of the energy service. In some cases, increases in service demand is the entire point of improving energy efficiency, e.g. to create an affordable healthy indoor climate for "energy poor" households in some countries.

measures for example in the form of higher carbon taxes. Hence, improved understanding of the mechanisms and scale of the rebound effects has relevance for policy-making and long-term industrial planning.

Better data on rebound effects would also provide important information to the construction of energy system scenarios, which usually neglect connections between adoption of energy efficiency and development of demand. Moreover, without a well-developed understanding of the rebound effects of real energy efficiency measures, there is a risk that the perception of energy efficiency may tilt from naive belief in the effects of technology to exaggerated claims that energy efficiency has no role to play in climate change mitigation. For example, the Confederation of Swedish Enterprise (Fölster & Nyström 2009) seems to have adopted a pessimistic view of the importance of energy efficiency improvements by focusing too much on rebound effects. The rebound effect is also often pointed out as a major issue by proponents of sufficiency strategies as an argument against industrial ecologists' visions of a seamless transformation towards a sustainable society (Sanne 2000). Further research on the actual effects of energy efficiency improvements is needed to provide a better foundation for improved scenarios, policy-making and planning.

The results of quantitative rebound effect analyses clearly depend on several different aspects. Which of the different categories of rebound effects are analyzed? What assumptions are made about the costs related to the improvements and what type of technological change is analyzed? Also, most of the previous literature on rebound effects is based on theoretical models using data from cross-sectional statistical analyses (e.g. comparing households at different income levels) or aggregate data on price fluctuations and consumption. Paper V instead approach this problem using a simple statistical approach.

4.1 Paper V: Do people really drive more when they change to a fuel-efficient car?

Paper V analyze the actual behavioral changes of households who change car by following the changes in fuel efficiency and annual driving distances for individual households in the years before and after they change their car. By means of the Swedish car registry a longitudinal analysis of annual driving distances for 8,810 single car households is conducted. Because of discrepancies between type-approved fuel consumption (based on the New European Driving Cycle) and real-world reported figures (Ntziachristos et al 2014) a model was constructed that allowed for a correction of type-approval estimates.

4.1.1 Objective

Paper V estimates the direct rebound effect for personal automotive transport. The direct rebound effect for the entire sample is estimated and effects for specific socio-demographic groups are examined. The results are illustrated in Figure 4 below.

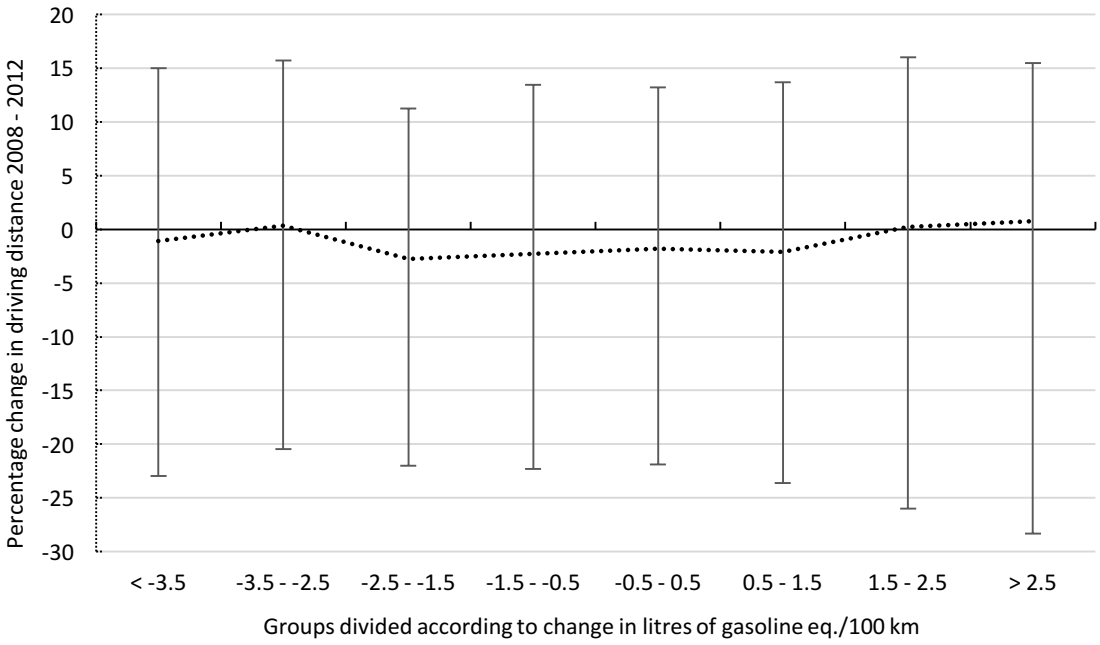

Figure 4: Mean value change in driving distance between 2008 and 2012 split into groups according to change in (type-approval) fuel consumption per kilometer. Vertical bars represent inner quartile ranges. A hypothetical rebound effect would emerge as a line from the upper left to the lower right in the figure.

4.1.2 Main Findings

- The results for the full sample indicate no direct rebound effect, as households who changed to a more fuel-efficient car did not increase their driving distances in relation to those who bought a less fuel-efficient car (see Figure 4).
- Significant but relatively small rebound effects are found for low-income earners (8-10%) and for people living in rural areas (6.6%, although only for estimates using our corrected "real-world" fuel consumption and only weakly significant) when the whole sample populations is included (both households who changed to a more/less fuel efficient car.
- When the direct rebound effect is estimated only for households who change to a more fuel efficient car (the left half of Figure 4), the rebound effect for low income earners is higher (10-18%), and also for households in rural areas (14-22%).

4.1.3 Relevance and reflections

Paper V provides a novel attempt to estimate the direct rebound effect within the private transport sector, and the findings suggest that, on average, Swedish households do not drive more if they buy a more fuel efficient car. This result strongly diverges from previous research where the median direct rebound effect from transport has been estimated to around 25% (Sorrel et al 2009). Employing the same methodology for other countries would therefore provide valuable information as to the generalizability of these results.

Since small direct rebound effects are likely to translate into large indirect rebound effects, the examination conducted in Paper V cannot determine the overall rebound effect of improved fuel efficiency. However, since car fuel is one of the most GHG intensive consumption items the indirect rebound regarding total GHG emissions is probably limited. Indirect effects are likely to be comparatively small but the economy-wide effects of a more competitive private transport sector may prove to be significant over time.

Depending on the generalizability of results found in Paper V they may also play a role in the overall understanding of the relative importance of different factors contributing to rebound effects. Rebound effects are often portrayed within a neo-classical framework and although economic factors certainly play a role in determining the size of the rebound effects, peoples' habits, strivings and collectively agreed aspirations also determines how household budgets are spent. In order to better understand the size and nature of the rebound effects in different sectors, one would need to follow several households who invest in different energy efficiency improvements, and ideally also analyze both the direct and indirect rebound effects related to these changes. Changes in spending patterns should also be analyzed in relation to a broader field of social factors.

5 Future research: A novel ICT-based approach

The work in this thesis is largely descriptive, analyzing factors that affect households GHG emissions, examining the relationship between subjective well-being and environmentally relevant behaviors and investigating the rebound effects caused by the change to more fuel efficient cars. Understanding these issues may be important, but in the end, what is really interesting is to learn more about how unsustainable lifestyles are reproduced and how the emergence of more sustainable lifestyles may be promoted. During my five years as a PhD student I have spent some time thinking about these issues and also developed a novel idea for an ICT solution that has the potential to further such changes. This ICT solution may also enable some highly relevant research within the field of sustainable consumption, and in this section I will give a brief description of this idea.

Much has been written about the role of citizen empowerment and ICT solutions in bringing about a more sustainable development. Modern ICT has changed the way we communicate and inform ourselves, it permits social networks between friends, neighbors and peers to form all kinds of formal or informal relations. Governments are also interested in seizing the opportunities of ICT-based solutions to improve the efficiency and service of their infrastructure. ICT also holds promises for increased citizen empowerment through information and transparency and hereby also potentially increasing the legitimacy of government. Still, comparatively little "real" development seems to have been realized, no new groundbreaking apps have surfaced that actually helps people live more sustainably or feel empowered vis-a-vis government or businesses, and the benefits of ICT solutions are still largely awaited.

The web-service www.svalna.se provides the user with a picture of his/her GHG emissions and is currently being beta-tested. The service has been developed with financial support from Västra Götaland Region, Chalmers, and the municipality of Gothenburg that also plan to use the service as a platform to connect to individuals who are devoted to living more sustainably. In order to calculate users' GHG emissions the service employs inputted data, registry data and transactions data from the users' bank statements. If the users choose to connect their bank account to the service[6], each transaction is automatically classified according to a certain categorizations scheme (an adjusted COICOP scheme) and combined with estimates

[6] The European commission and Parliament has adopted the revised Directive on Payment Services (PSD2). The directive regulates payment services and payment service providers throughout Europe. The PSD2 will open up payment markets to third party service providers which will facilitate the development of services that can make use of this technology in all of Europe. Some Swedish banks have chosen to act progressively and allow for third party usage already today.

of CO_2e per monetary unit from environmentally extended input-output (EEIO) analysis[7] this provides an assessment of that person's emissions from consumption of goods and services.[8]

Building on this data it is relatively straightforward to present the user with different sets of information and the inflow of data allows some new dynamics. The system allows for drill-downs on different consumption categories and since banks in Sweden store transaction data of up to a year, a user is often able to follow his/her emissions a year back in time to see how different months affect their GHG emissions. The project has not yet been able to obtain sufficient funds to allow the development of many key features. The current system nevertheless allows for the design, screening and computation of tailored *suggestions* on different investments or behavioral changes and their corresponding GHG reductions. Additional opportunities to match data on the type of building or vehicle the user owns in order to improve the accuracy of suggestions are being elaborated, and the mapping of available registry data available for individual households and bottom up models on energy efficiency improvements has been verified.

The system also supports the use of *campaigns,* in the form of more general and playful ways of testing new lifestyles. This feature allows the user to "pledge" to try something new for a shorter period of time and he/she also becomes member of a group allowing specified feedback and aggregate data to be collected to be able to evaluate the effect of that certain campaign. The beta version also allows the individual to make *comparisons* of his/her GHG emissions with averages in different nations. The opportunities to extend on comparisons to also allow for comparisons with friends (identified through social networks) and local communities etc. would further add to the dynamic of comparison, self-efficacy (for example, assessing emission reductions since last month) and possibly also competition with others. The system also provides an estimate of the annual GHG emission abatements needed in order for the user to reach one ton of GHG emissions per year by 2050.

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[7] EEIO-based approaches have been used for analysis of global carbon emissions (Peters & Hertwich 2008, Wiedmann 2009, Minx 2009, Davis & Caldeira 2011), water (Hoekstra & Chapagain 2007, Hoekstra & Mekonnen 2012), ecological (usually the area of wilderness of both land and sea needed to supply resources, see Bicknell et al 1998, Wiedmann et al 2006, Galli et al 2013), nitrogen (Leach 2012) and biodiversity/wildlife footprints (Lenzen et al 2012, Kitzes 2012). Other uses beyond environmental accounting could include for example estimations of the share of consumption originating from different countries, the total tax payments generated from all consumption etc.

[8] Obviously consumption data only provides a rough estimate on GHG emissions, and for food and air travel these estimates may be very different from the "real" GHG emissions caused by the individual. The Svalna system currently being tested relies on transaction data for GHG estimates of most consumption but also use an online questionnaire to estimate dietary choices and a specific carbon calculator for estimates on air travels.

Before we continue to describe the potentials for experimental research based on this system, it should be noted that the mere measuring and surveying of Svalna users would provide reliable estimates needed for the kind of work done in this thesis, which would also allow for much needed comparisons between results and studies (e.g., Gatersleben, Steg, & Vlek 2002).

The use of research findings from social and environmental psychology, where the screening may allow for messaging using moral foundation theory can be evaluated and employed. By using opportunities for visual communication based on personalized information it may also be possible to use future self-continuity experiments where the idea is to counteract short-sighted behavior (in this case non-environmental friendly behaviors) by a temporal broadening of the concept of the self. For example, by showing a timeline where past and future life-events (pension, anniversaries, death, kids lifespan, grandchildren's lifespan etc.) could be mapped on a chart showing increased global temperatures and consequences hereof. Other theories from marketing research and behavioral economics including nudging theory are also strikingly appealing, and much could be learned given the opportunities to set up experimental designs and use large samples of users. But these "manipulations" also entail the risk for compensatory reactions as the user may feel he/she is being controlled and should only be used in experimental settings where users are "debriefed" after new interventions.

It may also be fruitful to conceive of other social theories. In her provocative paper Elisabeth Shove (2010) "reflect on what seems to be a yawning gulf between the potential contribution of the social sciences and the typically restricted models and concepts of social change embedded in contemporary environmental policy…", hereby criticizing the economic and psychological models and understandings of behavioral change that supposedly dominates the policy landscape. Her suggestion is to instead use *practice theory* to be able to better understand social change. Practice theory (Bourdieu et al. 1999: 19) represents a possible unifying theory between the individual and systemic approach, as it "seeks to explain the relationship(s) that obtain between human action, on the one hand, and some global entity which we call 'the system' on the other." (Ortner 2006). Sustainable consumption research involves research both at the individual level (e.g. identifies drivers of consumption behaviors and how they evolve over time) and at the system level (e.g. how a policy has effected the development), and could benefit by employing an approach that allows a bridging of these two perspectives (Spaargaren 2011). These two approaches both have limits to entirely understand the complexity of the quest for more sustainable consumption; the individualist approach neglects the system in which individuals act and shape their behavior while the systemic

approach fail to explain the role of consumers within the system (Røpke, 2009; Spaargaren 2011). Here practice theory is often put forward as a promising idea.

This approach could prove interesting as it seems much of the work relating ICT to the possibilities to "generate" behavioral change, revolves around concepts taken from psychology while not much quantitative work seems to have been done to analyze environmentally relevant practices. Through the access to consumption data from many different users it should be possible to cluster users based on broadly defined concepts of lifestyle parameters. Further, through data analyses of differences in consumption between people it ought to be possible to identify and operationalize certain practices. For example, the practice to "play golf with friends" could thus be identified through key consumption characteristics such as spending on a green-fee or maybe a snack at the country club, somewhat increased costs from the categories "sporting gear" and "gasoline", and further analyses of other practices held by this individual. By combining clustering and identified practices it is also possible to follow the evolvement of certain lifestyles and specific practices and how they emerge, and through surveying it is possible to learn more about their meaning.

A weakness is that data collection would need to rely on voluntary sharing of data (in order not to scare off users). But the spread of recent trends in citizen research suggests the involvement of users in research and sharing findings may convince at least a portion of users would be willing to share certain anonymous. Beyond opportunities for research an ideal approach is of course to spread knowledge and understanding of climate and sustainability issues. The user's utilization of a web-service that continuously provides interesting feedback on consumption, mind provoking comparisons together with information on environmental impacts of different activities, could in itself form the groundwork for intellectual processes that alters the user's understanding of what is desirable and fruitful. Hence, new routines may appear gradually.

The system itself, if allowing social interaction and a sense of shared understanding, could even prove to be a pocket where new ideas, solutions, and cultures can evolve and spread. The question of if and how to further the emergence of such "sustainability enlightened" communities that could "redefine the rules of the game" is an open and future issue, but providing a room for a larger social setting where people can jointly deal with the change to a sustainable future seems promising.

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