A carbon footprint proportional to expenditure - a case for Norway?*

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Abstract

Motivated by the importance of consumption as an underlying driver of CO_2 emissions, we examine the link between consumption and CO_2 emissions for Norwegian households. The main goal is to investigate whether there is a decoupling of consumption expenditures and the environmental impact as we move up the income ladder. By combining a 2007 Norwegian consumer expenditure survey with emission coefficients from an environmental input-output model, reflecting emissions embodied in both domestically produced and imported goods and services, we calculate the per capita carbon footprint. The results from the analysis suggest that the per capita carbon footprint is directly proportional to expenditure with an estimated elasticity close to unity, implying no decoupling. The finding is partly driven by a near zero-emission power sector, which leads to comparatively low emissions embodied in domestically-produced goods and services.

Keywords: Carbon footprint, CO_2 emissions, consumption, international trade, decoupling

JEL codes: C31, C67, D12, Q56

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1 Introduction

Climate change is a global threat, requiring a global solution. Yet, current and previous climate mitigation policies, such as the Kyoto protocol, regional treaties and national policies, fall short of being global. While the Paris agreement adopted in 2015 was the first-ever universal agreement on climate change involving all nations of the world, it contains no overall, global policy to combat climate change. Instead, it relies on a bottom-up approach, where nations have to submit so-called intended nationally determined contributions (INDCs). As for most climate mitigation policies, the policy goals are primarily stated in terms of a territorial-based accounting framework for GHG emissions. In a territorial-based accounting framework direct emissions generated by domestic production are included, while emissions embodied in imported goods and services are not.[1] As a consequence, the effect of a nation's policy could potentially be offset by international trade flows. Carbon leakage, i.e. the re-allocation of emission-intensive activities to regions with laxer constraints on GHG emissions, is a well-known, potential adverse effect of the territorial-based accounting framework.[2] As the framework is based on the geographical location of production, a country could in principle reduce its emissions by outsourcing emission-intensive activities, while maintaining the same level of consumption via imports. If we want to reduce global emissions, it is therefore essential to address the relationship between emissions and consumption. Goods and services are ultimately produced for consumption purposes, and reallocating production without a decoupling[3] of emissions and consumption will not bring us any closer to a solution to the climate threat.

In recent years several researchers have advocated a stronger focus on consumption-based emissions when designing climate policies (see e.g., Baiocchi and Minx, 2010; Helm, 2012; Machado et al., 2001; Peters et al., 2012; Peters, 2008; Peters and Hertwich, 2006; Steinberger et al., 2012; Davis and Caldeira, 2010). In a consumption-based approach, the emissions related to exports are subtracted from the national inventories, while emissions embodied in imported

[1] More precisely, a territorial-based accounting framework records a nation's inventories as GHG emissions generated within the national territory, as well as offshore areas over which the country has jurisdiction (see e.g.,, Fleurbaey et al., 2014, p. 306). This implies that emissions generated as a consequence of domestic production are included - independent of whether the goods produced are exported or used for domestic consumption. At the same time emissions embodied in imports are excluded. Note that GHG emissions emitted in international territory, like international aviation and shipping, are not allocated to individual countries and are hence not included in the territorial-based calculations.

[2] As an example, studies of the effects of the Kyoto Protocol using Computable General Equilibrium models typically find carbon leakage to be in the range of 5-20% Barker et al. (2007).

[3] The term *decoupling* refers to a situation in which the growth rate of an environmental pressure is less than that of its driving force. A more detailed explanation of the term, as well as the distinction between absolute and relative decoupling, is provided in section 2.

goods are included. The result is an accounting framework where the consumption pattern in a country determines a country's emissions rather than the geographical location of the production sites. Emissions resulting from the consumption-based accounting framework are often referred to as the *carbon footprint*.[4]

Motivated by the importance of consumption as an underlying driver of CO_2 emissions, we investigate the consumption pattern and the associated environmental impact of Norwegian households, where we are particularly interested in (i) the distinction between domestically produced and imported goods, and (ii) how the environmental impact varies as we move up the income ladder. By combining a 2007 consumer expenditure survey (CES) with an environmental input-output model, we calculate the carbon footprint of Norwegian households, allowing us to compare direct and indirect emissions from consumption activities to the expenditure level of different households.[5]

We (and others before us) argue that the distinction between the territorial-based and the consumption-based accounting approach is particularly relevant for the case of Norway due to the country's characteristics (see e.g., Peters and Hertwich, 2006). First, Norway has high import levels, which are also increasing over time (SSB, 2012b, 2013), implying that a growing share of the carbon footprint is related to emissions embodied in imports. A narrow focus on territorial-based emissions could therefore be particularly misleading for the case of Norway. Second, Norway has one of the "greenest" power sectors in the world, owing to an extensive use of hydro-power. As a consequence energy-intensive goods produced in Norway have relatively

[4] While the term *carbon footprint* is widely used in both science and commerce, the meaning of the term vary both across academic studies and between public and academic use Wiedmann and Minx (2007). According to the fourth report from the Intergovernmental Panel on Climate Change (IPCC) "[t]here is no single accepted carbon footprinting methodology (...), nor is there one widely accepted definition of carbon footprint" (IPCC, 2007, pp. 306). The report then gives an example of a definition from Peters (2010): [t]he carbon footprint of a functional unit is the climate impact under a specific metric that considers all relevant emission sources, sinks and storage in both consumption and production within the specified spatial and temporal system boundary (pp. 245). Another definition is provided by the International Organization for Standardization (ISO), which define the carbon footprint of products (CFP) as "the sum of greenhouse gas emissions and removals in a product system, expressed as CO_2-equivalents and based on a life cycle assessment using the single impact category of climate change" (see `http://www.iso.org/iso/home.html`). Based on these definitions, the term carbon footprint used in our study only covers a subset of the environmental stressors resulting from consumption. First, we are only looking at CO_2 emissions, which is the most important of the man-made greenhouse gases. This means that other greenhouse gases, like methane (CH_4), nitrous oxide (N_2O) or fluorinated gas (F-gas), are not included. Second, we do not consider emissions resulting from (changes in) sinks and storage, like land use, land-use change and forestry. What we capture with our analysis is emissions resulting from the use of fossil fuels and process emissions. While our study has the limitation of not including the entire portfolio of climate impacts, it also has the benefit of clarity (see e.g., the discussion in Wiedmann and Minx, 2007). When comparing our estimate of the carbon footprint to estimates found in other studies, it is important to note which definition is used in the relevant study.

[5] The expenditure level can, to some degree, be seen as a proxy for income or how affluent a household is, in particular if the expenditure level is adjusted for the household structure. In our analysis we use expenditures, and not income, but adjust the expenditures for the family structure to arrive at a per capita estimate.

low embodied emissions, making it particularly important for the case of Norway to distinguish between the domestic energy mix and the one's of importing countries.[6] Lastly, the relationship between the carbon footprint and the expenditure level of Norwegian households will most likely be different from the average European households as many consumption categories, like heating, cooking, lighting and the use of electrical appliances, generate close to zero indirect emissions due to the green electricity mix.

Our main finding from the data analysis is that the 2007 carbon footprint of Norwegian households is directly proportional to expenditures, with an estimated elasticity close to unity. This suggests that there is no decoupling of emissions and expenditures as we move up the expenditure ladder, from low expenditure quintiles to higher expenditure quintiles. The close to linear relationship between the per capita expenditures and the per capita carbon footprint can partly be explained by the very low emissions from the Norwegian electricity production. Further, we find that high-expenditure households tend to consume relatively more imported goods than domestically produced goods, compared to low-expenditure households. While three previous studies looking at non-Norwegian households (Brazil, China and the UK) find weak or no evidence of a decoupling (Cohen et al., 2005; Golley and Meng, 2012; Druckman and Jackson, 2009), most of the existing literature tend to find that the environmental impact grows in a less than proportional way with income (see e.g.,, Lenzen et al., 2004; Girod and De Haan, 2010; Peters et al., 2006; Weber and Matthews, 2008). We therefore provide new evidence on the relationship between the carbon footprint of households and expenditure or income levels that contrast some of the previous findings. In addition to generating new evidence for the case of Norway, we contribute to the broader literature on sustainable consumption and the role of international trade in at least four aspects.

First, we use non-aggregated household expenditure survey data to calculate the consumption-based emissions. While there are several cross country studies addressing the issue of carbon-leakage (see e.g., Barker et al., 2007), as well as the so-called environmental Kuznets curve[7] (see Stern, 2004, for an overview), we add to the literature on the environmental impact of consumption by exploiting within country variation.

[6]While the Norwegian power sector is predominantly hydro-power based, international trade in electricity may lead to a different energy mix with corresponding higher embodied emissions. We discuss this issue and how it affects the calculations of the carbon footprint in section 5.

[7]The environmental Kuznets curve hypothesizes that the relationship between emissions and income per capita has an inverted U shape, i.e. that emissions are increasing with income up until a certain "turning point", where emissions then start to decrease with income.

Second, we contribute to the specific literature on how the carbon footprint of households vary with expenditures or income. While there are several studies exploiting household surveys to calculate the environmental impact in terms of energy use, only a few studies calculate the carbon footprint (see e.g., Peters et al., 2006; Weber and Matthews, 2008; Girod and De Haan, 2010; Druckman and Jackson, 2009; Golley and Meng, 2012). As most of the electricity used in Norwegian households, as well as in energy intensive industries, generate close to zero emissions, looking at the carbon footprint will give a very different picture than focusing on the energy use.

Third, we contribute to the carbon footprint literature by using a detailed environmental input-output table reflecting emissions from the global production chain. A shortcoming of some of the previous studies is the assumption that imports are produced with domestic technology (like in Golley and Meng, 2012). Treating domestically produced goods and imported goods in the same way typically introduces a bias in the estimated carbon footprint from imports, where the bias depends on whether the domestic technology generates higher or lower carbon emissions than that of importing countries (Bouwmeester and Oosterhaven, 2013). A notable exception is Girod and De Haan (2010), where the authors differentiate imported goods from domestically produced goods when calculating the carbon footprint.

Fourth, while several previous studies (Druckman and Jackson, 2009; Peters and Hertwich, 2006; Weber and Matthews, 2008) use a multi-regional input-output model when estimating the carbon footprint, they often use a limited number of regions. In contrast, we build on recent research (Andrew and Peters, 2013) and estimate the carbon embodied in trade using a multi-regional model with 129 regions, where emission coefficients reflect emissions generated throughout the global production chain of the final good or service. This means that the carbon embodied in a particular product or service reflects the technology used in all the different parts of the production chain, both intermediate production and final production, a feature that is usually not accounted for in the previous literature. An exception is Andrew and Peters (2013). While they account for the multi-regional structure of imports by studying emissions at a national level, we take a different approach by looking at consumption patterns at the household level.

The remainder of this paper is structured as follows. We first give a brief overview of the literature addressing the relationship between economic drivers and the environmental impact (section 2). Next, we describe the methodology used for estimating a household's carbon footprint, followed by a description of the data (section 3). In section 4 we present the results from the data analysis on the relationship between the carbon footprint and household expenditures, followed by a section testing the robustness of our results (section 5). Lastly, we provide some concluding remarks (section 6).

2 A decoupling of economic drivers and environmental impact?

As the standard of living continue to increase in the world, a critical question is whether a *decoupling* of consumption and emissions is possible. Decoupling occurs when the growth rate of an environmental pressure is less than that of its driving force (OECD, 2002). While absolute decoupling refers to a case where the environmentally relevant variable is stable or decreasing while the economic driving force is growing, relative decoupling refers to a case where the growth rate of the environmentally relevant variable is positive, but less than the growth rate of the economic variable (OECD, 2002).[8]

While cross-country studies on income per capita and CO_2 emissions per capita tend to indicate a relative decoupling as countries grow richer (see e.g., Steinberger et al., 2012), within-country studies give more mixed results. Studies that find support for a relative decoupling between income and the environmental impact, either at a household or at a national level, include Peters et al. (2006), Weber and Matthews (2008), Lenzen et al. (2004) and Girod and De Haan (2010). Peters et al. (2006) explore the relationship between household expenditures and the environmental impact for Norwegian households in 1991-2001, and find that CO_2 emissions increase less than proportionally to expenditure increases. Weber and Matthews (2008) find the same pattern when studying the carbon footprint[9] of US households in 2004; as wealth increases, CO_2 emissions increase, but at a slower growth rate than wealth. In a study of households in Sydney, Lenzen et al. (2004) find that the growth rate of the energy footprint diminishes towards higher incomes, reflecting that wealthier households purchase proportionally more services, which have lower embodied energy. In a study by Girod and De Haan (2010), the authors investigate how GHG emissions per capita evolve with increasing expenditures at the household level in Switzerland. The authors use two different approaches to calculate the carbon footprint; one based on monetary units and one based on functional units (e.g.,, kg, kilometers, square meters). While the first approach reveals no relative decoupling between expenditures and emissions, the

[8]When we use the term decoupling in this paper we are referring to relative decoupling, unless stated otherwise. Note also that we are comparing households across different expenditure quintiles, and not the same household over time, when testing for decoupling.

[9]While the term carbon footprint is not explicitly defined, the authors are referring to embodied CO_2 emissions.

latter reveals a relative decoupling. The authors attribute the latter finding to quality differences in consumed goods across households, where richer households consume more expensive goods of (assumed) higher quality. While the authors conclude that neglecting quality differences could overestimate the carbon footprint of richer households, it is not clear-cut that one unit of a high quality good will have the same environmental impact as one unit of a low-quality (low-priced) good, as high quality goods could potentially be more energy demanding. If high quality goods are indeed more energy demanding, estimates based on functional units would be too optimistic. Here we take a hybrid approach by using monetary units for some categories, and functional units for other categories.[10].

While the study by Girod and De Haan (2010) use a more detailed approach that could potentially address parts of the concern about quality differences, they do not explicitly address the issue of different production technologies.[11] In contrast to their study, we use emission multipliers that take into account trade between 129 regions of the world, where each region has its own production technology. We hence put a much larger emphasis on the role of domestic vs. imported goods than Girod and De Haan (2010). As embodied emissions can vary substantially across country of origin, we argue that this aspect is important to address when calculating the carbon footprint. Further, if richer households consume relatively more imported goods (as we find for the case of Norway), neglecting these differences in production technologies could disguise an important aspect of moving up the income quantiles.

While the majority of previous studies find some support for a relative decoupling between income and the environmental impact, there are a few studies that come to the opposite conclusion. Cohen et al. (2005) study the direct and indirect energy requirements of Brazilian households and find that moving up the income classes, there is no substitution from energy intensive goods to non-intensive ones. There is hence no saturation in the energy requirements, except for food, which is not a very energy intensive category. In Golley and Meng (2012), the authors investigate the per capita CO_2 emissions across Chinese households with different income levels. Their results suggest that the carbon footprint increases more than proportionally with income. Further, in a study covering several waves of household surveys, Druckman and Jackson (2009) study the relationship between household expenditure and the carbon footprint[12]

[10]see section 3.1 for a discussion on the use of a functional vs. a monetary approach, and the limitations related to detecting a decoupling resulting from quality differences.

[11]The authors mention this issue, and argue that they partly address the problem by using a Life Cycle approach.

[12]The authors define the carbon footprint as “”the carbon dioxide from energy use attributable to people’s activities in attempting to meet their functional needs.” They acknowledge the limitation of excluding other

for UK households in the time period 1990-2004. While they find absolute decoupling in the early 1990s, this was mainly due to the UK's switch from coal to gas. Since then, they only find evidence of slight relative decoupling between expenditures and CO_2 emissions.

To summarize, there are few studies looking at household consumption patterns and the associated carbon footprint while explicitly taking into account emissions from the global production chain. As the relative share of imported goods in the consumption bundle might differ across household expenditure levels, failing to account for differences in embodied emissions (i.e. different emission coefficients) could potentially give a misleading picture of how emissions evolve with income. Studies that address the issue of different production technologies either use expenditures at the country level (as in Andrew and Peters (2013)), or they only include a small number of regions (like in Peters and Hertwich (2006) and Weber and Matthews (2008)). We therefore add to the literature by utilizing recent progress in the multi-regional input output literature (Andrew and Peters, 2013), and applying it to the household level for the case of Norway.

3 Methodology and data

3.1 Methodology

The carbon footprint reflects the consumption-based emissions, and consists of two parts; (i) direct emissions and (ii) indirect emissions. Direct emissions include emissions generated as the consumer drives a car, turns on a gas stove or uses products like heating oil and kerosene. Direct emissions are in other words generated by burning fuels directly, and usually stem from sources that are owned or controlled by the household. In this study we also include emissions stemming from households' electricity consumption in the direct emissions category. While these emissions are in practice generated at the power plant, we label them as direct as the associated emissions are so closely related to the consumption activity.[13]

In contrast to direct emissions, indirect emissions are generated throughout the production chain, from the extraction of raw materials, the production of intermediary goods, and the final production process.[14] Indirect emissions are emissions that are generated as a consequence of the activities of the consumer, but occur at sources owned or controlled by another entity.[15]

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environmental stressors, like non-CO_2 GHG and land use change, but highlight the benefit of clarity.

[13]Details on the different categories included in the direct emissions are provided in section B.1 in the appendix.

[14]See e.g. Golley and Meng (2012) for a more detailed explanation.

[15]Note that with this methodology emissions from public transportation, like bus and flight transport, are

Three different approaches are often used when calculating the carbon footprint; the financial approach, the physical approach or a hybrid approach, which combines the first two. In the financial approach CO_2 emissions are calculated based on expenditure data, where the monetary values are turned into either energy units or CO_2-units by using an environmental input-output-model (see e.g., Peters et al., 2006). The physical approach, sometimes referred to as process or life-cycle analysis, uses estimates of the physical units of goods and services consumed. The environmental impact is then calculated based on emission multipliers per physical unit (see e.g., Girod and De Haan, 2010).

Here we use a financial approach to calculate the *indirect* carbon emissions, while we use a mix of monetary and physical units to calculate the *direct* emissions. An advantage of using a financial approach to calculate the indirect emissions is that we can estimate the share of imported goods and services by using a national input-output table. As a result, we are able to explicitly take into account that different importing goods are produced with different production technologies. This is important as goods imported from countries heavily relying on fossil fuels and/or old production technology will generate more indirect emissions compared to goods and services imported from countries with a cleaner production process.

A limitation of using monetary units when calculating the indirect emissions (i.e. a financial approach) is that we have to assume a constant relationship between Norwegian kroner (NOK) spent on a good, and the resulting emissions. In other words, a doubling of expenditures on a given good corresponds to a doubling of emissions. This implies that a decoupling of the carbon footprint and expenditure is only detected if the consumption bundle changes as a household grows richer. If richer households prefer to consume the same consumption bundle, but with goods and services of higher quality (and price) (as suggested by Girod and De Haan, 2010), we are not able to detect the decoupling in indirect emissions. This shortcoming could underestimate the potential for decoupling. However, as we use physical units to calculate the direct emissions, we address parts of the concern of systematic quality differences across expenditure levels.

Further, we take into account that goods and services consumed in Norway have either been produced in Norway or abroad. To simplify the notation, countries other than Norway are referred to as the Rest of the World (RoW) in the following. The distinction between domestic and imported goods is critical because imported goods may be produced with different production technologies, hence emission coefficients may differ compared to goods and services

included in the indirect emissions.

produced domestically. Relying on the notation from Peters et al. (2006), we can express a household's carbon footprint, f_h^{total}, in the following way:

$$f_h^{total} = f_h^{direct} + f_h^{indirect,Norway} + f_h^{indirect,RoW} \quad (1)$$

, where h stands for a particular household. Direct emissions f_h^{direct} are obtained by multiplying direct carbon emitting activities measured in physical units (e.g., km driven in a year) or monetary units (e.g., electricity expenditures) by their direct emission intensity. Based on the work of Druckman and Jackson (2009), and adjusted to suit our study, indirect emissions from goods and services produced in Norway are calculated using the following equation:

$$f_h^{indirect,Norway} = u^{Norway} \cdot [(1 - s) \cdot (y_h \cdot C^{Norway'})] \quad (2)$$

where u^{Norway} is a row vector of emission multipliers for different goods and services produced in Norway, s is a vector of import coefficients, y_h is a row vector of a household expenditures on goods and services and C^{Norway} is a concordance matrix[16] linking domestic emission multipliers to household expenditures (see appendix A for more details). The expenditure vector y_h, measured in NOK, is unique to each household, while the other elements of Eq. (2) are constant across households.

Similarly, we calculate the indirect emissions embodied in imported goods and services and consumed by a Norwegian household in the following way:

$$f_h^{indirect,RoW} = u^{RoW} \cdot [s \cdot (y_h \cdot C^{RoW'})] \quad (3)$$

Eq. (2) and (3) allow us to (i) use different emission multipliers for different goods and services and (ii) use different emission multipliers for domestically produced and imported goods and services. In equation 3 the emission multiplier vector, u^{RoW}, reflects the CO_2 emissions associated with the global production chain, and takes into account trade between 129 regions in the world (see appendix B).[17] The emission multipliers used for calculating indirect emissions reflect emissions generated during the entire production process, independently of whether parts of the

[16] A concordance matrix is needed to match the different datasets, as they rely on different classification systems (see Section 3.2). A concordance matrix corresponds to a technological coefficient matrix, which is the term often used in other studies.

[17] For example, the production of chocolate in Norway relies on the use of cocoa, which had to be produced abroad and transported to Norway, thus generation emissions in other parts of the production chain.

production process has taken place abroad.

Finally, a household's needs grow with each additional member, although in a less than proportional way (Deaton and Muellbauer, 1980). To account for household structure, we deflate the consumption-based carbon footprint f_h^{total} using the OECD-modified equivalence scale (OECD, 2007). As a result we obtain an estimate of the per capita carbon footprint.[18] The OECD scale assigns a value of 1 to the household head, 0.5 to each additional adult member and 0.3 to each child. This means that a household with two adults and one child is assumed to have expenditure needs of 1.8 times the expenditure of a household with one adult in order to guarantee the same standard of living. By using expenditures adjusted for household structure, we might get closer to a measure of income or wealth, as argued in Girod and De Haan (2010).

3.2 Data

In order to calculate the carbon footprint of Norwegian household we compile data from several sources. First, we collect representative data on household expenditures from Statistics Norway's Survey of Consumer Expenditure, 2007.[19] The dataset covers 1,081 households, and contains information on expenditures on 183 different goods and services, classified according to the Classification of Individual Consumption According to Purpose (COICOP) model (UNSD, 2013b). From the household survey we use expenditures in NOK, as well as data on physical units for selected categories (e.g., km driven in a year).

Next, we split the data into two categories: consumption that generates direct emissions (electricity, gasoline, diesel, kerosene, heating oil, gas)[20] and consumption that generates indirect emissions (the remaining categories). To calculate the direct emissions we use emission coefficients from a variety of sources (see appendix B.1). E.g., for fuel combustion we calculate the direct emissions by using km driven multiplied by a coefficient for kg carbon released per km. In cases where km driven is not available, we use the expenditures on fuel, and then derive the quantity by using an average national price per liter. For electricity we use expenditures in NOK, and derive consumption in kWh by using electricity prices for 19 different Norwegian counties. As over 95 per cent of the power generation in Norway is hydro power, and imports are on average low, the associated emissions are, as a result, very low (around 7 grammes CO_2 per kWh (SSB,

[18] A similar type of methodology is used in Girod and De Haan (2010).

[19] See the following website for more information about the survey, as well as an overview of the data: www.ssb.no/en/inntekt-og-forbruk/statistikker/fbu

[20] The consumption of coal and coke is neglectable for Norwegian households.

2008), see appendix B.1).

To calculate the indirect emissions, we first need to identify the share of consumption resulting from imported goods. This involves splitting consumption into two subcategories: (i) domestically produced goods and services and (ii) imported goods and services. We do this by using a vector of import shares from a symmetric input-output table for Norway (SSB, 2012b).[21] The input-output table (IOT) is available for 59 products times 59 industries, where the products are organized according to the Classification of Products by Activity (CPA) (Eurostat, 2002) and the industries are organized according to ISIC ver.3 (NACE) (UNSD, 2013a). As the household expenditures (from the household survey) are organized by COPICOP, we need to use a concordance table that link the two classification systems COICOP and CPA (see Eurostat, 2002). Further, as the input-output table is reported in basic prices, while the household expenditures are reported in purchasers' prices, we need to adjust the household expenditures for taxes, subsidies, transport margins and trade margins. This is done by using the net taxes and margins reported in the input-output table, which are organized by products (CPA). While both net taxes and margins are subtracted from the reported expenditures for all consumption categories, the trade and transport margins are re-distributed to the margins sector, which consists of wholesale, retail and transport industries. By using the adjusted household expenditures organized by CPA, together with the input-output table (IOT) and a concordance table, we are able to get expenditure data in basic prices organized by ISIC ver.3 (NACE), as well as according to imports and domestically produced goods and services.

The next step is to multiply the expenditures in basic prices by the carbon footprint multiplier, i.e. the carbon emissions embodied in each unit of expenditure. The carbon footprint multipliers for Norway and RoW are based on data from the Global Trade Analysis Project 8 database (GTAP) (Narayanan G. Badri and McDougall, 2012), and are meant to reflect the global emissions associated with the whole supply chain of a product or a service. More specifically, the multipliers take into account trade between 129 regions of the world, where the regions are allowed to have different production technologies, see appendix B.2.[22] As the GTAP database and the corresponding footprint multipliers are classified under the GSC2 classification system,

[21]By using this approach we need to assume that households adopt similar import behavior for a given consumption item. For example, if one household consumes one kilogram of Norwegian potatoes and another household consumes one kilogram of imported potatoes, our approach assume that both houses consume half a kilogram of Norwegian potatoes and half a kilogram of imported potatoes.

[22]The carbon footprint multipliers were kindly provided by Glen Peters from the Center for International Climate and Environmental Research (CICERO). For a more detailed description on how these multipliers were estimated, see Andrew and Peters (2013).

we need to map the GTAP categories to ISIC ver. 3. To do this we rely on the concordance established by Mastoris and Welsh (2001). An overview of the links between the different classification systems are provided in appendix A.2.[23]

4 Results and discussion

Based on the sample of 1072[24] Norwegian households in 2007, we find an average per capita carbon footprint of around 12.2 tonnes CO_2, see Table 1.[25] The summary statistics reveal a large spread in the carbon impact of different households. Households that lie one standard deviation above the average have a carbon footprint 4.1 times that of the households lying one standard deviation below the average.

Table 1: Summary statistics for the expenditures and carbon footprint of Norwegian households. 2007.

	Mean	SD	Min	Max	N
Expenditures (in 1000 USD)	32.4	18.3	4.2	137.6	1,072
Total CO2-emissions (in tonnes)	12.2	7.4	1.4	51.2	1,072
Direct CO2-emissions (in tonnes)	1.6	1.5	0.0	18.7	1,072
Indirect domestic CO2-emissions (in tonnes)	5.8	3.9	0.7	31.0	1,072
Indirect imported CO2-emissions (in tonnes)	4.8	3.4	0.4	24.2	1,072

Notes: Expenditures are net of taxes and subsidies, and are converted to USD using the average 2007 exhange rate NOK $\approx$ 5.85 USD. Both expenditures and the carbon footprint are adjusted according to the OECD-modified equivalence scale (OECD, 2007) to arrive at a per capita estimate.

To investigate how the carbon footprint varies with consumption expenditures, we test four different functional forms; a linear, a quadratic, a cubic and a log-log specification. Table 2

[23]A drawback of using emission factors obtained via the GTAP database is the need to link various databases by establishing concordance tables between four different classification systems (COICOP, CPA, NACE and GTAP). The correspondence between COICOP (used in the consumer expenditure survey) and GTAP (used to calculate embodied emissions) is unfortunately incomplete. We therefore had to match some of the categories in an ad-hoc way. In addition, some of the COICOP categories are linked to several GTAP categories. For example, the COICOP category 01.1.1 (Bread and cereals) is linked to no less than 21 GTAP categories. Proportions of the household expenditure spent on each GTAP category therefore had to be allocated manually. This process was done at the most disaggregated level in order to minimize the size of the error.

[24]A total of nine observations (out of a total of 1,081), representing extreme values in per capita expenditure or in consumption-based per capita carbon footprint, were identified as outliers by comparing their predicted values to their residual (Heij et al., 2004) and dropped from the analysis. Including these outliers in the analysis would only marginally impact our results.

[25]The average carbon footprint per *household* is 22.5 tonnes CO_2. To transform the household average to a per capita average, we adjust the carbon emissions according to the OECD-modified equivalence scale (OECD, 2007), as explained in section 3.1. If we compare our per capita estimate to other carbon footprint estimates in the literature, Hertwich and Peters (2009) find a per capita carbon footprint of 14.9 tonne for Norway for 2001. Note, however, that this figure includes not only CO_2 emissions, but also other GHG, like CH_4, N_20 and F gases. The carbon footprint is also calculated based on other data sources and slightly different methods. The two figures are therefore not directly comparable.

shows the results for the different specifications, where y_i is the carbon footprint per capita in tonnes CO_2 and x_i is the expenditure per capita measured in thousand USD. When we estimate the linear functional form, we get a β coefficient of 0.38. This tells us that increasing expenditures with 1000 USD generates 0.38 tonnes of CO_2 emissions. If we use the mean values for CO_2 emissions and expenditures, we get an elasticity of about 1.00.[26] A mean elasticity of around 1 implies that emissions increase in a proportional way to expenditures, i.e. if we increase expenditures by 1 %, the carbon footprint increases by 1%.

Table 2: The relationship between the carbon footprint and expenditures: testing four different functional forms.

Functional form		α	β	γ	δ	t_β	t_γ	t_δ	R^2
(1)	$y_i = \alpha + \beta x_i$	-0.00	0.38***			65.50			0.86
(2)	$y_i = \alpha + \beta x_i + \gamma x_i^2$	-0.06	0.38***	-0.00		27.12	-0.22		0.86
(3)	$y_i = \alpha + \beta x_i + \gamma x_i^2 + \delta x_i^3$	0.80**	0.31***	0.00**	-0.00**	9.08	1.99	-2.01	0.86
(4)	$\log(y_i) = \alpha + \beta \log(x_i)$	-0.98***	0.99***			69.77			0.84

Notes: y_i is the carbon footprint per capita in tonnes CO_2, x_i is expenditure per capita in '000 USD. P-statistics and t-statistics are calculated using (heteroskedasticity) robust standard errors. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Adding a quadratic and a cubic term to test for potential non-linearities have minor effects on the β coefficient; while the quadratic and cubic coefficients are significant, the values are close to zero. Also, adding the two terms do not change the explanatory power, R^2. Lastly, we test a log-log functional form. From equation (4) in table 2, we see that the β coefficient of 0.99 is of a similar magnitude as the mean elasticity estimated using the linear model (1.00). The linear and log-log functional form hence give about the same predictions around the mean values for CO_2 emissions and expenditures. The four predictions are presented in Figure 1 and, as already seen in table 2, the different functional forms yield very similar results.

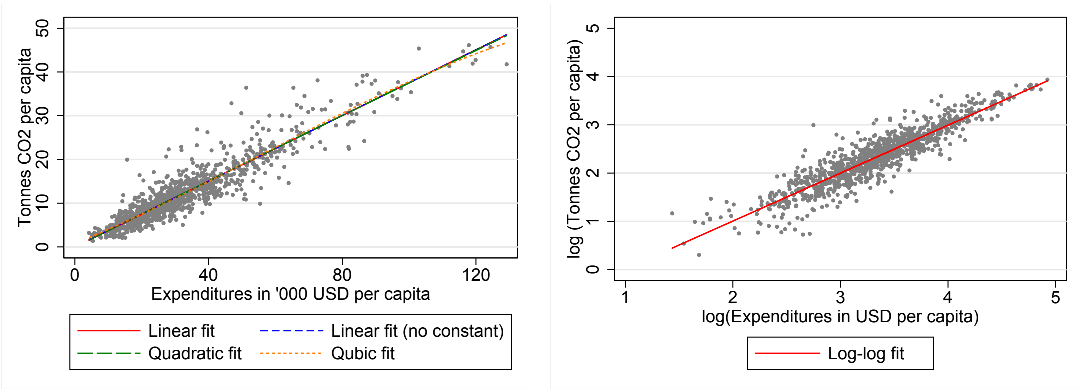
While we find a mean elasticity close to 1 for both the linear and log-log specification, previous studies often find CO_2-elasticities in the range 0.6-0.9 (e.g., 0.88 in Peters et al. (2006) and between 0.6 and 0.8 in Weber and Matthews (2008)).[27] In other words; while previous studies often find that the per capita carbon footprint increase in a less than proportional way, we find that the per capita carbon footprint increase in a close to *proportional* way to per capita expenditures.

[26] The elasticity is calculated using the following formula $\varepsilon = \frac{dy}{dx}\frac{\bar{x}}{\bar{y}}$, where $\frac{dy}{dx} = 0.38$, $\bar{x} = 32.4$ and $\bar{y} = 12.2$.

[27] Note that these estimates are not directly comparable as they rely on different datasets and different approaches to correct the data for the household structure. The studies also use data from the early 2000s, while we use data for 2007.

Figure 1: The (per capita) carbon footprint plotted against the (per capita) expenditures.

(a) Tonnes and '000 USD (b) Log



4.1 Disentangling the carbon footprint

To further investigate the consumption patterns and the associated carbon footprint, we focus on three different dimensions of the data; (i) expenditure quintiles, (ii) domestic vs. imported goods and (iii) consumption categories. A detailed overview is provided in Table 3. To see more clearly how the carbon footprint increases with expenditure quintiles, the numbers for the third (Q3) and fifth quintile (Q5) are expressed as relative to the first quintile (Q1).[28]

We start by focusing on the two first dimensions: expenditure quintiles (Q1-Q5) and domestic vs. imported goods and services. Looking at the last row in Table 3, we see that the per capita carbon footprint for the highest quintile (Q5) is 4.3 times higher that of the lowest quintile (Q1). We further see that the emissions from domestically produced goods and services are 3.8 times higher for Q5 relative to Q1, while the same ratio for imported goods and services is 5.3. This implies that emissions taking place outside the Norwegian jurisdiction contributes relative more to the carbon footprint as we move up the expenditure quintiles. While around 34% of the carbon footprint for Q1 is attributed to carbon emissions embodied in imported goods, the same figure for Q5 is around 42%.

In Table 4 we have estimated the mean elasticity for imported and domestically produced goods and services separately. The coefficients reveal that imported emissions increase in a more than proportional way as total expenditures increases (with a mean elasticity of 1.17), while domestic emissions increase in a less than proportional way (with a mean elasticity of 0.90). This finding is also illustrated in Figure 2, where we have plotted the log-log relationship between expenditures and the carbon footprint for domestic and imported emissions. From the figures

[28] A similar table with absolute figures for Q3 and Q5 is provided in appendix C.

Table 3: Expenditures (in '000 USD) and the associated carbon footprint (in tonnes CO_2), by consumption categories and expenditure quintiles. Absolute and relative terms.

	Expenditures ('000 USD)			Carbon footprint (tonnes CO_2)		
	Q1	Q3/Q1	Q5/Q1	Q1	Q3/Q1	Q5/Q1
Food (domestic)	2.1	1.5	1.9	0.6	1.5	1.8
Food (imported)	0.4	1.5	2.0	0.1	2.0	3.0
Food (total)	2.5	1.5	1.9	0.7	1.6	2.0
Energy (domestic)	1.1	1.1	1.3	0.3	1.0	1.3
Energy (imported)	0.0	.	.	0.0	.	.
Energy (total)	1.2	1.1	1.3	0.3	1.0	1.3
Transport (domestic)	0.9	2.6	7.4	1.7	1.9	3.6
Transport (imported)	0.6	2.8	10.7	0.6	2.3	6.7
Transport (total)	1.6	2.5	8.3	2.3	2.0	4.4
Clothing (domestic)	0.1	4.0	8.0	0.0	.	.
Clothing (imported)	0.4	3.0	6.0	0.3	2.3	5.3
Clothing (total)	0.6	2.5	5.3	0.3	2.7	5.7
Other (domestic)	6.3	2.3	4.8	0.9	2.6	6.0
Other (imported)	1.6	2.3	4.9	0.8	2.0	4.8
Other (total)	7.9	2.3	4.8	1.6	2.4	5.8
Total (domestic)	8.1	2.1	4.1	3.5	1.9	3.8
Total (imported)	3.2	2.2	5.5	1.8	2.3	5.3
Total (total)	11.3	2.1	4.5	5.3	2.0	4.3

Notes: For the first quintile (Q1) the table shows the mean of expenditures in 1000 USD and the carbon footprint in tonnes CO_2. For the third (Q3) and fifth (Q5) quintile. the expenditures and carbon footprints are expressed relative to Q1.

we see that imported emissions increase more sharply with expenditures compared to domestic emissions. The difference in estimated elasticities indicate that households in higher expenditure quintiles tend to consume more from categories of goods and services that rely comparatively more on imports. This finding could partly explain why we don't find a decoupling between expenditures and the carbon footprint as expenditures increases.

Our next step is to investigate different consumption categories. We do this by grouping expenditures and CO_2 emissions into five higher-order categories: *food*, *energy*, *transport*, *clothing* and *other goods and services*. Direct emissions from the consumption of heating oil, kerosene, gas products and electricity are included in the *energy* category, while consumption of diesel and gasoline is included in the *transport* category. Note that the transport category also includes indirect emissions from bus, rail, water and air transport. *Clothing* covers not only what is

Table 4: Expenditure and carbon elasticities for domestic and imported goods and services.

Category	Expenditure elasticity	Carbon elasticity
Domestic	0.93	0.90
Imported	1.18	1.17

Notes: The expenditure elasticity for domestic (imported) goods measures the ratio of the percentage change in expenditures on domestic (imported) goods to the change in total expenditures. The carbon elasticity for domestic (imported) goods measures the ratio of the percentage change in CO_2 emissions from domestic (imported) goods to the change in total expenditures.

generally associated to clothing, but also interior textiles. The final category *other goods and services* covers all remaining expenses, from recreational activities to telecommunication and financial services.[29]

Figure 2: The carbon footprint of Norwegian households, by domestic and imported emissions.

(a) Domestic emissions (b) Imported emissions

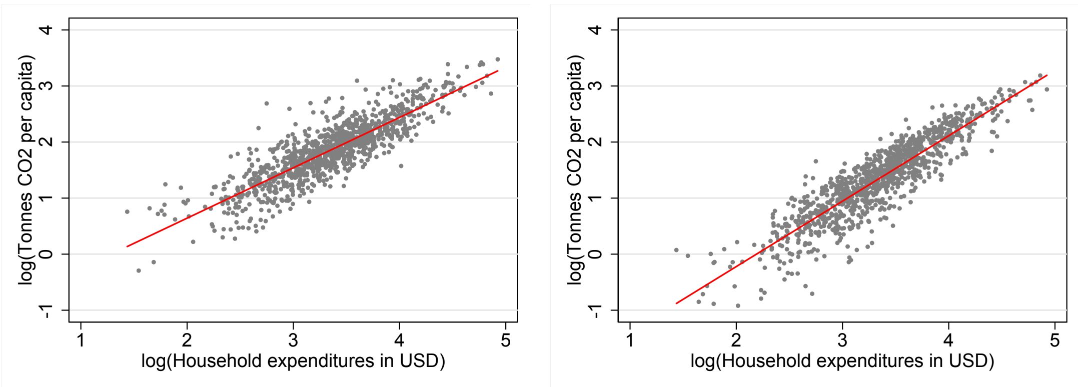
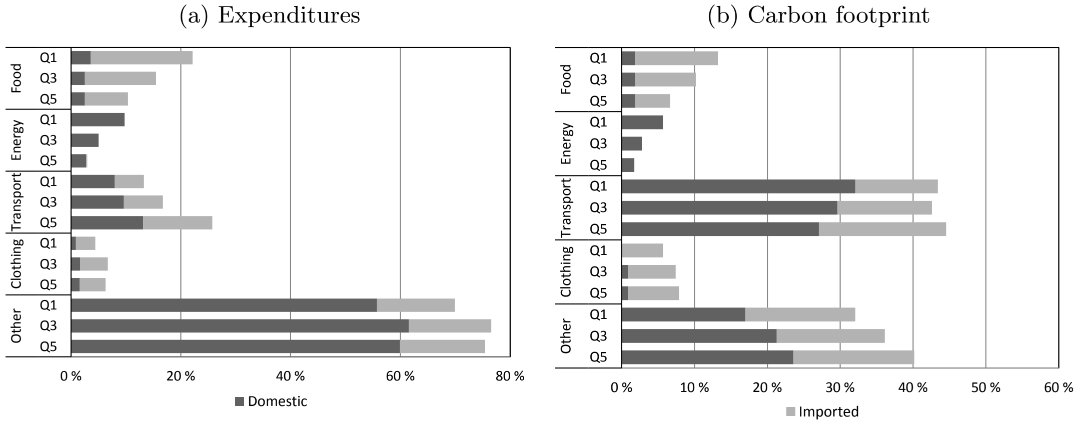


Figure 3 displays the different consumption categories' share of total expenditures and the carbon footprint. The share is calculated separately for expenditure quintiles Q1, Q3 and Q5. A first take-away from the figure is that transport and other goods and services are the top two contributers to the carbon footprint across all three expenditure quintiles. We further see that food and energy consumption's contribution to the carbon footprint is decreasing as we move up the expenditure ladder, while clothing and other goods and services are contributing relatively more to the carbon footprint as households become richer. The share of the carbon footprint attributed to transport is about the same across quintiles, but the importance of domestic transport (e.g., own car use) is decreasing as households become more affluent.

[29]See appendix A.1 for an overview of the different consumption categories. Note that the category includes parts of the trade margins that were re-distributed when adjusting the expenditures from purchases' prices to basic prices.

Figure 3: The share of expenditures and the associated carbon footprint, by consumption categories and quintiles



Notes: The figure shows the share of the expenditures and the carbon footprint attributed to five different consumption categories (food, energy, transport, clothing, other), calculated separately for each of the three expenditure quintiles (Q1, Q3, Q5). In other words, it shows how important each of the five consumption categories are for the three different expenditure groups.

The findings in Figure 3 are confirmed in Table 5, where we have estimated the expenditure and carbon elasticities for each of the five consumption categories. By running separate regressions for the different consumption categories, we see that the relationship between expenditures and the carbon footprint is no longer proportional. The coefficients tell us that emissions from *food* and *energy* are increasing in a less than proportional way with expenditures, while emissions from *clothing* and *other* are increasing in a more than proportional way with expenditures. Emissions from *transport* seem to be increasing in a proportional way to expenditures. However, if we exclude the direct emissions from the transport category, i.e. emissions from driving your own car, the carbon elasticity increases to 1.30. This is intuitive as driving you own car may be more of a necessity relative to other transportation modes, like air transport. The low expenditure elasticity for food is in line with theoretical and empirical predictions; according to Engel's law (Deaton and Muellbauer, 1980), the proportion of the total expenditure (income) spent on food usually fall as total expenditure (income) increases. A low expenditure elasticity for energy is also reasonable, as energy is often considered to be a necessity and hence not very sensitive to income changes.

Further, Figure 3 reveals large variation in the carbon footprint across different consumption categories and across different expenditure quintiles. While expenditures on *transport* ranges from 14% to 26% for the different quintiles, the related contribution to the carbon footprint ranges only from 43% to 45%. This result is partly driven by the consumption of petroleum products in private means of transportation; for lower expenditure groups the consumption of

Table 5: Expenditure and carbon elasticities for the categories *food, energy, transport, clothing, other.*

Category	Expenditure elasticity	Carbon elasticity
Food	0.51	0.50
Energy	0.21	0.25
Transport	1.48	1.01
Clothing	1.30	1.30
Other	1.05	1.16

Notes: The expenditure elasticity for food (energy, transport, clothing, other) measures the ratio of the percentage change in expenditures on food (energy, transport, clothing, other) to the change in total expenditures. The carbon elasticity for food (energy, transport, clothing, other) measures the ratio of the percentage change in CO_2 emissions from food (energy, transport, clothing, other) to the change in total expenditures.

petroleum products constitutes a larger share of the transport category. For *clothing* there is not a large difference in the carbon footprint across quintiles; expenditures range from 5% to 6% of the total expenditures, while the contribution to the carbon footprint ranges from 6% to 7%. The category has, however, a striking difference in embodied emissions for imported and domestically produced goods. While Norwegian textiles have a carbon footprint multiplier of around 0.25 kg CO_2/USD in 2007, the carbon multiplier of textiles imported to Norway was around 0.72 kg CO_2/USD - almost three times as high (see appendix B.2).

Looking at the highest quintile (Q5) 1.6% of the total expenditure on domestically-produced clothing contributed to 0.9% of the household's carbon footprint, whereas 4.7% of the household's expenditures was spent on imported clothing with a contribution of 7% to the household's carbon footprint. Given that over 90% of the emissions embodied in the consumption of clothing occurs abroad, our findings suggest that a narrow focus on territorial-based emissions could potentially omit a large share of the emissions related to the consumption of goods and services from this sector. For other sectors and categories of goods, trade seems to matter less. For example, the share of imported carbon in the *energy* category is almost negligible.

5 Robustness checks

Due to the extensive use of hydro-power, CO_2 emissions embodied in electricity production are very low compared to the rest of the Nordic countries and Europe. Further, as Norway has a low import share for electricity, this results in a very low average emission factor for Norwegian electricity consumption. While the emission factor used to calculate the carbon footprint from electricity consumption is based on an assumption of 7% imports of a Nordic electricity mix (see appendix B), there could be periods with very high demand, e.g., during cold weather events, where Norway has to import a much larger share of fossil-based electricity. Emissions would then be much higher, especially on the margin. Further, as the electricity grid in Europe is becoming more integrated, the carbon footprint from electricity consumption in Norway could potentially increase as a result.

These factors motivates us to investigate to what degree the low emission factors for electricity consumption are driving our results. What would happen to the carbon footprint and the carbon footprint elasticity if the energy mix was more similar to that of the Nordic or continental European countries, for instance due to higher imports? To see to what degree the low imports combined with a green power sector is driving our results, we replace the carbon footprint multiplier for the electricity sector with a multiplier reflecting the Nordic energy mix and the European energy mix. We also test for a higher estimate for the Norwegian electricity sector collected from a different source.[30].

The results from the robustness checks are presented in Table 6 and reveal that the carbon footprint elasticity is sensitive to the emissions multiplier used; using a higher estimate for the Norwegian electricity mix (0.050 kg CO_2/kWh instead of 0.007 kg CO_2/kWh) lowers the carbon elasticity from 0.99 to 0.94. Assuming a Nordic electricity mix further lowers the estimate to 0.81, while assuming an EU electricity mix leads to an elasticity of about 0.64. Going from the low to the high emission factor increases the carbon footprint from 12.2 to 19.7 tonne CO_2 per capita. The results from this simple test indicate that the high estimated expenditure elasticity of carbon is partly due to the particular characteristics of the Norwegian electricity sector.

To test for the importance of using different estimates for the emissions embodied in domestically-produced and imported goods and services, we perform a second robustness check. Assuming domestic emission factors for imported goods and services would lower the carbon footprint from 12.2 to 10.6 tonne CO_2 emissions. However, the carbon elasticity would remain almost unchanged.[31]

Lastly, we address the issue of potential underreporting in the consumer expenditure survey

[30]In the baseline calculations we assume a near-zero carbon footprint multiplier of around 7 grammes CO_2/kWh. As we use different prices for different counties in Norway, this leads to a carbon multiplier ranging from 0.053 kg CO_2/USD to 0.070 kg CO_2/USD, with a mean of 0.064 kg CO_2/USD.

[31]The estimated carbon elasticity is 0.98, with a 95% confidence interval ranging from 0.95 to 1.00.

Table 6: Carbon footprint and carbon elasticities using different estimates for the carbon embodied in electricity

Different estimates	kg CO_2/kWh	kg CO_2/USD	Carbon footprint	Carbon elasticity
Norway (baseline)	0.007	0.064	12.2	0.99
Norway (higher estimate)	0.050	0.458	12.8	0.94
Nordic mix	0.200	1.834	14.9	0.81
EU mix	0.542	4.971	19.7	0.64

Notes: The first estimate (Norway, baseline) is collected from SSB (2008). The three new estimates are collected from the "climate calculator" project (available at http://www.klimakalkulatoren.no/), and reflect the average carbon footprint multipliers for the time period 2007-2011. The column "kg CO_2/USD" shows the average embodied carbon per USD.

(CES). Underreporting occurs if certain purchases are not reported, or if expenditures are adjusted downwards. While it is hard to get reliable numbers on the degree of underreporting for specific products, there seems to be a recurring pattern, where small and irregular purchases, as well as items that may be considered socially undesirable, like alcohol, tobacco and sugar products, tend to suffer more from underreporting (see e.g., Mørk and Willand-Evensen, 2004).

To see how sensitive our results are to potential underreporting, we make an attempt at adjusting the expenditure data. We start by scaling up the expenditure data to reflect the total number of households in Norway in 2007. Next, we compare this number to the total expenditures reported in the National Accounts (NA) (SSB, 2007). Comparing the two figures, we find that the (scaled up) expenditures from the CES is about 7% lower than the total expenditures reported in the NA. This discrepancy could be interpreted as underreporting in the CES, but the difference could also be due to other factors. Given the assumption that the 7% discrepancy is due to underreporting, we scale up the total expenditures in the CES by 7%, and distribute this extra amount to different consumption categories based on the pattern of underreporting found in (Mørk and Willand-Evensen, 2004).[32]. Using the adjusted data, the carbon footprint increases slightly from 12.2 to 12.9, while the carbon elasticity is still close to unity (0.99).

6 Concluding remarks

In the absence of a global solution to curb climate change, uniform emission cuts often appear as the second best solution to mitigate GHG emissions. Yet, in a world driven by consumption, a

[32]More specifically, we use the absolute deviations (NA-CES) reported in Table 8 in (Mørk and Willand-Evensen, 2004) to construct relative weights, which we then use to distribute the excess amount

narrow focus on domestic-based emissions is problematic due to the large and growing importance of trade. As most goods and services are ultimately produced for consumption purposes, the carbon footprint of a nation will be closely tied to the standard of living. By ignoring the emissions embodied in imported goods and services, we could potentially conceal an important aspect of households and nations growing richer.

In an attempt to investigate the relationship between income and the consumption-based carbon footprint, we combine a 2007 consumer expenditure survey (CES) for Norway with carbon footprint multipliers reflecting the global CO_2 emissions related to the production of a good or a service consumed by Norwegian households. Our results indicate that the carbon footprint per capita is proportional with respect to expenditure per capita, with an elasticity close to unity. This result seems to be particular to the case of Norway, and is due to its unique characteristics. For instance, Norway has a nearly zero emission power sector, as well as low imports of electricity, which implies low carbon emissions from the use of power to produce goods and services and from the use of electricity to heat Norwegian houses. A robustness check demonstrates that the low carbon elasticity is, indeed, partly due to the near carbon free power sector; applying a carbon footprint multiplier reflecting the energy mix in the EU yields a significantly lower carbon elasticity. Further, as the amount of carbon embodied in imported goods and services constitute a large share of the total carbon footprint, failing to account for trade would underestimate the environmental impact of Norwegian households.

Disclaimer

The data from *the Norwegian Survey of Consumer Expenditure, 2007* is provided by Statistics Norway, and prepared and made available by the Norwegian Social Science Data Services (NSD). Neither Statistics Norway nor NSD are responsible for the analysis/interpretation of the data presented here.

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Appendices

A Classification Schemes

A.1 GTAP

Category	GTAP	Description	GTAP	Description
Food	G01	Paddy rice	G19	Bovine meat products
	G02	Wheat	G20	Meat products[1]
	G03	Cereal grains[1]	G21	Vegetable oils and fats
	G04	Vegetables, fruits, nuts	G22	Dairy products
	G05	Oil seeds	G23	Processed rice
	G06	Sugar cane, sugar beet	G24	Sugar
	G09	Bovine cattle, sheep and goats, horses	G25	Food products[1]
	G10	Animal products[1]	G26	Beverages and tobacco
	G11	Raw milk	G45	Water
	G14	Fishing		
Energy	G15	Coal	G43	Electricity
	G16	Oil	G44	Gas manuf., distr.
	G17	Gas	N/A	Direct emissions[2]
Transport	G38	Motor vehicles and parts	G49	Water transport
	G39	Transp. equip.[1]	G50	Air transport
	G48	Other transport[1]	N/A	Direct emissions[3]
Clothing	G07	Plant based fibers	G28	Wearing apparel
	G12	Wool, silk-worm cocoons	G29	Leather products
	G27	Textiles		
Other	all other GTAP categories			

Notes: The description of each GTAP category is reproduced from (Narayanan G. Badri and McDougall, 2012).
[1]not elsewhere classified.
[2]direct emissions due to the consumption of electricity, natural gas, heating oil and kerosene are added to the energy category
[3]direct emissions due to the consumption of gasoline and diesel are added to the transport category.

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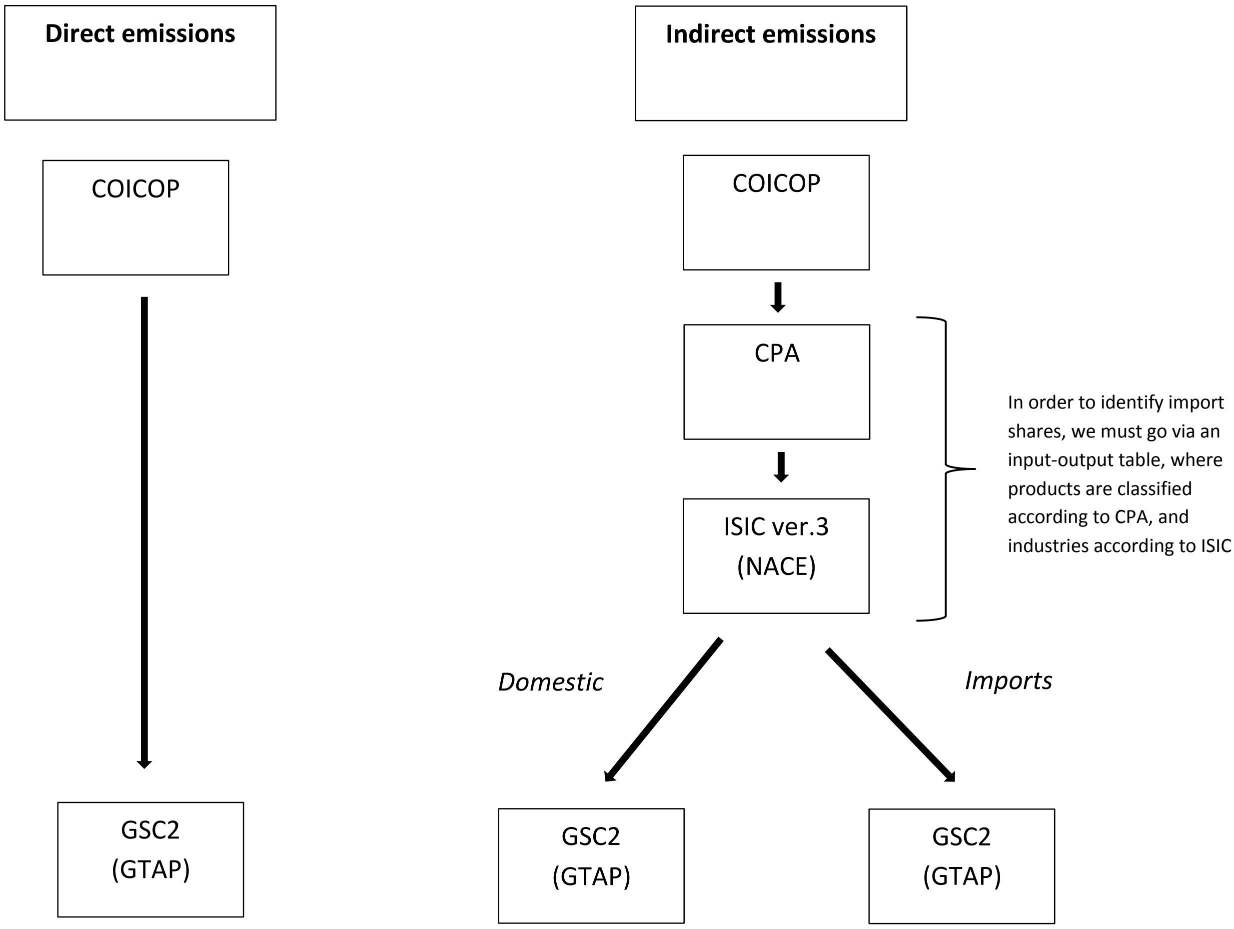
A.2 An overview of the different classification systems



A.3 High level data for the concordance matrix between COICOP and GTAP.

	GTAP				
COICOP	Food	Energy	Transport	Clothing	Other
Food and non-alcoholic beverages	95%				5%
Alcoholic beverages, tobacco and narcotics	98%				2%
Clothing and footwear			10%	71%	19%
Housing, water, electricity, gas and other fuels	7%	11%	1%		80%
Furnishings, HH equipment and routine maintenance	1%		13%	7%	78%
Health	4%		2%	1%	92%
Transport		1%	72%	1%	26%
Communication				0%	100%
Recreation and culture	2%		4%	3%	91%
Education					100%
Restaurants and hotels					100%
Miscelleous goods and services	2%		5%	3%	90%

Notes: Allocations were made between 183 COICOP categories and 57 GTAP categories. The detailed correspondence matrix can be made available on request.

B Data description and detailed methodology

B.1 Direct emissions

Direct emissions consists of the following consumption categories: electricity, heating oil, kerosene, gas, gasoline and diesel[33]. Details on prices and emission factors are reported in Table B.1. Emissions from gasoline and diesel are based on physical units (km driven) for the majority of observations, and are calculated using an estimate of CO2 emissions per km driven (0.16 kg CO_2/km) (derived from SSB, 2008, Table 3.3 and Table 3.4). In cases where the physical unit is missing, we use the average price per km driven (derived from the sample where both km and expenditures are non-missing) to back out km driven.

Table B.1: Details on prices and emission coefficients used to calculate the direct emissions.

	Energy source		CO_2 per physical unit		Unit from survey	Average price (NOK/physical unit)		CO_2 per monetary or physical unit	
1	Electricity								
		Region							
		Østfold	0.007	kg CO_2/kWh	NOK	0.62	NOK/kWh	0.011	kg CO_2/NOK
		Akershus		’	NOK	0.58	NOK/kWh	0.012	kg CO_2/NOK
		Oslo		’	NOK	0.61	NOK/kWh	0.012	kg CO2/NOK
		Hedmark		’	NOK	0.68	NOK/kWh	0.010	kg CO_2/NOK
		Oppland		’	NOK	0.67	NOK/kWh	0.010	kg CO_2/NOK
		Buskerud		’	NOK	0.60	NOK/kWh	0.012	kg CO_2/NOK
		Vestfold		’	NOK	0.62	NOK/kWh	0.011	kg CO_2/NOK
		Telemark		’	NOK	0.62	NOK/kWh	0.011	kg CO_2/NOK
		Aust-Agder		’	NOK	0.65	NOK/kWh	0.011	kg CO_2/NOK
		Vest-Agder		’	NOK	0.65	NOK/kWh	0.011	kg CO_2/NOK
		Rogaland		’	NOK	0.58	NOK/kWh	0.012	kg CO_2/NOK
		Hordaland		’	NOK	0.62	NOK/kWh	0.011	kg CO_2/NOK
		Sogn og Fjordane		’	NOK	0.68	NOK/kWh	0.010	kg CO_2/NOK
		Møre og Romsdal		’	NOK	0.69	NOK/kWh	0.010	kg CO_2/NOK
		Sør-Trøndelag		’	NOK	0.65	NOK/kWh	0.011	kg CO_2/NOK
		Nord-Trøndelag		’	NOK	0.79	NOK/kWh	0.009	kg CO_2/NOK
		Nordland		’	NOK	0.70	NOK/kWh	0.010	kg CO_2/NOK
		Troms		’	NOK	0.65	NOK/kWh	0.011	kg CO_2/NOK
		Finnmark		’	NOK	0.60	NOK/kWh	0.012	kg CO_2/NOK
2	Heating oil		3.17	kg CO_2/kg	liter	6.43	NOK/litre	2.28	kg CO_2/liter
3	Kerosene		3.15	kg CO_2/kg	liter	7.47	NOK/litre	2.52	kg CO_2/liter
4	Gas		2.75	kg CO_2/kg	NOK	23.47	NOK/kg	0.12	kg CO_2/NOK
5	Gasoline. diesel		0.16	kg CO_2/km	km			0.16	kg CO_2/km

Notes: 1 NOK ≈ 5.85 USD. Sources: SSB (2005, 2008, 2009, 2012b)

For the remaining categories (electricity, heating oil, kerosene, gas) we use reported expenditures in Norwegian kroner (NOK). For the electricity expenditures we use county specific electricity prices reported by SSB (2009) to back out the electricity consumption in kWh. We

[33] We cannot distinguish between gasoline and diesel as households report km driven and total expenditures without specifying the type of fuel.

then calculate emissions by using the average direct emission intensity for the Norwegian electricity consumption (0.007 kg CO_2/kWh) (SSB, 2008, Table 2.2). The emission factor collected from (SSB, 2008) is based on an assumption of 7% imported electricity from Nordic countries.[34] Emissions from kerosene, heating oil and gas are derived using average prices[35] and the direct emission intensities reported in Table B.1, which are collected from SSB (2005, Table 8). The correspondence between the energy consumption categories and the COICOP categories are listed in Table B.2.

Table B.2: Correspondence between energy consumption category and COICOP

Consumption type	**COICOP**
Electricity consumption	0451
Gas	0452
Heating oil	0453
Kerosene	0453
Gasoline and diesel	0722

Notes: See UNSD (2013b) for details on the different COICOP categories.

Note that when we group the different consumption categories into five main categories (food, energy, transport, clothing, other) in section 4.1, we include electricity (0451), gas (0452), heating oil (0453) and kerosene (0453) in the energy category, while we include gasoline and diesel (0722) in the transport category. To avoid double counting, electricity expenditures are subtracted from the household survey data before calculating the indirect emissions.

B.2 Indirect emissions

Table B.3: Indirect emissions

		Carbon footprint multiplier (kg CO_2/USD)	
GTAP	**Description**	**Norway**	**Rest of the World**
G01	Paddy rice	0.10	1.28
G02	Wheat	0.38	0.52
G03	Cereal grains nec	0.44	0.48
G04	Vegetables. fruit. nuts	0.27	0.38

[34] In one of the robustness checks in section 5 we also test for three alternative emission factors: 0.05, 0.200 and 0.542 kg CO_2/kWh.

[35] Average prices for kerosene and heating oil were collected from SSB (2012a) (for kerosene we use the price from 2005 as the 2007 value is missing), while the natural gas price is collected from the company Vestgass AS (`http://vestgass.no/`).

G05	Oil seeds	0.34	0.40
G06	Sugar cane. sugar beet	0.11	0.76
G07	Plant-based fibers	0.14	1.15
G08	Crops nec	0.13	0.45
G09	Cattle.sheep.goats.horses	0.28	0.34
G10	Animal products nec	0.27	0.38
G11	Raw milk	0.32	0.41
G12	Wool. silk-worm cocoons	1.38	0.65
G13	Forestry	0.17	0.26
G14	Fishing	0.50	0.60
G15	Coal	0.39	1.34
G16	Oil	0.17	0.22
G17	Gas	0.47	0.51
G18	Minerals nec	0.34	1.10
G19	Meat: cattle.sheep.goats.horse	0.23	0.35
G20	Meat products nec	0.26	0.32
G21	Vegetable oils and fats	0.27	0.50
G22	Dairy products	0.28	0.32
G23	Processed rice	0.28	0.65
G24	Sugar	0.22	0.18
G25	Food products nec	0.29	0.35
G26	Beverages and tobacco products	0.28	0.31
G27	Textiles	0.25	0.72
G28	Wearing apparel	0.24	0.67
G29	Leather products	0.22	0.48
G30	Wood products	0.22	0.36
G31	Paper products. publishing	0.22	0.38
G32	Petroleum. coal products	2.79	1.17
G33	Chemical.rubber.plastic prods	0.39	0.54
G34	Mineral products nec	0.78	0.86
G35	Ferrous metals	0.72	0.94
G36	Metals nec	0.62	1.11
G37	Metal products	0.35	0.48
G38	Motor vehicles and parts	0.30	0.32
G39	Transport equipment nec	0.27	0.41
G40	Electronic equipment	0.15	0.36
G41	Machinery and equipment nec	0.27	0.33
G42	Manufactures nec	0.31	0.42
G43	Electricity*	0.12	2.14
G44	Gas manufacture. distribution	0.31	1.53
G45	Water	0.14	0.94
G46	Construction	0.21	0.49
G47	Trade	0.13	0.35
G48	Transport nec	0.83	1.28
G49	Sea transport	1.80	2.67

G50	Air transport	1.17	1.77
G51	Communication	0.13	0.19
G52	Financial services nec	0.07	0.11
G53	Insurance	0.03	0.15
G54	Business services nec	0.12	0.16
G55	Recreation and other services	0.10	0.27
G56	PubAdmin/Defence/Health/Educat	0.07	0.24
G57	Dwellings	0.04	.

Notes: The numbers in the Rest of the World column reflect the average embodied CO2 emissions (in tonnes) per unit of expenditure (in USD) for goods imported to Norway from 129 regions of the world. *For Norwegian electricity consumption we use the geographically specific carbon footprint multipliers listed in Table B.1. Source: Andrew and Peters (2013). Details provided by Glen Peters at CICERO.

C Supporting results

Table C.1: Expenditures (in USD) and the associated carbon footprint (in tonnes CO_2), by consumption categories and expenditure quintiles

	Expenditure ('000 USD)			Carbon footprint (tonnes CO_2)		
Food (domestic)	2.1	3.1	4	0.6	0.9	1.1
Food (imported)	0.4	0.6	0.8	0.1	0.2	0.3
Food (total)	2.5	3.7	4.8	0.7	1.1	1.4
Energy (domestic)	1.1	1.2	1.4	0.3	0.3	0.4
Energy (imported)	0.0	0.0	0.1	0.0	0.0	0.0
Energy (total)	1.2	1.3	1.5	0.3	0.3	0.4
Transport (domestic)	0.9	2.3	6.7	1.7	3.2	6.2
Transport (imported)	0.6	1.7	6.4	0.6	1.4	4.0
Transport (total)	1.6	4	13.2	2.3	4.6	10.2
Clothing (domestic)	0.1	0.4	0.8	0.0	0.1	0.2
Clothing (imported)	0.4	1.2	2.4	0.3	0.7	1.6
Clothing (total)	0.6	1.5	3.2	0.3	0.8	1.7
Other (domestic)	6.3	14.7	30.5	0.9	2.3	5.4
Other (imported)	1.6	3.6	7.9	0.8	1.6	3.8
Other (total)	7.9	18.3	38.3	1.6	3.9	9.2
Total (domestic)	8.1	16.9	33.4	3.5	6.7	13.3
Total (imported)	3.2	7.1	17.5	1.8	4.1	9.6
Total (total)	11.3	23.9	50.9	5.3	10.8	22.9

Notes: The table shows the means for different quintiles, from the first quintile (Q1) to the fifth quintile (Q5).