19TH ANNUAL PACIFIC-RIM REAL ESTATE SOCIETY CONFERENCE
MELBOURNE AUSTRALIA, 13-16 JANUARY 2013

THE GREENHOUSE GAS IMPLICATIONS OF URBAN SPRAWL IN HELSINKI METROPOLITAN AREA

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ABSTRACT

Cities and urban activities within have been a hot topic in the climate change debate. The general opinion is that sprawling urban development is bad for the environment. The negative effects of urban sprawl are often associated with more households living at the urban edge's loosely populated areas where they have big detached houses and multiple cars. Consequently, in the literature the effects of sprawl have been studied mostly from the viewpoints of emissions from driving and home energy consumption.

In this paper sprawling of cities is related to the proliferation of semi-detached and detached houses, described as a low-rise lifestyle, at the expense of apartment house living i.e. high-rise lifestyle. We analyse differences between the low-rise and the high-rise lifestyles and their environmental effects in Helsinki Metropolitan Area. Environmental effects are assessed by combining greenhouse gas intensities from a consumption-based environmentally-extended input-output (EE I-O) model with expenditure data. Then these carbon footprints are further elucidated with multivariate regression analysis.

We found that low-rise lifestyle causes approximately 26 % more emissions than the high-rise one. Furthermore, there are significant differences in the structures of carbon footprints according to a type of dwelling. We believe that our consumption-based approach facilitates the understanding of urban lifestyles that are related to urban sprawl. We believe that our approach offers important insights for sustainable policy-design and urban planning.

Keywords: cities and climate change; urban sprawl, Environmentally Extended Input-Output analysis (EE I-O)

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1 INTRODUCTION

Warming of the global climate system is unequivocal (IPCC 2007, 5). Even though there is almost unanimous consensus on the existence of climate change the role of cities and urban activities in it has been hotly debated in recent years (Brown et al., 2009; Hoornweeg et al., 2011). The general opinion is that sprawling urban development is bad for the environment, and the denser the structures the better. When urban structures grow outwards the people living in the loosely populated surrounding areas are more car-dependent and may live in less eco-efficient apartments. Consequently, in the literature the effects of sprawl have been studied mostly from the viewpoints of emissions from driving and home heating (e.g. VandeWeghe & Kennedy, 2007; Glaeser & Kahn, 2010; Ewing & Cervero, 2010).

However, urbanization per se doesn't cause climate change: it is people who live, move, and consume in cities. Thus, in addition to driving and heating, the emissions from all other consumption activities should be assessed and allocated to the final consumer to reach a sufficient level of understanding on the consequences of sprawl, or density as well.

The proliferation of semi- detached and detached houses located at the urban edge is one of the best known characteristics of sprawl (e.g. Ewing & Rong, 2008; Glaeser, 2011). Combined with looser suburban structures and less accessible public transportation, this less-dense low-rise living represents the sprawl in an intraurban context. Thus we distinguish between different types of houses and analyze the differences in high-rise inner-city and low-rise sub-urban lifestyles and their environmental effects. Furthermore, it has been argued that policies that encourage home owning implicitly encourage people to move away from higher density living (e.g. Glaeser, 2011). Thus we also link urban sprawl to the proliferation of owner-occupied houses at the expense of rented houses. The analysis is done within a single metropolis, Helsinki Metropolitan Area (HMA) in Finland. This type of sprawl is a very interesting object of analysis since in an intraurban context the residents still maintain rather close proximity to all the consumption opportunities that a city or a metropolitan area offers, but rely predominantly on private driving and have more living space to be heated, furnished, and filled with domestic appliances.

In this study we assess household's environmental effects by calculating their consumption-based carbon footprints i.e. life-cycle greenhouse gas emissions, that can take place either home or abroad, but which are ultimately caused by consumption of products and services. What we add to the previous discussions is the perspective of how the emissions from consumption in its broad sense, beyond than those from driving and housing energy, affect its GHG consequences and the following policy implications. The study sheds light on proximity's effects on consumption suggesting that in the denser agglomerations the indirect emissions from consumption of goods and services grow, as has been argued to happen on country level (Heinonen & Junnila, 2011). Following the literature, the footprints are calculated by combining input data from Finnish household budget survey with environmentally-extended input-output (EE I-O) model ENVIMAT (Seppälä et al., 2009; 2011). The carbon footprints are further elucidated with multivariate regression analysis.

The selected case area, HMA, the capital region of Finland, consists of four cities: Helsinki, Vantaa, Espoo and Kauniainen. The area shares many traits with the globe's biggest metropolis areas, the results thus giving indication of more general patterns. Furthermore, within such a well-defined area some of the most uncertain assumptions of input-output technique, such as that of homogenous prices, are closer to reality. In addition, HMA is connected by an extensive public transportation network and possibilities to choose between private and public modes of transport are more or less diverse, with free parking options made available for those who need private cars to reach public transport hubs. In line with the sprawl hypothesis the division of housing types within the area is clear: the city core is dominated by apartment houses and semi-detached and detached houses are the main types of houses at the edge.

We believe that our consumption-based approach facilitates the understanding of urban lifestyles that are related to urban sprawl. We demonstrate that consumption's environmental impacts differ significantly according to the type of dwelling and that an understanding of these differences offers important insights for sustainable policy-design and urban planning.

The structure of our paper is as follows: first, we present the design of our research i.e. consumption data, both the methods, and research process in chapter 2. The results are presented in chapter 3 and discussion follows in chapter 4. We finish with conclusions in chapter 5.

2 RESEARCH PROCESS

2.1 Household budget survey data

We utilize the latest Finnish Household Budget Survey data from 2006 (Official Statistics of Finland, 2009). Dataset is cross-section in nature and alongside the actual detailed consumption expenditure data, classified according to the international COICOP (Classification of Individual Consumption by Purpose) classification, data contains a wide array of background and income information for each household. Budget Survey is a sample survey study which sampling design is one-stage stratified cluster sampling. The final sample size of the survey was 4,007 households. However the original sample was double the size and the magnitude of response was only 47.7 % — a situation that can be described as under coverage. However, non-response bias can be significantly reduced using weight coefficients and systematic biases can be avoided. In order to ensure the generalization of our results, the weight coefficients are utilized throughout this paper.

In this paper the sample of households is restricted to the metropolitan area, referring to the capital city of Helsinki and its neighbor cities Espoo, Vantaa and Kauniainen. Even if with approximately one million inhabitants it is relatively small in size when compared to the world's largest megacities, the Helsinki metropolitan area has multiple characteristics of a metropolis: a little more than a third of Finnish GDP is produced there, both the levels of education and wages are higher than the average, and there is an extensive public transport network. It has been said that "the challenges of metropolises are often different than in the rest of Finland, but similar to the other metropolises" (Alanen et al., 2010, 7).

In Table 1 our data and its background variables are described. In order to demonstrate the differences between Helsinki metropolitan area and the rest of the country also the characteristics of rest of the country are reported. Roughly speaking, the households in metropolitan area are richer and smaller. Furthermore, for households living in metropolitan area the average amount of cars per household is almost 40 % lower than in the rest of the country. Likewise, the share of carless households in 20 percentage points higher, depicting the availability of public transportation possibilities. In our data, 59 percent of households living in Helsinki metropolitan area are homeowners. In the rest of the country the figure is 70 percent. Furthermore, in metropolitan area share of households living in low-rise dwellings i.e. in detached or semi-detached houses is noticeable low, in particular 38 percentage points, relatively to the rest of country. The reported household and housing type characteristics are utilized in the econometric analysis.

Table 1: Descriptive statistics (n=568 for Helsinki metropolitan area and n=3439 for the rest).

	METROPOLITAN AREA		REST OF THE COUNTRY	
Variable	Mean	Std. Error	Mean	Std. Error
Household characteristics				
Disposable income	42 533	2926	33 634	447
Average household size	1,93	0,05	2,16	0,03
Number of cars per household	0,64	0,03	1,03	0,02
Share of carless households	0,46	0,02	0,26	0,01
Housing characteristics				
Average living area (square meters)	76,15	2,53	90,98	1,08
Share of owner-occupied dwellings	0,59	0,02	0,70	0,01
Share of low-rise dwellings	0,26	0,02	0,64	0,01

2.2 Environmentally Extended Input-Output model

In this paper we apply environmentally extended input-output (EE I-O) model, called ENVIMAT, which is recently developed for the Finnish economy. Environmentally extended input-output (EE I-O) analysis is one of the possible approaches of life-cycle analyses (LCA) that measure the direct and indirect environmental impacts of functional unit under consideration (Suh et al., 2004; Crawford, 2011). Besides environmentally extended input-output analysis, LCAs can be done with process-based life-cycle analysis and these two have been also combined which is referred as hybrid-analysis (Suh et al., 2004).

Environmentally extended input-output method is based on the input-output tables for national economies and related environmental impact categories. EE I-O method is often referred as a "top-down" measuring the product flows in monetary units (e.g. Wiedmann, 2009a; Crawford, 2011.) Usually the benefits of EE I-O method are said to be its capability to give an overview of the life-cycle effects of production and consumption of an economy, lack of problems related to system boundaries and truncation errors, and the easiness and repeatability of calculations once the model is developed (Suh et al., 2004; Tukker & Jansen, 2006)

In this paper we utilize the 2005 consumer-price version of ENVIMAT that has 52 commodity groups, classified according to COICOP classification and related GHG emission intensities (emission per € used to sector). The expenditure data is also organized according to COICOP-system so the model-data fit is excellent. In addition one of advantages of ENVIMAT is that it relaxes the domestic technology assumption (DTA-assumption) and uses a hybrid approach i.e. distinguishes between domestic and foreign production technologies. (Seppälä et al., 2009; 2011.)

2.3 Multivariate regression analysis

This section discusses our empirical approach that is based on the multivariate regression analysis where the dependent variable is per-capita greenhouse gas emissions e.g. carbon footprint. The regression analysis is employed to analyze further which factors actually affect the carbon footprints. As our starting point we use the non-linear exponential relationship between environmental impact and households' expenditures often found from the literature (Lenzen et al., 2006; Roca & Serrano, 2007; Kerkhof et al., 2009; Shammin et al., 2010).

$$Y_i = A \times E_i^{\beta} \times f_1(D_1) \times \varepsilon_i \qquad (1.1)$$

Where the dependent variable Y is per-capita carbon footprint, A is constant, E is per-capita expenditure, and dummy variable D refers to the household size. For dummy variable $f_i=\exp(\eta D_i)$ and for multiplicative error term $\varepsilon_i=\exp(u_i)$.

We linearize the non-linear relationship of (1.1) with natural logarithm transformation. The transformed model satisfies the assumptions of a general linear model and thus the parameters can be conveniently estimated using the highly developed theory of linear relationships. We follow the aforementioned literature and obtain the following equation that is estimated separately for both subsamples:

$$lnY_i = lnA + \beta ln\, E_i + D_1 + u_i \qquad (1.2)$$

For log-transformed equation (1.2) an estimate for slope β, and partial regression coefficient for explanatory dummy variable (Di) can be efficiently estimated with weighted least squares (WLS). One of the benefits of log-log model (1.2) is that the estimate β for continuous explanatory variable is elasticity which in our case tells us so called expenditure elasticity of carbon i.e. it describes how much a relative change in expenditures will affect the relative "demand" for greenhouse gases.

2.4 Research process

First, we calculate carbon footprints of Helsinki metropolitan area dwellers by combining greenhouse gas intensities derived from ENVIMAT-model with household budget survey data. This is done by aggregating expenditure data's categories to match the 52 COICOP categories of ENVIMAT and then multiplying expenditures with the corresponding ENVIMAT sector's value of greenhouse gas intensity (CO2e / €). It has been broadly acknowledged that combination of the two allows the assessment of amount of greenhouse gases that consumption choices cause directly and indirectly (Lenzen et al., 2006; Roca & Serrano, 2007; Kerkhof et al., 2009; Shammin et al., 2010).

In this paper, instead of looking only at the average footprints, we analyze footprints' direct and indirect shares based on building type. Our hypothesis is that living in owner-occupied detached house is a lifestyle closely associated with sprawl. With the direct share we refer to energy demand (electricity, gas, liquid and solid fuels, and heat energy) for home, second home and summer house, and gasoline for private cars. The indirect share is all the rest i.e. greenhouse gases caused by consumption of products and intangible services. A similar direct-indirect distinction was used by e.g. Bin & Dowlatabad (2005) and Druckman & Jackson (2009). With this setting we can analyze if the lifestyles in the sprawl areas differ from the rest of the metropolitan area in terms of the both direct and indirect emissions. Furthermore, conclusions from the overall GHG impacts of sprawl in HMA can be made.

Second, we further analyze these footprints with multivariate regression technique in order to study how expenditure and household size affects the footprints of different types of dwellers. The tradition dates back to 1970s when the first study of direct and indirect energy consumption of U.S. households was done (Herendeen & Tanaka, 1976). Also more recent examples of such regression can be found from the literature (e.g. Vringer & Blok, 1995; Lenzen et al., 2006; Roca & Serrano, 2007; Weber& Matthews, 2008; Kerkhof et al., 2009; Shammin et al., 2010).

3 RESULTS

The average of annual per-capita carbon footprint of a Helsinki Metropolitan dweller is 10.3 tCO2 equivalents with 95 % confidence interval ranging from 9.6 tCO2e to11.1 tCO2e. Besides looking at the average figure, we further decompose the footprints to four broad categories of which two are direct and the other two indirect, as explained earlier. Furthermore we cross tabulate the key household characteristics and GHG emissions of each according to a house type. The house types are divided to low- and high-rise ones. The low rise ones are household living in either detached (n=97) or semi-detached houses (n=73) and high rise refers to households living in apartment houses (n=398). The results are presented at the following Table 2.

Table 2: Descriptive statistics for sub-samples based on dwelling type (n=170 and n=398)

	LOW-RISE		HIGH-RISE	
Variable	Mean	Std.error	Mean	Std. Error
Household characteristics				
Disposable income	62 719	9 456	35 410	1 866
Number of cars per household	1,00	0,07	0,51	0,03
Share of carless households	0,26	0,04	0,53	0,03
Average household size	2,45	0,11	1,75	0,05
Share of households with children	0,37	0,04	0,19	0,02
Housing characteristics				
Average living area (square meters)	118,31	7,36	61,28	1,52
Number of rooms per person*	1,93	0,10	1,53	0,05
Share of owner-occupied dwellings	0,81	0,04	0,51	0,03
GHG characteristics				
Total carbon footprint	12,84	1,01	9,44	0,36
Direct energy	3,07	0,46	0,78	0,07
Direct fuel	1,14	0,14	0,86	0,08
Indirect products	4,16	0,28	3,62	0,14
Indirect services	4,47	0,41	4,17	0,22

*rooms (no kitchen) per a household member

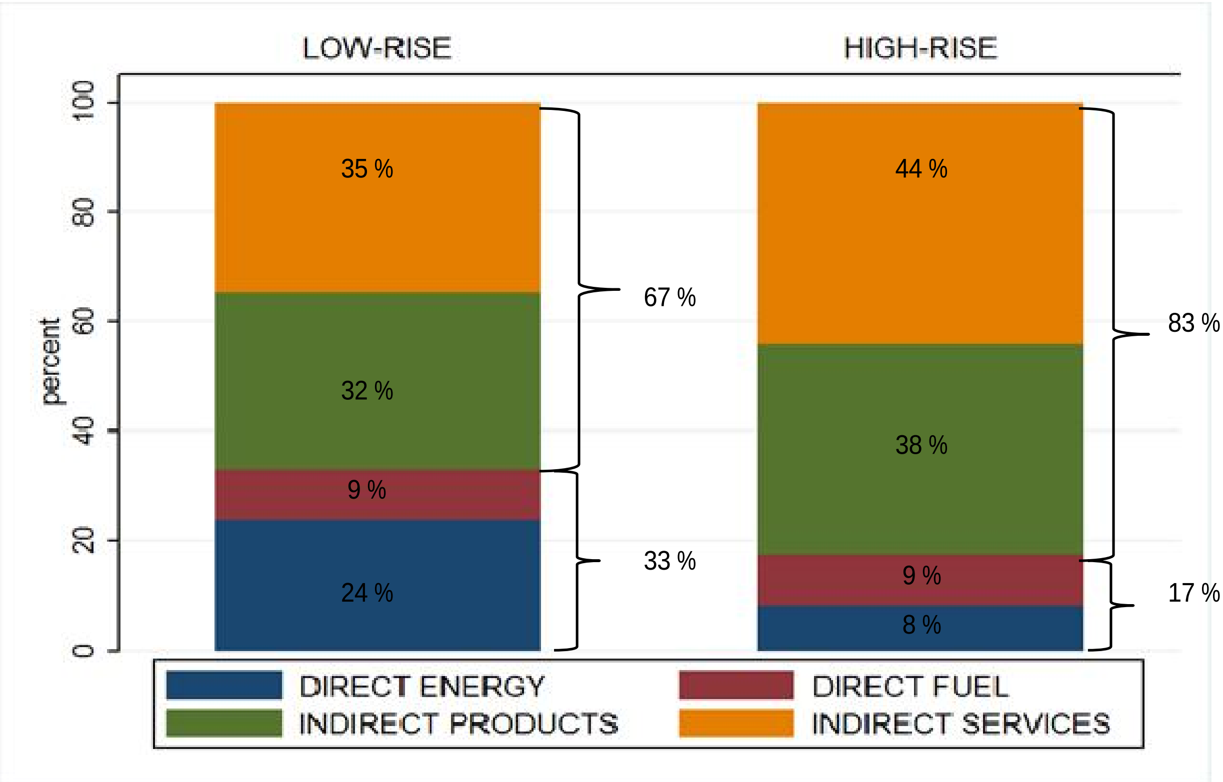
There are some interesting between-subsample differences in household characteristics. Households living in semi-detached or detached houses are the wealthiest and have the most cars, as expected, since the hypothesis was that a low-rise lifestyle is a lifestyle leading to car-dependence. Accordingly, the share of carless households in the apartment houses is more than half, precisely 53 %, which indicates that the apartment houses in Helsinki metropolitan area are on average located close to public transportation possibilities. Furthermore, families with children are likely to live in either detached or semi-detached houses, whereas the share of households with children in apartment houses is less than one fifth. Interestingly, 42 % of these high-rise households with children are single parent families.

Also housing type differences are rather expected. Average living space area in low-rise houses is 118.3 m^2, almost twice the living area of apartment houses. When compared on per-capita level, the living area is 1.4 times bigger in low-rise houses relatively to high-rise ones. There are also significant differences in share of owner-occupied dwellings between the sub-samples. As expected, the majority (81 %) of people living a low-rise life own their own apartments. On the other hand, the division between tenants and homeowners in apartment houses is approximately half and half.

The average footprints of low-rise dwellers are on average 3.4 tCO2e - or 26 % - larger than those of high-rise dwellers. The average for low-risers is 12.8 tCO2e and 9.4 tCO2e for high-risers. Likewise, the partial footprints for all the indirect and direct footprint sub-categories are the biggest for detached house dwellers. The between-subsample differences are biggest in the direct energy category.

One of the most interesting facts that can be seen from the table 2 is that the absolute amount of greenhouse gases derivable to indirect products and services is relatively stable for both dweller types. Even if the mean disposable income of apartment dwellers is clearly lower than that of detached dwellers, the differences in amounts emission embodied in products and services are fairly moderate. Likewise an interesting matter is the difference concerning the GHG's from fuel combustion for private driving: the difference between low-rise dwellers and those living in apartment buildings is only 0.3 tons, despite the significant difference in the number of cars possessed on average. In order to further demonstrate the differences of dwellers living in different types of houses, we plot percentage shares of home energy use, fuel, and emissions embodied in consumption of products as well as services. The results are presented in figure 1.

Figure 1: Direct and indirect emission shares of carbon footprints for different dwellers.



From Figure 1 it can be concluded that there are substantial differences in the sources of greenhouse gas emissions. Only the share of GHG emissions of consumption of private fuels is constant, approximately 9 % for both dweller types. The share of energy consumption's GHGs is 24 % for low-rise dwellers and 8 % for high-rise inmates. The percentage share of products is 32 % for low-risers and 38 % for high-risers from total footprints. For services the figures are 35 % and 44 % in a respective order.

The next steps of our analysis are the regression analyses that are based on the equation (1.2). First, we perform univariate regressions for both subsamples with a logarithmic expenditure level as a sole explanatory variable. The results are presented in the following Table 3.

Table 3: Results from univariate regression models. The coefficients are all statistically significant at 0.001 level. Standard errors are reported in the parenthesis.

	ALL		LOW-RISE		HIGH-RISE	
EXPENDITURE ELASTICITY	0,97	(0,023)	0,99	(0,057)	0,94	(0,019)
R2	0,85		0,77		0,90	
N	568		170		398	
DIRECT EXPENDITURE ELASTICITY	0,95	(0,100)	1,08	(0,165)	0,80	(0,103)
R2	0,21		0,29		0,19	
N	561		168		393	
INDIRECT EXPENDITURE ELASTICITY	0,95	(0,018)	1,00	(0,033)	0,93	(0,020)
R2	0,90		0,92		0,90	
N	568		170		398	

The average expenditure elasticity of HMA resident is 0.97 meaning that a 10% increase in expenditures is related to, on average, a 9.7 % increase in consumption-based greenhouse gas emissions. Thus carbon footprints, even if indirectly demanded, can be defined to be normal goods with expenditure elasticity very close to unity. The expenditure elasticity for low-rise dwellers is moderately higher, 0.99. Respectively, the expenditure elasticity for apartment dwellers is somewhat lower, 0.94. The order of magnitude of expenditure elasticity values for direct and indirect shares of emissions is similar, low-rise dwellers having the highest values. These results suggest that in low-rise group the consumption choices are somewhat more greenhouse gas intensive than those of apartment dwellers, especially so when only the direct share of footprint is explained.

We also tried controlling wealth level with income per capita. These income elasticites are smaller and approximately equal, rounded to 0.65, meaning that a 10% rise in per-capita disposable income is related to a 6.5 % increase in carbon footprint for both dweller-types. This could indicate that a rather large share of all consumption is directed to necessary goods and on higher levels of income the income growth is faster than the growth in needs. It is also possible that time restrictions decelerate the growth in purchases.

In the next step we do another regression analysis based on the equation (1.2). Now we add one categorical explanatory variable, household size, to the model. Household-size is analyzed with a 3-step dummy with single dwellers as a reference group. So the household size categories (2 person households and more than 2 person households) are compared to single dwellers, and the percentage difference in carbon footprints is approximated with $p=100(\exp\beta-1)$ (Hardy 1993, 58). The results of multivariate regression presented in the following Table 4.

Table 4: Multivariate regression models with logarithmic per-capita expenditure and household size dummy as explanatory variables. Standard errors are reported in the parenthesis.

	ALL				LOW-RISE				HIGH-RISE			
VARIABLE	ESTIMATE		SE	% effect	ESTIMATE		SE	% effect	ESTIMATE		SE	% effect
LN E/PER CAPITA	0,97	***	0,024		0,92	***	0,068		0,94	***	0,020	
HOUSEHOLD SIZE (single)												
2 persons	0,05		0,025	4,6	-0,02		0,085	-2,3	0,03		0,194	3,5
more than 2	0,02		0,026	2,0	-0,18		0,094	-16,1	0,02		0,025	2,1
N	568				170				398			
R2	0,847				0,786				0,896			

***Significant at 0.001 level

In the literature it has been suggested that there would be so called economics of scale in GHG's, implying that the coefficients on bigger household sizes should be negative. However, in our model specifications none of the coefficients on household size did get a statistical significance. Nonetheless, an interesting fact emerging from Table 4 is that the signs of size-dummies are positive in all but low-rise group, indicating that economics of scale, such as sharing of greenhouse gas intensive resources, would be present only for detached and semi-detached house dwellers. However, in the absence of statistical significance no further conclusion can be made. However, this could indicate interesting avenues for further research.

4 DISCUSSION

4.1 Discussion

The purpose of this paper was to explore how the phenomenon of urban sprawl shows in the GHG emissions of the residents of HMA in Finland. For this purpose HMA was divided according to the housing type. We followed a hypothesis that living in detached and semi-detached-houses can be typified as living in the less dense sub-urban areas where the proximity to services is higher and public transportation networks less efficient, thus representing the features of sprawl that are considered the most negative in an intraurban context. The consumption-based GHG's were assessed with an EE I-O LCA model and further elaborated with a multivariate regression analysis.

Our results suggest that there are substantial differences in the characteristics and lifestyles of different types of households living in different types of houses, and the following GHG consequences, within the metropolitan area. Our case area, HMA, is a rather typical metropolis with a sprawling urban structure, but also with multiple positive features typical to metropolitan areas, the most important being its efficient public transportation network.

Furthermore, our results suggest that living at an owner-occupied detached house is the most greenhouse gas intensive metropolitan lifestyle. It seems that larger households with children tend to reside in the larger detached and semi-detached-house residences. To some extent, the results also support earlier findings that the use of private vehicles increases (e.g. Ewing & Cervero, 2010). However, the differences in private transportation's emissions are remarkably small indicating that the private driving related gains of higher density are moderate at best. This may also suggest that the better public transportation possibilities available for inner-city dwellers are not utilized up to their fullest potential.

In the earlier urban sprawl literature several other authors have also raised the issue of house type's role in greenhouse gas emissions (e.g. Lenzen et al., 2006; Shammin et al. 2010). Also negative externalities of subsiding home-ownership are widely reported (e.g. Oswald, 1999; Gervais, 2002; Poterba & Sinai, 2008). It has been argued that current policies, i.e. mortgage interest deduction policy, push people away from city centers, make them more car-dependent and thus are bad for the environment (e.g. Glaser 2011, 176). It has been demonstrated that housing market has impacts on migration also in Finland. Especially, the high housing prices and large share of owner-occupied dwellings reduce working-age population migration to Helsinki metropolitan area. (Hämäläinen & Böckerman, 2004).

We also show that in order to make relevant policies aimed at reductions in GHG emissions, the structures of carbon footprints have to be kept in mind. For dwellers living in different house types the percentage shares indirect and direct shares of footprints are composed very differently, as demonstrated in Figure 1. The differences are likely to be even more dramatic I looked at more disaggregated level. However, the different trends are present also at the much aggregated 4-category analysis.

However, even if we believe that our paper brings out important insights on how consumption patterns and their environmental consequences vary with building type and ownership form the disparities within each category cannot be neglected. Precisely the less wealthy, whatever their housing conditions were, are not likely to cause great amounts of greenhouse gas emissions.

4.2 Limitations

One of the main limitations of the study related to housing prices. The budget survey does not count purchase of a house for consumption but data contains information about either rent actually paid or computed if living in owner-occupied dwelling. Even when a relatively limited area is considered, like HMA in this paper, it is clear that the rental costs (both actual and computed) vary significantly according to the e.g. spatial location, average per square meter prices being higher at the metropolitan core. We recognize this to be one of the paper's uncertainties. However, since the area of the study is relatively limited, it can be concluded that prices in the other sectors are likely to be rather homogenous. For example the regional wage differences and different costs of public transportation are not present. In addition, the assumption of homogenous prices probably overestimates greenhouse gas implications of the wealthiest households of which the majority lives in detached houses. These households likely buy more expensive goods that don't necessarily indicate higher emissions. However, this type of qualitative differences in consumption cannot be differentiated with the utilized data. There are also some other limitations that are mainly related to the general weaknesses of EE I-O models (look e.g. Wiedmann, 2009, 176-177).

Secondly, there are some important uncertainties related to the assessment of the emissions from direct energy, the sector with the highest variations between the samples. First, there is a bias related to the fact that the majority of apartment house dwellers pay at least part of their utilities within rents and housing management fees (e.g. Kyrö et al., 2011) and thus the share of home-energy use's greenhouse gas consequences is likely to be underestimated. Consequently, the share of energy paid within housing fees increases the share indirect emissions in the assessment and partially explains the small differences between the samples.

Thirdly, in the lack of exact spatial data on how households on our data are located, the results of this paper are based on a strong assumption on how the different building types are, on average, located within Helsinki metropolitan area (HMA). However, we believe that our results can be generalized since in HMA apartment houses are almost invariably located in the centers of HMA cities (Helsinki, Espoo, Vantaa and Kauniainen), share of apartment houses being highest in the capital (86 %) (Official Statistics of Finland, 2012).

Finally, we do not use other explanatory variables than expenditure to explain carbon footprints. However, in the literature a wide array of variables have been included e.g. education-level, car ownership, and age (eg. Lenzen et al., 2006; Shammin et al., 2010). However, none of these haven't found to be of a similar importance as the level of expenditures and furthermore, analyses are often complicated by multicollinearity and endogeneity issues.

5 CONCLUSIONS

According to the study the phenomenon of urban sprawl is revealed in the increased carbon footprints of suburban dwellers. We found that the consumption-based GHG consequences of the dwellers of detached and semi-detached-houses in HMA are significantly higher, precisely 26 %, than those of apartment dwellers. Notwithstanding the certain deficiencies that are likely to lead to overestimations in the emissions of suburban group and underestimations in the emissions of the apartment house dwellers, some important policy implications arise. Firstly, it would seem that the emissions from private driving decrease only moderately in the dense areas within HMA, but the emissions from housing energy consumption are significantly lower in apartment houses. Thus, controlling the building energy efficiency would be of primary importance in preventing the negative effects of sprawl. In addition, the differences in the indirect emissions from consumption of products and services were very small in the study despite the large differences in the disposable incomes. This could suggest that better proximity may increase the consumption in the dense city core areas. This leads to a conclusion that actually more detailed information about different lifestyles and the connections between the urban form and the consumption choices of households is needed in order to understand and mitigate the GHG consequences of urban sprawl.

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