The effect of work hours on energy use A micro-analysis of time and income effects

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Abstract

In the environmental movement there is an idea that a reduction in work hours could be good for the environment. This idea is especially forceful since shorter work hours have possible positive consequences such as less time pressure and more time for activities which are important for subjective well being like social contacts, volunteer work and child care.

This paper aims to contribute to the understanding of this issue, analyzing the impact of work hours on energy use and greenhouse gas emissions in Sweden. We use a micro-data approach analyzing how a change in work time affects the energy use of households via changing income and changing time use patterns. We assume that a change in work hours gives a proportional effect on income. We identify the marginal consumption through carrying out linear regressions. In addition we make similar regressions in order to estimate how the time is used when work hours are changed. The regression results are matched with energy intensities and greenhouse gas emissions per expenditure and per minute of time use.

The results of this study indicate that an increase or decrease in work time by 10 percent gives a change in energy use and greenhouse gas emissions by about 8 percent on average, a bit less for high income households and a bit more for low income households. The increase or decrease in energy use with work hours is dominated by the effect of income. The effect due to more available time for leisure activities is more than an order of magnitude smaller than the income effect.

1 Introduction

The current discussion on how society should be transformed to mitigate climate change is primarily focused on technological changes such as switching of fuels and energy carriers, carbon capture and storage technologies, and more efficient uses of energy. In the environmental movement there is an idea that a reduction in work hours could be good for the environment (Hayden 1999; Axelsson 2005). They argue that the choice of path between a consumption oriented future and a future with more spare time will have consequences for society's environmental impact. This thought has also been incorporated in some future scenarios for energy and environment (Azar and Lindgren 1998; Åkerman et al. 2007). The base for this idea is that the development of energy use and greenhouse gas emissions is coupled to the volume of consumption which in turn depends on to what extent society's increasing productivity is realized in terms of increasing income or in reduced work time (Schor 2005; Sanne 2007). This idea is especially forceful since shorter work hours have possible positive consequences such as fewer problems with feelings of time pressure (Larsson 2007; Lippe 2007). Several studies have shown that shorter work hours are used for activities such as child care, sleep, meals, social contacts, volunteer work (Albertsen et al. 2007) and these types of activities have also been shown to be more important for subjective well being than material consumption acquired by increasing income (Layard 2005).

Very few previous studies have specifically addressed the link between work time, energy use and greenhouse gas emissions. Schor (2005) conducted an analysis, using data from 18 OECD-countries, linking national ecological footprint and average hours per employee and found a significant positive correlation which means that increasing working hours increases ecological footprint. Rosnick and Weisbrot (2006) also approached this issue on the macro-level by comparing work time and energy use in 48 countries. The central estimate in this paper was that a 1 percent increase in work hours per worker resulted in a 1.32 percent increase in energy use per capita (controlling for GDP/hour, worker/population and temperature).

In addition to the effect on income, a change in work time also affects the availability of leisure time, which also may affect the composition of consumption. Schipper et al (1989) carried out calculations on energy use per hour for different activities. Binswanger (2001; 2004) used Becker's (1965) approach of a household production function to show that a time-saving innovation in the production of a service ought to lead to an increased demand for that service. In any case where the time-saving innovation affects a service that is energy intensive (which is the case for mobility), it will also result in an increased demand for energy. In a similar way, Jalas (2002) illustrated time-use rebound effects by looking at examples of measures in the eco-efficiency literature. One such example is delivery services of food which have been claimed to save both time and energy (since several households can be served by the same delivery service). The time-use rebound effect then depends on what activity that increases when more time is available. Under the assumption that the rebounding activity has the average time energy intensity (J/hr) of all activities, scaling down activities with lower than average time energy intensity would increase the total energy demand.

This paper aims to contribute to the understanding of this issue by analyzing the impact of work hours on energy use and greenhouse gas emissions in Sweden. In contrast to Schor (2005) and Rosnick & Weisbrot (2006) we use a micro-data approach analyzing how a change in work time affects the energy use of households via changing income and changing time use patterns.

2 Method

A change in the number of work hours can have many different consequences. In this paper we explore the effect on expenditures through changing income and time use patterns. Micro-data including both time use and expenditures in the same data set is not available. Instead we have carried out an analysis in two steps: first we have investigated the income effect (Section 2.1) and then the time effect (Section 2.2).

2.1 INCOME EFFECT

In this part of the analysis we estimate how the consumption of various goods and services are affected by a change in income (Section 2.1.1), and what this means in terms of energy use (Section 2.1.2).

A general reduction in work hours in the future would limit the income gains which otherwise would be possible due to the normal productivity improvements in the economy. However, it is not certain that a change in work hours is proportional with the effect on income. It is for example sometimes assumed that a work time reduction results in an increase in productivity per hour. In this study we make the assumption that a change in work hours results in a proportional change in income.

2.1.1 Expenditure regressions

This analysis is based on data from the Swedish Household Budget Survey for 2006 (Statistics Sweden). This data set contains expenditure data from around 2000 Swedish households on around 800 different goods and services. In this study however, we use an aggregation level of 104 goods and services since these can be matched with available energy intensities (Section 2.1.2). Since the focus in this study is on changing work time, households where one or more of the adults were unemployed or retired were excluded from the set.

For each of these 104 goods and services we carry out linear regressions with the expenditure as the dependent variable and disposable income as the independent variable. In order to improve the fit of the model we also include a set of other independent variables. Several different combinations of variables were tested and the model with the highest average adjusted R^2 value that did not cause multicollinearity was chosen for the analysis:

Expenditure on good or service = f(Income, Age, Cohabit, Child 0-6, Child 7-15, Child 16-19, Low educ., High educ., Large city, Small city)

Income	Disposable income	[continuous variable]
Age	Adults' average age (20 years or older)	[continuous variable]
Cohabit	More than one adult in the household (20 years or older)	[dummy]
Child 0-6	At least one child in the age 0-6 (pre-school)	[dummy]
Child 7-15	At least one child in the age 7-15 (primary school)	[dummy]
Child 16-19	At least one child in the age 16-19 (secondary school)	[dummy]
Low educ.	Households in the quartile with the shortest education	[dummy]
High educ.	Households in the quartile with the longest education	[dummy]
Large city	Stockholm, Göteborg or Malmö (>250000 inhabitants)	[dummy]
Small city	Other city	[dummy]

The resulting regression coefficients for disposable income are interpreted as the marginal consumption, i.e. the increase or decrease in consumption of a good or service for a change in income. We assume that a change in income results in an equally large change in total expenditures. Hence the estimated coefficients are adjusted so that the sum equals disposable income[1]. This was done by multiplying the expenditures on all items by same factor.

For the purpose of this study, we are not interested in the values of the regression coefficients for the other independent

1. In the data set, 18 percent of the disposable income was not attributed to expenditures, suggests very large savings. However, other statistics show that savings only constituted 7 percent of the disposable income in 2006 (Statistics Sweden 2008). Hence, we conclude that the 18 percent difference to a large extent may depend on that some households have failed to report some expenditures. If expenditures were not adjusted to match disposable income this would cause an underestimation of the marginal energy intensity. In any case, it would have been unrealistic to assign a zero energy intensity to these apparent savings.

variables. It is important to notice that these variables are included only to improve the explanatory value of the regression model.

2.1.2 Energy use and greenhouse gas emissions

Energy use and greenhouse gas emission data are taken from an input-output analysis from Statistics Sweden's Environmental Accounts[2] for 2005. In this methodology primary energy use and CO_2 equivalents (global warming potential, GWP, of carbon dioxide, methane and nitrous oxide) per unit of final consumption are calculated using monetary transactions between sectors together with multipliers of direct energy use and emissions in each sector. Thus the method re-allocates energy use and emissions from production to consumption, including indirect contributions from an unlimited number of upstream sectors[3]. The energy use and greenhouse gas emissions for imported goods and services have been calculated as if they had been produced domestically[4] (Carlsson-Kanyama et al. 2007). The underlying method for compilation and analysis of input-output matrices is well described in a publication by the United Nations (1999).

2.2 TIME EFFECT

In this second step of the analysis we estimate how the time use off work are affected by a change in work hours (Section 2.2.1), and what this means in terms of energy use (Section 2.2.2).

2.2.1 Time use regressions

The time effect is analyzed using data from the Swedish Time Use Survey 2000/2001. Time use for almost 4000 individuals has been recorded for one weekday and for one day on a weekend.

The time use were described for every ten minutes and later coded in 134 primary activities (simultaneously performed secondary activities were not included in our data set).

In this study we have aggregated this into 12 time use categories. As in the analysis of the income effect we have excluded households were one or more of the adults were unemployed or retired. We have also excluded households where both adults have not participated in the study (but single household are included). The reason for this is that we aggregated the two adults' time use in order to include the effect that one partner's change in working time affects the partner's time use patterns. Slightly more than 1000 individuals are included in the analyses.

As a base for the final analysis of how a change in working hours is affecting the total energy use we first describe the average non-work time use. The second step is to estimate what effect an increase or decrease in working hours has on the non-work time use categories. How is an extra work hour affecting the time used for domestic work, child care, sleep, travel etc? We estimate this marginal time use by means of linear regression analyses. In the first regression domestic work is the dependent variable and time for paid work is an independent variable (then child care is the dependent variable, etc)[5]. In order to keep the analyses of income and time separate we are controlling for income in the time regressions.

Time use on various non-work categories = f(*Work time, Income)*

Work time	Minutes used for paid work/studies, including breakes	[continuous variable]
Income	Disposable household income	[continuous variable]

2.2.2 Energy use

In order to approximate the intensities of energy use and greenhouse gas emissions of different time use categories we construct an allocation matrix where expenditures on 104 different items are allocated to 12 categories of time use. Similar methods to establish time energy intensities have previously been used by Schipper et al, (1989), Jalas (2002; 2005), Wadeskog et al (2003) and Hille et al (2007). The different allocation shares are based on the following assumptions:

- A large number of expenditure items have been assumed to be independent of time use: housing, heating fuels, food, clothes, furniture, day care, insurances and other services.
- Vehicles, transport fuels and travel tickets are allocated to the three different time categories of travel.
- Electricity consumption is first divided on end uses based on energy statistics (SEA 2008):
  - Electric heating is assumed to be independent on time use.
  - Lighting is allocated based on the time of activities at home and awake.
  - Electricity for household appliances is allocated to time for domestic work.
  - Electricity for computers is allocated to time for hobbies/other leisure time.
  - Electricity for radio and TV is allocated to time for TV/radio/reading.
- Household appliances and tools are allocated to time for domestic work.
- Telephone and telephone services are allocated to time for socializing.

Major durables for outdoor recreation (e.g. boats), sport equipment and services are allocated to time for sports/outdoor activities.

2. Available from http://www.mir.scb.se.

3. Figures on primary energy use for electricity production depend on the definitions used. In this analysis we use conversion efficiencies of 0.37 for nuclear and thermal power. This estimate is based on the national energy supply statistics (Statistics Sweden 2005). For hydro and wind, primary energy is calculated as produced electricity plus internal energy use. This gives a total weighted average conversion efficiency of 0.52 from primary energy to electricity.

4. Since the Swedish energy system, particularly the electricity sector, is relatively low in CO2 emissions, this results in an underestimation of the emissions abroad (Carlsson-Kanyama et al, 2007). In this study, were we analyse relative and not absolute changes this has little or no impact on the results.

5. For the three different travelling modes we lack access to basic data. Instead we have used mean values for 20 subsets based on work hours and income for our regression analyses.

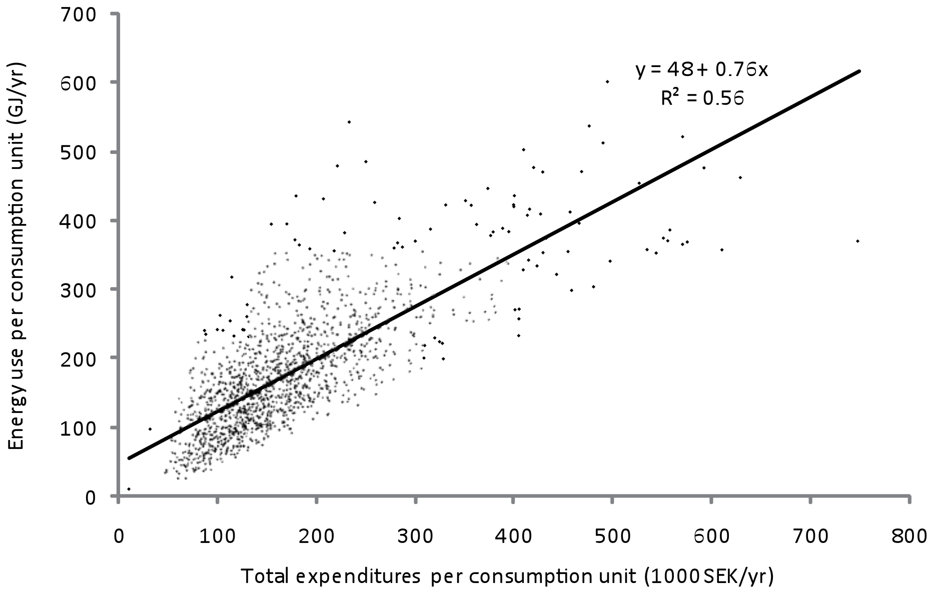

Figure 1. Energy use and total expenditures for Swedish households in 2006. Households with one or more unemployed or retired were excluded from the set.

- TVs, radios, books and papers are allocated to time for TV/radio/reading.
- Photographic equipment, computers, music instruments, games, toys and gardening equipment are allocated to time for hobbies/other leisure time.
- Appliances and products for personal care are allocated to time for personal care.
- Coffee, tea, cocoa, soft drinks and alcohol are assumed to be partly independent on time use (as the assumption for food) and partly allocated to time for socializing.

Still, one problem remains. With the fixed energy intensities (MJ/h) constructed as described above, it will appear as if more spare time always leads to a higher energy use. However, in reality the energy intensities of some activities are not necessarily fixed. With more time available, some equipment may be used more extensively (a longer tennis match with the same racquet or a longer night's sleep in the same bed). Also, since the estimates of marginal time use with respect to working time (Section 2.2.1) are carried out including disposable income as an additional independent variable, the marginal time use with respect to working time should be interpreted as for households with similar income (the income effect is estimated separately in Section 2.1). This means that the time effect should not lead to an increase in total expenditures.

In order to ensure that the total expenditures are not changed, we divide the activities in two types:

Type 1. Activities with a strong dependence of energy use on time use: Travel; Entertainment and culture; TV, radio and reading; Domestic work. We assume that two hours of for example car travel or lawn mowing always result in twice as much energy use as one hour.

Type 2. Activities with a weak dependence of energy use on time use: Child care; Sleep, eating, hygiene; Sports and outdoor activities; Socializing; Hobbies. We assume that more time spent on these activities does not per definition require more consumption and energy use.

The expenditures on activities of Type 2 are adjusted so that the sum of expenditures does not exceed income.

3 Results

3.1 INCOME EFFECT

We make a first estimate of the relationship between income and energy use simply by plotting energy use per consumption unit[6] against total expenditures per consumption unit for the households included in the analysis (Figure 1).

The equation of the linear trend line in Figure 1 gives that an increase in income (total expenditures, see footnote 1) of 1 SEK[7] would increase energy use by 0.76 MJ. The linear estimate gives a reasonably good fit but energy use grows a bit slower as a function of income for high income households. Dividing the data set into two groups based on income gives a marginal energy intensity of 0.95 MJ/SEK for the lower income group and 0.65 MJ/SEK for the upper income group.

However, there is also a large spread in these results. The energy use for households with similar total expenditures per consumption unit varies by approximately a factor of 4. This spread may at least to some extent be explained by the other independent variables included in the more detailed regressions of 104 different goods and services (see method in Section 2.1.1). The results of these regressions along with average expenditure shares and intensities of energy use and CO_2-equivalents are presented in Table 1.

For several small expenditure items, the significance of the income regression coefficient is very low, but for the major ex-

6. Consumption unit (c.u.) is a simple measure of household size: single adult 1.16 c.u., two cohabiting adults 1.92 c.u., additional adult 0.96, child 0-3 years 0.56 c.u., child 4-10 years 0.66 c.u., child 11-17 0.76 c.u.

7. The average exchange rate in 2006 was 1 SEK = 0.108 Euro.

Table 1. Average and marginal expenditure shares together with energy intensities and CO2-eq intensities for 104 goods and services.

	Expenditure shares		Energy intensity	CO_2-eq intensity
	Average	Marginal		
	SEK/1000 SEK	SEK/1000 SEK	MJ/SEK	gCO_2-eq/SEK
Bread, cereals	20.8	8.5***	0.77	49
Meat	24.5	15.7***	0.95	103
Fish, seafood	6.4	2.8*	0.96	54
Milk, cheese, eggs	19.8	8.6***	1.01	114
Oils, fats	2.8	0.9*	0.93	72
Fruit	10.0	4.5***	1.00	145
Vegetables	14.1	7.2***	0.99	132
Sugar, jam etc	11.8	5.0***	0.80	58
Salt, spices etc	5.5	3.3***	0.71	60
Coffee, tea, cocoa	2.9	1.0+	0.79	77
Mineral water, soft drinks, juices	7.1	4.7***	0.68	45
Spirits	1.4	-1.0	0.20	11
Wine	7.4	11.6***	0.33	18
Light beer	0.4	-0.3	0.57	31
Beer	1.8	0.3	0.35	18
Tobacco	6.0	-1.8	0.21	9
Clothing materials	0.1	-0.4	0.67	29
Garments	46.4	49.4***	0.45	21
Clothing accessories	2.2	3.4***	0.49	22
Cleaning, repair and hire of clothing	0.4	0.1	0.34	15
Footwear	10.5	14.1***	0.49	28
Repair of footwear	0.2	0.4	0.39	16
Housing excl. maintenance and energy	135.4	28.4*	0.36	17
Maintenance and repair of dwelling	20.6	8.7	0.69	28
Electricity	36.9	19.7***	8.69	58
Liquid fuels	2.6	0.0	4.85	335
Solid fuels	0.9	-0.6	22.83	47
District heating	2.3	3.4*	3.57	134
Summer house excl. energy	4.5	14.6***	0.22	13
Summer house energy	2.0	10.9***	8.69	58
Furniture and furnishings	26.0	27.2***	0.62	23
Carpets and other floor coverings	2.1	8.6**	0.55	21
Repair of furniture	0.0	0.0	0.39	16
Household textiles	6.5	7.6	0.57	21
Major household appliances	9.1	7.1*	0.52	19
Small electric household appliances	0.7	1.4+	0.53	19
Repair of household appliances	0.0	0.0	0.38	16
Glassware, tableware and household utensils	6.6	9.6*	0.67	27
Major tools and equipment	1.1	0.2	0.42	17
Small tools and accessories	6.4	1.1	0.53	20
Non-durable household goods	7.8	5.2**	0.76	27
Household services	0.3	0.0	0.32	16
Pharmaceutical products	7.2	7.3**	0.46	17
Other medical products	0.2	-0.3	0.47	17
Therapeutic equipment	3.7	25.5***	0.38	15
Medical services	1.5	0.2	0.26	8
Dental services	6.1	-2.2	0.24	8
Paramedical services	1.8	2.9*	0.29	10
Hospital services	0.0	0.0	0.24	8
Cars	77.7	197.0***	0.53	20
Motor cycles	6.1	8.8	0.56	22
Bicycles	1.9	2.0*	0.56	22
Spare parts for vehicles	7.3	7.6	0.59	22
Fuels and lubricants for vehicles	55.8	38.3***	3.40	216
Maintenance and repair of vehicles	11.4	23.3*	0.44	15
Vehicle tests	0.6	-0.9	0.25	11
Hire of vehicles	0.7	-0.2	0.56	26
Parking	0.8	0.6	0.19	8
Driving lessons and licenses	1.2	-3.0	0.17	5

	Expenditure shares		Energy intensity	CO_2-eq intensity
	Average	Marginal		
	SEK/1000 SEK	SEK/1000 SEK	MJ/SEK	gCO_2-eq/SEK
Bridge tolls	0.1	0.0	1.15	78
Passenger transport by railway	3.5	-2.4	1.73	32
Passenger transport by road	6.7	-0.2	0.51	27
Passenger transport by air	1.2	5.2*	1.93	123
Passenger transport by sea and waterways	1.1	1.5	3.14	231
Combined passenger transport	1.0	0.7	1.70	62
Other transport services	0.1	-0.3	0.69	41
Postal services	0.6	0.4	0.35	13
Telephone and telefax equipment	2.8	0.7	0.30	12
Telephone and telefax services	28.8	7.2**	0.26	10
TV sets, radios, gramophones etc	10.6	24.2***	0.33	13
Photographic and cinematographic equipment	2.7	0.4	0.34	13
Information processing equipment	13.4	-1.5	0.43	18
Recording media	1.9	1.1	0.51	19
Repair of audio-visual, photogr., info. equipment	0.1	0.0	0.38	15
Major durables for outdoor recreation	10.6	55.2***	0.57	27
Musical instruments, durables for indoor recreation	1.4	0.5	0.49	19
Games, toys and hobbies	4.9	4.0*	0.51	19
Equipment for sport, and outdoor recreation	7.8	16.3*	0.55	22
Gardens, plants and flowers	6.9	15.3***	0.83	108
Pets and related products	4.9	1.5	0.86	90
Veterinary services	0.7	-0.3	0.35	40
Recreational and sporting services	10.5	12.4*	0.38	17
Cultural services	17.4	8.2***	0.40	19
Games of chance	4.2	2.3	0.28	13
Books	4.5	2.5	0.54	19
Newspapers, periodicals	5.6	2.4	0.56	18
Miscellaneous printed matter	0.7	1.1**	0.55	18
Drawing materials	1.4	1.1	0.75	24
Package holidays	41.7	77.2***	0.94	55
Education	1.1	1.7	0.28	9
Restaurants, cafés	41.2	56.1***	0.90	52
Accommodation services	3.7	5.4	1.01	59
Hairdressing, personal grooming	7.0	7.9**	0.26	10
Electric appliances for personal care	0.4	0.2	0.55	20
Other appliances and products for personal care	15.1	9.9***	0.70	26
Jewelry, watches	3.3	1.7	0.44	17
Other personal effects	2.3	1.9	0.53	27
Daycare, kindergarten	11.5	9.2***	0.09	2
Insurance	31.9	25.1***	0.23	5
Financial services	0.4	0.6	0.13	5
Other services	1.0	-0.4	0.31	11
Union dues, unemployment benefit funds	17.0	5.3**	0.50[1]	29[1]
Other payment of interest	0.0	0.2	0.50[1]	29[1]
Taxable fringe benefits	8.0	40.7***	0.50[1]	29[1]
Sum	1000	1000		

[1] Data not available; estimated from the average intensity of all non-energy goods and services

Significance levels: + = $p < 0.1$; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

penditure items the significance is high. Items with p-values of < 0.001 constitute 79 percent of the marginal expenditures.

Using the results in Table 1, the energy intensity of the average consumption can be calculated to 1.06 MJ/SEK, and the energy intensity of the marginal consumption to 0.94 MJ/SEK. This gives a relation of 1:0.89, which shows that there is a rather strong coupling between income and energy use. This means that a decrease in work time/income by one percent results in a decrease of energy use by 0.89 percent.

The relation for greenhouse gas emissions is very similar, 44.7 g CO_2-eq/SEK for the average consumption and 39.0 g CO_2-eq/SEK for the marginal consumption, i.e. 1:0.87.

3.2 TIME EFFECT

The results of the regressions along with average time use and intensities of energy use and CO_2-eq are presented in Table 2.

The column with marginal time use illustrates how one hour of less work is used on average. When one type of time use is

Table 2. Average and marginal time use together with energy intensities and CO2-eq intensities.

	Time use		Energy intensity	CO_2-eq intensity
	Average	Marginal		
	Minutes/hour	Minutes/hour	MJ/cap/h	$kgCO_2$-eq/cap/h
Time at work	15.1	-60.0	8.9	0.41
Domestic work	5.5	14.1 ***	34.3	0.72
Child care	1.2	4.4 ***	10.2	0.42
Sleep, eating, hygiene	24.6	14.4 ***	11.5	0.48
Sports, outdoor and participatory activities	1.4	3.4 **	19.4	0.98
Entertainment, culture	0.2	1.3 **	54.8	2.57
Socializing	2.4	5.2 ***	24.1	1.16
TV, radio, reading	5.0	9.0 ***	19.4	0.54
Hobbies	1.1	5.0 ***	43.0	1.95
Travel - bicycle/foot	0.8	1.7 ** [1]	10.3	0.46
Travel - bus/train	0.5	-0.8 ** [1]	44.9	2.01
Travel - car/motorcycle	2.1	2.4 ** [1]	134.1	7.61

Significance levels: + = p < 0.1; * = p < 0.05; ** = p < 0.01; *** = p < 0.001

[1] Significance level for total travel time. The shares of the different transport modes are based on other estimates (see footnote 5 in Section 2.2.2).

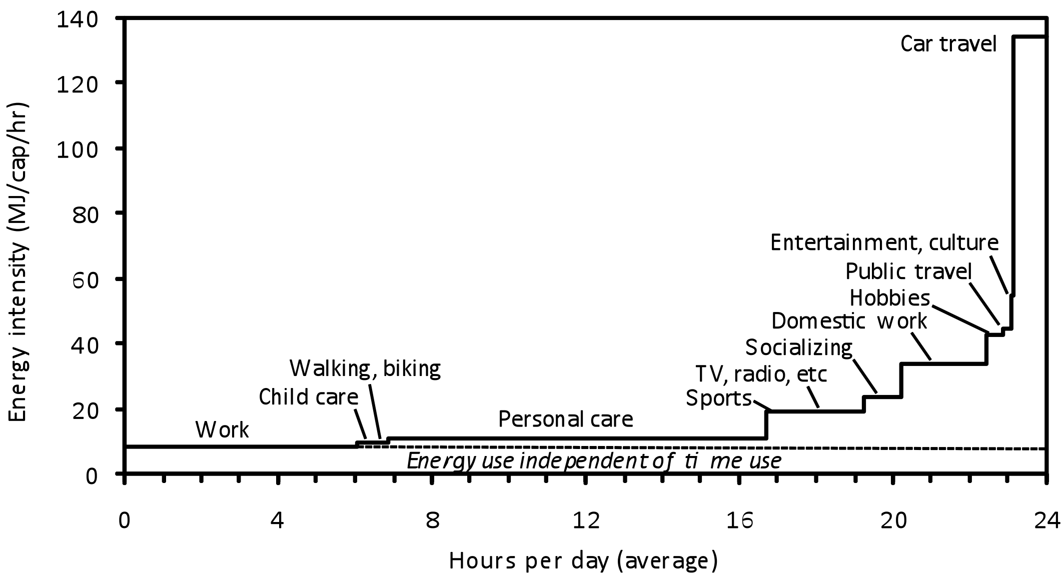

Figure 2. The energy use of different activities during an average day. Energy use below the broken line is considered to be independent on how time is spent (e.g. space heating).

decreasing it is expected that other types of time use are increasing. About fourteen minutes are used for domestic work and equally much is used for personal care (sleep, eating and hygiene). Nine minutes are used for TV, radio and reading. Five minutes each for socializing and hobbies. The four minutes for child care is an average number, being much higher for parents. From an energy point of view it is especially interesting to see that more than two minutes are used for travel by car or motorcycle.

The figures in the column with energy intensities and time use for different activities are illustrated in figure 2. The area below the curve represents energy use. A similar but more rudimental figure is found for US households in Schipper et al. (1989).

What does this mean for the time effect on energy use? Using the fixed energy and CO_2 equivalent intensities from Table 2 a reduction of work time by one percent would increase energy use by 0.24 percent and the greenhouse gas emissions by 0.20 percent. However, with fixed expenditure intensities (SEK/h), expenditures would also increase by 0.22 percent which violates the income constraint. Using the method described in Section 2.2.2 we adjust the expenditures, and with it energy use and greenhouse gas emissions, on Type 2 activities (those where energy use is only weakly dependent on time use) so that the total expenditures do not exceed income.

The resulting time effect (the income effect is analysed separately in Section 3.1) is that a decrease in work time by one percent causes an increase in energy use by 0.06% and an increase in CO_2 equivalents by 0.02%.

Table 3. Income and time effects. The effect on energy use and greenhouse gas emissions of an increase and decrease in work time / disposable income by 1 percent.

	Longer work hours by 1%		Shorter work hours by 1%	
	Energy use	CO_2 equivalents	Energy use	CO_2 equivalents
Income effect	+ 0.89%	+ 0.87%	- 0.89%	- 0.87%
Time effect	- 0.06%	- 0.02%	+ 0.06%	+ 0.02%
Total effect	+ 0.83%	+ 0.85%	- 0.83%	- 0.85%

3.3 TOTAL EFFECT OF A CHANGE IN WORK HOURS

The results from Section 3.1 and 3.2 are summarized in Table 3. It is assumed that an increase in work time by one percent is associated with a proportional increase in disposable income[8]. The total effect on energy use and greenhouse gas emissions is estimated as the sum of the income and time effects.

4 Discussion

4.1 LIMITATIONS

Which weaknesses are linked with our results? One apparent weakness with our approach is that we have carried out a cross-sectional study where we compare different households. Would we have gotten the same results if we would have followed changes within households over time in a longitudinal study?

Another problem is that the effect of the number of workdays is not included since the analysis is limited by the data to a constant 5-day workweek. It is likely that a change in working hours in some cases mean a change in the number of workdays. A 6-day workweek would increase time spent on commuting, and a 4-day decrease it accordingly. The length of the weekend probably also affects how weekends are spent. For instance, 3-day weekends might result in longer weekend trips. The effect of the number of workdays needs to be analyzed in more detail.

Despite several shortcomings of our micro-level results, they are well in line with previous macro-level results which indicate a robustness regarding the overall picture: the number of work hours has a significant effect on energy use and greenhouse gas emissions.

4.2 WORK TIME IN A LONGER PERSPECTIVE

Since the work time is relevant for energy use and greenhouse gas emissions it is interesting to dwell on the development over time. When doing this it is important to note that our results are based on the situation in the first years of the twenty-first century. It is far from obvious that they hold for making predictions regarding the coming decades. One must keep this in mind when making macro-level conclusions for the future based on our micro-level results of today.

The average amount of work hours per working age person have decreased with about 0.1 percent per year in Sweden during the period of 1980-2005 (SOU 2008:105). The increase in productivity (production per work hour) during the same time has been 2.0 percent (ibid). This shows that the vast majority of the productivity gains have been transformed into private and public consumption, and not into work time reductions.

How will the working time develop in the future? On average workers in the 15 "old" EU-member states work 14 percent, equivalent to seven weeks, less than their US counterparts (Rosnick and Weisbrot 2006). The workweeks in many developing countries are often very long. Some economists argue that Europeans have to work longer in order to enhance competitiveness in the increasingly globalized economy. Politicians tend to argue for much work in order to ensure financing of the public sector, especially the increasing costs of the ageing population. Subsequently there are strong forces for longer work hours in the EU. Our results indicate that this would result in increasing energy use which would make it harder to reach climate targets.

But on the other hand a reduction of work hours is also possible. The historic tendency that Europeans, to a larger extent than Americans, collectively choose time instead of income probably has reasons deeply rooted in European culture. Maybe post material values will become more common along with a feeling of saturation regarding "stuff". Maybe work – life balance, time for relations and for realizing one's dreams will become relatively more prioritized.

One can speculate on what would happen if one third of the yearly productivity gain of two percent would be used for reduced work time and the rest for increased private and public spending. 0.67 percent of yearly decrease in work time would add up to over 25 percent by 2050 compared with 2005. This would, according to our estimates result in about 20 percent decrease in energy use and greenhouse gas emissions (or a bit less if the energy intensity is lower for high income households as indicated by the results in Section 3.1).

If work time reduction would be used as a way to reduce environmental impact there are many social factors to consider. Individual, voluntary downshifting of work and consumption can be an appealing way for some people, and our research shows that it is significantly lowering ones environmental impact. But most people are not willing to give up income. Swedish studies reveal that one in six are ready to take the step of cutting work and income individually, but one in two are in favor of a collective work time reduction instead of higher salaries (Sanne 1995). In order to reach substantial effects the majority of the population has to be involved. The politically feasible approach is probably to transform a part of the future productivity gains into reduced work time for the majority of

8. If marginal income taxes are higher than average income taxes, which is the case for high income households in Sweden, disposable income changes less than the change in work time, and hence the income effect is smaller. A part of this difference is however offset by increasing tax financed public consumption.

the population. This way the individual would not experience a cut in income and furthermore the work time reduction would not give the individual less income than others in society.

It is also relevant to consider if a strong focus on work time reduction in large parts of the world in the coming decades would result in significant lower energy use and greenhouse gas emissions. Or would other mechanisms take over? Work time reductions would make GDP lower in comparison with stable working hours. Some environmental problems have been diminishing along with increasing GDP. This is usually called the Environment Kuznets Curve and it has been found for pollutants such as sulphur dioxide, nitrogen oxides, carbon monoxide and particulate matter (Selden and Song 1994), but not for greenhouse gas emissions. But it is not totally unlikely that there is such an effect. With relatively lower income increases the exchange rate for our cars might be slower; the tax revenue would be lower which would give less money for investments in public transportation systems, etc. But on the other hand slower increases in income would surely decrease some energy demanding consumption, e.g. air travel.

5 Conclusions

The results of this study indicate that an increase or decrease in work time causes a change in energy use and greenhouse gas emissions by almost the same amount. A decrease in work time by 10 percent reduced energy use and greenhouse gas emissions by about 8 percent on average, a bit less for high income households and a bit more for low income households. This estimate is lower than in the macro-analysis by Rosnick and Weisbrot (2006) where a 10 percent reduction in work time was found give a 13 percent reduction in energy use.

The increase in energy use with work hours is dominated by the effect of increasing income. The effect due to more available time for leisure activities is more than an order of magnitude smaller than the income effect.

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