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THE ECONOMIC DAMAGE OF CLIMATE CHANGE: A QUESTION OF SCALE?

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INTEGRATION OF SCALES IN ASSESSMENTS OF IMPACTS AND ADAPTATION TO CLIMATE CHANGE.

THE CASE OF TRANSPORT MODE CHOICE.

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1 INTRODUCTION

Studies of impacts and adaptation to climate change typically consider actions and policies on the local level, with the perspective of assessing social vulnerability and resilience. Attempts to estimate the economic costs of climate change to a country catch up only a general picture from these studies. In order to make a notable difference to the national economy, impacts will have to be significant, such as major disasters or impacts on large economic activities. Possible local characteristics of importance tend to vanish in a national context. The messages to policy makers therefore seem to deviate depending on what level the impact studies are based: While studies of local impacts argue that adaptation to climate change and mapping of vulnerability is urgent, evaluations of national strategies to reduce greenhouse gas emissions conclude that only moderate actions are beneficial.

The reason for this seemingly double communication may of course be that it is costly to reduce emissions while adaptation can be carried out at low or even negative costs. But it is also a fact that very few have been concerned with the interchange between the different levels of aggregation, although it is quite clear that climate policy should be based on an understanding of how climate impacts affect local, national and global societies simultaneously. The aim of this paper is to show how local and national impacts are integrated by the example of how climate change may affect the pattern of personal transport. The background for the choice of example is, firstly, that individual data were available. This enabled a mapping of transport patterns on a local level, and at the same time in such a form that local patterns could be generalized to regional and national patterns. Second, transport represents a major challenge in trying to reduce emissions of greenhouse gases in the future. If transport patterns are affected even slightly by climate change, national consequences might be notable. The outcome of the study is therefore of interest in itself both for the purpose of getting an overview of the impacts of climate change, and to find whether climate change in itself may change behaviour such that the reduction of greenhouse gas emissions becomes more easy or more difficult.

This study utilizes individual data, but of relatively low detail if compared with many other studies of local impacts and adaptation. However, some main features of the local studies are intact. Thus, the point of departure is how single individuals respond to a change in climatic conditions, such as temperature and precipitation. We show how characteristics of social groups can be identified from the behaviour of individuals and how the findings on the local scale can be generalized and apply to an aggregate of social groups.

The openness as to how individuals respond to climate change and allowing them to respond differently is a main advantage of local studies, whereas national studies usually consider the responses exogenously and similar for the whole population. But focusing entirely on local communities also has its limitations. One is, of course, that one cannot draw immediate conclusions about the national impacts from local studies. Significant impacts on a local level need not imply significant national impacts. In a national context, small impacts that affect many communities may be more important than large impacts to one community. The characteristics of communities and regions must therefore be taken into account when the information is aggregated.

A second limitation of a local focus is that opportunities to adapt are usually framed within a given location, leaving out possibilities to solve local problems outside the community to exogenous assumptions. These possibilities include both interventions from regional or national bodies and implications of changes studied in the local community on the national scale. A change in the pattern of personal transport, for example, implies a change in consumer behaviour and thereby the demand for goods and services. The whole economy will be affected, which will affect also the local community where the examination of impacts and adaptation started.

We start by trying to identify relationships between climatic conditions and choice of transport modes in the city of Bergen in Norway. This is based on a coupling of a survey of travelling habits (Bergen Fylkeskommune, 2000) covering 16 204 local travels between 15th of March and 31st of May in 2000 and data for temperature, precipitation and wind speed in the same period. The travels are identified according to similarities in the relationship between choice of transport mode and weather indicators. These relationships are utilized to predict travelling patterns in Bergen under climate change, based on climate scenarios for the Bergen area in 2030, and a blow-up of the survey data to apply for Bergen. In the next step, we estimate impacts of climate change in other large and medium cities in Norway. It is assumed that individual responses to the weather on the choice of transport modes is the same as in Bergen, taking into account that the transport pattern as well as the weather differ among cities from the outset, and that the climate changes to different degrees. Finally, the national impacts are estimated by means of a macroeconomic model in order to find the resulting changes in the composite of consumption goods.

2 CHOICE OF TRANSPORT MODE AND THE WEATHER

It is probably uncontroversial to claim that weather conditions can affect individual choices of transport. For example, it is more tempting to walk or bicycle to work on a sunny day than on a rainy day, or to take the bus instead of the car when it snows heavily. But individuals may react differently, and they are faced with different options. Some may choose the bus instead of the car if it is snowing, while others may find it likely that the bus will be delayed and choose the car that day. The challenge is to say what the relationship between the weather and travelling patterns is. Then, one need to find a systematic pattern among identifiable groups, which can be described reasonably well with available data and be related to predictable variables about population, travelling patterns and future climate.

There are only few studies of how the weather may affect transport decisions, but those available indicate that general patterns may be identified. A study of the impact of adverse weather on commuters travel decision in Brussels (Khattak and de Palma, 1997) reports that for 54% of commute trips by car, either the choice of transport mode, departure time and/or the choice of transport route, were influenced by the weather. Similarly, de Palma and Rochat (1999) found weather to have a significant effect on travel conditions for 40% in their study of commuters travel decisions among commuters in Geneva. They also found that "departure time decision is much more sensitive to adverse weather than the mode or route decisions".

There are also some studies on the possible impacts of climate change on transportation. Changon (1996) has studies implications for road accidents, and Adams (1997) show that reduction in extreme colds will reduce mechanical failures. Perry and Symons (1994) consider implications of an increase in floods and windstorms, and Askildsen (2004) assesses the costs of delays due to closed winter roads for goods transport, but do not include personal transport. The focus of this study is less dramatic. There are no reasons to expect dramatic shifts in local travelling habits because of the predicted changes of climate in Norway, but on the other hand, it may be that many people change their habits slightly. The socioeconomic consequences may therefore be notable, for example in terms of changes in the demand for public transport, demand for fuel and road congestions.

Throughout this paper we make the assumption that the weather will not affect the decision of whether or not to travel, because this question was not asked in the survey on which this study is based. Thus, the issue at stake is more or less to what extent the weather may affect the decision of *how* to make a travel that is to be made under any circumstance.

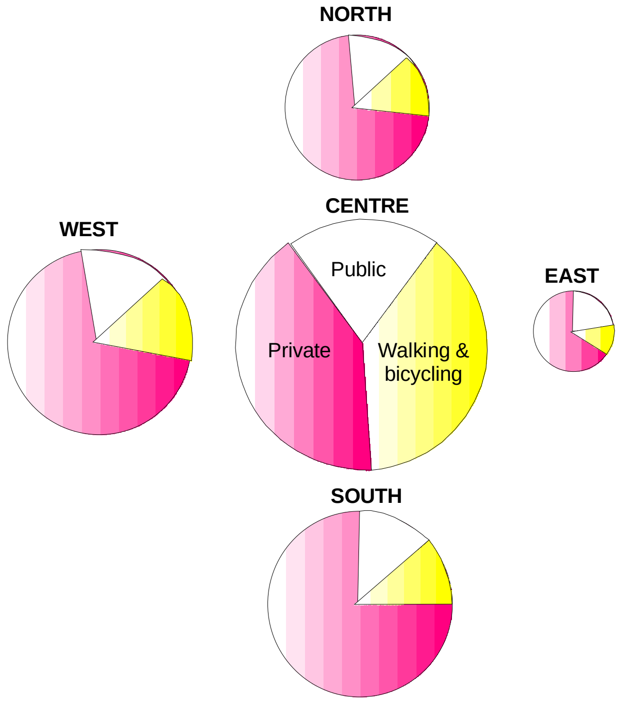
2.1 Explanatory factors behind the choice of transport mode

Although the travelling habits survey (Bergen Fylkeskommune, 2000) provides a broad range of information about each travel, there are significant limitations in the data. The most problematic is that the information about where the travel started and where it ended is very general, and insufficient to consider the supply of alternative transport opportunities. This is clearly important for the decision of how to travel, and may affect decisions even over small distances. If there is a bus stop 50 meters down the road it is much easier to switch to it when it rains than if you have to walk half a kilometre.

Such details were not available, but in order to at least test geographical differences, for example with respect to the supply of public transport, the Bergen area was divided into five regions, and the region from where the travel started was recorded. Figure 1 displays the composition of transport mode choices in each region. The size of each circle indicates the number of travels covered by the survey starting in that region. The transport modes are divided into walking and bicycling, private (private cars, taxi and motorcycles) and public transport (bus, train and ferry). There are differences between the regions that indicate differences in the supply of opportunities. The use of private transportation is considerably less in the city centre, while especially walking and bicycling is used to a much greater extent. In the four outer regions private transportation contributes between 65 and 75 percent of all travels. Public transport and walking and bicycling share an equal amount of the travels in these regions except for the eastern region where public transport dominates.

As mentioned, the regional differences may be explained by differences in the supply of public transport for the starting and the ending points of each travel. Another possible explanation is that the distance of a typical travel varies depending on where the travel starts. The lack of information about the starting point and end point of every travel implies that distances cannot be calculated directly. Instead, distance was approximated from the reported duration of each trip, including information about the total time of waiting, and assumptions about speed of the chosen mode, and classified into travels shorter than 1 km, 1 – 2.5 km, 2.5 – 7.5 km, 7.5 – 25 km and above 25 km.

Figure 1. Division of observed travels into region of departure and mode in Bergen



According to the estimates, walking and bicycling totally dominates travels shorter than 1 km, contributing approximately 95 percent of these short trips. For longer distances the share of walking or biking travellers decline rapidly, and contribute less than 10 percent for distances more than 2.5 km. The share of walking and bicycling in the centre of Bergen can be explained by the fact that the share of short trips is larger than in the other regions. Private transportation dominates all travels more than 2.5 km, but as the length of travels increase, use of public transportation becomes more frequent. For travels over 25 km approximately 25 percent use public transportation.

The travels were also divided into three categories of travelling purpose. The first category is travels to work and school, which contributes 40 percent of the travels. The second is travels in connection to daily errands and include shopping, following kids to the kindergarten etc. 39 percent of the travels is within this category. The third is travels in connection to leisure activities, which contribute 21 percent. These include, *inter alia*, travels in connection with cultural activities, visits to family and friends and exercising.

Information about the individual characteristics of those who made the trip is relatively sparse in the survey. In this study, only gender and age were included as explanatory variables. We have also information about access to car and income. Access to car is, however, strongly correlated with age, so age was used as a proxy for access to car. Income was divided into classes of relatively wide ranges. It is, moreover, difficult to obtain reliable data on income in telephone interviews, and it was therefore excluded as an explanatory variable.

The weather is indicated by daily averages of wind and temperature, and total daily precipitation. The data were taken from one particular observation spot in Bergen (Florida). Situated at the coast of the Atlantic, beneath high mountains, Bergen is well known for rapid and vigorous weather changes. Thus, daily averages and totals are not ideal measures to represent the weather in connection with temporal decisions such as the choice of travelling mode. Regardless of morning sunshine from a clear sky; in Bergen you are always recommended to bring an umbrella with you. However, since the weather is not reported in the survey, we had to confine ourselves to observations at one station and to couple these observations with the date on which the travels were made.

There are no reasons to hide the fact that there are weaknesses in this attempt to explain why the travellers choose mode as they do. The characterisation of each travel is hampered, in particular, by the lack of information of starting point and end point and consequently a good representation of transport opportunities. But perhaps most important is that we try to explain the choice of mode, which indeed is an individual choice, with very sparse information about the individuals. An alternative approach, from which a much richer set of information could be obtained, is to extend the comprehensiveness of the interviews and ask explicitly about the motivation for the choice of mode in each case, and to what extent the weather made an influence.

This would better correspond to the bulk of other local studies of impacts and adaptation to climate change. For the purpose of generalising results and aggregating to larger scales, however, such an approach is also hampered with weaknesses. First, one would have to limit the number of included travels dramatically, and therefore accept a much lower degree of representation. Second, extending the dispersion of individual characteristics inevitably increases the difficulties in identifying social groups. In any case, one is forced to a compromise: Either to sustain the description of individual characteristics and resign on the degree of representation, or to sustain the degree of representation and resign on the description of individual characteristics.

It is clear from what has been written so far that sustaining representation is preferred in this study, but we have to admit that individual characteristics is not taken sufficiently care of by age and gender. In order to account for this, at least in part, the relationships between mode choice and weather are estimated with some general assumptions about the distribution of other individual characteristics, which is described below.

2.2 Estimation of relationships

In order to capture individual characteristics of people's choice of transport mode, we straightforwardly apply a simple quantal response model, which is thoroughly described in the literature (see e.g. Domenchich and McFadden, 1975 or Maddala, 1982). For the purpose of this paper, it therefore suffices to present the main properties of the approach of relevance for the estimation of transport mode choices.

Assume that each individual who are to travel gains utility x_i from the transport. The utility of choosing mode n, x_n, is partly derived from a vector of observable characteristics, b_n, attached to each transport mode. b_n represents region, purpose, distance, gender, and the three climate variables temperature, precipitation and wind. In addition, one particular individual's utility of choosing mode n also has an unobservable element, ε_{in}, which implies that the utility of choosing mode i is specific for each individual. We assume that the utility of the travel can be written as

$$x^i(b,\varepsilon_i) = \sum_n \exp(\alpha_n + \sum_k \gamma_{nk} b_{nk} + \varepsilon_{in}), \qquad (1)$$

where α_n is a constant, γ_{nk} are parameters and k is the number of observable characteristics.

The transport mode is chosen by maximising the individual utility of the travel. When the utility of a travel is the sum of utilities of each mode, as in (1), the alternatives become mutually exclusive: one ends up in choosing only one mode. Because of the unobservable term ε_{in}, two individuals may, however, choose different modes for identical travels.

Individual characteristics not described by the survey data can now be replaced by an assumption about the distribution of ε_{in}. That is, we define ε_{in} as an observation of the stochastic variable z, attached to individual i by its choice of mode. It follows that also x_n^i is stochastic. The probability that individual i will prefer mode n to mode m for a given travel equals the probability that mode n yields higher utility than mode m for individual i:

$$\Pr\{x_n^i > x_m^i\} = \Pr\{\alpha_n + \sum_k \gamma_{nk} b_{nk} + \varepsilon_{in} > \alpha_m + \sum_k \gamma_{mk} b_{mk} + \varepsilon_{im}\} \qquad (2)$$

Let $\lambda_n = \alpha_n + \Sigma_k \gamma_{nk} b_{nk}$. For N alternative mode choices, the probability that an arbitrarily chosen person chooses mode n can now be written as the joint probability

$$\pi_n = \int_{-\infty}^{\infty} F(\lambda_n - \lambda_1 + z, \lambda_n - \lambda_2 + z, ..., \lambda_n - \lambda_N + z)dz \qquad (3)$$

What remains is an assumption about the distribution of z. Domenchic and McFadden (1975) show that if z has a Weibull distribution the probability can be written as the logit function

$$\pi_n = \frac{\exp(\lambda_n)}{\sum_{m=1}^{N} \exp \lambda_m} \qquad (4)$$

All the parameters of the utility function in (1) can now be estimated.

The recorded travels were divided into 15 groups depending on which of the five regions the travels started, and which of the three purposes the travel were made for. Then, the choice probabilities were estimated with the six explanatory variables temperature, precipitation, wind, gender (dummy), age and distance. There are tendencies in the data, but they are far from significant enough to draw clear conclusions about the relationship between the weather observations and the transport choices. When comparing each parameter across the 15 groups, most of the estimates turn out with the same sign, but there are exceptions for all parameters, in particular for travels with the purpose of daily errands. Moreover, relatively few parameters are significantly different from zero.

The tendencies are nevertheless that the more wind, the more rain or the lower the temperature, the higher is the probability that a person switch from walking or bicycling to public transport and from private to public transport. Switches between walking or bicycling to private transport cannot be read directly out of the estimated parameters, but it can be calculated from the simultaneous probability distributions. The mode choice seems to be more sensitive to wind speed than to temperature and precipitation. Among the other explanatory factors, distance is clearly the most important, primarily by the aforementioned tendency away from walking or bicycling to motorized transport. The same tendency, weaker but still significant, is found for age. As for gender, the explanatory power is even weaker, but women tend both to walk or use bicycle and to use public transport to a higher degree than men.

On this background, it takes courage to claim that we have been able to identify social patterns in the relationship between mode choice and climatic factors. Thus, there are unobserved factors that systematically make a difference to individuals with the same travelling purpose within the same region. There is a possibility that these factors also vary systematically across regions and travelling purposes. In that case, aggregation across regions or travelling purposes may weaken the influence of systematic disturbances in the data, and thereby contribute to improve the estimated relationships. In order to check this out, the material was regrouped into two regions and two purposes. The city centre was maintained as one separate region, and the remaining four regions were coupled into one "outer region". Daily errands were also kept as one travelling purpose, whereas all travels with the purposes of work/school and leisure were gathered into one group.

After regrouping the data, the estimates were, in fact, improved to some extent, though the pattern is somewhat similar to that commented on above. Table 1 shows the change of mode choice by an increase of 1 ºC temperature, 1 mm/day precipitation or 1 m/sec wind. The average levels in Bergen during the observation period were 3.8 ºC, 7.5 mm/day and 4.7 m/sec, respectively.

Table 1. Changes in transport mode choice shares at increases in temperature precipitation and wind. Percentage points.

	Central region		Outer region	
	Work and leisure	Daily errands	Work and leisure	Daily errands
Temperature increases 1 ºC				
Walk and bike	0.17	-0.09	0.27	0.00
Private transport	-0.12	-0.03	-0.37	-0.35
Public transport	-0.05	0.06	0.10	0.34
Precipitation increases 1 mm/day				
Walk and bike	-0.32	-0.02	0.13	0.01
Private transport	0.15	0.27	-0.18	-0.04
Public transport	0.17	-0.25	0.05	0.02
Wind speed increases 1 m/sec.				
Walk and bike	-0.74	0.42	-0.06	-0.03
Private transport	-0.36	-1.61	0.50	1.09
Public transport	1.10	1.19	-0.44	-1.06

Increasing temperature reduces private transport in both purposes in both regions. The most notable substitute to private transport is walking and biking to work and leisure purposes. This is probably a seasonal phenomenon, which means that people use less private transport in the warm season. Interpreted as an impact of climate change, it may result from an extension of the warm seasons.

Precipitation is probably more decisive for day-to-day decisions. What may seem surprising is that walking and biking in the outer region increases with more rain. The explanation is that the length of travels also shortens when precipitation increases. This effect is only partly taken care of by the distance variable. Shortening of travels within each distance class is indirectly captured by the precipitation parameter. Thus, more precipitation shortens the travelling distance, and shorter travels increase the probability of walking and biking. The reason why this effect is stronger in the outer region may be that average travelling distance is much longer in the outer region than in the centre.

An increase of 1 m/sec cannot easily be compared with increases of 1 ºC or 1 mm/day, but it may nevertheless be fair to say that, according to the results, mode choice is more sensitive to wind than to the other two climate indicators. Wind speed seems, with the exception of work and leisure purposes in the central region, to affect mode choice in the opposite direction when compared with precipitation. This seems to be due to local conditions, for example that the response to wind turned out to be very different in the western and the eastern regions.

The estimates may therefore depend on the usual wind direction in the Bergen area, which could make the estimates inapplicable in other cities.

Despite the weaknesses and the relatively uncertain estimates, which are not unusual in studies of impacts and adaptation to climate change, we will use these estimates related to temperature and precipitation to represent the individual responses to climatic changes. This will be the reference to which regional and national estimates will be made. In other words, we take the estimated responses by individuals in the survey of Bergen to represent how, not only all the people in Bergen, but in the entire nation react to climatic changes.

3 RESPONSES TO CLIMATE CHANGE AND AGGREGATION

Expectations about climate change in Norway for the period 2030 – 2050 are available from Førland and Nordeng (1999). By a downscaling of results from global circulation models they predict a general increase in temperature as well as more precipitation in all parts of Norway. The climate predictions are shown in table 2. While the northern part of the country is expected to get the highest temperature increase, the western part will experience the highest increase in precipitation. As for seasonal changes, the highest temperature increase will come during winters, while precipitation will increase most in the autumn in most parts of the country. Predictions of wind speed were not available, and we will therefore assume that wind speed is unaltered.

Table 2 Present temperature and precipitation and expected changes from the period 1980-2000 to the period 2030 – 2050. Annual averages.

Country region	Temperature (ºC)		Precipitation (mm/day)	
	Present average	Change	Present average	Change
Northern Norway	2.8	1.6	2.8	0.3
Western Norway	7.6	1.0	6.2	0.8
Eastern Norway	6.2	1.1	3.1	0.2

Changes in the choice of transport modes are not expected to affect the whole country. In particular, the patterns shown for Bergen are likely to be related to the behaviour in or nearby cities or city areas of some size, and limited to the 10 largest cities.[1] It was also assumed that the behaviour within the city centre of Bergen corresponds to that within the centres of Oslo,

[1] The cities are Oslo, Trondheim, Stavanger, Tromsø, Kristiansand, Tønsberg, Drammen, Porsgrunn, Skien, Fredrikstad and Sarpsborg.

Trondheim and Stavanger, whereas the behaviour in the remaining cities, as well as the outer regions of these three large cities, corresponds to the behaviour of the outer region of Bergen.

Differences in the change of travelling patterns between cities occur as a result of differences in the predicted changes of climate (temperature and precipitation), differences in compositions of age and gender as well as differences in present observations of travelling patterns. For some cities, we know the travelling mode, the purpose of travelling, regional divisions of travels and we have good indications on travelling distance. For other cities, one or more of these observations are missing. In these cases, we had to base the estimates on assumptions.

City-specific response functions were calibrated on the basis of observations of the transport mode shares in each city, π_n^c. The interpretation of equal individual response is that the estimated set of parameters γ_{nk} is invariant across cities, but that α_n and the observations b_{nk} differ across cities. Then, the city specific constant term α_n can be calibrated from equation (4) as (see Aaheim and Hauge, 2005):

$$\alpha_n^c = \frac{\pi_N^c}{\pi_n^c} \sum_k \gamma_{nk} b_{nk}^c \tag{5}$$

Table 3 Estimated changes in travel mode uses due to climate change by city. Percent

City	Region	Purpose	Walk/bike	Private	Public
Oslo	Urban	Work/leisure	1.8	-1.0	-0.2
		Errands	0.4	-1.1	3.4
	Suburban	Work/leisure	0.4	-0.2	-0.0
		Errands	-2.0	0.5	0.5
Bergen	Urban	Work/leisure	3.2	-2.4	-0.7
		Errands	1.3	-2.4	5.6
	Suburban	Work/leisure	-0.1	-0.0	0.3
		Errands	-4.0	0.9	-0.1
Tr.heim/Stavanger	Urban	Work/leisure	0.6	-0.3	-0.1
		Errands	1.6	-0.5	-1.2
	Suburban	Work/leisure	-1.1	0.4	0.7
		Errands	-0.2	0.1	-1.2
Other cities	Urban	Work/leisure	3.2	-1.5	-0.0
		Errands	2.0	-0.9	5.9
	Suburban	Work/leisure	0.3	-0.2	0.1
Total		Errands	1.3	0.8	0.5

Table 3 displays the estimated changes in travel mode usage for each city. Although the extent of changes differs across cities because of different degrees of climate change, the pattern is more or less similar across cities. Walking and biking increases while motorised transport decreases for work and leisure purposes, while public transport for errand purposes in the urban region increases. However, the changes in Trondheim and Stavanger differ somewhat from the other cities, first and foremost by being less sensitive. This is not because the climatic changes in these cities are more moderate, but because the calibration of mode choice by the present travelling pattern reflects less sensitivity to climate than the other cities. In other words, generalisation of the results in Bergen by calibration allows the sensitivity of the climate on the choice of mode also to differ across cities, to the extent that this is reflected in the present transport pattern.

Generalisations may take different forms and may be based on different sets of assumptions. In this respect, the disadvantage of applying a rather general approach to the local analysis of Bergen, especially when it comes to the description of the travellers, turns into an advantage in this case, because the local characteristics described in Bergen can easily be varied in accordance with observed variables when generalising the results to other cities. It might be difficult, not only to utilise further details in the Bergen survey to improve the estimates for the other cities, but also to identify even aggregates of a more detailed set of characteristics of Bergen in other cities.

For example, there is no doubt that more detailed information about the availability of public transport would improve the analysis of Bergen. An improvement of the travelling habit survey in Bergen for this purpose would be to ask explicitly for transport opportunities instead of roughly separating between urban and suburban regions to indicate differences in public transport supply. But it would be impossible to use this information in other cities, and one would have to accept to generalise the results from Bergen to other cities with no regional differentiation. Thus, the general recording of region is to be preferred for the purpose of aggregation. In other words, what is the best approach to understand local impacts and adaptation may not always be the best approach to establish knowledge about local conditions for the purpose of understanding impacts and adaptation in general.

4 National responses

The estimates presented in the previous section give a bottom-up approach to the assessment of impacts and adaptation of climate change in the case of personal transport patterns in

Norway, provided that transport patterns are affected only in cities of a notable size. The traditional critique of such bottom-up analyses is that the sum of local responses may have impacts on a national scale, which affect the general frames that were assumed unaffected in the local analyses. Typically, the sum of individual responses may affect market prices, which make an influence on individual behaviour.

Aaheim and Schjolden (2004) point out that estimates of economic impacts and adaptation based on bottom-up studies apply to quantify the shift of the macro technology or the shift of the social preference structure implied by climate change. Calculation of economic costs and savings resulting from the responses on travelling patterns can then be understood as a way to bring responses of different kinds on to a common scale in order to make them comparable. For example, a shift from walking and bicycling to public transport is made comparable with a shift from private to public transport by comparing the cost of using public transport instead of walking and bicycling and the cost of using public instead of private transport. The ground for further economic analyses is thereby opened.

The economic costs and savings from the estimated changes in transport patterns shown in table 2 consist mainly of three items from the households budgets. A change in the use of public transport changes the expenditures to public services in terms of transport tickets. A change in the use of private transport affects two items, namely expenditures to transport fuels and road toll, which is paid in some of the largest cities of Norway. An estimate of the average cost of each private and public travel were made on the basis of data about travelling volume, total sales of transport tickets by city and total expenditures to mobile fuels and toll roads. It was assumed that 2/3 of all the traffic that passes a toll point is private transport.

Some expenditure that may be affected by a change in travelling patterns are not included in these calculations. First, it is assumed that the change in the use of private transport does not cause changes in the household capital expenditures, such as car repairs, accidents or the purchase of cars. Second, no costs are attached to the change in the duration of a travel when switching mode. Third, the cost of shifting travelling distance from one distance category to another is disregarded, but the cost of a change of length within a given category of distance is implicitly included by the impact of precipitation.

Table 4 displays the estimated costs of the predicted climate change by city region and travelling purpose. Climate change will initially lead to a total savings of 48.2 mill. NOK, while the expenditure to public transport will increase by 9.9 mill. NOK. If evaluated as the contribution to impacts of climate change for the country in total, this is of course negligible. This is, first and foremost, because local transport contributes only 4 – 4.5 percent of the households' budget, but is also due to the fact that the transport patterns are not expected to change dramatically.

Table 4 Change in transportation costs due to climate change by city. Mill NOK.

City	Region	Purpose	Private	Public
Oslo	Urban	Work/leisure	-14.7	-0.6
		Errands	-10.2	4.0
	Suburban	Work/leisure	-1.9	-0.3
		Errands	4.7	0.7
Bergen	Urban	Work/leisure	-13.8	-3.5
		Errands	-9.7	8.4
	Suburban	Work/leisure	-0.1	0.4
		Errands	1.4	-0.0
Tr.heim/Stavanger	Urban	Work/leisure	-2.0	-0.3
		Errands	-2.8	-1.3
	Suburban	Work/leisure	1.6	1.2
		Errands	0.3	-0.5
Other cities	(Suburban)	Work/leisure	1.3	0.5
		Errands	0.2	1.6
Total			-48.2	9.9

Note, however, that within some segments, the changes are notable. For example, the expenditures to public transport for daily errands in urban Bergen increase by more than 8 mill. NOK. Thus, the public transport business may consider this worth mentioning. Also the savings from the reduction in private transport, especially for work and leisure, are countable. These may also cause further savings related to congestions and accidents, which were excluded from the calculation. As expected, the most substantial changes take place in Oslo and Bergen, which are the two largest cities. In the case of Bergen, this is also because the climatic change is expected to be relatively strong in comparison with the other cities.

It is assumed that walking and bicycle travels are made without costs, and the initial economic impact of changes in walking and bicycling is, therefore, zero. In a macroeconomic context, the changes of travelling modes reflect an exogenous shift of the preferences, which is due to the change of climate. The resulting net savings of 38.3 mill. NOK in this case will be spent on other goods and services. In order to estimate the final socioeconomic impact we need to restore the market equilibrium. To do so, the estimated costs in table 4 were used to correct the cross deliveries between the affected sectors in a standard general computable equilibrium model for Norway (see Aaheim and Rive, 2005 for a description of model structure). Changes in private transport affect deliveries from the fossil fuel sector to the households because of changes in the use of fuel. The expenditure to private transport also includes toll roads, which affect the deliveries from the public and private services sector to the households. Change in public transport affects deliveries from the private and public services sector to the households.

Table 5. Direct and indirect economic impacts of responses in travelling pattern to climate change

	Direct response (bottom-up)	Macroeconomic impact	Difference
	Million NOK		Percent
Demand for fossil fuels	-43.7	-37.4	-14.4
Expenses to toll roads	-4.5	-4.5	0.0
Expenses to public transport	9.9	10.3	4.1

Table 5 shows the initial change of deliveries, which is taken from table 4, and the final macroeconomic impact when equilibrium is restored after climate change. The changes occurring to attain a new equilibrium can be considered a second step in the process of adaptation. In this case, the adaptation relates mainly to the allocation of savings caused by less motorized transport and more walking and biking. The resulting savings are partly ploughed back to the fossil fuel and service sector, thereby lowering the final socioeconomic impact when compared with the initial bottom-up based estimates. In the macroeconomic accounts this reallocation of economic resources results in an enhancement of GDP by 17.2 million NOK. This is, of course, minor in a national context, where the GDP amounts to 1 500 000 million NOK, but must considered on the background that we have dealt with one among many possible impacts which are all small if taken in isolation.

Our main concern is, however, the comparison between the bottom-up estimates and the resulting macroeconomic top-down estimates. Not only do the estimates of the direct expenses differ significantly; the estimated total net savings of 38.3 mill. NOK in the bottom-up approach is reduced to a net increase in GDP at half of the amount. This illustrates the importance of including all aspects of adaptation when considering national impacts of climate change. People adapt by a shift of behaviour, which in terms of economics is reflected by a shift of preferences. The resulting shift of economic behaviour, which can be interpreted as adaptation to the shift of the climate contingent preferences, mitigates the initial behavioural shift.

5 CONCLUSIONS

Interpreted in a broad sense the results of this study conform to the impressions given from other local and aggregated impacts assessment, which also motivated this study: Some local actors may have to prepare for adaptation to climate change, but when aggregating local impacts to a national level, the impacts become small, even negligible. The two messages do not, therefore, necessarily contradict each other: moderate mitigation policies may be consistent with notable activity aimed at adapting to climate change. The reduction in the use of private transport of nearly 50 million NOK on the country level is the same as the reductions in urban Oslo and Bergen. Even in the urban parts of these two cities, this reduction is far from dramatic, but in certain locations of the cities, the change may be worth noting.

The main effects on the choice of transport mode of the expected climatic changes confirm prior expectations. Higher temperature makes more people walk or bike, especially in the city centre where the trips are short. It may seem like a surprise that more precipitation increases the tendency of walking and biking in some areas and for some purposes, but this can be explained by the fact that precipitation leads to shorter trips. One crosses the street to the nearest shop instead of jumping into the car and drive to the supermarket. The wind is also decisive for the mode choice, but the results suggest that also the direction is important. The impacts of wind speed are, therefore, not easily generalised. The climatic changes predicted for Norway also leads to a slight increase of public transport, at the expense of private modes. This is due, mainly to an increase in precipitation.

Despite these tendencies, the responses of people from changing weather are far from being uniform. The estimates are generally weak, and reflect a variation of different responses within each social group. One reason for this is the problem of identifying social groups with similar preconditions and opportunities, such as lack of data for starting and end point for the trip, and information about daily variation in the weather. The results suggest, however, that these unobserved factors vary in a somewhat systematic manner, because the estimates were slightly improved when the population were divided into larger social groups. What may seem confusing and disturbing when considered at a close hand, may, in other words, exhibit a pattern on a more aggregated level.

Applying the results from Bergen to other cities of Norway, we find, as expected, a similar response in the other cities. The changes are, however, weaker, partly because the weather does not change as much as in Bergen, and in some cases because the initial composition of modes reflects less sensitive choice of mode in the other cities. For the country at large, a net savings of nearly 40 million NOK were estimated, which is due mainly to more walking and biking. To the extent that this figure is of interest, it is important to add that they exclude the indirect economic implications of these savings. The income effect of the savings will contribute an increase in transport in general, and the final reduction in transport costs is thereby reduced to 32 million NOK. This reduction is a result of a general increase in the activity of the economy, which is indicated by an increase in GDP at approximately 17 million NOK. That is, the estimate based on local assessments shows savings more than twice the final increase in GDP.

The question, in the end, is under what conditions can national authorities limit their scope to consider national aggregates when developing a mitigation strategy? The immediate answer is that the aggregates apply if the impacts to certain groups, or composites of the aggregate, are not given particular attention by the authorities. This means, for example, that mitigation is regarded independent of whether 100 000 people loose or save 10 NOK or 10 people loose or save 100 000 NOK. In the wake of the famous Allais paradox in decision making under uncertainty, it is commonly accepted that decision makers do not meet this criterion for rational behaviour. In other words, when it comes to serious impacts for a few, the aggregates probably provide insufficient information for decision making on the national level.

The case of mode choice studied here, where no dramatic effects for anyone have been detected, the aggregates for the country can therefore be used to safely conclude that climate change will not affect the travelling habits to such an extent that it matters for the choice of mitigation strategy. Strictly speaking, this conclusion is based on two assumptions. First, that we have been able to identify all relevant social groups whose choice of local trips is sensitive to climate change. With reference to the problems in identifying social groups with similar behaviour on the local level, one can hardly claim that this assumption is met, although a better identification is not likely to change the overall conclusion. The second assumption is that the transport system and the choices made by people in Bergen is reasonably representative for the other cities. Apart from the fact that this may be understood as an offence both by the people in Bergen and by the people in the other cities, the weakest point of this assumption is that Bergen is extreme when it comes to the weather, both in terms of the climate of today and of the expectations for future changes.

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