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Climate Change and Energy Consequences

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Climate Change and Energy Consequences[1]

Abstract:
Although the relationship between economic growth and pollution is not simple, increased production and consumptions seems to be an important drag factor for environmental problems. Economic modelling of these links, description of climate impacts and policy analyses of economic instruments to decouple the link is highly presented in the literature. Except from fossil fuels and nuclear energy, most of the primary energy sources are captured directly from short-term natural conditions. An interesting climate change factor that is not debated in the literature then is the link between climate change and primary energy supply. This is the background for this paper taking into account that Norway is a country not only filled up of fossil fuels but also capturing a lot of energy from the water falls and having a big potential in the forests, the long coast (wind) and large areas (sun etc).

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[1] This Document is based on a presentation at an international workshop in Copenhagen 8-9 November 2001. The issue for the workshop was "Climate impacts on energy production and energy use in the Nordic and Baltic region".

Table of contents

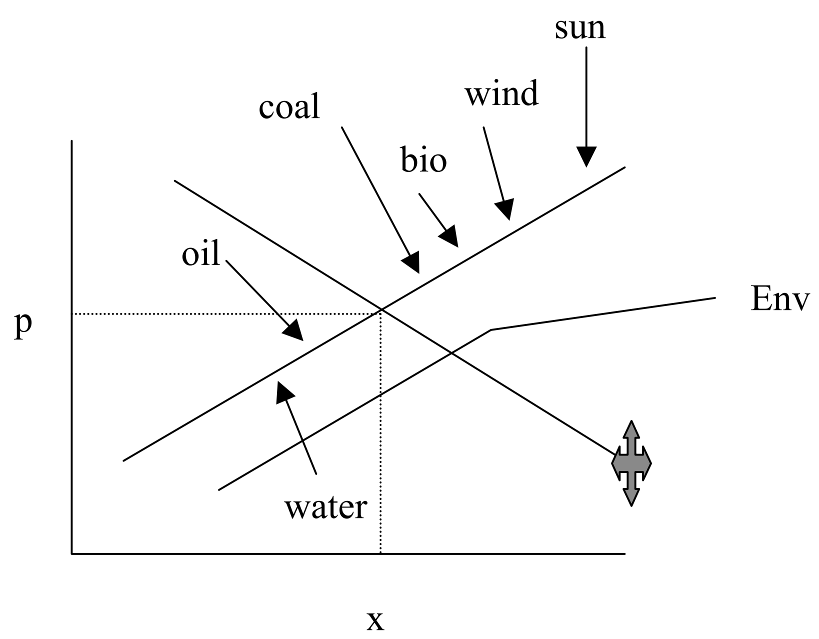
1. Introduction

Although the relationship between economic growth and pollution is not simple, increased production and consumptions seems to be an important drag factor for environmental problems such as air pollution. Emissions of greenhouse gases accumulate, and according to the literature, then have a severe impact on climate change. This involves changes in the energy markets in different ways. First of all politicians may introduce instruments to reduce emissions, for instance taxes, tradable emission permits or regulations. The prices of fossil fuels increase either directly or through shadow cost (regulation), which entails substitution between "black" and "green" energy sources. This both influence the cost of production and composition of economic growth and the demand for renewable energy. Economic modelling of these links, description of climate impacts and policy analyses of economic instruments to decouple the link is highly presented in the literature. These issues then have been studied thoroughly the last decade. Therefore we will skip this issue in the rest of this article.

Except from fossil fuels and nuclear energy, most of the primary energy sources are captured directly from short-term natural conditions. An interesting climate change factor that is not debated in the literature then is the link between climate change and primary energy supply. This forms the background for this paper taking into account that Norway is a country not only filled up of fossil fuels but also capturing a lot of energy from the water falls and having a big potential in the forests, the long coast (wind) and large areas (sun etc).

Let us introduce a simple energy market, see figure 1.1. In the real world the market is of course much more complex, however, this does not change the principle questions raised here. The supply of different kinds of energy is ranked according to marginal unit cost of production along the upward sloping line. This constitutes what economists call a long-term marginal cost curve. The higher the price in the market is the more of the energy sources are profitable. The demand curve is downward sloping - i.e. the lower the price the higher the demand. Equilibrium prices and volumes is found in the crossing point of the demand and the supply curve (p,x).

Figure 1.1. A normal energy market. Supply by marginal cost and demand by willingness to pay.



Climate change, as the phrase indicate, may have a severe impact on different aspects of the climate, as for instance precipitation, wind size, velocity and circumference, sunny periods and cloudiness, and bio production. This may influence the amount of profitable and exploitable renewable energy sources in different ways that introduces upward and downward shifts in the supply. It may even introduce shifts in the ranking of projects, which introduces simultaneous impacts from one energy source to another energy source in the market. The impacts will even be carried forward to the market for non-renewable energy sources by competition and equating prices. In the figure we have also illustrated some environmental consequences from energy supply. Shifting the supply curve shifts the environmental consequences. For ease of discussion we have exempted environmental concerns from demand. Some of the aspects about climate change and impacts on the supply curve are discussed further in chapter 2.

Climate change may have an impact on the average outdoor temperature. Since some 50 per cent of the energy use in the Nordic countries is used for heating purposes this may have a major impact on the energy demand. This is further discussed in chapter 3.

When we are talking about energy markets in general it is hard to grasp the overall impact from climate change to the energy markets. Different energy sources are used for different purposes; some energy sources have limited transportation possibilities or introduce capacity constraints in transport facilities. This regionalizes the energy markets. Since climate change may be different from region to region this introduces even more complex impacts from climate change to energy markets. Regionalized energy markets are the subjects in chapter 4.

We give some summarizing comments and conclusions in chapter 5.

2. Climate change and the primary Energy Sources - the supply side

Climate change may influence both the energy demand and supply side of the economy. Important supply side effects are increased precipitation, increased wind, warmer climate and increased bio supply. This is the issue of this actual chapter.

2.1. Non-renewable energy

Non-renewable energy sources are typically long time stored and developed, in this context we are talking about million or billion of years, which excludes them from being relevant to discuss under a climate change primary energy supply scenario. The stock of primary non-renewable energy will not change. That is, fossil fuels as oil, gas, coal etc is excluded from the supply side discussion in this paper, as is nuclear energy based on the non-renewable uranium. In an infinite time horizon of course this simplification is too rude.

One aspect on fossil energy that will be discussed, however, is the effect on the supply side driven by changing demand and profitability of non-renewable energy. That is discussed under chapter 3.

2.2. Water inflow

As climate change, precipitation will change. Norway is close to a hundred per cent based on precipitation and water inflow in its electricity production system. Sweden is almost 50 per cent based on hydro, while Finland produces on average almost 20 per cent of its electricity from hydro sources. Denmark has no hydropower, but changing inflow to the other Nordic countries will still influence them in two ways. The Danish electricity grid is connected to the other countries' grid and market signals in one of the countries affects the market signals in the other country. Secondly, the Danish are presently putting a lot of effort in expanding their wind power capacity. As the blowing wind is stochastic they rely heavily, and increasingly heavy, on the flexibility in the neighboring hydropower system. As changing water inflow may change the flexibility rate, Denmark also faces a changing market although they are not hydro based.

In Cicero (2001) we find estimates of changes in precipitation in two regions of Norway. These regions are interesting in several ways. They represent two typical regions in a hydropower-based system as the Nordic system. The western part of Norway is a region with excess supply of power, while the eastern part is a deficit area. From table 2.1 we note that this aspect may well be even more important as climate change. The figures indicate that in the excess area (western part) the precipitation may increase by 13.5 percent, while in the deficit area (eastern part) the precipitation will increase by only 4.3 per cent. This implies that there should be an increased attention to the transmission challenges this may lead to.

Another interesting aspect in these figures is that the biggest increase happens during the autumn in the excess part of the country; however, there is also an important shift in the summer period. Depending upon how the summertime increase is distributed the economic effect may vary. If the increased precipitation occurs in the early summer increased water will simply add up to the spring - early summer - snow melting in the mountains. This will stress the water storages and thereby have an important impact on the pricing in the pre winter and spring market. Remember that future capacity limitations in a hydro power system based on water storages influences on the pre period pricing.

Table 2.1 Average estimated change in precipitation from (1980-2000) to (2030-2050)

		Change in precipitation mm/24 hours	Percentage change
North-Norway	All year	1,6	7,8
	Spring	1,4	5,0
	Summer	1,2	1,5
	Autumn	1,7	18,2
	Winter	2,0	5,2
Western Norway	All year	1,0	13,5
	Spring	0,9	1,2
	Summer	0,7	18,2
	Autumn	1,1	23,5
	Winter	1,2	9,3
Eastern Part of Norway	All year	1,1	4,3
	Spring	1,0	-4,1
	Summer	0,6	1,7
	Autumn	1,3	6,9
	Winter	1,3	13,1

Source: Cicero, Norway

If the increased precipitation happens in late summer the summer market is stressed, as storages should be lowered before the autumn raining period. The increased precipitation in the autumn also influences the summer market and thereby previous periods as explained above. The increased precipitation in wintertime is probably snow. This does not affect the storages directly, however, the snow-melting period in the late spring and early summer will be more important. The shadow prices of storage capacities, generation capacities and transmission capacities will probably increase. This affects the profitability of new investments in all capacities.

In North-Norway the biggest challenge will probably be the increased precipitation in the autumn period. The dynamic effects throughout the periods will be the same as for the western country part.

In the eastern part of the country some special concern should be addressed. In this area the largest effect is on winter precipitation, i.e. snow. In this area there are already flooding problems during the snow-melting period in the spring and early summer. Besides, in this area, the power plants are mostly based on fluctuating water from rivers and not on water from huge storages.

Another aspect that does not show from this table is the change in the winter period effect. As we can see from table 3.1 in chapter 3, outdoors temperatures increases as climate changes. This may reduce the winter length in the Nordic countries. On the supply side this may be important as the cold winter period is shortened, and the snow melting period comes earlier.

2.3. Normal wind and amplitude

Strand and Grønås (2001) shows that during the last 40-50 years there have been an increasing amount of wind at the coastline of Norway. Their article does not state that this is a consequence of climatic change, but let us for a matter of discussion suppose it is. Then the potential of wind power may increase. However, several kinds of problems may arise. First of all, the increased wind force may be too harsh to be technically exploitable. Second, the wind force amplitude may increase, and larger part may be too harsh. Or it could be quit the opposite; more wind in average could imply longer periods with wind power activity.

Less wind reduces the amount of production and thereby reduces the profitability of windmills. If windmills are at the margin, because the politicians have introduced instruments to reduce environmental problems, this implies higher energy prices in the market. Or, the other way round, more wind, higher production and better profitability, contributes to less energy prices and more energy use.

There are at least two more aspects with more windmills production that should be considered in an economic context. The first is that increased windmill energy production in excess areas increases the need for transportation against deficit areas. Besides the congestion periods in the transmission system increases. This has two effects; the profitability of increasing capacity rises. The number of hours with congested lines increases, i.e. regionalized markets occur more often and market power possibilities may be exploited. Second, windmill production is still stochastic, that is energy from windmills must be outweighed by variation in hydropower production with impacts on prices and the energy demand.

2.4. Sunny days

In the Nordic countries photovoltaic cells do not contribute much to the energy supply side. However, some effort is put into increasing the use of this technology. Less radiation will reduce the profitability of this energy source.

Ljones and Sæbø (1983) tested the energy demand dependency on temperature based on monthly data for energy demand and calculated weighted average of temperatures in Norway. In his model he introduced what he called a spring effect. The spring effect was significant in his model. What is this spring effect? Well, during the springtime the sun shines more and more effectively. Even if the outdoor temperature still is high (cold) the sun radiation implies a greenhouse effect in houses. This reduces the need for energy for heating.

2.5. Temperature, forestry and bio-fuel

CO_2 concentration by itself increases the growth rate for bio fuels. Greenhouse gases contribute to higher temperatures and higher bio growth rate. The initial effect then should be larger supply of bio-fuels and increased profitability in utilizing such fuels. In Norway there is a net increment of bio stock already. The supply effect from increased bio growth on energy supply is then questionable. Another stabilising effect is however important. Increased bio fuel growth captures more CO_2 and the net climate effect is shortened.

3. Climate change and Energy Demand

3.1. Higher temperature and less demand

One important reason why energy demand is much higher in the Nordic countries than in southern Europe is lower temperatures[2] (colder). In southern Europe there is possibly an increasing need for air-conditioning that partly outweighs the higher need for energy for heating purposes in the Nordic countries, but only partly.

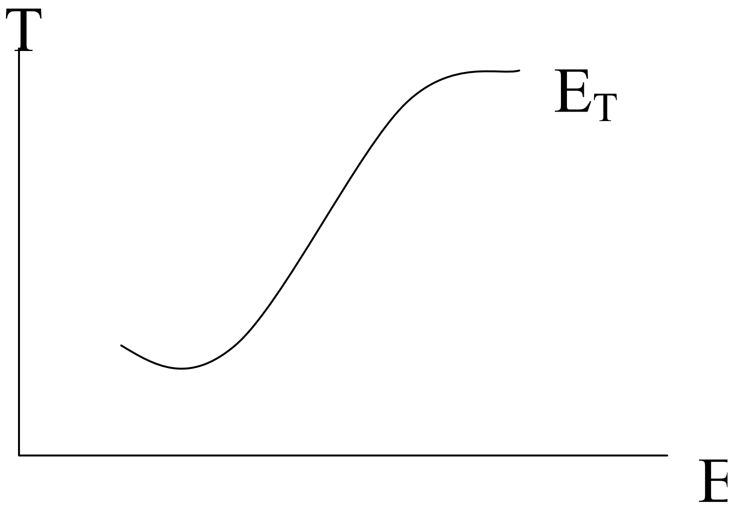
In figure 3.1 the temperature effect on energy demand is illustrated as a partial marginal temperature effect normalized to neutral temperatures (deviation from a mean temperature). Energy demand increases as inverse temperatures increases (i.e. its getting colder). This is the monotonic increasing linear part of the figure.

At the same time inverse lower temperatures (warmer) may lead to marginal increases in energy use, i.e. the left u-turn part of the curve. The reason is that even in the Nordic countries there are some air-conditioning, see for instance Bye and Hansen (1989) and Døhl (1998).

When temperatures are higher (colder) energy demand is not increasing as much, or stops increasing at all, see the right inverted u-part of the curve. This typically happens when capacity limits of the heating equipment are reached. If we concentrate on each energy commodity, the use of one energy source may even decrease as temperatures increases above a certain level.

[2] There are several other reasons as higher income, more energy intensive industries, low population density etc.

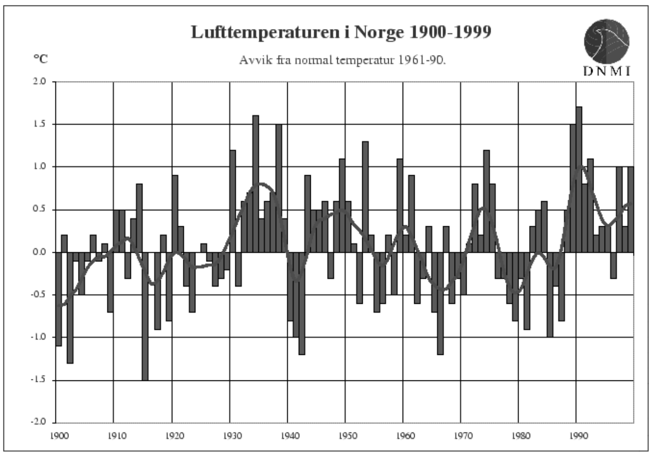
Figure 2.1. Energy and temperature.



The reason for this is that when you reach the infrastructure capacity of one energy source (for instance electricity heating equipment) you turn on a more heating efficient equipment (for instance wood burning stove) that is hard to regulate. Then you may regulate down the capacity utilization of the electricity equipment. This implies that temperature may have impact on both total energy demand and on energy composition, see Bye and Hansen op cit. for å more detailed discussion of this aspect.

Figure 2.2 shows the change in temperature (deviation from mean) in Norway in the period 1900 to 1999. The long-term trend shows an increase in temperature of about 1 degree over this period. Analyses of the future perspectives of temperature increase indicate a possible increase of 2 degrees in a hundred years to come. The figure shows the average temperature change over the country, and hides both seasonal and regional effects that may be larger.

Figure 2.2 Air temperature in Norway, 1900-1990. Discrepancy from normal temperature. Degree Centigrade.



Source: The Norwegian Weather Office.

Døhl (1998) reports the following temperature elasticity's on total energy demand, see table 2.1. The elasticity's in the winter period, i.e. from November to April is three times as high as the elasticity's in July and August, while it's in between for may, June, September and October. This elasticity's says that when average monthly temperature rises by 10 per cent (standardised to the normal temperature) energy demand rises by 4.7 per cent in January and 1.4 per cent in August.

Table 2.1. Monthly temperature elasticity's on demand. Average for the period 1991-1996

Month	Jan	Feb	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Temp.el.	0.47	0.48	0.45	0.43	0.31	0.20	0.14	0.14	0.28	0.38	0.44	0.47

If average temperature increases by 2 per cent over some decades this implies that energy demand increases by a yearly weighted average of less than 1 per cent if temperature increases approximately even over a year. In electricity demand this is well 1 TWh a year.

Both changing energy supply and changing energy demand influence on prices of energy to all consumers, also consumers that do not respond to temperature changes as transports, processes etc.

3.2. Less sunny, more humid

As mentioned in chapter 2 Ljones and Sæbø (1983) found a significant spring effect in their model. The reason was more sunny days and an in-house greenhouse effect. The Norwegian Weather Office has made some simulations of the radiation over the next 50 years, and indicates a lower radiation both in the non-heating and in the heating seasons. This is probably due to a warmer, cloudier, and more humid climate. In the spring period this could lead to higher energy use, see Ljones et al op cit. In the summer period the effect is ambiguous as colder climate could lead to both increased heating and reduced air-conditioning. In the wintertime a milder climate would probably shift demand inwards, i.e. give lower energy use.

4. The relevant market

So far we have been discussing possible energy market effects from climate change without actually addressing the question of the circumference of the relevant market, although the underlying discussion have addressed the Norwegian or the Nordic market. Let us address some aspects of regionalized markets in two directions - smaller regions and international markets.

4.1. Regional markets

Many of the relevant primary energies are tradable goods without any specific limits with respect to transportation capacities. Some energies, however, is being traded through pipelines (gas) or by transmission lines where capacity constraints occur now and then, or often. Capacity constraints are normal when the transportation lines represents infrastructure with discrete large capacity change options, high investment cost and decreasing short run marginal utilisation cost. These capacities are typically exploited over time. When climate change and energy supply conditions change this alter the restrictions on the transportation capacities. Capacity constraints occur more often, or less often. Shadow prices of the capacity limits influence on energy prices and energy markets. The impact from climate change on regional and interregional markets varies dependent upon both the energy supply and energy demand effects and capacity constraints in each region. The climate effect on the energy market in western Norway may be different from the impact on the energy market in South-Sweden. The changing energy supply side is only a first order effect. Secondary effects arise from the demand side and from restricted capacities in the transmission networks/lines. Such secondary effects may outweigh or strengthen the primary supply side effects. To calculate the net effects you need to know both changing volumes and costs on the supply side and market responses on the demand side. Mixed with capacity constraints this should constitute an energy market model where such simultaneous effects may be possible to calculate.

4.2. International market

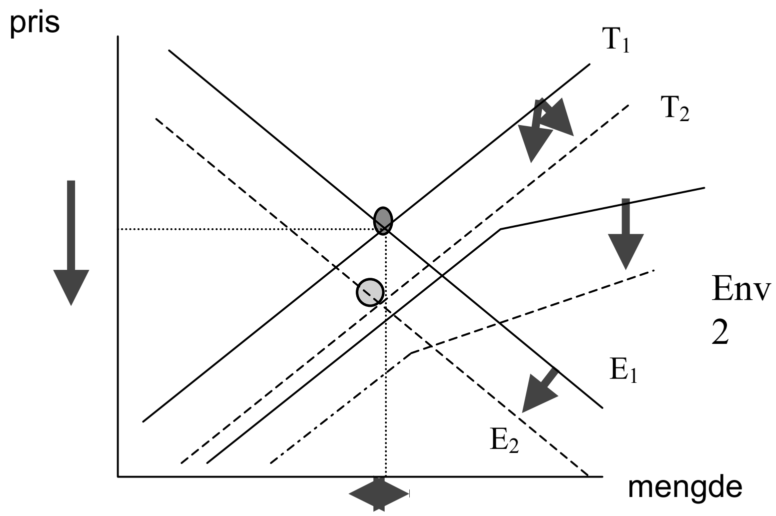
The composition of the energy supply side is very different in the Nordic countries - see the comments in chapter 1. This implies that climate changes effect on in the energy supply side also differs between countries. Since the energy markets are interrelated, however, there will be spill over effects from one country to another. Increasing precipitation in Norway will influence on energy prices in Denmark. Increasing wind in Denmark will influence on the utilization rate over periods in the Norwegian hydropower system. Higher temperatures in Sweden changes demand and thereby contribute to changing equilibrium prices in the electricity market in Finland etc.

Climate effects may be different in the Nordic area and the southern world. More rainy periods probably occur in the north contrast to more drought periods in the south. The initial effect of climate change on energy markets may be different in different areas. However, some of the primary energy sources are international tradable goods overlong distances. Then there will be spill over effects between the different markets.

5. Summarizing comments and conclusions

In figure 5.1 we summarize some of the main results from this exercise. The original supply and demand curves are T_1, E_1. Climate change introduces changes in the supply curve to T_2. More energy at a lower cost will be available at least in some region in the Nordic countries. In addition the composition of the demand curve shifts. The ranking of the marginal cost of different energy sources shifts. Then the environmental consequences change too.

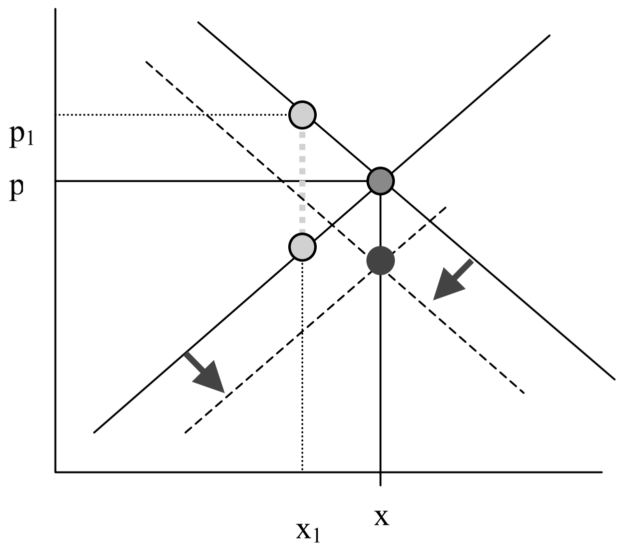
Figure 5.1. Climate change and changing energy markets.



At the same time demand shifts inwards, i.e. ceteris paribus, demand goes down. Energy prices drops. What happens to energy demand is an open question; demand may both increase and decrease. This should be a question for further empirical research.

Figure 5.1 addresses an open non-restricted energy market. A regional market with restrictions on transmission possibilities between the regions is specified in figure 5.2. The full open market with no restrictions is replicated in the equilibrium (x,p), while equilibrium in the regional restricted transmission capacity market is (x_1, p_1). We clearly see that shifting supply and demand curves as an outcome of climate change have different impact in the two cases.

Figure 5.2. Climate change and changing energy markets. Regional markets and restricted transmission capacities.



The climate change effects on energy markets may be divided into partial moments: Supply side effects and demand side effects. In this paper we have been discussing some nontrivial effects both on the supply side and the demand side. In addition, some of the energy markets - especially the electricity and gas markets, face transportation constraints that make the outcome of the partial effects through the market more complex. Besides, inclusion of both supply and demand effects introduces simultaneity effects.

Analysing energy markets effects from climate change calls for studies on both volume and cost effect on the supply side, behavioural studies on the demand side, and more complex modelling work for regionalized markets and time dependent markets.

References:

Bye, T. and M. I. Hansen (1989): An economic model for adjusting demand to temperature change. Internal Notes 89/30, Statistics Norway

Cicero (2001): Uncertainty in the estimated global warming. Cicerone 5/2001.

Døhl, Ø. (1998): Temperature and Energy Demand. Internal Notes 98/81, Statistics Norway

Strand (2001):

Ljones, A., and H.V. Sæbø (1983): Temperature and Energy Demand. Internal Notes 83/7, Statistics Norway

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