De Økonomiske Råd
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ECONOMY AND ENVIRONMENT, 2019
SUMMARY AND RECOMMENDATIONS

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This report from the Chairmen of the Danish Economic Council of Environmental Economics contains two chapters focusing on the distribution of environmental impacts and leakage due to Danish climate policies. There are two main conclusions:

In Denmark, there is relation between high environmental exposure and individuals with low income. However, the relation found in the Danish data is very weak. On the other hand, large differences in environmental exposure are found between individuals within the same income groups, indicating that income does not contribute significantly to the explanation of differences in environmental exposure between individuals.

Denmark's overall leakage rate is 45-53 per cent. The leakage rate is particularly high for the Danish quota sectors and for agriculture. Agriculture should, however, still contribute significantly to the overall reductions of greenhouse gas emissions in the non-quota sector because of socio-economic benefits related to better aquatic environment and less air pollution.

Economy and Environment, 2019

ENGLISH SUMMARY

This report from the Chairmen of the Danish Economic Council of Environmental Economics consists of two chapters:

- Environmental exposure and distribution
- Leakage due to Danish climate policies

The first chapter contains various analyses of environmental exposure and distribution in Denmark. The distribution of environmental exposures is analysed using Lorenz curves and the Theil index followed by statistic descriptions and regression analysis.

The second chapter presents calculations of the overall leakage rate for Denmark as well as leakage rates for different sectors in the Danish economy. The chapter discusses the consequences for Danish climate policy of adjusting for leakage.

CHAPTER I: ENVIRONMENTAL EXPOSURE AND DISTRIBUTION

The focus in the public debate on distributional issues of the environment in Denmark is often related to the distributional effects of green taxes. However, there has not been a similar focus on the distributional aspects of environmental exposure. The relation between income and environmental exposure has been examined in the international literature, with findings indicating that individuals with low income to a higher extent are prone to environmental exposures. Similar studies have not been conducted on a national level for Denmark.

Chapter I shed light on different aspects of environmental exposure and distribution in Denmark. Firstly, the distribution of different environmental exposures among the Danish population is analysed. Secondly, it is examined whether there is a link between the degree of environmental exposure and income. Finally the chapter examines what characterises highly exposed houses and apartments.

More specifically, the analyses focus on the environmental exposures from traffic noise and air pollution due to particulate matter ($PM_{2,5}$) and nitrogen dioxide (NO_2). Furthermore, analyses are conducted on the distribution of proximity to nature (forest, lakes and coast). Nationwide, register data on the environmental exposures, which can be linked to all homes in Denmark, is enriched with individual data on income and other socioeconomic characteristics, of the individuals living in the respective homes.

The results obtained in chapter I cannot be generalized to encompass environmental exposures not included in the analysis. The availability of geographically detailed nationwide data, which can be linked to the individuals, has been the main cause for the choice of environmental exposures included in the analyses. A range of similar international studies only focuses on one environmental exposure, which makes the current study more comprehensive than many earlier studies.

THE DISTRIBUTION OF ENVIRONMENTAL EXPOSURES

When analysing the distributional issues, the Lorenz curve is often used to illustrate the degree of inequality in the distribution of income. However, the Lorenz curve can also be used to illustrate the distribution of environmental exposure among individuals. Figure A shows the Lorenz curves for air pollution ($PM_{2,5}$ and NO_2), noise and proximity to nature. For comparison, the Lorenz curve for the distribution of income is also shown. If the Lorenz curve is close to the 45-degree line, the distribution of income or environmental exposures can be considered equal.

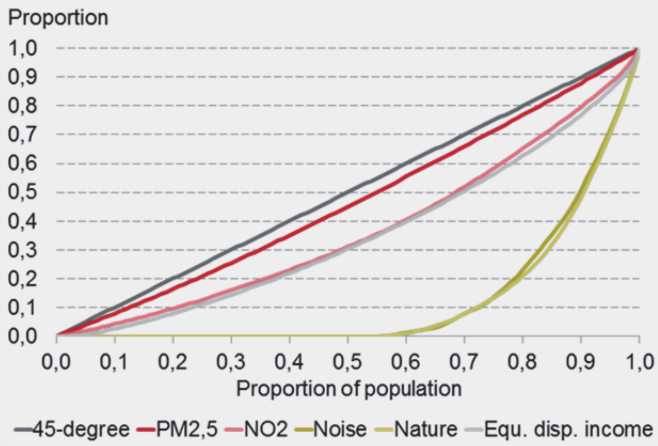
The results show large differences in distributional inequality across the different environmental exposures and proximity to nature. Relatively small differences are seen in the distribution of $PM_{2,5}$ and NO_2 between individuals. Compared to the distribution of income, $PM_{2,5}$ is more equally distributed, while NO_2 has more or less the same distribution as income. A larger inequality for NO_2 compared to $PM_{2,5}$ reflects that the concentration of NO_2 to a larger extent originates from local sources, e.g. power stations, traffic and shipping, while $PM_{2,5}$ is based on more regional sources mostly originating from non-domestic pollution.

For both noise and proximity to nature, the distributional inequality between individuals is larger than for the two types of air pollution. This reflects that noise and proximity to nature are of a very local character.

There is a risk of overestimating the inequality of proximity to nature because only housing within certain distances from nature (0.6 to 1 km dependent on the type of nature) are included in the analyses. If individuals experience a value from proximity to nature further away than the defined distances, the inequality shown in the Lorenz curve might be overestimated. Similarly, smaller nature areas are not included in the analyses which as well can give rise to an overestimated inequality of proximity to nature between individuals.

FIGURE A INEQUALITY IN ENVIRONMENTAL EXPOSURES

The inequality is illustrated using Lorenz curves for air pollution ($PM_{2,5}$, NO_2), noise, proximity to nature and income, respectively.



Note: Lorenz curves are based on concentrations of air pollution, noise above 50 dB and proximity to nature within 0.6 to 1 km from nature (dependent on the type of nature), respectively. The Lorenz curve for income is calculated from the equivalent disposable income in 2016.

Source: Own calculations.

ENVIRONMENTAL EXPOSURES AND INCOME

A range of international studies investigate the relation between environmental exposure and income. These analyses often show that individuals with low income are more prone to environmental exposures than individuals with high income.

The analyses based on the Danish data reveals only a weak relation between environmental exposure and income. Moreover, the analyses show large differences in the distribution of environmental exposure between individuals within the same income group. As Figure A and Figure B, in box A, illustrate, the difference of environmental exposure between individuals within the same income group is much larger than the difference of environmental exposures between individuals in the lowest and highest income group. This indicates that differences in income between individuals only explain a small part of the variation in environmental exposures.

Even though the relation between environmental exposures and income is weak in Denmark, there is a tendency towards individuals with low income being more prone to environmental exposures than individuals with high income, cf. box A. Calculations in the current chapter show that individuals with an equivalent disposable income, DKK 100,000 higher than the average, are less prone to the environmental exposures corresponding to values of DKK 30 for $PM_{2,5}$, DKK 30 for NO_2 and DKK 5 for noise, respectively.

INDIVIDUALS WITH HIGHEST ENVIRONMENTAL EXPOSURE

In chapter I housing, which are most prone to environmental exposures, are characterized in terms of type of housing and residential characteristics. Housing most prone to environmental exposures is defined as the houses and apartments where the 10 percent of the population exposed to most air pollution and noise lives. Proximity to nature is not a part of the selection of housing most prone to environmental exposures.

A majority of the housing with most environmental exposure are located within or nearby the capital of Denmark, Copenhagen, or other larger cities. In contrast, most of the housing least prone to environmental exposures are located in rural areas.

By using unit values, environmental exposure per house in Denmark can be converted to costs in Danish Kroner (DKK) per year. Unit values reflect inconvenience costs related to e.g. noise and costs of serious health effects including premature death. The estimated yearly cost from air pollution and noise is about DKK 4,100 higher for individuals living in housing most prone to environmental exposures compared to individuals living in an average polluted residence. This corresponds to 1.5 percentage of the average equivalent disposable income for an individual in Denmark. A large share of the costs is attributable to an increased risk of premature death. The increased health risk corresponds to an expected risk of losing 40 hours of expected life per year when living in a residence mostly prone to environmental exposures compared to an individual living in an average polluted residence.

BOX A RELATION BETWEEN INCOME AND ENVIRONMENTAL EXPOSURE

The two figures illustrate the relation between income and the concentrations of NO_2 and noise, respectively.

The X-axis shows the equivalent disposable income divided into percentiles. The first point on the X-axis represents the one percentile of the population with the lowest income, while the point most to the right represents the one percentile of the population with the highest income. The green curves illustrate the average level of NO_2 and noise for all individuals within each of the 100 income groups.[a)] The figures show that there is a tendency towards lower income groups having higher levels of NO_2 and noise.

FIGURE A **NO_2 AND INCOME**

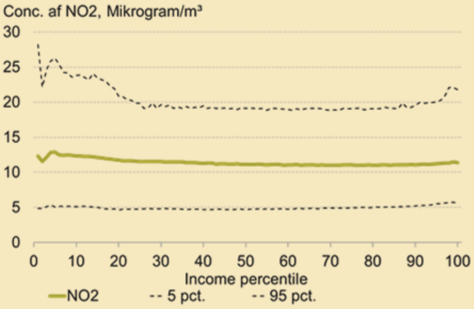
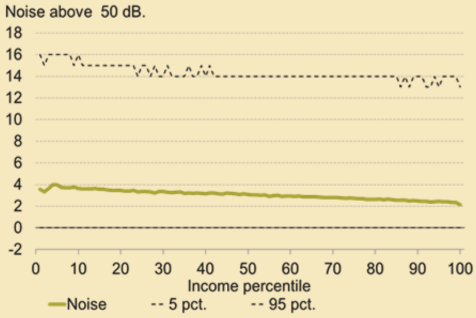


FIGURE B **NOISE AND INCOME**



Note: Income percentiles are calculated based on the equivalent disposable income in 2016.

Source: Own calculations based on registry data and data for air pollution and noise from Aarhus University and MOE|Tetraplan respectively.

The dotted lines in the figures illustrate the variation in NO_2 and noise within each income group. The dotted lines show the 5 and 95 percentage fraction for NO_2 and noise, which means that 90 percentage of the individuals in each of the income groups are exposed to a level of NO_2 or noise within the two dotted lines. It appears that the differences in environmental exposure between individuals within the same income group are much larger than the differences between individuals in the lowest and highest income group.

Figures describing the relation between income and concentrations of $PM_{2,5}$ and between income and proximity to nature, shows the same tendency, cf. section I.4 in chapter 1.

a) The curves show the relation between income and NO_2 and noise, respectively corrected for differences in level in income, NO_2 and noise in different parts of Denmark (calculated based on commuting areas).

Apartments, co-housing flats and private rental flats are to a higher extent represented among housing most prone to environmental exposures compared to the general distribution of housing in Denmark. In contrast, non-profit public housing is less often among housing most prone to environmental exposures compared to the general distribution of housing.

The analyses in the current chapter show small differences in socioeconomic characteristics among residents in housing most prone to environmental exposures compared to residents in housing with average level of environmental exposure, corrected for geographical differences. More specifically, the results show that individuals living alone, families without children and ethnic minorities more often live in housing with more environmental exposure. In contrast, fewer senior citizens are living in housing, which are more prone to environmental exposures compared to the general distribution. The international literature primarily shows that individuals with lower education more often lives in housing prone to negative environmental exposures. In contrast, the current analysis shows that this is not the case in Denmark. The analysis shows a tendency towards higher educated individuals more often living in housing, which are more prone to environmental exposures compared to the general distribution of population in Denmark.

Children are considered a vulnerable group in terms of being prone to environmental exposures. In the current chapter it is analysed whether children who have grown up in the most environmentally-compromised homes have parents with other socioeconomic characteristics than other children. Only small differences are found between the two groups of children. However, children with higher educated parents are slightly overrepresented among children living in housing with more prone to environmental exposures compared to other children.

CHAPTER II: LEAKAGE OF GREENHOUSE GAS EMISSIONS AND DANISH CLIMATE POLICY

Danish climate policy reduces CO_2e-emissions in Denmark but may at the same time increase CO_2e-emissions abroad.[1] This phenomenon is known as CO_2e-leakage. CO_2e-leakage implies that Danish

1) CO_2e is used to denote the emission of all greenhouse gases (including agricultural emissions of methane and nitrous oxide), converted to CO_2-equivalents.

climate policy has a smaller impact on global reductions than on domestic reductions in greenhouse gas emissions.

According to Denmark's obligations with the EU, Denmark must reduce emissions of greenhouse gasses in the non-quota sector by 39 per cent towards 2030 compared to the emissions in 2005. In addition, the Danish government has committed to a strategy of climate neutrality by 2050. The obligation for the non-quota sector and the target of climate neutrality are specifically related to emissions from Danish territory. It has been argued that Danish climate policy should focus on *global* emissions of greenhouse gasses in addition to the focus on emissions from Danish territory.

Chapter II presents calculations of leakage rates in Denmark and discusses the consequences for Danish climate policy of adjusting for leakage.

LEAKAGE RATES FOR DENMARK

The so-called leakage rate expresses the share of the domestic reductions in emissions that is replaced by increased foreign emissions. The analyses in chapter II indicate that Denmark's overall leakage rate is between 45 and 53 per cent. This implies that a national CO_2e reduction of 1 million tonnes results in a global CO_2e reduction of about 0.5 million tonnes.

The leakage rate for Denmark is calculated by imposing a tariff of DKK 100 per tonne CO_2e on all emissions in Denmark in the so-called GTAP-E model. GTAP-E includes a description of global trade flows, energy consumption and corresponding greenhouse gas emissions, which makes the model suitable for assessing the impact of such a tariff on emissions in Denmark as well as abroad.

The calculations encompass a number of mechanisms behind CO_2e leakage. The default GTAP-E model includes mechanisms via foreign trade and via the price of fossil fuels: As the CO_2e tariff in Denmark weakens Danish CO_2e-intensive firms' international competitiveness, some of the CO_2e-emitting production that currently takes place in Denmark moves abroad. And as the CO_2e tariff reduces Danish demand for fossil fuels, the world market price on fossil fuels is (slightly) reduced, and the consumption of fossil fuels increases abroad.

The leakage rate in Denmark is largely affected by the climate policy in the EU. The EU CO_2 quota system has been designed such that climate policy that reduces emissions in the Danish quota sector has a limited impact on the total emissions in the EU's quota sector in the long run. This contributes to a higher leakage rate in Denmark. Conversely, the CO_2e leakage in the non-quota sector is reduced by many EU countries' binding targets for their non-quota sector emissions. This lowers the overall leakage rate in Denmark. The GTAP-E model has been expanded to account for these mechanisms.

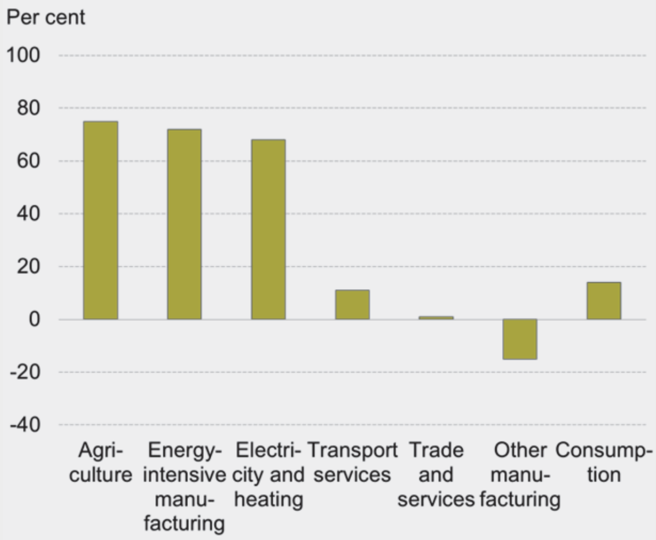
There are some mechanisms that may affect the leakage rate, which are not included in the calculations. A tighter climate policy in Denmark may for example encourage technological development that makes it easier to reduce emissions in other countries. This would lower the leakage rate. A tighter Danish climate policy may also give rise to higher reduction targets for other countries (the so-called pioneering country argument), which would lower the leakage rate as well. However, a tighter climate policy could also reduce other countries' incentive to undertake climate policy themselves, by solving a part of the global challenge.

LEAKAGE RATES FOR DIFFERENT SECTORS

The calculations indicate large differences in the leakage rates for different sectors in the Danish economy, see figure B.

FIGURE B **LEAKAGE RATES FOR SECTORS**

The leakage rates are high for agriculture and for sectors covered by the EU quota system (energy-intensive manufacturing and electricity and heating).



Note: The figure shows the leakage rates in a scenario where the long run effects of permanent climate policy is considered. The chapter includes calculations of leakage rates under different assumptions and adjustments in the model.

Source: Own calculations.

The leakage rates are high for the energy-intensive manufacturing and for the electricity and heating sectors, all of which are subject to the EU quota system. The leakage rates are relatively high for the quota sectors because a reduction in emissions in these sectors to a large extent results in an increase in future emissions in the rest of the EU. This is due to the design of the EU quota system implying that reductions in emissions in these sectors only to a limited extent reduce the long-term quantity of allowances in the EU.

The leakage rates are generally lower for the sectors not covered by the EU quota system. One reason for this is that many EU countries are expected to reduce their emissions from the non-quota sectors towards 2030. These countries are therefore not able to increase their emissions in this part of the economy in response to a tighter climate policy in Denmark.

The leakage rate is higher for Danish agriculture than for the remaining non-quota sectors. This reflects, among other things, that consumption of food is less affected by changes in income and prices than other products. Consequently, the production and associated emissions in agriculture increase relatively much abroad when production in agriculture decreases in Denmark as a result of regulation. The leakage rate for agriculture is, however, limited by the fact that many EU countries have binding targets for their emissions in the non-quota sector towards 2030.

The leakage rate for agriculture is very dependent on the climate policy outside the EU as well. A sensitivity analysis shows that the leakage rate for agriculture is more than halved if a number of countries outside the EU is assumed to have binding targets as well, while the leakage rates in other sectors are almost unaffected.[2] The sensitivity analysis illustrates the considerable uncertainty associated with the calculation of the leakage rate for agriculture.

LEAKAGE AND DANISH CLIMATE POLICY

The design of a cost-effective regulation that reduces greenhouse gas emissions depends on the political objective of the regulation. If the objective of Danish climate policy is to meet the goals of reducing CO_2e emissions from Danish territory, this is achieved most cost-effectively by a uniform (increasing) CO_2e tariff on all emission sources. Thus, differences in leakage rates between different sectors should not be taken into account.

If, however, the objective of Danish climate policy is to reduce global emissions over and above what follows from the existing international obligations and national reduction targets, the regulation should take CO_2e leakage into account. If such a supplementary objective is to be pursued cost-effectively, the climate effort must to some extent be

2) It is assumed in sensitivity analysis that all countries except large economies such as China, Russia, India and the United States have binding targets and that they therefore cannot increase their emissions. It should be emphasized that there is considerable uncertainty as to whether different countries have binding climate goals according to "business-as-usual". As an example, it is assumed in the analysis that the USA does not have binding climate targets. The USA's affiliation with the Paris Agreement is assessed by some as binding, but at the same time, the USA has indicated an intention to withdraw from the Paris Agreement.

shifted from sectors with high leakage rates to sectors with low leakage rates. Such a shift can be achieved by introducing leakage-adjusted CO_2e tariffs that are lower for sectors where the leakage rate is high.

Leakage-adjusted tariffs increase the socio-economic costs of reaching the purely national obligations and objectives, but a larger global reduction of CO_2e can be achieved for this additional price. The additional socio-economic costs associated with leakage-adjusted tariffs compared to a uniform tariff are calculated in the chapter to DKK 220-660 per tonne extra global reduction of CO_2e. This is about the same magnitude as estimates in the literature for the global marginal damage cost for a tonne of CO_2e emissions – the so-called social cost of carbon.[3]

The analysis in the chapter illustrates the effects of adjusting for leakage while reaching the 2030-obligations for the non-quota sector.[4] However, the analysis should not be seen as an optimal Danish climate policy to reduce global emissions. The reason is that e.g. climate-differentiated consumption taxes or a reduction of the North Sea oil and gas extraction could potentially be included in an optimal leakage-corrected Danish climate policy.

The analysis is based on calculated socio-economic reduction costs in 2030 for various parts of the non-quota sector. These were presented in the 2018 Economy and Environment report by Danish Economic Councils. Here it was found that the marginal socio-economic reduction costs were significantly higher for passenger cars than for agriculture and the remaining non-quota sector.

The calculations indicate that the different sectors' contributions to the overall reduction requirement for the non-quota sector do not change significantly when imposing leakage-adjusted tariffs instead of a uniform tariff.

Despite of its relatively high leakage rate, agriculture should still contribute significantly to the overall reduction when adjusting for leakage. The high leakage rate does, however, contribute to a slightly smaller

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3) In previous reports by the Danish Economic Councils, DKK 563 per tonne CO_2e (2017 prices) is stated as a good estimate for the social cost of carbon based on an overview study by Tol (2013). It should, however, be emphasized that there is large uncertainty related to the size of the social cost of carbon.

4) The calculations illustrate the additional effort needed to achieve the reduction requirement in the non-quota sector by 2030. There is uncertainty about the exact size of the reduction requirement, so the calculations are done for reductions of 2.5 million tonnes as well as 4.0 million tonnes CO_2e in 2030.

reduction in agriculture when adjusting for leakage.[5] The relatively modest effect on agriculture's share of the overall reductions reflects the fact that there are socio-economic benefits associated with reducing greenhouse gas emissions for this sector specifically, in the form of a better aquatic environment and less air pollution.

Even though the leakage rate is very small for consumption of transport fuel, increased tariffs on CO_2 from passenger cars are not a part of the leakage-adjusted tariff policy. This is because the marginal socio-economic costs of further reductions are relatively high, since passenger cars are already heavily regulated in Denmark.

According to an agreement with the EU, Denmark may use cancellations of quota allowances corresponding to at most 0.8 million tonnes per year to meet the reduction requirement. There is a *negative* leakage rate associated with this type of quota cancellations of approximately -53 per cent in the long run, which reflects mechanisms linked to the reform of the quota system from early 2018. The calculations in the chapter show that the quota cancellations should be fully utilized if the reduction requirement in 2030 is 4.0 million tonnes CO_2e, regardless of whether a uniform or leakage-adjusted tariff policy is used. If the reduction requirement is only 2.5 million tonnes CO_2e, quota cancellations should only be used when adjusting for leakage.

The analysis shows that there is a relatively limited impact on global emissions of introducing leakage-adjusted tariffs instead of a uniform tariff. With a national reduction requirement of 4.0 million tonnes in 2030, global emissions are reduced by 3.2 million tonnes with a uniform tariff. With leakage-adjusted tariffs, global emissions are reduced by 3.4 million tonnes. The relatively limited effect of introducing leakage-adjusted regulation is in line with studies for other countries. This is not in itself an argument for not using a leakage-adjusted climate policy, but it is important not to have unrealistic expectations for the effect on global emissions.

5) Agriculture's share of overall reductions decreases from 43 to 33 per cent with a reduction requirement of 2.5 million tonnes, and from 37 to 29 per cent with a reduction requirement of 4.0 million tonnes.

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