lo. 148 | September 1995 | Discussion Papers

Statistics Norway
Research Department

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Abstract:
The welfare effects of introducing taxes on emissions of carbon dioxide is analysed within an empirical general equilibrium model of the Norwegian economy. A CO_2 tax regime where we aim at stabilising the CO_2 emissions at the 1990 emission level in 2020 is compared to a reference scenario without such taxes. In the simulations introduction of CO_2 taxes reduces gross domestic product, but increases net national real disposable income, private consumption and money metric utility. This difference in sign is due to a positive terms of trade effect, some of the CO_2 taxes will be paid by foreigners through exports. The welfare effects differ from household to household depending on the composition of their total consumption. Poor households are less favourably affected than rich households, due to smaller budget shares for the rich households on consumer goods which imply relatively much CO_2 emissions.

Keywords: CO_2 taxes, general equilibrium model, money metric welfare, terms of trade.

JEL classification: E1, H3, I3, Q4.

Acknowledgement: Financial support has been provided by the Norwegian Research Council (Project no. 2734205 and 108527/510). Erling Holmøy has given valuable comments on an earlier draft.

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1 Introduction

Most macroeconomic studies concerned with the cost of reducing air pollution discusses the reduction in GDP following introduction of an emission tax, see for instance Bye, Bye and Lorentsen (1989), Barns, Edmonds and Reilly(1992), Jorgenson and Wilcoxen (1992), and Manne and Richels (1992). Some studies discusses a "climate cost function", i.e. a set of paths showing the model correlation between different emission goals and GNP reductions, see Johnsen, Larsen and Mysen (1995) and OECD (1992). Alfsen, Brendemoen and Glomsrød (1992) also include environmental benefits, such as reduced health damage, traffic damage and congestion etc., from reducing emissions. A recent study by Bergmann (1995) discusses the cost of both reduced GNP, GNI and changes in an environmental quality index. The head point of the Bergmann study is that energy taxation may lead to positive changes in terms of trade, i.e. the real gross national income is reduced less than the gross national product. Bergmann also includes environmental benefits in his calculations to stress that carbon dioxide taxation may be a no regret policy. Brendemoen and Vennemo (1993) discusses the advantage of changing tax policy from taxation of factor input to taxation of external effects such as polluting activities in the context of financing public funds[1]. Other studies like Jorgenson and Wilcoxen (1992) introduces endogenous technical change and intertemporal optimisation in their models.

We analyse the welfare effects of introducing taxes on emissions of carbon dioxide within an empirical general equilibrium model of the Norwegian economy. A CO_2 tax regime where we aim at stabilising the CO_2 emissions at the 1990 emission level in 2020 is compared to a reference scenario without such taxes. Some main elements of the Norwegian long term equilibrium model MSG-EE is presented in section 2. A detailed description is given in Alfsen, Bye and Holmøy (1995).

In the simulations introduction of CO_2 taxes reduces gross domestic product, but increases net national real disposable income and private consumption in fixed prices. This difference in sign is due to a positive terms of trade effect, some of the CO_2 taxes will be paid by foreigners through exports. A short discussion of terms of trade effects are presented in section 3.

Emission taxes also influence the relative prices on consumer goods. The effects on money metric utility is thus more positive than the effects on private consumption in fixed prices. In section 4 we present our model for consumer demand and money metric utility. A detailed description of this model is given in Aasness and Holtsmark (1993).

In section 5 we present our calculations of household effects. These effects differ from household to household depending on the composition of their total consumption. Poor households are less favourably affected than rich households, due to smaller budget shares for the rich households on consumer goods which imply relatively much CO_2 emissions. During the simulation period the average household size decreases and the relative number of children and adults changes. This makes the welfare level and policy effects rather different for the macro household, the average household and a reference household (with constant number of children and adults during the period). We give some concluding remarks in section 6.

[1] Clarete and Whalley (1987) discusses marginal welfare costs of commodity and trade taxes. See also Johnson (1951-1952)

2 The macro model

In our analyses we apply a long term general equilibrium model of the Norwegian economy[2]. In this model the international market growth, import prices, technical change rates, crude oil prices, taxes, the hydro power production potential, governmental expenditures and the supply of labour are all exogenous, see the ovals in figure 1. The model is closed by a fixed exogenous rate of return on capital and an exogenous trade balance. The price model comprises econometrically estimated generalised Leontief cost functions for 36 production sectors in the five inputs, labour, capital, materials, transports and energy for stationary combustion. The transportation aggregate includes transport fuels while the intermediate inputs covers energy used in production processes. In the price model endogenous aggregate input coefficients are calculated subject to relative price changes between the inputs. In several regulated private sectors like agricultural production, oil and gas production and in the public sectors production is exogenous just like the world market prices for crude oil, natural gas and shipping. The input coefficients, the supply of primary inputs, and exogenous demands goes into the quantity model that calculates the endogenous sector demand and production. Total private consumption is residually determined through a general budget constraint and secures full employment in the model. An emission model calculates the development of 9 pollutants linked to the use of energy by end use specific emission coefficients[3]. The complete set of consumer demand functions for the 22 consumer goods is derived from utility maximisation with a household specific three level nonhomothetic utility tree, and with perfect aggregation across households in Norway[4].

3 Emission taxes, GNP and real gross national income

That an emission tax affects income generation measured by for instance GNP is obvious. However, real gross national income may also be influenced by what happens with the external trade balance both in volume and value terms. In the Norwegian economy exports and imports amount to approximately half of the gross national product. Exports is concentrated on relatively few intermediate goods with varying prices. Imports are more diversified and average imports prices thereby fluctuate less than export prices. This imply that changes in the terms of trade may be important for the development of real disposable income[5]. The contribution from change in terms of trade has been both positive and negative for the development of real disposable income in Norway in the past. During the seventies and the eighties increases in Norwegian wages and prices were considerably higher than the average for other European countries. On this background a more negative contribution from changes in terms of trade than we have observed were to be expected. An explanation for the modest terms of trade effects may be that

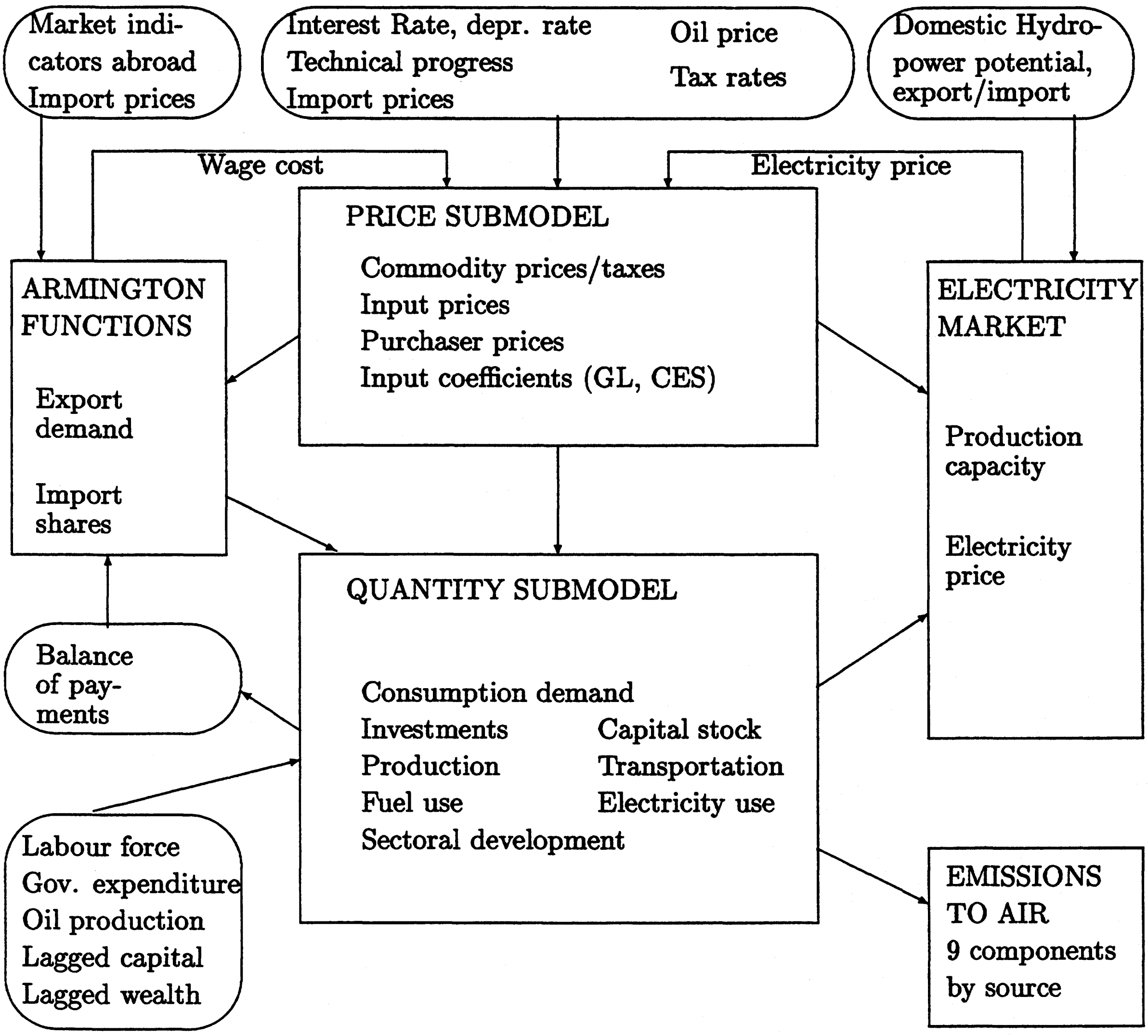
[2] The MSG-EE model, see Alfsen, Bye and Holmøy (1995).

[3] For a detailed description of the emission submodel, see Brendemoen, Hansen and Larsen (1994).

[4] Aasness and Holtsmark (1993) presents this consumer demand model in detail.

[5] A change in real disposable income can be decomposed into the contribution from output growth, a change in the interest and transfers balance, and a change in the terms of trade (difference between the trade balance deflated by a domestic price index and the trade balance when exports and imports are deflated by their respective price indices.

Figure 1: Structure of the MSG-EE model. Some exogenous (ovals) and endogenous (squares) variables



Norwegian exports to a certain degree show price setting rather than price taking behaviour.

Assuming differentiated products and monopolistic competition Lindquist (1993)[6] shows that applying the Armington model for explaining exports development, encompasses the small open economy model (price taking behaviour) for most Norwegian export commodities. She states that "if the assumption of homogenous products of a commodity within a country is violated and Norwegian firms produce differentiated products, we may well find small price elasticities for Norwegian commodities, even if firms at the micro level face price elasticities well below minus one. This is due to the substitution effect between Norwegian products."

Within this context an export tax policy, for instance through taxation of emissions of CO_2, may be optimal, see also Helpman and Krugman (1989). If exports are inelastic the country may obtain a positive terms of trade effect by taxing CO_2 emissions. We may even have an increase in real gross national income (GNI) even though when GNP is reduced. When analysing welfare effects of taxing CO_2 emissions this imply that taking into account terms of trade effects may be important, as we shall see also later in this paper.

4 Consumer demand and money metric utility

Taxing CO_2 emissions changes both incomes and prices for the consumers in the economy. Different households have different expenditure patterns and are thus affected differently by the relative price changes. Consumers can adapt to these changes by substituting away from goods with relatively increasing prices.

In our general equilibrium model of the Norwegian economy every household has an indirect utility function of the Gorman-Polar form, i.e.

$$u_{ht} = (y_{ht} - m_{ht})/p_t, \quad h \in H, \tag{1}$$

where y_{ht} is total expenditure for household h in time period (or situation) t, m_{ht} can be interpreted as minimum expenditure and p_t is a price index (the cost of one unit increase in utility). In the model, the minimum expenditure is a linear function of the number of children (a_{1h}) and the number of adults (a_{2h}) in the household,

$$m_{ht} = m_{0t} + m_{1t}a_{1h} + m_{2t}a_{2h}, \quad h \in H, \tag{2}$$

where m_{0t} is the fixed minimum expenditure of a household, representing economics of scale, and m_{1t} and m_{2t} are minimum expenditures for an additional child and an additional adult, respectively. This is a simple linear structure, but the variables m_0, m_1, m_2, and p are rather complex functions of the prices of the 22 commodities in our complete demand system, cf. Aasness and Holtsmark (1993). The demand system and the indirect utility function are derived by specifying the direct utility function through a three level utility tree, with quasi-homothetic sub-utility functions of the LES or the CES form. At the bottom level there are large substitution possibilities between for instance air transport and other forms of public transport, at the intermediate level there are considerable substitution possibilities between public and

[6] See also Naug (1995)

private transport, and at the top level there are moderate substitution possibilities between, say, transport and food. The model takes account of the fact that for instance the estimated income elasticity for bus transport is much less than the income elasticity for air transport, and the implications of this fact for the structure of the direct and cross price elasticities for the 22 consumer goods.

The cost of living as a function of the utility level u_{ht} can be found by inverting the indirect utility function (1),

$$(3) \qquad y_{ht} = m_{ht} + p_t u_{ht}, \quad h \in H.$$

We define our money metric utility as the cost of obtaining the utility level u_{ht} (i.e. a particular indifference curve) at the prices in our base year (1988, symbolised by 0),

$$(4) \qquad y_{ht0} = m_{h0} + p_0 u_{ht}, \quad h \in H.$$

Thus we compute the households utility u_{ht} using (1) and total expenditure and equilibrium prices in year t, and transform this to a money metric utility using (4).

The macro demand functions are derived by perfect aggregation over all Norwegian households, and are characterised by the following expenditure functions for commodity j

$$(5) \qquad Y_{jt} = m_{j0t}N_t + m_{j1t}A_{1t} + m_{j2t}A_{2t} + \beta_j(Y_t - m_0 N_t + m_{1t}A_{1t} + m_{2t}A_{2t}),$$

where N_t, A_{1t}, and A_{2t} is the number of households, the number of children, and the number of adults in Norway, respectively, cf. Aasness and Holtsmark (1993). The m-variables are (rather complex) functions of the prices.

Redistribution of income across households do not affect the macro demand for the 22 consumer goods due to the linear Engel curves. This is a convenient property for our general equilibrium model. Similarly, due to the linear modelling of demographic effects, a redistribution of children or adults across the households do not affect the macro demands. But the total number of households is important, because economics of scale in household production represented by a fixed cost. The demographic variables (N_t,A_{1t},A_{2t}) are projected all up to the year 2020 by a separate demographic model.

Macro total consumption expenditure (Y) is determined by the equilibrium conditions in our model, although our households consider total expenditure as exogenous when deciding how to allocate it between the different goods. Our equilibrium model do not specify how the macro total expenditure (Y) is distributed on the different households in the economy. We shall therefore specify some average and some more special households, when analysing the welfare effects.

Let e_h be the number of equivalent adults of household h according to the OECD equivalence scale, i.e.

$$(6) \qquad e_h = 0.3 + 0.5a_{1h} + 0.7a_{2h}, \quad h \in H.$$

Thus the cost of living of an extra child is half of that of a single adult, while the cost of living of an extra adult is 70% of a single adult, within the scheme in (6). Furthermore let $E_t = \sum_h e_h$ be the total number equivalent adults in the Norwegian economy.

Define first a *reference household* r as a household with

$$(7) \qquad a_{1r} = 0.65, \quad a_{2r} = 1.76, \quad y_{rt} = e_r Y_t / E_t,$$

i.e. a household with 0.65 children, 1.76 adults (averages in the base year), and total expenditure per equivalent adult equal to macro total expenditure per equivalent adult in the period (situation) under analysis.

The average household (a) is defined as a household with average number of children, adults and total expenditure for each time period,

$$(8) \qquad a_{1at} = A_{1t}/N_t, \; a_{2at} = A_{2t}/N_t, \; y_{at} = Y_t/N_t.$$

Note that the preferences of the average household changes, reflected in changes in minimum quantities and minimum expenditures, as the average number of children and adults changes. This is in contrast to the reference household.

The *macro household* is defined as a household with all children, all adults and all total expenditure in the economy and with the indirect utility function

$$(9) \qquad U_t = (Y_{ht} - M_t)/p_t, \;\; where \;\; M_t = m_0 N_t + m_{1t} A_{1t} + m_{2t} A_{2t}.$$

Maximising the utility of the macro household generates the macro expenditure functions (5), which can also be derived by perfect aggregation over all households. Maximising the utility of the average household also generates macro demands when multiplying by the number of households. But the welfare implications are different. To see this, imagine that the number of children, adults and total expenditure per household is constant, while the total number of persons and households increases. Then the utility of the average household will be constant while the utility of the macro household increases proportionally with the number of persons in the economy.

We can define an infinite number of specific households and calculate their welfare measures defined by (1-4). In this paper, however, we will in addition to the three households above present results for the following five specific households. A *rich reference household* is defined as a household with the same demographic characteristics as the reference household above, but with twice as much total expenditure. The *poor reference household* has also the same demographic characteristics, but only 60% of the total expenditure of the reference household. Finally we define the three households *single adult* ($a_1 = 0, a_2 = 1$), a *couple* ($a_1 = 0, a_2 = 2$) and a *couple with three children* ($a_1 = 3, a_2 = 2$). These last three household groups are given the same total expenditure per equivalent adult as the reference household.

5 Simulation results

We have conducted three simulations on the macro model. In the *reference scenario*[7] we have kept the level of the CO_2-tax constant in real terms throughout the whole simulation period 1988

[7] See Johnsen, Larsen and Mysen (1995) for a detailed discussion of this scenario. In their paper a traditional GDP measure is used to classify the effects of a CO_2 tax.

to 2020. In the *stabilisation scenario* we have increased the CO_2 taxes so as to keep the CO_2 emissions at the 1989 level in 2020. Finally, in the *high tax scenario*, the CO_2 tax is increased to obtain a ten percent reduction in the emissions in 2020 compared with the 1989 level.

The simulations are summarised in table 1. We notice that while increased CO_2 taxes lead to a decrease in GNP in the model simulations, total private consumption increases. This rise in private consumption may seem odd and is also in contradiction with other studies. However, this is due to the terms of trade effects discussed earlier in this paper. In all industries the prices of output increase due to the incremental CO_2 taxes. The prices increases most in the energy intensive industries since they have high fuel cost shares, but also because these industries have high *electricity* cost shares. The electricity prices increases when fuels are taxed because substitution leads to growing demand for electricity and expansion of the hydro power capacity at increasing marginal cost. Producers seek to increase their export prices to cover the rise in production costs. Exports decreases according to the estimated elasticities[8], however the value of exports decreases less. To keep the trade balance constant, imports must be reduced less than exports in volume, i.e. more of the domestic supply of primary resources may be utilised to produce goods for domestic demand. Increased consumption will lead to a higher welfare for the households when the CO_2 tax is introduced.

Table 1. CO_2 taxes, reductions in CO_2 emissions and some macro economic effects. Percentage deviation from the reference scenario. Year 2020

Scenario	USD/t CO_2	CO_2 2020	CO_2 1989[1]	GNP	Consum-ption	Exp.	Imp.
Stabilisation	65	-22	0	-0,66	1,42	-2,56	-0,16
High	200	-30	-10	-1,27	2,77	-5,65	-0,84

[1] CO_2 in the two scenarios compared to the level in 1989

Table 2 presents the welfare effects represented by changes in the money metric utility index for different types of households for the three scenarios. Percentage differences between the reference scenario and the two emission reduction scenarios are also included. Generally the macro household money metric utility increase at the highest rate since the macro household also includes population growth. We find the magnitude of the population growth effect to be approximately one third of the total increase in the macro utility index by comparing the macro and the average household utility index. This states the importance of utilising household specific utility indexes instead of a macro index when studying welfare changes in the long run.

The reference household money metric utility index increases more than the index for the average household. In 2020 the utility level for the reference household is about eight percent higher than the utility level for the average household. Two counteracting effects are important. As time passes the size of the average household decreases. This implies a reduced economic of scales effect implicitly represented through equation (2). However, the reduced household size is partly compensated through distribution according to the equivalence scales in equation (7). It

[8] The elasticities varies between products (between -1.5 and -2.5), see Lindquist (1993). See also Naug (1995).

Table 2. Money metric utility index in 2020 for different household types and emission scenarios and percentage differences between the scenarios. 1989=1

Household type	Reference Scenario (1)	Stabilisation Scenario (2)	High Tax Scenario (3)	$\frac{(1)-(2)}{(1)}100-1$	$\frac{(1)-(3)}{(1)}100-1$
Reference	1.642	1.660	1.674	1.040	1.910
Average	1.520	1.540	1.555	1.330	2.340
Macro	1.770	1.793	1.811	1.330	2.340
Rich	1.648	1.672	1.689	1.440	2.470
Poor	1.635	1.643	1.654	0.541	1.170
Single	1.645	1.658	1.940	0.780	1.940
Couple	1.644	1.660	1.674	0.970	1.780
Couple+3 children	1.639	1.659	1.673	1.220	2.070

turns out that the economic of scale effect dominates the compensation effect in our empirical model.

The rich households increase their utility more than poor households. This is due to the different composition of these households consumption and the composition of price changes in the reference path. The prices of consumer goods that constitute a relatively large part of the poor households total consumption increases more than prices of consumer goods that form a large part of rich households total consumption. We also find that the increase in the utility index of households with a couple and three children are close to the average of the increase in the utility index for the poor household and the reference household. Single households do have the highest growth rate next to the rich households.

Both the stabilisation scenario and the high tax scenario indicate certain differences between the households types as to how their welfare is affected by an increase in the CO_2 taxes. Most striking is the fact that a poor household seems to be less favourable affected[9] by an increase in the CO_2 taxes than a rich household. A separate calculation shows that keeping total consumption constant, i.e. calculating only price effects, the utility of a rich family in the high tax scenario is reduced by 4 percent while the utility of a poor family is reduced by 5,3 percent compared to the reference scenario. The main reason for the smaller price effect on a rich family is that the budget share of oil products is larger in a poor household than in a rich household.

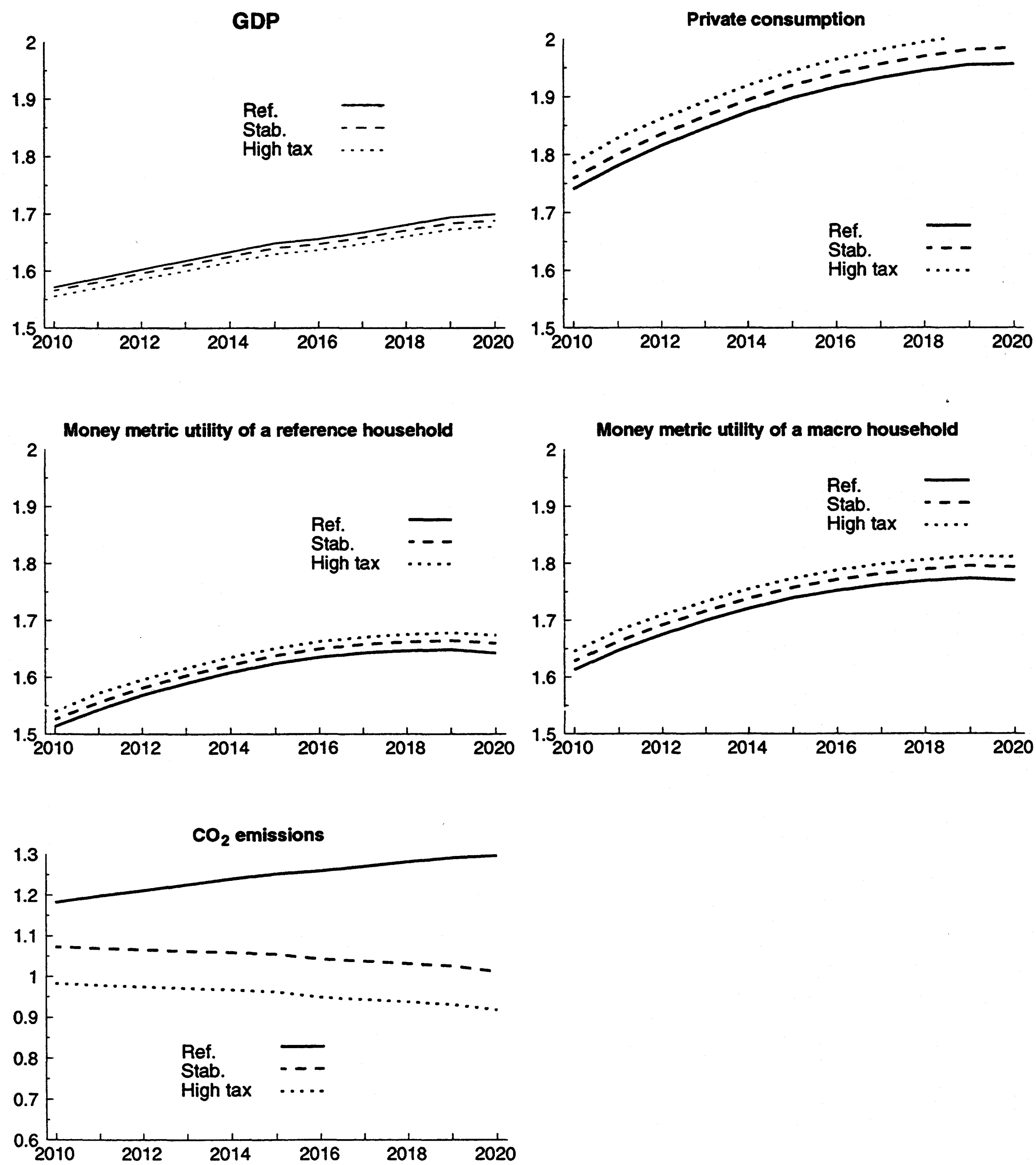
Some similar differences, although not of the same magnitude, are found between other types of households. An increase in CO_2 taxes is less favourable for the welfare of the reference household than the average household because the budget share of goods with relatively sharp increasing prices are higher in the reference than in the average household. Several effects influence the budget shares and the total effects are theoretically unclear and again this shows the importance of calculating the total effect empirically. We also find that taxes are less favourable for the welfare of the couple without children than for the couple with three children.

The distribution of the welfare effects of CO_2 taxes are valid for different assumptions of

[9] More punished if terms of trade effects are small and total private consumption decreases. Some sensitivity analysis indicated that the main conclusions about the welfare effects of CO_2 taxes for *different types of households* are valid for both increasing and decreasing consumption paths.

the total private consumption effect. Figure 2 indicates that the differences in welfare effects between two pairs of households are practically independent of the assumptions concerning the development of the level of the private consumption between the scenarios. This is not fully true for the difference between the welfare effects for the reference household and the average household which seems to be smaller as the reduction in private consumption gets larger.

Figure 2. GDP, Private consumption, utility level and CO_2 emissions for the different scenarios. 1989=1.



6 Conclusions

Our simulations on an empirical general equilibrium model of the Norwegian economy suggests that gross national income may increase when raising the CO_2-taxes even when gross national product is reduced. This difference between the GNI and GDP effect is due to a positive terms of trade effect, some of the CO_2 taxes will be paid by foreigners through exports. In addition emission taxes influence the relative prices on consumer goods. The effects on money metric utility is thus more positive than the effects on private consumption in fixed prices. The effects also differ from household to household depending on the composition of their total consumption. Poor households are less favourably affected than rich households, due to smaller budget shares for the rich households on consumer goods which imply relatively much CO_2 emissions. During the simulation period the average household size decreases and the relative number of children and adults changes. This makes the welfare level and policy effects rather different for the macro household, the average household and a reference household.

References

Aasness, J. and B. Holtsmark (1993): Consumer Demand in a General Equilibrium Model for Environmental Analyses, Discussion Papers 105, Statistics Norway.

Alfsen, K., A.C. Brendemoen and S. Glomsrød (1992): Benefits of Climate Policies: Some Tentative Calculations, Discussion Papers 69, Statistics Norway.

Alfsen, K., T. Bye and E. Holmøy (1995): *An Integrated Energy Environment General equilibrium Model of the Norwegian Economy*, Forthcoming in the series Social and Economic Studies, Statistics Norway.

Barns, D.W., J.A. Edmonds and J.M. Reilly (1992): Use of the Edmonds Reilly Model to model Energy-Related Greenhouse Gas emissions, OECD Economics Department Working Papers 13, Paris.

Bergmann, L. (1995): "CO_2 taxes and Economic Welfare" in Braden, J. and T. Ulen (eds.): *Environmental Policy with Political and Economic Integration*, Cheltenham: Edward Elgar Publishing Ltd, Forthcoming 1995.

Brendemoen, A. and H. Vennemo (1993): The Marginal Cost of Funds in the Presence of External Effects, Discussion Papers 99, Statistics Norway.

Bye, B., T. Bye and L. Lorentsen (1989): Studies of Industry, Environment and Energy Towards 2000, Discussion Papers 44, Statistics Norway.

Brendemoen, A., M.I. Hansen and Bodil Larsen (1994): *Framskriving av utslipp til luft i Norge*, Reports 94/18, Statistics Norway.

Clarete, R.L. and J. Whalley (1987): Comparing the Marginal Welfare Costs of Commodity and Trade Taxes, *Journal of Public Economics*, **33**, 357-362.

Helpman, E., and P.R. Krugman(1989): *Trade Policy and Market Structure*, Massachusetts and London: MIT Press.

Johnsen, T.A., B.M. Larsen and H.T. Mysen (1995): "Economic Impacts of a CO_2 Tax Policy" in Alfsen K., T. Bye and E. Holmøy (eds.), Forthcoming, Statistics Norway.

Johnson, H.G (1951-52): Optimal Welfare and Maximum Revenue Taxes, *Review of Economic Studies*, **19**, 28-35.

Jorgenson, D.W., and P.J. Wilcoxen (1993a): Reducing U.S. Carbon Dioxide Emissions: An Assessment of Different Instruments, *Journal of Policy Modelling*, **15**, 5-6, 491-520.

Jorgenson, D.W. and P.J. Wilcoxen (1993b): Reducing U.S. Carbon Dioxide Emissions: An Econometric General Equilibrium Approach, *Resource and Energy Economics*, **15**, 1, 7-25.

Lindquist, K. G. (1993): Empirical Modelling of Norwegian Exports: A Disaggregated Approach, Discussion Papers 100, Statistics Norway.

Naug, B.E. (1995): *En økonometrisk modell for norsk eksport av industrielle råvarer*, Reports 95/2, Statistics Norway.

Manne, A. and R.G. Richels (1991): Global CO_2 Emission Reductions: the Impact of Rising Energy Costs, *Energy Journal*, **12**, 1, 87-107.

Moum, K. (1992): *Klima, økonomi og tiltak (KLØKT)*, Reports 92/3, Statistics Norway.

OECD (1992): Costs of reducing CO_2 Emissions. Evidence form six Global Models, Economics and Statistics Working Papers, OECD.

Vennemo, H. (1992): Five Studies of Tax Policy using Applied General Equilibrium Models, Doctoral Dissertation in Economics 10, Department of Economics, University of Oslo.

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ISSN 0803-074X

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