

A Service of

ZBW

Leibniz-Informationszentrum Wirtschaft Leibniz Information Centre for Economics

Bye, Brita; Nyborg, Karine

# Working Paper The Welfare Effects of Carbon Policies: Grandfathered Quotas versus Differentiated Taxes

Discussion Papers, No. 261

**Provided in Cooperation with:** Research Department, Statistics Norway, Oslo

*Suggested Citation:* Bye, Brita; Nyborg, Karine (1999) : The Welfare Effects of Carbon Policies: Grandfathered Quotas versus Differentiated Taxes, Discussion Papers, No. 261, Statistics Norway, Research Department, Oslo

This Version is available at: https://hdl.handle.net/10419/192243

#### Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

#### Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



# WWW.ECONSTOR.EU

### Discussion Papers No. 261, October 1999 Statistics Norway, Research Department

### Brita Bye and Karine Nyborg

# The Welfare Effects of Carbon Policies: Grandfathered Quotas versus Differentiated Taxes

#### Abstract:

Recently, it has been demonstrated that pre-existing distortionary taxes can substantially increase the costs of market-based instruments which do not raise revenue, such as non-auctioned emissions quotas. Revenue-raising market-based policy tools, such as carbon taxes, encounter other problems: The redistribution of property rights implied by introduction of such instruments is politically controversial, and in practice, tax rates are often differentiated to reduce political resistance. In the latter case, marginal abatement costs are not equalized between polluters. When comparing a policy with differentiated carbon taxes to a policy of free-issued quotas, financed through distortionary taxes, it is thus not obvious which alternative yields the highest social welfare.

In this paper, we use a numerical intertemporal general equilibrium model for the Norwegian economy to compare the welfare effects of a differentiated carbon tax regime, exemplified by the current Norwegian carbon tax structure; a system of grandfathered tradable emission permits; and a uniform carbon tax regime. Grandfathered tradable quotas yield substantially lower welfare than the other two alternatives. However, differentiated taxes produce almost as high welfare as uniform taxes.

Keywords: Dynamic equilibrium analysis, Free issued quotas, Environmental tax reforms.

JEL classification: C68, D58, D60, D90, H20, J51, J60, Q43.

Acknowledgement: The authors would like to thank Birger Strøm for excellent computer assistance.

Address: Brita Bye and Karine Nyborg, Statistics Norway, Research Department, Box 8131 Dep. N-0033 Oslo, Norway. E-mail: Brita.Bye@ssb.no, Karine.Nyborg@ssb.no, Statistics Norway, Research Department. **Discussion Papers** 

comprise research papers intended for international journals or books. As a preprint a Discussion Paper can be longer and more elaborate than a standard journal article by including intermediate calculation and background material etc.

Abstracts with downloadable PDF files of Discussion Papers are available on the Internet: http://www.ssb.no

For printed Discussion Papers contact:

Statistics Norway Sales- and subscription service N-2225 Kongsvinger

 Telephone:
 +47 62 88 55 00

 Telefax:
 +47 62 88 55 95

 E-mail:
 Salg-abonnement@ssb.no

### **1. Introduction**

Environmental economists have long argued that market-based instruments provide more costefficient tools for environmental protection than traditional command-and-control measures. A major reason for this view is that the price signals of market-based instruments enable the regulatory authority to equalize marginal abatement costs between polluters even in the absense of extensive information on polluters' cost structures.

However, in the recent double dividend debate, a new insight has emerged (Bovenberg and de Mooij 1994; Goulder, 1995; Goulder et al., 1997; Parry, 1997, Parry and Williams, 1999): If there are preexisting distortionary taxes in the economy, the price effects of market-based instruments may amplify the distortions. This tax interaction effect implies that the costs of such policy tools may be - ceteris *paribus* - higher, and perhaps much higher, than previously thought.<sup>1</sup> On the other hand, the revenues raised from instruments like emission taxes and auctioned tradable emission quotas can be used to reduce the distortionary taxes. This revenue recycling effect can, ceteris paribus, at least partially offset the tax interaction effect.<sup>2</sup> However, some market-based policy tools do not raise revenue, and thus cannot produce revenue recycling effects. In particular, non-auctioned tradable emission permits provide price signals which yield equal marginal abatement costs between polluters, but also tax interaction effects. These permits produce no public revenue, and hence no revenue recycling effects. Recently, it has been demonstrated that non-auctioned tradable emission permits may be a very costly means to achieve environmental policy goals when initial tax distortions are present (Parry et al., 1999; Goulder et al., 1999). For example, Goulder et al. (1999) found that achieving the  $NO_x$ emissions requirements of the US 1990 Clean Air Act Amendments would be more costly under tradable permits than under performance standards, unless the permits were auctioned and the revenue used to reduce distortionary taxes.

This argument seems to indicate that one should move further in the direction of using green taxes or auctioned tradable emission quotas as policy instruments for environmental protection. However, as pointed out by Pezzey and Park (1998), revenue-raising market-based instruments face an overwhelming political problem: "Existing, regulated levels of emissions tend to be regarded as de

<sup>&</sup>lt;sup>1</sup> See Parry et al. (1999). For an intuitive understanding of the tax interaction effect, note that although a tax on a polluting consumption good ensures that environmental effects are internalized, it will also widen any exisiting tax wedge between leisure and consumption.

<sup>&</sup>lt;sup>2</sup> Goulder et al. (1999) claim that the revenue recycling effect typically only partially offsets the tax interaction effects. However, several empirical studies (e.g. Bye 1999a, 1999b, Håkonsen and Mathiesen, 1997) have found that the revenue recycling effect is dominating, i.e. a "strong double dividend". This may occur when the initial tax system is not second-best optimal.

facto rights, and will be defended by the interest groups which benefit from them" (Pezzey and Park, 1998, p. 547).<sup>3</sup> If the ex ante policy regime is one of non-tradable emission permits, and the government wishes to switch to a market-based policy instrument, one way to do this is simply to make the existing permits tradable, in which case polluters keep their previous *de facto* property rights.<sup>4</sup>

Introducing auctioned quotas or emission taxes, on the other hand, shifts the property right of pollution quotas from polluters to the government, so that polluters have to pay to get their previous rights back. Such deprivation of implicit property rights is likely to trigger political resistance. According to the interest group theory of Becker (1983), pressure groups increase their lobbying activities up to the point where their marginal efforts equal the marginal payoff of lobbying, given the lobbying activities of everybody else. If the existing system is in a political Nash equilibrium, and the government proposes to introduce an environmental tax, this must be expected to set off a wave of lobbying activity by prospective losers. Protest actions imply real costs, of course, but this will not be our focus here. However, protest actions may also, at least partially, be successful; and as a consequence, final policy design may be modified, for example by a differentiation of tax rates, which may lead to a much less cost-efficient instrument than the textbook ideal.<sup>5</sup>

A common feature of many European systems of environmental and energy taxes, is indeed that of extensive exemptions and differentiation of tax rates (see Ekins and Speck, 1999). In the Norwegian system for  $CO_2$  taxes, the  $CO_2$  tax on gasoline is for example more than twice as high as for other fuel oils (measured per ton emission of  $CO_2$ ). Several industries have substantially reduced tax rates, or no carbon tax at all. For North sea oil and gas production, on the other hand, tax rates per ton  $CO_2$  are almost as high as for gasoline, and thus much higher than the implicit emission taxes paid by mainland industries. Such differentiated taxes will not equalize marginal abatement costs<sup>6</sup> between polluters, which was, after all, one main reason for advocating market-based instruments in the first place.

In this paper, we will compare three types of market-based instruments for  $CO_2$  emission control: A differentiated  $CO_2$  tax, exemplified by the current Norwegian carbon tax system; a uniform  $CO_2$  tax,

production levels are reduced, or fuel is substituted by other inputs.

<sup>&</sup>lt;sup>3</sup> See also Vollebergh et al (1997).

<sup>&</sup>lt;sup>4</sup> These rights become even more valuable than before, of course, since they can now be traded.

<sup>&</sup>lt;sup>5</sup> "In fact, the compromises and 'imperfections' inherent in the design and implementation of incentive-based systems virtually guarantee that they also will be unable to realize the formal least-cost result" (Cropper and Oates, 1992, p. 699.) <sup>6</sup> As there is currently no economically feasible cleaning technology for  $CO_2$  emissions, "abatement cost" cannot be interpreted as meaning end-of-pipe abatement in this context. However, "abatement" may still take place in the sense that

which in our model framework is equivalent to auctioned tradable emission permits; and a system of grandfathered  $CO_2$  emission quotas, i.e. tradable emission permits which are issued for free to previous polluters.<sup>7</sup> The case of differentiated taxes was studied neither by Parry et al. (1999) nor by Goulder et al. (1999), since their models do not take producer heterogeneity into account. Our analysis is conducted using a numerical multi-sector general equilibrium model for the Norwegian economy. The tax reforms are made revenue neutral through changes in the payroll tax. As in Parry et al. (1999), we assume that there are fixed  $CO_2$  emission coefficients associated with combustion of fossil fuels, so that a fossil fuels tax is equivalent to an emission tax.

Compared to the case of grandfathered quotas, differentiated taxes do raise revenue, but have the disadvantage that they do not equalize marginal abatement costs. Thus, when comparing differentiated taxes to grandfathered quotas, the quota alternative may in fact yield the highest welfare of the two regimes, even if taxes produce more revenue. Our numerical simulations can obviously not provide general conclusions about differentiated tax regimes, since the welfare properties of such systems must depend on (among other things) exactly how taxes are differentiated. Nevertheless, we believe that the example of the Norwegian carbon tax system has some interest, since it provides an example of a regime which has indeed proved to be politically feasible in practice. The perhaps somewhat surprising conclusions from our simulations are that although free issued quotas yield lower welfare than uniform carbon taxes, as expected, differentiated taxes produce almost the same level of welfare as uniform taxes. One reason for the latter is that differentiated taxes produce more public revenue than the uniform tax, given the level of  $CO_2$  emissions. This implies that other distortionary taxes - that is, the payroll tax - can be kept lower in the differentiated tax regime.

In section 2, an outline of the numerical model is provided. Section 3 specifies the policy alternatives we examine, while section 4 discusses whether there are *a priori* reasons to expect one alternative to be welfare superior to the others. Section 5 presents our results, while section 6 concludes.

## 2. Basic features of the computable general equilibrium model

To analyse the welfare effects of environmental policy reforms, we use a numerical intertemporal general equilibrium model for the Norwegian economy, MSG-6.<sup>8</sup> Since the model gives a detailed description of taxes, production and consumption structures in the Norwegian economy, with a special

<sup>&</sup>lt;sup>7</sup> Unlike Parry et al. (1999), we will not study command-and control regimes.

<sup>&</sup>lt;sup>8</sup> The MSG model has been developed by Statistics Norway, and earlier versions of the model have been used routinely by the Norwegian Ministry of Finance for long-term forecasting and policy analysis.

emphasis on demand and supply of energy commodities, it is well designed for analysis of environmental tax reforms. The model has 41 private and 8 governmental production activities, all listed in appendix A, and 17 consumer goods. The next sections briefly outline some of the important features of the model. A more detailed description of the model is found in Bye (1999a) and Fæhn and Holmøy (1999).

#### 2.1. Producer behaviour and technology

The structure of the production technology is represented by a nested tree-structure of CES-aggregates given in figure B.1, appendix B. The input structure has a detailed description of the use of energy commodities and the demand for polluting and non-polluting transport activities. All factors are completely mobile and malleable<sup>9</sup>.

The model of producer behaviour in the MSG-6 model is described in detail by Holmøy and Hægeland (1997). The model incorporates both the small open economy assumption of given world market prices, and avoids complete specialisation through decreasing returns to scale. Producer behaviour in an industry is generally specified at the firm level. All producers are considered as price takers in the world market, but have monopoly power in the home market. Empirical analyses of Norwegian producer behaviour support the existence of some domestic market power, see e.g. Klette (1994) and Bowitz and Cappelen (1994). The entry-exit condition for the marginal firm requires that the after tax pure rents equal fixed costs. The dynamics due to intertemporal behaviour is captured by model consistent capital gains in the user cost of capital. The tax code in the model represents the system of the 1992 tax reform, which established approximate equality between the effective tax rates levied on most of the different capital incomes.<sup>10</sup>

#### 2.2. Consumer behaviour

Consumption, labour supply and saving result from the decisions of an infinitely lived representative consumer, maximising intertemporal utility with perfect foresight. The consumer chooses a path of full consumption, i.e material consumption and leisure, subject to an intertemporal budget constraint requiring that the present value of full consumption in all future periods does not exceed total wealth (current nonhuman wealth plus the present value of after tax labour income and net transfers). The distribution of full consumption on material consumption and leisure is determined by the equality of

<sup>&</sup>lt;sup>9</sup> Except in the production of electricity, see Holmøy, Nordén and Strøm (1994).

<sup>&</sup>lt;sup>10</sup> However, with significant positive or negative capital gains during transitions, the effective rate of capital taxation will deviate from the neutral rate.

the marginal rate of substitution between leisure and material consumption, and the corresponding consumer real wage rate. The environmental benefit from reduced fossil fuel combustion is not modelled explicitly in the numerical model. However, in all model simulations reported in this paper, CO<sub>2</sub> emissions are kept exogeneously fixed; thus, the relevant welfare effects of the studied policy alternatives are still captured by the model. For further details, se Appendix B.

Total material consumption is allocated across 17 different consumer goods according to a nested OCES (Origin adjusted Constant Elasticity of Substitution), see Holtsmark and Aasness (1995).<sup>11</sup> The demand system is well designed for studying the effects of environmental tax reforms due to the detailed description of both the use of energy commodities for residential purposes, and the demand for public and private transport services.

### 2.3. The government and intertemporal equilibrium

The government collects taxes, distributes transfers, and purchases goods and services from the industries and abroad. Overall government expenditure is exogenous and increases at a constant rate equal to the steady state growth rate of the model. The model incorporates a detailed account of the government's revenues and expenditures. In the policy experiments it is required that the nominal deficit and real government spending follow the same path as in the baseline scenario, implying revenue neutrality in each period.

Intertemporal equilibrium requires fulfillment of the two transversality conditions; the limit value of net foreign debt and real capital must both be zero, as time goes to infinity. The model is characterised by a path dependent steady state solution. A necessary condition for reaching a steady state solution is equality between the real interest rate and the consumer's rate of time preferences, at least in the last part of the simulation period.<sup>12</sup> Firms determine their net investments by maximising total discounted value of each firm, given the transversality condition for the value of real capital. The other transversality condition, regarding the net foreign debt, is fulfilled by adjusting the optimal level of full consumption for the representative consumer, see Bye and Holmøy (1997) for a description of the numerical solution procedure.

<sup>&</sup>lt;sup>11</sup> See figure B.2, appendix B.

<sup>&</sup>lt;sup>12</sup> See appendix B for further details.

### 3. The policy experiments

The main purpose of this paper is to compare the welfare effects of different market-based environmental policy instruments when pre-existing distortions in the economy are present. We compare three regimes: A differentiated tax regime, which will be our base case; a uniform tax regime, and a regime of grandfathered tradable carbon emission permits. To make the policy alternatives comparable, we have imposed the restriction that aggregate  $CO_2$  emissions are kept at the same level in all three cases. Also, introduction of any alternative policy instrument has been made revenue neutral as compared to the base case scenario by corresponding changes in the payroll tax.<sup>13</sup>

The baseline scenario, or the *differentiated tax scenario* (alternative 1) is a simulation of the current (1999) Norwegian system for carbon taxation. Obviously, this represents a carbon tax system which has demonstratedly been politically feasible to implement. As mentioned in the introduction, the existing carbon tax in Norway differs substantially between different kinds of fossil fuels and between industries, see Table 1. For most fossil fuels, especially for gasoline, the carbon tax is levied on top of other commodity taxes,<sup>14</sup> which is also the case in this analysis.

In the *uniform tax scenario* (alternative 2), all industries and consumers, and all kinds of fossil fuels are taxed by the same tax rate. The tax rate is determined endogenously to generate the same  $CO_2$  emissions as in alternative 1. The revenue effects are offset by a corresponding change in the payroll tax, ensuring that the nominal deficit follows the same path as in alternative 1.

In the *quota scenario* (alternative 3), tradable  $CO_2$  emission permits are issued for free to previous polluters (grandfathering), defined here by each sector's emissions in the baseline scenario. The right to receive quotas is assumed to be independent of current production; thus, if a production plant shuts down, its owners will still receive quotas, which they can sell to earn a quota rent.<sup>15</sup> With this assumption, the allocation of quotas does not affect firms' exit-entry decision.<sup>16</sup> The quota price is determined endogenously, while the aggregate  $CO_2$  emission level is set equal to the emission level in alternative 1. In our model, the quota regime is formally equivalent to a uniform  $CO_2$  tax combined with a lump-sum transfer from the government to those who receive quotas. This virtual lump-sum subsidy is financed through increased payroll taxes.

<sup>&</sup>lt;sup>13</sup> The initial payroll tax rate differs between industries. However, when using the payroll tax to keep reforms revenue neutral, the rate of change in the payroll tax is equal for all industries.

<sup>&</sup>lt;sup>14</sup> In an analysis of the effects of optimal carbon taxes on the Norwegian economy by Brendemoen, Bye and Hoel (1995), it is argued that there are substantial arguments for keeping the existing taxes on gasoline since they can be justified by internalising other externalities as traffic congestion and emissions of local pollutants as  $NO_X$  and  $SO_2$ .

<sup>&</sup>lt;sup>15</sup> See the discussion in Holtsmark (1999).

Fuels	
Gasoline	397.00
Light fuel oils, diesel	173.20
Heavy fuel oils	148.00
Coal for energy purposes	189.40
Coke for energy purposes	144.00
Coal and coke for processing (Ferro alloys-, carbide- and aluminium industry)	0.00
Gas (land-based use not covered by the petroleum tax legislation)	0.00
North Sea petroleum extraction	
Oil extraction	335.10
Natural gas extraction	381.00
Industries with reduced rates:	
Wood processing industry, herring flour industry	
Light fuel oils, transport oils (petrol, diesel etc.)	86.60
Heavy fuel oils	74.10
Industries with exemptions	
Air transport	0.00
Foreign carriage by sea	0.00
Domestic goods traffic by sea	0.00
Inshore fishing	0.00
Fishing and catching in foreign waters	0.00
Cement and leca production	0.00
*1 USD = 7.74 NOK (August 9, 1999)	

Table 1. Carbon taxation in Norway, 1999. NOK<sup>\*</sup> per ton CO<sub>2</sub>.

Source: Statistics Norway

### 4. Anticipated welfare effects

Parry et al. (1999) identify three effects contributing to the total welfare effect of a revenue neutral environmental policy change in the case of reducing carbon emissions. The first is denoted the *primary welfare gain*, which consists of the environmental benefit from reduced fuel combustion, net of the reduction in the consumer surplus for users of fossil fuels. The second is the *revenue recycling effect*, which is the efficiency gain from using additional carbon tax revenues, if any, to reduce distortive tax rates, e.g. labour taxation. The third is denoted the *tax interaction effect*, which has three components. The first of these is the efficiency loss from the reduction in labour supply occurring when carbon taxes increase: A higher carbon tax increases goods prices, reducing the real wage rate

<sup>&</sup>lt;sup>16</sup> MSG-6 assumes decreasing returns to scale. If the right to receive quotas were contingent on positive production levels, quotas would affect firms' profits and thus entry-exit. Neutrality of the quota allocation further requires that quota rents are taxed by the same rate as firms' profits.

and thus labor supply. Such a reduction in labour supply further reduces revenue from the labour taxes, and the cost of replacing this revenue is the second component of the tax-interaction effect. Because higher carbon taxes raise the price of consumption, nominal government spending must rise to hold real spending constant. The third component is the efficiency loss from raising this additional revenue.

Before we turn to the numerical results, let us just sketch some theoretical arguments concerning what results to expect. Compared to alternative 1 (differentiated taxes), alternative 2 (uniform tax) will have a higher primary welfare gain, since abatement costs are equalized across sectors and fuels, implying lower welfare costs to consumers of fossil fuels. However, welfare may still be higher in a differentiated tax system, due to revenue recycling and tax interaction effects: For a given aggregate emission level, the uniform tax may produce either less or more public revenue than differentiated taxes. A loss of revenue must be financed through distortionary taxes, which will in turn have negative welfare effects (i.e. a negative revenue recycling effect). Further, since preexisting taxes differ between sectors, both for fossil fuels and other resources, there will generally also be tax interaction effects: Reducing a high fuel tax rate may for example yield more significant welfare effects if pre-existing distortionary taxes on this particular fuel are substantial. Payroll tax rates, effective tax rates on capital and subsidized electricity prices vary, and in addition there are distortions due to the Norwegian trade protection system and the existence of domestic market power. Changes in the carbon tax rates may amplify or reduce the importance of each of these distortions. The sign of the net welfare change induced by all these complex effects is difficult to predict *a priori*.

As regards the difference between alternatives 1 and 3 (quotas), the latter instrument does not produce revenue, and a change from policy alternative 1 to 3 would thus yield a negative revenue recycling effect. There will also be tax interaction effects as above, since tax rates (quota prices) are generally different in the two scenarios, but it is not clear whether this effect is overall positive or negative. However, a change from 1 to 3 must be expected to produce a positive primary welfare gain: Since marginal abatement costs are unequal in alternative 1, but equal in 3, aggregate abatement costs will be lower in the quota alternative.

Concerning alternative 2 (uniform taxes) and 3 (quotas), these two differ formally only in the sense that lump-sum transfers, and thus also the level of distortionary taxes, are higher in the latter case.<sup>17</sup> Thus, one would expect that welfare is higher in alternative 2 than in 3.

Although intuition may suggest that the uniform tax scenario is welfare superior to the other two, one actually cannot on purely theoretical grounds conclude that uniform taxes outperform differentiated taxes. Further, if differentiated taxes and grandfathered quotas are the only politically feasible alternatives, we cannot tell a priori which of these two alternatives will produce highest welfare. While the former does produce public revenue, the latter minimizes primary abatement costs; and it is not obvous, which of these two advantages turns out to be most important. We do believe that the case study presented here still has general interest, however, in that it illustrates some important mechanisms that come into play in an environmental policy setting with pre-existing distortionary taxes.

### 5. Numerical results

#### 5. 1. Baseline alternative

The effects of the different policies are measured as deviations from the baseline scenario (alternative 1). The model is calibrated to the benchmark year (1992). We simulate a baseline alternative by keeping all tax rates and other exogenous variables constant at their benchmark values. The exception is, the system of differentiated carbon taxes, which is substituted by the 1999 system of carbon taxation, see Table 1. The economy adjusts along a saddle point stable path, and in the long run the economy reaches a steady state solution with constant growth rate and relative prices.<sup>18</sup> The steady state solution of the model is path dependent. In the other policy simulations both the path and the long run stationary solution differ from the baseline alternative. The tax reforms are implemented immediately, minimizing announcement effects.

#### 5. 2. A comparison of policy alternatives: Results

Below, we will focus on the long run solution, since the transitional dynamics have relatively low impact on welfare effects. In Table 2 below, the long run effects for some important variables are summarized. The variable "full consumption" (see Appendix B) is an aggregate of material

<sup>&</sup>lt;sup>17</sup> Empirically, they differ with respect to the  $CO_2$  tax level (i.e. level of the quota price) as well, since this variable is determined endogenously in the model simulations and is influenced by the higher payroll tax in alternative 3.

<sup>&</sup>lt;sup>18</sup> The steady state solution is reached after approximately 30 periods.

consumption and leisure, and its long run value indicates the representative consumer's (nonenvironmental) utility in the steady state.<sup>19</sup>

	Uniform carbon tax	Carbon quotas
	(alternative 2)	(alternative 3)
Full consumption	0.007	-0.12
Material consumption	-0.03	-0.35
Leisure	0.06	0.24
Employment	-0.08	-0.31
Real capital	-0.12	-0.29
Export surplus	-0.43	-0.54
Wage costs per hour	0.10	0.35
Price of leisure	-0.58	-1.37
Price of material consumption	-0.43	-0.39
Payroll tax rate	4.00	10.00
Uniform carbon tax/quota price <sup>1)</sup>	97.2 NOK <sup>*</sup>	92.1 NOK <sup>*</sup>

 Table 2.
 Long run effects. Percentage deviation from the baseline scenario (alternative 1)

<sup>\*</sup> 1 USD = 7.74 NOK (August 9, 1999)

1) Absolute levels in NOK.

The main sources of welfare effects of the reforms are found in markets where the initial total tax wedges are large. Notably, in the labour market, the marginal social value of leisure is considerably lower than the marginal social utility of consumption generated by additional labour supply, due to direct and indirect taxation of labour.<sup>20</sup> Also, there are initial tax wedges caused by capital taxation. The taxation of interest income implies that the social marginal value of savings is larger than the private marginal value. Increased savings contribute positively to welfare due to this discrepancy. In addition, as mentioned in section 4, there are pre-existing differences between the industries in the taxation of resources, including fossil fuels, which generate welfare effects. The uniform tax scenario (alternative 2) increases welfare (total discounted utility) by 0.026 percent as compared to the differentiated tax scenario. The uniform carbon tax is 97.20 NOK (12.60 USD) per ton  $CO_2$  emissions, which implies a substantial fall in the carbon tax on gasoline, while the production of industrial

<sup>&</sup>lt;sup>19</sup> Here, we will only provide a brief description of the main welfare effects generated by the tax reforms considered. More detailed discussions of sources of welfare effects of similar environmental tax reforms analysed with the MSG6 model can e.g. be found in Bye (1999a, 1999b).

<sup>&</sup>lt;sup>20</sup> The total tax wedge between private and social marginal return on labour in the Norwegian economy includes three main components: the marginal tax on wage income, payroll tax and VAT and indirect taxes on consumer goods. The total tax wedge is approximately 2,4 (see Bye, Holmøy and Strøm (1999))..

chemicals, metals and refined oil products experience a large increase in their fossil fuels costs for processing purposes. The uniform carbon tax required to keep  $CO_2$  emissions unchanged, generates less revenue than the differentiated tax system of the baseline scenario. Thus, the payroll tax rate increases by 4 percent to keep the tax reform revenue neutral, corresponding to an increase of approximately 0.6 percentage points in the overall payroll tax rate. This induces an increase in the hourly wage costs of 0.1 percent, in spite of reduced labour demand and a corresponding reduction in the equilibrium consumer wage rate (net of tax) of 0.58 percent.

The welfare effect is slightly positive, even though employment and the stock of real capital is reduced. Capital is reallocated from real to financial capital, and increased savings in financial capital have a positive welfare effect as mentioned above. In addition, there are capital stock reallocations away from housing. The marginal utility of housing capital is comparatively low, since the effective tax rate on housing capital is small. Hence, reallocations towards other capital goods, as well as inter-and intra-industry reallocations towards less labour intensive production, contribute positively to overall productivity. The negative effect of lower employment and stock of real capital is also modified by decreasing returns to scale in production.

Manufacturing of industrial chemicals and metals are negatively affected by a uniform carbon tax. These industries use subsidised hydropower intensively in the baseline alternative, but reduce their demand for electricity when a uniform carbon tax is introduced. This induces a fall in the average electricity price of 1.4 percent. Together with lower carbon taxes, this fall in the energy costs induces a negative shift in the cost curve for most industries, which is not outweighed by higher labour costs. Together with lower domestic demand for investment and consumption purposes, this negative shift leads to a fall in the domestic producer prices. However, for production of industrial chemicals, metals and refined oil products, costs increase. These industries represent a relatively large share of total exports; consequently, aggregate export is reduced. Import is reduced through lower domestic demand for investment and consumption purposes, especially along the transitional path towards the new stationary solution, but domestic demand is also reallocated towards the home market due to the fall in the domestic producer prices. Net financial wealth is accumulated along the path, which is mirrored by the lower long run export surplus. In sum, the uniform tax alternative produces a small, but positive welfare gain as compared to differentiated taxes, even though the economy experiences an

13

without increasing the labour taxation, i.e. if the decreased carbon tax revenues could have been financed through lump-sum taxation, the welfare gain would of course have been larger.<sup>21</sup>

The quota alternative (alternative 3) implies a redistribution of carbon tax revenue from the government to the private sector. This is financed by a 10 percent increase in the payroll tax. Compared to the baseline scenario, the quota alternative implies a reduction in welfare of 0.23 percent. Quite similar mechanisms are present as in the uniform tax alternative, but the positive primary welfare effect of equalized marginal abatement costs is more than outweighed by the negative effects of a higher payroll tax. Wage costs per hour increases by 0.35 percent, giving an upward shift in the cost curve for nearly all industries. Lower consumption and production in the economy following the higher payroll tax imply a lower uniform quota price (92.10 NOK = 11.90 USD) than the required uniform tax in alternative 2.

The results support the hypothesis that freely issued tradeable quotas induce a substantial welfare loss compared to a uniform tax, due to the loss of tax revenue, when lump sum taxation is not available. But why is the welfare gain of changing from a differentiated carbon tax system to a system of uniform tax rate so small? Although second-best theory of optimal taxation recommends uniform Pigouvian taxes on polluting commodities and factor inputs in production, it also tells us that overall tax levels should be adjusted to take other considerations than pollution into account.<sup>22</sup> Sandmo (1975) demonstrated that the optimal commodity tax in a second-best economy with externalities should be a weighted average of what we may call a Ramsey term, reflecting efficiency effects on the general economy, and the Pigouvian term. In the case of independent demand, goods with low elasticity of demand should be taxed relatively more. Further, relatively more weight should be put on the Ramsey term compared to the Pigou term when the initial burden of taxation (the marginal costs of public funds) is generally large.

Although Sandmo's result is based on a model of constant returns to scale, and therefore not directly consistent with the MSG-6 model,<sup>23</sup> his results suggest an intuitive explanation of our numerical

<sup>&</sup>lt;sup>21</sup> In that case, total discounted utility would have increased by 0.17 percent (rather than just 0.026 percent). Since lump sum transfers have no real effects in the model, while a higher payroll tax has negative effects on the economy, the uniform carbon tax must be higher (103 NOK per ton  $CO_2$  emissions) to keep carbon emissions at the baseline level. The total tax revenue effect from the uniform carbon tax would still be lower than in the baseline scenario, but this is financed by a lump sum withdrawal from households.

<sup>&</sup>lt;sup>22</sup> See Bovenberg (1999), Bovenberg and van der Ploeg (1994).

<sup>&</sup>lt;sup>23</sup> Diamond and Mirrlees (1971) demonstrated that it is not optimal to tax non-polluting input factors in production. However, note that their model is based on constant returns to scale, or alternatively a 100 percent profit tax, so the result is not immediately transferable to the MSG-6 model.

results: Compared to a uniform carbon tax (for given  $CO_2$  emissions), the current differentiated carbon tax system seems to be quite efficient in collecting carbon tax revenue, even if it is not all that efficient in reducing marginal abatement costs. In particular, note that the carbon taxes on the production of North Sea oil and gas are very high in the differentiated system (see Table 1). Since these activities are quite regulated and thus insensitive to changes in the carbon tax, the reduction in their carbon taxes rates gives a substantial revenue  $loss^{24}$ . Naturally, replacing these revenues by increased labour taxation yields significant welfare effects.

### 6. Concluding remarks

Recent research has demonstrated that the costs of using market-based environmental policy instruments are substantially increased if initial tax distortions are present in the economy. For policy instruments which produce public revenue, this revenue can be used to reduce preexisting distortionary taxes, offsetting at least parts of these costs.

Freely issued (grandfathered) carbon emission permits do not yield public revenue, and may thus be much more costly than uniform carbon taxes. However, uniform carbon taxes appear to be politically controversial. In practice, carbon taxes tend to differ substantially between sectors and/or fuels; implying that abatement costs are not equalized. Still, in the literature on instrument costs with preexisting tax distortions, there has been little focus on differentiated tax regimes.

Our initial hypothesis motivating this project was that a system of differentiated carbon taxes may indeed produce less welfare than a regime of grandfathered tradable emission permits, even with preexisting tax distortions, due to the former regime's higher direct abatement costs. Using a numerical intertemporal general equilibrium model for the Norwegian economy, we compare the welfare effects of a differentiated carbon tax regime, reflecting current Norwegian carbon taxation, to a uniform tax regime and a system of grandfathered quotas.

The differentiated tax regime performs very well in the numerical simulations. Discounted utility under differentiated taxes is lower than under uniform tax rates, but the difference is hardly distinguishable. To achieve the same level of  $CO_2$  emissions with a uniform tax as with the current differentiated tax regime, the  $CO_2$  tax revenue is significantly reduced. Consequently, other

<sup>&</sup>lt;sup>24</sup> Approximately 1 bill. NOK. Note that this effect may possibly be overestimated in our model simulations: While we assume constant carbon emission coefficients, the emission coefficients for North sea petroleum production have in fact decreased over time, and one cannot exclude the possibility that this is related to the high carbon taxes.

distortionary taxes must be increased. The question of whether the above is simply a coincidence, or whether Norwegian politicians have in fact deliberately designed the carbon tax system to extract as much revenue as possible, remains to be answered.

Since the welfare level of the differentiated tax regime does not differ much from that of the uniform tax regime, it is hardly surprising that the quota alternative produces significantly lower welfare than both tax alternatives. Thus, our initial hypothesis is not confirmed for the Norwegian case: According to our simulations, grandfathered carbon emission quotas is a less cost-efficient policy instrument than the current carbon tax system. This conclusion, however, may obviously come out different for other economies with other differentiated tax regimes.

### References

Aaberge, R., J. K. Dagsvik and S. Strøm (1995): Labour supply responses and welfare effects of tax reforms, *Scandinavian Journal of Economics* **97** (4), 635-659.

Alfsen, K. H., T. A. Bye, and E. Holmøy (1996): MSG-EE: An Applied General Equilibrium Model for Energy and Environmental Analyses, *Social and Economic Studies 96*, Oslo: Statistics Norway.

Becker, G. S. (1983): A Theory of Competition Among Pressure Groups for Political Influence, *Quarterly Journal of Economics* **98** (3), 371-400.

Bovenberg, L. (1999): "Environmental Policy, Distortionary Labour Taxation and Employment: Pollution Taxes and the Double Dividend", in C. Carraro and D. Siniscalco (eds.): *New Directions in the Economic Theory of the Environment*, Cambridge (UK): Cambridge University Press, pp.69-104.

Bovenberg, L., and R. A. de Mooij (1994): Environmental Levies and Distortionary Taxation, *American Economic Review* **94** (4), 1083-1089.

Bovenberg, L., and F. v. d. Ploeg (1994): Green Policies and Public Finance in a Small Open Economy, *Scandinavian Journal of Economics* **96** (3), 343-363.

Bowitz, E., and Å. Cappelen (1994): Prisdannelse og faktoretterspørsel i norske næringer," *Social and Economic Studies 85*, Oslo: Statistics Norway.

Brendemoen, A., T. A. Bye and M. Hoel (1995): Utforming av CO<sub>2</sub>-avgifter: Teoretisk grunnlag og økonomiske konsekvenser, *Norsk Økonomisk Tidsskrift* 109, 77-106.

Bye, B. (1999a): Environmental tax reform and producer foresight: An intertemporal computable general equilibrium analysis, forthcoming in *Journal of Policy Modeling*.

Bye, B. (1999b):\_"Labour market rigidities and environmental tax reforms: Welfare effects of different regimes". Forthcoming in Harrison, G. W. et al (eds): *Using dynamic general equilibrium models for policy analysis*, North-Holland, Amsterdam.

Bye, B., and E. Holmøy (1997): Household behaviour in the MSG-6 model, *Documents 97/13*, Oslo: Statistics Norway.

Bye, B., E. Holmøy and B. Strøm (1999): Virkninger på samfunnsøkonomisk effektivitet av en flat skattereform: Betydningen av generelle likevektseffekter. *Rapporter* 99/26, Statistics Norway.

Cropper, M. L., and W. E. Oates (1992): Environmental Economics: A Survey, *Journal of Economic Literature* **XXX**, 675-740.

Diamond, P. A. and J. A. Mirrlees (1971): Optimal taxation and public production I: Production efficiency and II: Tax rules, *The American Economic review* 61, 8-27 and 261-278.

Ekins, P. And S. Speck (1999): Competitiveness and Exemptions from Environmental Taxes in Europe, *Environmental and Resource Economics* **13**, 369-396.

Fæhn, T. and E. Holmøy (1999): "Welfare effect of trade liberalisation in distorted economies: A dynamic general equilibrium assessment for Norway". Forthcoming in Harrison, G. W. et al (eds): *Using dynamic general equilibrium models for policy analysis*, North-Holland, Amsterdam.

Goulder, L. H. (1995):, Environmental taxation and the double dividend: A reader's guide, *International Tax and Public Finance* **2**, 157-184.

Goulder, L. H., I. W. H. Parry and D. Burtraw (1997): Revenue-raising vs. Other approaches to environmental protection: The critical significance of pre-existing tax distortions, *Rand Journal of Economics*, 28, 708-731.

Goulder, L. H., I. W. H. Parry, R. C. Williams, and D. Burtraw (1999): The Cost-Effectiveness of Alternative Instruments for Environmental Protection in a Second-Best Setting, *Journal of Public Economics*, 72, 329-360.

Holmøy, E., G. Nordén, and B. Strøm (1994): MSG-5, A complete description of the system of equations, *Rapporter 94/19*, Oslo: Statistics Norway.

Holmøy, E., and T. Hægeland (1997): Aggregate Productivity Effects and Technology Shocks in a Model of Heterogeneous Firms: The Importance of Equilibrium Adjustments, *Discussion Paper 198*, Oslo: Statistics Norway.

Holtsmark, B., and J. Aasness (1995): Effects on consumer demand patterns of falling prices in telecommunication, *Working Paper 1995:8*, Center for International Climate and Environmental Research - Oslo (CICERO).

Holtsmark, B. (1999): "Kostnadseffektiv klimapolitikk med doble gevinster", Norsk Økonomisk Tidsskrift, 113, 49-70.

Håkonsen, L. and L. Mathiesen (1997): CO<sub>2</sub>-stabilization may be a "no-regrets" policy, *Environmental and Resource Economics* 9, 171-198.

Klette, T. J. (1994): Estimating price-cost margins and scale economies from a panel of micro data, *Discussion Papers 130*, Oslo: Statistics Norway.

Mysen, H. T., (1991): Substitusjon mellom olje og elektrisitet i produksjonssektorene," *Rapporter 91*/7, Oslo: Statistics Norway.

Parry, I. W. H. (1997): Environmental taxes and quotas in the presence of distorting taxes in factor markets, *Resource and Energy Economics* **19**, 203-220.

Parry, I. W. H. (1999): When can carbon abatement policies increase welfare? The fundamental role of distorted factor markets, *Journal of Environmental Economics and Man*agement **37**, 52-84.

Parry, I. W. H., R. C. Williams III (1999): A Second-Best Evaluation of Eight Policy Instruments to Reduce Carbon Emissions, *Resource and Energy Economics* **21**, 347-373.

Parry, I. W. H., R. C. Williams III, L. H. Goulder (1999): When Can Carbon Abatement Policies Increase Welfare? The Fundamental Role of Distorted Factor Markets, *Journal of Environmental Economics and Management* **37**, 52-84.

Pezzey, J., and A. Park (1998): Reflections on the Double Dividend Debate, *Environmental and Resource Economics* **11** (3-4), 539-555.

Sandmo, A. (1975): Optimal taxation in the presence of externalities, *Swedish Journal of Economics* 77, 86-98.

Steigum, E. Jr. (1993): "Accounting for long run effects of fiscal policy by means of computable overlapping generations models," in S. Honkapohja and M. Ingberg (eds.) *Macroeconomic modelling and policy implications*, Amsterdam: Elsevier Science Publishers B.V..

Svendsen, I. (1990): Importmodell i MODAG og KVARTS, *Rapporter 90/20*, Oslo: Statistics Norway.

Vollebergh, H. R. J., J. L. de Vries and P. R. Koutstaal (1997): Hybrid Carbon Incentive Mechanisms and Political Acceptability, *Environmental and Resource Economics* **9**, 43-63.

MSG-6 Code	Production Activities
11	Agriculture
12	Forestry
13	Fishing
14	Breeding of Fish
21	Fish Products
22	Meat and Dairy Products
16	Grain Vegetables Fruit Oils etc
10	Beverages and Tobacco
18	Textiles wearing Appeal and Footwear
26	Furniture and Fixtures
20	Chemical and Mineral Products incl. Mining and Quarrying
27	Printing and Publishing
20	Manufacture of Puln and Paper Articles
37	Manufacture of Industrial Chemicals
57 41	Gasolino
42 4	Diasol Fuel
42A 42D	Heating Eucle Deroffin ato
42D 42	Menufacture of Metals
43	Manufacture of Metal Droducts, Machinery and Equipment
40	Wanufacture of Metal Floquets, Machinery and Equipment
47	Duilding of Shine
40	Duniung of Sinps
49	Construction and repair of on unning rigs and snips, on production platforms etc.
55	Construction, excl. Off wen Drifting
60	Einenee and Insurance
05	Crude Oil
67	Vide OII
69	Natural Gas
08	Direction Transport of Oil and Cas
09	Production of Electricity
/1	Production of Electricity
12	Power Net Renting
13	Sales and Distribution of Electricity
15	Car and Other Land Transportation
/6	Air Transport
77	Railroads and Electrical Commuters
/8	Ocean Transport - Domestic
79	Post and Tele Communication
81	Wholesale and Retail Trade
83	Dwelling Services
85	Other Private Services
89	Imputed Service Charges from Financial Institutions
	Government Input Activities
	Central Government
92C	Defence Exclusive of Military Submarines and Aircraft
920	Military Submarines and Aircraft
93S	Central Government Education and Research
94S	Central Government Health-Care and Veterinary Services etc.
95S	Other Central Government Services
	Local Government
93K	Local Government Education and Research
94K	Local Government Health-Care and Veterinary Services etc.
95K	Other Local Government Services

Table A.1: Production Activities in MSG-6

## **Appendix B**

#### **Consumer behaviour**

In year t the representative consumer chooses a path of "full consumption", F, by maximising intertemporal utility given by

(B.1) 
$$U_t = \sum_{s=t}^{\infty} (1+\rho)^{t-s} \frac{\sigma_F}{\sigma_F - 1} F_s^{\frac{\sigma_F - 1}{\sigma_F}}$$

subject to the intertemporal budget constraint, see Bye and Holmøy (1997) for further details.  $\sigma_F$  is the intertemporal elasticity of substitution in full consumption. The intertemporal utility maximisation gives the demand for full consumption

(B.2) 
$$F_{s} = \left[\frac{1+r(1-t^{D})}{1+\rho}\right]^{\sigma_{F}t} (\lambda PF_{s})^{-\sigma_{F}},$$

where *r* is the world market interest rate on financial wealth,  $t^{D}$  is the tax rate on capital income,  $\lambda$  is the marginal utility of wealth and *PF* is the ideal price index of full consumption. Full consumption is a CES-composite of material consumption, *C*, and leisure, *LE*. The corresponding ideal price index is given by

(B.3) 
$$PF_{s} = \left[\alpha_{C} PC_{s}^{(1-\sigma_{C})} + (1-\alpha_{C})\left(\frac{PLE_{s}}{1+g}\right)^{(1-\sigma_{C})}\right]^{\frac{1}{1-\sigma_{C}}},$$

where *PC* is the price index of material consumption and *PLE* is the price of leisure (net of tax wage rate) measured in efficiency units such as labour, implying that the price of leisure must be adjusted with *g*, the factor augmenting technical change.  $\sigma_c$  is the elasticity of substitution between material consumption and leisure, and  $\alpha_c$  is the intensity parameter for material consumption.

In each period full consumption is distributed between leisure and material consumption, and the demand functions follow from applying Shepard's lemma to equation (B.3).

(B.4) 
$$C_s = \alpha_C \left(\frac{PC_s}{PF_s}\right)^{-\sigma_C} F_s$$

(B.5) 
$$LE_s = \left(1 - \alpha_C\right) \left(\frac{PLE_s/(1+g)}{PF_s}\right)^{-\sigma_C} F_s$$

Then total labour supply  $L_s^S$  is determined by

$$(B.6) L_s^S = T - \frac{LE_s}{1+g}.$$

The aggregate endowment of total available time in each period, T, is exogenous and grows at the constant rate, g, which determines the long run (steady state) growth rate of the economy. The wage rate is determined by equilibrium between labour supply and labour demand.

### Intertemporal equilibrium

A necessary condition for reaching a steady state solution is

(B.7) 
$$1+r(1-t^D)=(1+\rho)(1+g)^{\frac{1}{\sigma_F}}$$

which is a "razor's edge" condition since r,  $t^{D}$ ,  $\rho$  and g are all considered as exogenous. In the analyses, equation (B.7) is assumed to hold at all points in time.

#### Data and parameters

The model is calibrated to the 1992 national accounts. For the production functions the elasticities of substitution between machinery and energy, the elasticity of substitution between the energymachinery aggregate and labour and the elasticity of substitution between the modified real value added and various material inputs (see figure B.1.), are adjusted to parameters of a Generalized Leontief (GL) cost function estimated on time-series data from the national accounts, see Alfsen et al (1996). The elasticities of substitution between electricity and fuel oil in the energy aggregate are based on CES-function estimates on time series data by Mysen (1991). Most of these elasticities of substitution are smaller than 1. The elasticities of substitution between non-polluting and polluting transports, and the corresponding elasticities between the modified real value aggregate and various material inputs are set to 0.5, for all industries. In the model of producer behaviour the elasticities of transformation between deliveries to the domestic and foreign market are set equal to 4. The elasticities of scale in different industries are then calibrated to 0.83, given the elasticities of transformation. The elasticities of substitution between domestic products and imported goods are partly based on estimated parameters (see e.g. Svendsen (1990)), but adjusted upwards such that all are around 4. For further details of the calibration of the model of producer behaviour, see Holmøy and Hægeland (1997).

In the consumer model the intertemporal elasticity of substitution,  $\sigma_F$ , equals 0.3, Steigum (1993). Econometric estimates of  $\sigma_F$  vary considerably between different sources, and 0.3 is in the lower end of the range of the estimated parameters. The elasticity of substitution between material consumption and leisure equals 0.6, which is based on estimates of labour supply for married women and men on micro-data by Aaberge, Dagsvik and Strøm (1995). The share of leisure in the full consumption aggregate is set equal to 0.4, see also Bye, Holmøy and Strøm (1999) for details. The calibration of the parameters in the complete demand system for material consumption is based on detailed econometric studies using both micro and macro data, see Holtsmark and Aasness (1995).

Figure B.1. Production technology



### Figure B.2. Material Consumption



### **Recent publications in the series Discussion Papers**

- 168 R. Aaberge, A. Björklund, M. Jäntti, M. Palme, P. J. Pedersen, N. Smith and T. Wennemo (1996): Income Inequality and Income Mobility in the Scandinavian Countries Compared to the United States
- 169 K. Nyborg (1996): Some Norwegian Politicians' Use of Cost-Benefit Analysis
- 170 E. Berg, S. Kverndokk and K. E. Rosendahl (1996): Market Power, International CO<sub>2</sub> Taxation and Petroleum Wealth
- 171 R. Aaberge, U. Colombino and S. Strøm (1996): Welfare Effects of Proportional Taxation: Empirical Evidence from Italy, Norway and Sweden
- 172 J.K. Dagsvik (1996): Dynamic Choice, Multistate Duration Models and Stochastic Structure
- 173 J.K. Dagsvik (1996): Aggregation in Matching Markets
- 174 H.C. Bjørnland (1996): The Dynamic Effects of Aggregate Demand, Supply and Oil Price Shocks
- 175 A. Bruvoll and K. Ibenholt (1996): Future Waste Generation. Forecasts Based on a Macroeconomic Model
- 176 T. Fæhn and L. A. Grünfeld (1996) Recent Leaps Towards Free Trade. The Impact on Norwegian Industry and Trade Patterns
- 177 R. Barrell and K. A. Magnussen (1996): Counterfactual Analyses of Oil price Shocks using a World Model
- 178 E. Bowitz and S. I. Hove (1996): Business cycles and fiscal policy: Norway 1973-93
- 179 H.C. Bjørnland (1996): Sources of Business Cycles in Energy Producing Economies: The case of Norway and United Kingdom
- 180 K. Nyborg (1996): The Political Man and Contingent Valuation: Motives Do Count
- 181 E. Berg, S. Kverndokk and K.E. Rosendahl (1996): Gains from Cartelisation in the Oil Market
- 182 R. Aaberge and I. Aslaksen (1996): Decomposition of the Gini Coefficient by Income Components: Various Types of Applications and Interpretations
- 183 B. Bye (1996): Taxation, Unemployment and Growth: Dynamic Welfare Effects of "Green" Policies
- 184 T.J. Klette and F. Johansen (1996): Accumulation of R&D Capital and Dynamic Firm Performance: A Not-sofixed Effect Model
- 185 B. Bye (1996): Environmental Tax Reform and Producer Foresight: An Intertemporal Computable General Equilibrium Analysis
- 186 S. Grepperud (1997): Soil Depletion Choices under Production and Price Uncertainty
- 187 N.M. Stølen and T. Åvitsland (1997): Has Growth in Supply of Educated Persons Been Important for the Composition of Employment?
- 188 T.J. Klette and Z. Griliches (1997): Empirical Patterns of Firm Growth and R&D Investment: A Quality Ladder Model Interpretation
- 189 J. Aune, S. Glomsrød, V. Iversen and H. Wiig (1997): Structural Adjustment and Soil Degradation in Tanzania. A CGE-model Approach with Endogenous Soil Productivity
- 190 E. Biørn and T.J. Klette (1997): Panel Data with Errorsin-Variables: A Note on Essential and Redundant Orthogonality Conditions in GMM-estimation

- 191 L. Belsby and B.K. Wold (1997): Primary Schooling in Zambia Squeezed at Community and Household Level
- 192 E. Bowitz and Å. Cappelen (1997): Incomes Policies and the Norwegian Economy 1973-93
- 193 S. Glomsrød, M.D Monge A. and H. Vennemo (1997): Structural Adjustment and Deforestation in Nicaragua
- 194 F. Johansen and T.J. Klette (1997): Wage and Employment Effects of Payroll Taxes and Investment Subsidies
- 195 T. Fæhn (1997): Non-Tariff Barriers the Achilles' Heel of Trade Policy Analysis
- 196 R. Aaberge and A. Langørgen (1997): Fiscal and Spending Behavior of Local Governments: An Empirical Analysis Based on Norwegian Data
- 197 A.C. Hansen and H.K. Selte (1997): Air Pollution and Sick-leaves - is there a Connection? A Case Study using Air Pollution Data from Oslo
- 198 E. Holmøy and T. Hægeland (1997): Aggregate Productivity Effects of Technology Shocks in a Model of Heterogeneous Firms: The Importance of Equilibrium Adjustments
- 199 E. Berg, P. Boug and S. Kverndokk (1997): Norwegian Gas Sales and the Impacts on European CO<sub>2</sub> Emissions
- 200 H.C. Bjørnland (1997): Estimating Core Inflation The Role of Oil Price Shocks and Imported Inflation
- 201 R. Aaberge, A. Björklund, M. Jäntti, P.J. Pedersen, N. Smith and T. Wennemo (1997): Unemployment Shocks and Income Distribution. How Did the Nordic Countries Fare During their Crises?
- 202 L. Brubakk (1997): Estimation of Price Elasticities from Norwegian Household Survey Data
- 203 J. Aasness and L. Belsby (1997): Estimation of Time Series of Latent Variables in an Accounting System: Petrol Consumption of Norwegian Households 1973-1995
- 204 A. Rygh Swensen (1997): Change in Regime and Markov Models
- 205 K. Nyborg and I. Spangen (1997): Cost-Benefit Analysis and the Democratic Ideal
- 206 L. Belsby and J.F. Bjørnstad (1997): Modelling and Estimation Methods for Household Size in the Presence of Nonresponse: Applied to The Norwegian Consumer Expenditure Survey
- 207 K.O. Aarbu and T.O. Thoresen (1997): The Norwegian Tax Reform; Distributional Effects and the High-Income Response
- 208 T. Hægeland and T.J. Klette (1997): Do Higher Wages Reflect Higher Productivity? Education, Gender and Experience Premiums in a Matched Plant-Worker Data Set
- 209 J. Gjerde, S. Grepperud and S. Kverndokk (1998): Optimate Climate Policy under the Possibility of a Catastrophe
- 210 T. Eika and K.A. Magnussen (1998): Did Norway Gain from the 1979-85 Oil Price Shock?
- 211 K.O. Aarbu and J.K. MacKie-Mason (1998): Why Some Corporations Pay More Tax than Necessary
- 212 R. Aaberge (1998): UMP Unbiased Tests for Multiparameter Testing Problems with Restricted Alternatives

- 213 M. Søberg (1998): "EPA's New Emissions Trading Mechanism: A Laboratory Evaluation" – A Comment
- 214 K. Nyborg (1998): Non-Verifiable Emissions, Voluntary Agreements, and Emission Taxes
- 215 H. C. Bjørnland (1998): Economic Fluctuations in a Small Open Economy - Real versus Nominal Stocks
- 216 L.C. Zhang (1998): Post-Stratification and Calibration A Synthesis
- 217 R. Aaberge and Y. Zhu: The Pattern of Household Savings during a Hyperinflation. The Case of Urban China in the Late 1980s
- 218 L.C. Zhang (1998): A Note on Post-stratification when Analyzing Binary Survey Data Subject to Non-response
- 219 T.J. Klette and J. Møen (1998): From Growth Theory to Technology Policy – Coordination Problems in Theory and Practice
- 220 L.C. Zhang (1998): Synthetic Graphical Modelling of Binary Panel Data Subject to Non-response. A Case Study
- 221 J.K. Dagsvik (1998): Choice among Lotteries when Preferences are Stochastic
- 222 J.K. Dagsvik (1998): Nonparametric Identification of Discrete Choice Models
- 223 L. Brubakk and J.K. Dagsvik (1998): Consumer Demand and Unobservable Product Attributes
- 224 E. Holmøy (1998): Potential Aggregate Gains from Improved Sectoral Efficiency: General Equilibrium Estimates for Norway
- 225 B.H. Vatne and J.K. Dagsvik (1998): Estimation of Generalized Extreme Value Models by a Max-spectral Representation
- 226 I. Svendsen (1998): Rational Expectations in Price Setting – Tests Based on Norwegian Export Prices
- 227 K.A. Brekke and R.B. Howarth (1998): The Social Contingency of Wants: Implications for Growth and the Environment
- 228 K.A. Brekke and E. Moxnes (1998): Do Models Improve Fishery Management? Empirical Evidence from a Experimental Study
- 229 J.K. Dagsvik, Yu Zhu and R. Aaberge (1998): A Framework for Empirical Modelling of Consumer Demand with Latent Quality Attributes
- 230 R. Aaberge, U. Colombino and S. Strøm (1998): Social Evaluation of Individual Welfare Effects from Income Taxation: Empirical Evidence Based on Italian Data for Married Couples
- 231 R. Nesbakken (1998): Residential Energy Consumption for Space Heating in Norwegian Households. A Discrete-Continuous Choice Approach
- 232 R. Nesbakken (1998): Price Sensitivity of Residential Energy Consumption in Norway
- 233 M. Søberg (1998): Uncertainty and International Negotiations on Tradable Quota Treaties
- 234 J.K. Dagsvik and L. Brubakk: Price Indexes for Elementary Aggregates Derived from Behavioral Assumptions
- 235 E. Biørn, K.-G. Lindquist and T. Skjerpen (1998): Random Coefficients and Unbalanced Panels: An Application on Data from Norwegian Chemical Plants
- 236 K. Ibenholt (1998): Material Accounting in a Macroeconomic Framework. Forecast of waste generated in manufacturing industries in Norway

- 237 K-G. Lindquist (1998): The Response by the Norwegian Aluminium Industry to Changing Market Structure
- 238 J.K. Dagsvik, A.S. Flaatten and H. Brunborg: A Behavioral Two-Sex Model
- 239 K.A. Brekke, R.B. Howarth and K. Nyborg (1998): Are there Social Limits to Growth?
- 240 R. B. Howarth and K. A. Brekke (1998): Status Preferences and Economic Growth
- 241 H. Medin, K. Nyborg and I. Bateman (1998): The Assumption of Equal Marginal Utility of Income: How Much Does it Matter?
- 242 B. Bye (1998): Labour Market Rigidities and Environmental Tax Reforms: Welfare Effects of Different Regimes
- 243 B.E. Naug (1999): Modelling the Demand for Imports and Domestic Output
- 244 J. Sexton and A. R. Swensen (1999): ECM-algorithms that converge at the rate of EM
- 245 E. Berg, S. Kverndokk and K.E. Rosendahl (1999): Optimal Oil Exploration under Climate Treaties
- 246 J.K. Dagsvik and B.H. Vatne (1999): Is the Distribution of Income Compatible with a Stable Distribution?
- 247 R. Johansen and J.K. Dagsvik (1999): The Dynamics of a Behavioral Two-Sex Demographic Model
- 248 M. Søberg (1999): Asymmetric information and international tradable quota treaties. An experimental evaluation
- S. Grepperud, H. Wiig and F.A. Aune (1999): Maize Trade Liberalization vs. Fertilizer Subsidies in Tanzania: A CGE Model Analysis with Endogenous Soil Fertility
- 250 K.A. Brekke and Nils Chr. Stenseth (1999): A Bio-Economic Approach to the study of Pastoralism, Famine and Cycles. Changes in ecological dynamics resulting from changes in socio-political factors
- 251 T. Fæhn and E. Holmøy (1999): Welfare Effects of Trade Liberalisation in Distorted Economies. A Dynamic General Equilibrium Assessment for Norway
- 252 R. Aaberge (1999): Sampling Errors and Cross-Country Comparisons of Income Inequality
- 253 I. Svendsen (1999): Female labour participation rates in Norway – trends and cycles
- 254 A. Langørgen and R. Aaberge: A Structural Approach for Measuring Fiscal Disparities
- 255 B. Halvorsen and B.M. Larsen (1999): Changes in the Pattern of Household Electricity Demand over Time
- 256 P. Boug (1999): The Demand for Labour and the Lucas Critique. Evidence from Norwegian Manufacturing
- 257 M. Rege (1999): Social Norms and Private Provision of Public Goods: Endogenous Peer Groups
- 258 L. Lindholt (1999): Beyond Kyoto: CO<sub>2</sub> permit prices and the markets for fossil fuels
- 259 R. Bjørnstad and R. Nymoen (1999): Wage and Profitability: Norwegian Manufacturing 1967-1998
- 260 T.O. Thoresen and K.O. Aarbu (1999): Income Responses to Tax Changes – Evidence from the Norwegian Tax Reform
- 261 B. Bye and K. Nyborg (1999): The Welfare Effects of Carbon Policies: Grandfathered Quotas versus Differentiated Taxes