Emissions Trading under a Relative Cap: an alternative for conventional emissions trading that would prevent carbon leakage and protect exposed sectors of industry?

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ABSTRACT

Given potentially negative impacts of Kyoto-type climate change policies on the competitiveness of Dutch exposed sectors and the possibility of international carbon leakage, is there a possibility to do better? This paper examines the option of a relative, or rate-based emissions ceiling for exposed sectors in the Netherlands. An analysis of Performance Standard Rate (PSR) emissions trading for the Netherlands was carried out with the GTAP-E model that was extended to simulate PSR trading and variable returns to scale in production. The model simulations suggest that PSR emissions trading would reduce carbon leakage and loss of competitiveness of exposed sectors, but that it would not improve welfare. This result is sensitive to assumptions on trade elasticities and returns to scale.

Keywords: emissions trading; international competitiveness; carbon reduction policies; carbon leakage; international trade and the environment.

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1. INTRODUCTION

There is concern that the implementation of CO_2 reduction policies in the Netherlands could have adverse effects on the international competitiveness of certain exposed sectors of industry. Even under the relatively mild reduction targets of the Kyoto Protocol and taking into account the flexibility offered by that Protocol, exports of the Dutch exposed sectors could be negatively affected. This paper examines a proposal to reduce the negative impacts on the competitiveness of Dutch exposed sectors. The proposal is to engage the exposed sectors in a system of domestic emissions trading with a *relative* rather than an *absolute* ceiling on the allowed level of emissions. This system is also known as the Performance Standard Rate (PSR) trading system.

The basic idea of a PSR trading system is that the government defines emission limits in terms of a maximum allowable level of emissions *per unit of activity*. If a CO_2-emitting source is able to generate fewer emissions per unit of activity than allowed by the PSR, the source is allowed to sell the difference between the allowed volume of emissions and the actual level of emissions. Conversely, if a source generates more emissions per unit of activity than allowed, it can buy the difference on the market for CO_2 allowances.

It is examined in this chapter whether such a PSR system in the Netherlands could, under certain conditions, reduce the national welfare costs of reaching a *global* level of emissions reductions and at the same time improve the competitive position of its exposed sectors of industry. Such a win-win result could possibly be realised if PSR trading would strongly reduce carbon leakage. In the case of less international carbon leakage, *regional* emissions can be reduced less to achieve the same *global* rate of reduction, and hence CO_2 reduction costs could be lower than in the standard-cap-and-trade system.

The paper is organised as follows. Section 2 discusses the background of PSR trading and presents a partial equilibrium model of PSR trading. Section 3 describes how the GTAP-E model is adjusted to model PSR trading. Section 4 describes the design of the simulation experiments, while Section 5 presents their results. Section 6 discusses the results of the sensitivity analysis that was carried out, while Section 7 concludes.

2. PERFORMANCE STANDARD RATE (PSR) TRADING: BACKGROUND AND THEORY

The idea of PSR trading is not new. Baron and Bygrave (2002) pointed to the fact that countries under the Kyoto Protocol may implement portions of their emissions reduction commitment through both absolute and relative targets. An absolute target is expressed as total emissions during a specified period, while "a relative target is expressed as an emissions rate per unit of output or activity such as GDP or energy consumption, or per unit of input" (Baron and Bygrave, 2002: 23). An example of such a system is the UK Emissions Trading System that allows for both absolute and relative (rate-based) targets.[1]

The system of rate-based or PSR trading provides incentives for technological innovation and diffusion of CO_2-efficient production techniques. There is an incentive because any reduction in CO_2-intensity (CO_2 emissions per unit of output) can directly be 'sold' on the market for emissions allowances. According to several authors, the linkage between a 'relative' (rate-based) sector and an 'absolute' sector

[1] Other examples of rate-based systems may be found in Canada, France and Switzerland (Haites & Mullins, 2001).

poses some administrative difficulties that have to be solved before such a system can work in practice. Haites and Mullins (2001) argued that if the firms in the rate-based sector were allowed to sell their allowances/credits to firms/households in the 'absolute' sector, the incentive for firms in the 'rate-based' sector to increase output and emissions would lead to an 'inflation' of the amount of credits for firms and households in the absolute sector. To prevent an overall increase in emissions, the UK has set up a complicated mechanism (the 'Gateway') to regulate the trade of emission allowances between the 'absolute' and 'relative' sectors (Baron and Bygrave, 2002).

The idea of rate-based trading was picked up in the Netherlands by a government-appointed Commission that studied the feasibility of introducing a system of domestic emissions trading in the Netherlands. The Commission – the CO_2 Trading Commission – published its findings in January of 2002 (Commissie CO2-handel, 2002). The Commission proposed a phased introduction of emissions trading, starting from about 2004-2005. From the very start of the system a distinction should be made between energy-and trade-intensive firms (the 'exposed' sector), and other firms (the 'sheltered' sector). While the sheltered sector would be faced with an absolute cap on emissions, firms in the exposed sector would be subject to relative standards, Performance Standard Rates (PSR), based on emissions per unit of output.

In the proposal of the CO_2 trading Commission, firms in the sheltered sector have to buy allowances to cover for their CO_2 emissions in an accounting year. Firms in the exposed sector only have to buy allowances to the extent that they fall short of their PSR, so they never have to buy allowances to cover for their total emissions. In the event that they exceed (outperform) their PSR, i.e., their CO_2-intensity is *lower* than that specified by the PSR, they get allowances *for free*, and the more output they produce, the more allowances they get.

Gielen et al. (2002) developed a partial equilibrium model to study the system of PSR trading. They argued that while the standard cap-and-trade system and the PSR trading system would generate the same, efficient, level of abatement at the firm level, total industry output and therefore emissions would be higher under the PSR trading system. The PSR trading system is equivalent to the *combination* of an efficient cap-and-trade system and a *production subsidy*. To reach the same *national* level of emission reduction, prices of emission permits, the level of abatement, and the output of goods under a system of PSR trading are higher than under the standard cap-and-trade system (Gielen, Koutstaal, & Vollebergh, 2002).

This argument can best be illustrated by a simple mathematical model of a price-taking firm that tries to maximise its profits under the restrictions posed by its production technology and environmental policy. First, the situation is examined in which the environmental policy has the form of a standard cap-and-trade system that restricts the total amount of pollution that is allowed (it puts a "cap" on pollution). Pollution permits are distributed amongst polluters according to a 'grandfathering' distribution rule. Assume that the firm receives a volume of z^* pollution allowances. Pollution allowances can be traded for a unit price of t in the secondary market. The firm produces output y by employing one factor of production. The production of y generates a certain amount of pollution z. The firm can abate pollution by shifting some of its input from the production of y to the abatement of z. Hence, total pollution z by the firm is a function of output y and abatement activity a. The firm can *sell* its pollution reduction on the secondary market for pollution allowances at the going market price for these allowances t. Total costs C of the firm depend on the one hand on the costs of production and abatement $c(y,a)$, and on the other hand on its sales or purchases of pollution allowances, $t \cdot (z(y,a)-z^*)$:

$$C(y,a) = c(y,a) + t \cdot \left(z(y,a) - z^*\right) \tag{1}$$

If pollution z is greater that the initial allowance of the firm z^*, the firm should *buy* pollution allowances at the secondary market at the unit price t. If pollution is less than z^*, the firm can *sell* pollution allowances. It is assumed that the firm's costs increase, at an increasing rate, when it increases its production of y and when it increases its abatement activities a. It is also assumed that pollution z increases as output y increases and falls with abatement a.

The profit of the firm equals revenues minus costs. Revenues are output y times the market price p, which is assumed to be beyond the control of the individual firm. The costs were presented in Equation (1) above. The profit function of the firm can be written as:

$$\pi = p \cdot y - c(y,a) - t \cdot \left(z(y,a) - z^*\right) \tag{2}$$

The two decision variables for the firm are output level y and abatement effort a. The first-order conditions for profit maximisation are:

$$\pi_a = -c_a - t \cdot z_a = 0 \quad \rightarrow \quad c_a = -t \cdot z_a \tag{3}$$

$$\pi_y = p - c_y - t \cdot z_y = 0 \quad \rightarrow \quad c_y = p - t \cdot z_y \tag{4}$$

Equation (3) says that the firm should reduce pollution until marginal abatement costs equal the value of a pollution allowance (the *abatement* effect). Equation (4) says that the firm should adjust its output until marginal costs are equal to the (exogenous) market price for good Y *minus* the market value of the additional pollution due to the last unit of output. Given the assumption of increasing marginal costs, the profit-maximising level of output must decline (the *output-substitution* effect).

What happens to the profits of the exposed firm in the PSR trading system? In this case the pollution "cap" is defined as a *performance standard rate* $psr^* = \left(z/y \right)^*$.

The profit function of the firm can now be written as:

$$\pi = p \cdot y - c(y,a) - t \cdot \left(z(y,a)/y - psr^* \right) \cdot y \tag{5}$$

If the emission-intensity of the firm exceeds the prescribed *psr**, $\left(z/y \right) > \left(z/y \right)^*$, it should buy an amount of $\left(z/y - psr^* \right) \cdot y$ at the market price *t*. If the firm achieves a lower emissions intensity than prescribed, it can sell its unused volume of pollution allowances at the market price *t*. The first-order conditions for profit maximisation with respect to abatement is simply:

$$\pi_a = -c_a - t \cdot z_a = 0 \quad \rightarrow \quad c_a = -t \cdot z_a \tag{6}$$

To derive the first-order condition for profit maximisation with respect to output we first rewrite equation (5) as:

$$\pi = p \cdot y - c(y,a) - t \cdot \left(z(y,a) - psr^* \cdot y \right) \tag{7}$$

It then follows immediately that

$$\pi_y = p - c_y - t \cdot \left(z_y - psr^*\right) = 0 \ \rightarrow c_y = p - t \cdot \left(z_y - psr^*\right) \tag{8}$$

Equation (6) is equal to equation (3), showing that the optimal abatement effort is equal in both schemes. However, equation (8) differs from equation (4) by the term $t \cdot psr^*$. The marginal costs are lower under the PSR scheme than under the standard cap-and-trade scheme, hence total output y will be higher under the PSR scheme. The expression $t \cdot psr^*$ can be interpreted as an output subsidy.

Gielen et al. (2002) argued that this output subsidy will increase total industry output in comparison to the cap-and-trade scheme.[2] Abatement per unit of output is the same under the PSR scheme and the cap-and-trade scheme. Hence, in order to have the same effect on aggregate emissions from the industry, the abatement per unit of output under the PSR scheme should be increased, and the psr* should therefore be tightened. Gielen et al. argued that this would lead to an inefficient outcome at the industry level, i.e., total mitigation costs under PSR trading would be higher than total mitigation costs under an absolute cap-and-trade system of emissions trading.

While the above analysis may be appropriate for domestic pollution, there may be a complication in the case of an international pollution problem. Notably, suppose that PSR trading would have an effect on the international rate of carbon leakage. If this effect would be negative (less leakage under the PSR scheme than under the standard cap-and-trade scheme), it would be possible, in principle, that PSR emissions trading (again in comparison to a standard cap-and-trade system) would reduce global emissions per euro of (welfare) costs.

[2] In general equilibrium analysis, this output effect may also depend on the way that the revenues of the sales of the permits are recycled. In their partial equilibrium analysis, Gielen et al. could neglect this complication.

While there might thus be a *possibility* of a reduction of world CO_2 emissions under a PSR trading system in comparison to a traditional cap-and-trade system of emissions trading, it remains to be seen whether this possibility has any chance of occurring in an empirical setting under conditions of general equilibrium. More specifically, we ask the question whether it would be possible that PSR trading among certain exposed sectors in the Netherlands could lead to a reduction of global emissions at lower costs than under a traditional system of cap-and-trade for all sectors.

3. MODEL AND DATA

For the present analysis, the GTAP-E model was extended in two ways: to allow for PSR trading and to allow for increasing returns in production. Moreover, energy substitution elasticities were adjusted to better reflect Dutch estimates.

PSR TRADING

Section 2 argued that PSR trade can be interpreted as a combination of a standard cap-and-trade system of emissions trading and an output subsidy. An output subsidy is a typical exogenous parameter in GTAP-E and had, for the purposes of this paper, to be modelled as an endogenous variable. The subsidy for additional output of the exposed sectors is equal to the product of the carbon tax and the sector's PSR (see Eq. (8)) and its succeeding paragraph): $t{\cdot}psr^*$. Because psr^* is equal (by assumption) to the ratio of CO_2 emissions over output, the PSR subsidy (in percentage) is equal to the ratio of the revenues of the carbon tax over output. The GEMPACK computer code to calculate the PSR subsidy rate is presented in Annex I.

INCREASING RETURNS TO SCALE

In the standard GTAP-E model, a perfectly competitive market is assumed where each firm employs a homothetic, constant returns to scale technology. Francois (1998) offers a way to model increasing returns to scale, based on the so-called 'Cost Disadvantage Ratio' (CDR), that measures the rate of *unrealised* scale economies in an industry. CDR is defined as:

$$CDR = \frac{AC - MC}{AC} \tag{9}$$

Francois (1998) shows that the elasticity of output with respect to input is:

$$\varepsilon_{XZ} = \left[\frac{1}{1 - CDR}\right] \tag{10}$$

This elasticity is used as a variable parameter in the extended GTAP-E model. Its base value must be exogenously specified.

Francois (1998) suggests that increasing returns due to the presence of fixed (or set-up) costs can be associated with a monopolistic firm that is forced to set its output price equal to its average costs by fear of real or threatened entry of competitors. The assumption of this so-called 'contestable' market rules out strategic behaviour and allows us to preserve the zero-profit condition as one of the central equilibrium conditions of GTAP-E. In the case of increasing returns to scale, the zero profit condition (in percentage change) becomes:

$$p_X = p_Z - \varepsilon_{XZ} q\left(p_X, p_Z\right) \tag{11}$$

With a carbon tax that increases the price of inputs P_z, the supply price of output X increases by the percentage increase in the price of inputs P_z, plus the term $\left[-\varepsilon_{XZ} q\left(p_X, p_Z\right)\right]$, that reflects the *increase* in average costs due to foregone scale economies. The scale economies therefore add to the reduction of the comparative advantage of industry X in international trade.[3]

ENERGY ELASTICITY PARAMETERS

In their calibration of the Netherlands Energy Demand Model (NEMO), Koopmans et al. (1999) developed a set of industry-specific long-term price elasticities of demand for fuels and electricity, respectively. These elasticities were based on a detailed database of the technical possibilities (with respect to replacement, retrofit, and good housekeeping) for energy savings in Dutch industry (ICARUS version 3, see De Beer et al., (1994)). When the NEMO price elasticities of demand are compared to the implied price elasticities of GTAP-E it appears that the NEMO elasticities are considerably *lower* than the price elasticities of energy demand implied by GTAP-E. Overall, Koopman et al. (1999) report an overall *conditional* long-term price elasticity of demand for energy of – 0.29, while the corresponding figure implied by GTAP-E is – 0.53. Table1 shows that differences between price elasticities between GTAP-E and NEMO can be even larger at the level of individual industries. For example, the price elasticities of fuel demand by the base metal sectors in GTAP-E are around – 0.8 to – 1.0, while those in NEMO are around – 0.10 to – 0.20. The price elasticities of demand for electricity differ widely between GTAP-E and NEMO.

While this price elasticity is close to minus unity in GTAP-E, NEMO employs elasticities of around – 0.11 to – 0.12 for the most energy-intensive sectors.

Table 1 around here

The relatively high price elasticities of energy demand in the Netherlands in GTAP-E might lead to an *under*estimation of the adjustment costs to CO_2 emission constraints and would hence also *under*estimate the negative effects of carbon reduction policies on the export performance of exposed industries. Thus, the energy substitution parameters of GTAP-E were adjusted to better match the price elasticity of energy demand of NEMO. This produced price elasticities of demand for fuels and electricity as reported in Table1 in the columns 'GTAP-E new'. Although it was difficult to reproduce the NEMO elasticities exactly,[4] the adjusted GTAP-E elasticities are much closer to them. The energy share-weighted average price elasticity of energy demand in Dutch industry in the adjusted GTAP-E is – 0.28, which is relatively close to various estimates reported by Koopman et al. (– 0.18 to – 0.27).

In the simulations below, the adjusted energy substitution parameters were used to model energy demand in the Netherlands as well as in the rest of the EU. For the other regions, the original GTAP-E energy substitution parameters were retained. This is a rather crude division, of course, and it is only a first attempt to bring more realism (based on *bottom-up* information) in the energy substitution behaviour of the model. It

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[3] An extended GTAP-E model that is able to simulate PSR trading as well as increasing returns to scale can be found on www.vu.nl/ivm > projects > carbon leakage.

[4] The reproduction was basically achieved through a process of trial-and-error.

is recommended that future research be directed towards a better representation of energy substitution possibilities in different industries and regions in AGE models, including GTAP-E.

AGGREGATION OF SECTORS AND REGIONS

GTAP-E sectors are aggregated into fifteen sectors, including ten sectors that are commonly regarded as 'exposed' in the Netherlands. Exposed sectors have high share of energy input in their production functions and a high exposure to international trade (cf. Berkhout et al., 2001). .

In the simulations in this chapter the primary focus is the Netherlands. Therefore, the regional aggregation of the GTAP-E database includes the Netherlands and its main European trading partners: Germany, United Kingdom, France and Belgium. Other regions include the rest of Europe, Eastern Europe and the former Soviet Union, other OECD, and the rest of the world.

Table 2 around here

4. DESIGN OF MODEL EXPERIMENTS

The standard policy scenario against which we compare PSR trading is called the AXI scenario. In this scenario, the EU15 member states meet their Kyoto targets trough the EU Burden Sharing Agreement. Eastern Europe has a zero reduction target and the other Annex I countries reduce their emissions by 5 percent below baseline (see Table 3). There is no international emissions trading. The AXI scenario is taken as the central scenario in this paper because it is a scenario in which export losses are relatively large and carbon leakage is relatively small. If PSR trading could be globally cost-effective in a scenario with low carbon leakage, it would certainly be cost-effective in a scenario with high carbon leakage.

Table 3 around here

PSR trading in the Netherlands is simulated in the following way. Starting from the standard AXI policy scenario, it is assumed that four sectors that would experience significant export losses under this scenario (refineries, ferrous and non-ferrous metals, and chemicals) would be assigned a PSR target, while the rest of the economy would be assigned an absolute target. Henceforth, the industrial sectors with a PSR target are collectively labelled as 'PSR sector', and the other sectors are labelled as 'Absolute sector'. Firms in the 'PSR sector' are allowed to freely exchange emissions credits with firms and households in the 'absolute' sector.

The government of the Netherlands is assumed to have three options to control the total amount of emissions credits in the Netherlands. The first option is to do nothing. In this option, the government issues the same amount of emissions credits as in the standard AXI policy scenario (i.e., 6.73 % below baseline), and does nothing to prevent potential domestic 'inflation' of emissions because of the creation of additional credits by the PSR sector. Additional new credits that are created by the PSR sector will therefore increase the national volume of emissions permits and reduce the Dutch rate of emissions reduction (less than 6.73 % below baseline). This option is modelled by fixing the CO_2 price at its original AXI level. 'Inflation' of allowances is *not* countered by a rising CO_2 price, and therefore the total amount of allowances (the emissions ceiling) is allowed to increase. The option is called AXI_PSR_FP (*F*ixed *P*rice).

The second option for government is to prevent 'inflation' by offsetting new PSR credits by an equally large reduction of the supply of emissions permits, so that the total volume of emissions permits remains constant and hence the Dutch rate of emissions reduction (at 6.73 % below baseline). This option is modelled by fixing the national emissions ceiling. Potential 'inflation' of emissions is countered by a rising CO_2 price. In equilibrium, the CO_2 price is such that the *national* emissions ceiling is exactly met. This variant is called AXI_PSR_DC (*D*omestic emissions *C*eiling).

In the third option it is assumed that the government has such excellent knowledge on carbon leakage that it is able to adjust the domestic supply of emissions permits in such a way so that the volume of *global* emissions remains constant. If PSR trading would reduce the rate of carbon leakage, less domestic reduction would be required to achieve a given rate of global emissions reduction. In such a case, the Dutch rate of emissions reduction could be reduced (less than 6.73% below baseline). In this option the *global* emissions ceiling is fixed at the level of global emissions in the standard AXI scenario. This option is called AXI_PSR_GC (*G*lobal emissions *C*eiling).

Hence, we have four policy options that give rise to four experiments:

1) AXI: Standard cap-and-trade scenario
2) AXI_PSR_FP: PSR trading with "inflation" of the national emissions ceiling (fixed price).
3) AXI_PSR_DC: PSR trading with a fixed domestic emissions ceiling (domestic ceiling).
4) AXI_PSR_GC: PSR trading with a fixed global emissions ceiling (global ceiling).

5. RESULTS OF EXPERIMENTS

This section presents the results of the simulations. Table 4 reports key results of the four variants under the assumption of constant returns to scale.

Table 4 around here

PSR trading – in all its variants – leads to an improvement of the international competitiveness of the firms in the exposed sector as compared with the AXI scenario. The average loss of exports of 1.7 percent is reduced to 0.1–0.2 percent. Among the sectors with the largest export losses in the AXI scenario, PSR trading supports the competitiveness ferrous metals and chemicals, although it does little to nothing for refineries and non-ferrous metals. We will return to this difference later.

PSR trading comes at a price, though. Unless the government would be willing to let the national emissions ceiling be 'inflated', the CO_2 price has to increase to keep emissions below the internationally agreed level. For the present calculations it is assumed that the government can do this by reducing the supply of emission permits. By restricting this supply the CO_2 price increases from € 17.49 in the standard AXI scenario to € 19.90 in the 'DC' variant of PSR trading. If the supply of permits would not be restricted, emissions reduction would fall from the required 6.73 percent to 5.97 percent (see national CO_2 emissions in the 'FP' variant).[5]

PSR trading does, however, reduce leakage. PSR trading in the Netherlands reduces the global rate of leakage from 14.16 to 14.06 percent. This reduces emissions in non-Annex-I countries by 0.4 $MtCO_2$. The "GC" variant of PSR trading shows that

[5] This is 0.78 percent-point or 11.3 percent of the agreed emissions reduction.

global emissions would remain fixed if PSR trading were combined with a decrease of the national reduction percentage from 6.73 to 6.52 percent.

PSR trading has a non-negative effect on GDP. In all variants of PSR trading, GDP is at least as large as in the standard AXI policy scenario. GDP is not equal to welfare, though. In terms of the common money-metric of welfare – equivalent variation – PSR trading causes welfare in the Netherlands to fall in all variants, and most in the 'DC' variant. In all variants, welfare in the rest of the world increases because of the Dutch PSR policy. Global welfare increases in the 'FP' and 'GC' variants, but falls in the 'DC' variant of PSR trading.

For an interpretation of these results, we will take a closer look at the simulation results. We will focus on the DC and GC variants of PSR trading, i.e., the variants with a fixed national or global emissions ceiling. While we will not analyse the FP variant in detail, it serves as a warning that a non-critical implementation of PSR trading (without an adjustment to the total supply of emissions permits) could lead to an 'inflation' of emissions, undermining climate policy objectives. With respect to the DC and GC variants, we will focus on three questions: 1) what exactly happens in the PSR sectors and how does that affect the rest of the economy?, 2) why would PSR trading reduce carbon leakage?, and 3) how can the welfare results be explained?

As explained above, in the current experiments PSR trading is allowed for four energy-intensive sectors: refineries, ferrous metals, non-ferrous metals, and chemicals. The PSR standards in these sectors are computed by GTAP-E and are consistent with the computed equilibrium CO2 price. That is, given the equilibrium CO2 price, the PSR standards reflect the cost-minimising rate of CO2 reduction per unit of output from the perspective of the individual sectors. Because the CO2 price differs across the PSR variants, PSR standards may also differ. Yet, for refineries and non-ferrous metals PSR standards are equal to their present CO2-intensities under all PSR variants. This means that increasing CO_2 efficiency[6] is not an economically attractive option for these sectors in any of the policy variants.[7] By contrast, for ferrous metals and chemicals it would be cost-effective to increase CO_2 efficiency of production in all variants. In the standard AXI variant, the increase of CO_2 efficiency (the technique effect) is 18 percent for ferrous metals and 21 percent for chemicals. As shown in Table 4, in the DC variant of PSR trading the CO_2 price is higher than in the standard scenario (AXI) and hence the increase in CO_2 efficiency is also higher: efficiency increases to 20 and 24 percent for ferrous metals and chemicals, respectively.

Given an equal CO_2 price, marginal costs of production of the firms in the PSR sector are less under PSR trading than under a standard cap-and-trade system of emissions trading. Equation (8) above indicated that the difference is $t{\cdot}psr^*$, which we will call the PSR output subsidy. PSR subsidy rates for ferrous metals and chemicals are 1.30 and 1.54 percent, while those for refineries and non-ferrous metals are zero and 0.09 percent. The reason for the low subsidy rate for non-ferrous metals is that its CO_2-intensity (and hence its psr^*) is very low. Its energy use is for 80 percent covered by electricity, and the emissions generated by the production of electricity are

6 CO_2 efficiency is defined here simply as the inverse of CO_2 intensity. Hence, if CO_2 intensity goes down, CO_2 efficiency goes up.

7 In GTAP-E, energy substitution elasticities for refineries are zero and this effectively precludes energy-efficiency improvements. The problem for non-ferrous metals in the Netherlands is that its fuel mix is already so CO_2 poor (18 % gas and 82 % electricity) that it is difficult (and costly) to increase its CO_2 efficiency further.

attributed to the (sheltered) electricity sector. The reason for the export loss of non-ferrous metals is therefore not the direct effect of the price increase of CO_2 emissions, but the effect of the price increase of electricity. The reason for the zero PSR subsidy for refineries is that its emissions are generated by *own-use* of oil products. In GTAP-E, own-use of oil products by refineries is not taxed, as this would lead to double taxation: first by taxing the production process of oil products and then taxing the oil products themselves when they are used by the final user. Because own-use is not taxed, the product $t{\cdot}psr^*$, and hence the PSR output subsidy, is zero. Furthermore, the estimated loss of exports of refineries must be attributed to a reduction of demand for its output, not to an increase in its costs.

PSR trading reduces the marginal costs of output of ferrous metals and chemicals. In the AXI scenario, CO_2 reduction measures would increase the marginal costs of ferrous metals and chemicals by 1.49 and 1.59 percent. PSR trading dampens the increase in marginal costs to 0.54 and 0.29 percent.[8] Hence, ferrous metals and chemicals are the only two sectors that effectively benefit from PSR trading.[9] But they are important sectors, together responsible for almost 50 percent of the CO_2 emissions from the exposed sector.

For a detailed overview of what happens in the PSR sector and in the rest of the economy, the reduction of emissions (in Mt CO_2) in the AXI and PSR-DC

[8] The comparison between the standard AXI scenario and the PSR variants is slightly complicated because the CO_2 price differs across the variants. For ferrous metals, for example, the increase in marginal costs without the PSR subsidy in the DC variant is 1.84 percent (against 1.49 percent in the standard AXI scenario). Including the PSR subsidy, the increase in marginal costs is 1.84 – 1.30 = 54 percent.

[9] Note that it is assumed that the Netherlands is the only country that implements PSR trading.

variants are decomposed into scale, composition and technique effects. A distinction is made between the PSR sector and the rest of the economy (firms, households), labelled "non-PSR sector" (Table 5). The AXI and PSR-DC variants generate the same level of emissions reduction (12.85 Mt CO_2), but they do so in different ways.

Table 5 around here

The *scale* effect of PSR trading is positive (0.07 MtCO_2), hence, all else being equal, emissions would rise because of PSR trading. This is not surprising, as PSR trading can be seen as a subsidy on industrial activity. By contrast, the *technique* effect of PSR trading is negative (– 0.75 MtCO_2). The technique effect is negative because of the increase in CO_2 price in the PSR variants, which stimulates energy-efficiency improvements in both the PSR and the non-PSR sector.

The PSR sector and the non-PSR sector have a very different *composition* effect. While the composition effect is very positive for the PSR sector (increasing emissions by 1.33 Mt), it is negative for the non-PSR sector (reducing emissions by – 0.64 Mt). The total composition effect would increase emissions by 0.69 Mt CO_2. PSR trading therefore shifts the economy into a more CO_2-intensive direction. Under a fixed national emissions ceiling, this shift is only possible at a cost to the non-PSR sector – exposed sectors not included in the PSR regime, the sheltered sector and private households. The non-PSR sector has to increase its CO_2 reduction. From a national perspective the question then is whether the benefits of PSR trading for the PSR sector outweigh the costs for the non-PSR sector. Before we answer this question, we first look at the effects of PSR trading on carbon leaks. Table 4 showed that the effects of the various PSR variants on global emissions differ. As discussed above, the

DC variant of PSR trading increases the global reduction of emissions by 0.4 Mt CO_2. The reason for this is that, on average, Dutch exposed sectors are less CO_2 intensive than their foreign competitors. Figure.1 shows the relative CO_2-intensities of all Dutch exposed sectors, expressed as ratios of world CO_2 intensities. The figure shows that almost all Dutch exposed sectors have lower CO_2 intensities than world averages, except for agriculture, refineries and water transport. The sectors ferrous metals and chemicals that are supported by PSR trading are, on average, less CO_2-intensive than foreign competition. All else being equal, an increase in the world share of Dutch production in these sectors would reduce global emissions. This explains why PSR trading in the Netherlands would reduce carbon leakage and global emissions. It also explains the GC variant of PSR trading, where, compared to the standard AXI scenario, the same rate of global emissions reduction can be achieved at a lower rate of national reduction.

Figure 1 around here

So far it has been established that PSR trading can lead to benefit for the PSR sector, but only at a cost for the non-PSR sector. In addition, PSR trading can lead to a reduction of global CO_2 emissions. In the final analysis we want to establish whether PSR trading is welfare enhancing, taking both conventional economic costs and benefits and climate change costs and benefits into account. Table 6 shows a decomposition of the change in welfare for the Netherlands (NLD) and the rest of the world (ROW) between the standard AXI scenario on the one hand, and the DC and GC variants of PSR trading on the other hand.

Table 6 around here

PSR trading with a fixed domestic emissions ceiling (DC) results in a welfare loss for the Netherlands of € 242 million and an almost similar welfare gain for the rest of the world of € 217 million. The reduction of CO_2 leakage in the DC variant is too small to result in noticeable climate change benefits in the Netherlands, but for the rest of the world they are around € 2 million. The shift in the composition of Dutch industry towards the PSR sector leads to a slight deterioration in allocative efficiency of € 7 million. There is also a slight welfare loss due to price changes of savings and investments. The big loss, however, is due to a deterioration of the Dutch terms of trade (– € 221 million).[10] PSR trading acts like an *export subsidy* on ferrous metals and chemical products, predominantly benefiting foreign consumers (+ € 221 million in ROW). The welfare effect of the GC variant of PSR trading is only slightly less negative for the Netherlands (– € 211 million).

Hence, even when the effect of PSR trading on carbon leakage is taken into account, PSR trading would not seem to be a welfare-enhancing proposition, given our current assumptions. The results might be different, though, if we change our assumptions, especially regarding returns to scale.

6. SENSITIVITY TO INCREASING RETURNS TO SCALE AND TRADE ELASTICITIES

How sensitive are the results of this paper to model and parameter assumptions? First, we examine the effects of increasing returns to scale in the ferrous metals and chemicals sectors. Second, we examine the consequences of a standard scenario with

[10] The export prices of the goods of the PSR sector fall because of PSR trading (especially chemicals: – 0.18 percent-point), while import prices are not affected.

a higher *initial* rate of leakage. Third, it may be assumed that trade elasticities play an important role in the analysis. Therefore, we examine the consequences of higher or lower trade elasticities.

The sensitivity analysis focuses on the GC variant of PSR trading. While the GC variant may not be the most practical option from a policy point of view, it offers the best comparison between conventional domestic emissions trading and PSR trading because the ultimate environmental effects (global emissions) of these policy instruments are identical. We examine the sensitivity of the relative change in national welfare of PSR trading to the following factors:

1. Increasing returns to scale in the Dutch ferrous metals and chemicals sectors. We vary the rate of return to scale between a CDR value of zero (constant returns to scale) to a CDR value of 0.15. For simplicity it is assumed that foreign sectors operate under constant returns to scale.
2. The rate of global carbon leakage. We differentiate between the AXI scenario with a leakage rate of 14.2 percent and an alternative scenario, the BSA scenario, with a leakage rate of 41.6 percent. In the BSA scenario it is assumed that only the EU countries reduce emissions, according to the Burden Sharing Agreement (see Table 3).
3. Trade elasticities of ferrous metals and chemicals. We differentiate between the standard trade elasticities of GTAP-E and trade elasticities that are 50 percent higher (+50%). With higher trade elasticities, it is more difficult for sectors to pass on increases in costs to foreign buyers. Hence, with higher trade elasticities cost-increasing CO_2 reduction measures will have larger effects on the exports of the affected sectors. In the GTAP-E database the

trade elasticities for ferrous metals and chemicals are 2.8 and 1.9 for the substitution between domestic and foreign supply (σ_D) and 5.6 and 3.8 for the substitution between different foreign suppliers (σ_M). The higher trade elasticities are σ_D= 4.2, resp. 8.4 and σ_D= 2.85, resp. 5.7 for ferrous metals and chemicals. Some AGE models do indeed employ trade elasticities in these orders of magnitude, although most models have elasticities that are closer to those of GTAP-E.

Figure 2 shows the results of the sensitivity analysis. The horizontal axis measures the rate of returns to scale: returns to scale increase from zero (constant returns to scale) to a CDR value of 0.15. The vertical axis measures the difference in national welfare (€ million) between the standard policies (AXI and BSA) and the PSR trading alternatives (AXI_PSR_GC and BSA_PSR_GC). We will denote this difference by the letter d. Thus, the welfare difference between BSA and BSA_PSR_GC is indicated by dBSA and the welfare difference between AXI and AXI_PSR_GC by dAXI. A welfare difference of zero indicates that standard policy and PSR trading are welfare neutral. A negative difference indicates that PSR trading reduces national welfare and a positive difference indicates that PSR trading is welfare improving. Higher trade elasticities are denoted by "+50%". The two variants are evaluated over a range of CDR values of 0.0, 0.5, 0.10 and 0.15.

Figure 2 around here

With constant returns to scale in the ferrous metals and chemicals sectors (CDR=0), PSR trading results in a loss of national welfare between € 41 and € 211 million, except in the case of dBSA+50%, that is, in the case of high leakage and high trade elasticities. In the latter case, PSR trading is slightly welfare improving (+ € 22 million). If increasing returns to scale are assumed, PSR trading becomes more attractive. With standard trade elasticities, dAXI and dBSA cross the 0-line at CDR values of 0.10 and 0.075, respectively. If returns to scale are higher than 0.10 (or 0.075), PSR trading yields a welfare improvement. PSR trading is also more attractive if it is assumed that the trade elasticities of ferrous metals and chemicals are higher than in the GTAP-E model. Especially the combination of high trade elasticities and strongly increasing returns to scale yield high welfare improvements. The question is, of course, if this combination of strongly increasing returns to scale and high trade elasticities is very likely.

7. CONCLUSIONS

Some time ago, Bovenberg argued that a unilateral carbon tax would impose high costs [especially to the exposed sectors] but would yield only small or even perverse environmental effects from a global point of view (Bovenberg, 1993:236). The fundamental cause for the disappointing performance of a carbon tax in this situation is an *international distortion*, i.e., the fact that environmental costs are not internalised abroad. To stimulate CO_2 reductions by the energy-intensive exposed sectors in the Netherlands, Bovenberg advocated a mix of subsidies and voluntary agreements.

The simulations in this paper suggest that while the international distortion of carbon leakage has not been completely removed by the Kyoto Protocol, PSR trading – which basically is Bovenberg's mix of subsidies and voluntary agreements, might not be welfare improving after all. The decisive difference between the present analysis and the analysis of Bovenberg is the presence of an overall absolute emissions ceiling. In the presence of an overall absolute emissions ceiling (be it national or global), any benefits granted to exposed sectors must be weighed against potential additional costs for the sheltered sector. The quantitative trade-off of these costs and benefits has been the subject of this chapter. The simulations of this chapter suggest that the welfare costs of PSR trading to the sheltered sector are likely to exceed the welfare benefits due to the protection of the exposed sector, even if the effect of PSR trading on carbon leakage is taken into account and the absolute CO_2 emissions ceiling refers to *global* emissions. The simulation results further suggest that the welfare effects of PSR trading would be rather insensitive to the initial rate of global leakage. Whether the EU would unilaterally reduce its CO_2 emissions (resulting in a large rate of leakage) or whether all Annex-I regions would constrain emissions (resulting in a lower rate of leakage) would have little impact on the welfare effects of PSR trading in the Netherlands.

In our analysis, the case for PSR trading would primarily rest on one's belief that exposed sectors, such as the ferrous metals and chemicals sectors, would operate under strongly increasing returns to scale *at the sector level*. PSR trading becomes more attractive, the stronger the increasing returns to scale and the higher the trade elasticities of these sectors.

But then again, if one believes that returns to scale at the sector level would be close to zero and that the trade elasticities of GTAP-E were approximately correct, then PSR trading would not be welfare improving, irrespective of the rate of carbon leakage.

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ANNEX I GEMPACK CODE FOR MODELLING PSR TRADING IN GTAP-E

The endogenous determination of the PSR output subsidy in GTAP-E is relatively easy. In this Annex we present the GEMPACK computer code that can be attached to the GTAP-E model in order to accomplish this.

The PSR output subsidy (dpsrsub) must be defined and initialised in the GTAP-E model code before it is used in the GTAP-E equation OUTPUTPRICES (see below). The PSR output subsidy is defined over the set of all producing sectors (in the set PROD_COMM) and over all region (in the set REG). (The language between # # are descriptions that do not affect the model's operations).

```
VARIABLE (all,j,PROD_COMM)(all,r,REG)
dpsrsub(j,r)
# % change of the power of the PSR subsidy to exposed
firms #;
COEFFICIENT (all,j,PROD_COMM)(all,r,REG)
PSRS(j,r)      # PSR subsidy to exposed firms #;
UPDATE (all,j,PROD_COMM)(all,r,REG)
      PSRS(j,r) = dpsrsub(j,r);
Read  PSRS FROM FILE GTAPDATA HEADER "PSRS" ;
```

The variable dpsrsub is included in the original GTAP-E equation that calculates producer supply prices, the equation OUTPUTPRICES. The equation forces the percentage change in supply prices (ps) to be equal to the sum of percentage changes in output subsidies or taxes (to: an exogenous parameter), percentage changes in the market prices (pm), and the PSR output subsidy rate (dpsrsub).

```
Equation OUTPUTPRICES
# eq'n links pre- and post-tax supply prices for all
industries  (HT 15) #[11]
(all,i,PROD_COMM)(all,r,REG)
    ps(i,r) = to(i,r) + pm(i,r) + dpsrsub(i,r);
```

The code that actually calculates the PSR subsidy can be attached to the end of the original GTAP-E model code. The parameter EXPO is read from the basedata, it indicates which sectors are exposed (for the exposed sectors EXPO=1, for the sheltered sectors EXPO = 0).

```
COEFFICIENT (PARAMETER)(all,j,PROD_COMM)
EXPO(j)
    # Exposed industry = 1 #;
Read EXPO FROM FILE GTAPDATA HEADER "EXPO";
```

The next step is to define three level variables that specify all purchases of the firms, the prices of which include carbon taxes. The firms in all regions (in the set

[11] The code (HT 15) in the description of the equation means that the equation is explained as equation 15 in Hertel (1997).

REG) purchase intermediate goods (in the set TRAD_COMM), and primary factors or endowment commodities (in the set ENDW_COMM)

```
VARIABLE(all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
VDFAC_L(i,j,r)   # value (Million $) of domestic
purchases by firms, including carbon tax #;
VARIABLE (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
VIFAC_L(i,j,r) # value (Million $) of imported purchases
by firms, including carbon tax #;
VARIABLE (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
EVFA_L(i,j,r) # value (Million $) of endowment purchases
(labour, capital) by firms # ;
```

Next, the level variables are initialized. Their initial values are set to the benchmark values of the firms' purchases of domestic and imported intermediate goods and of endowment commodities in the basedata.

```
Formula (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
       VDFAC_L(i,j,r)=VDFA(i,j,r);
Formula (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
       VIFAC_L(i,j,r)= VIFA(i,j,r);
Formula (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
        EVFA_L(i,j,r)= EVFA(i,j,r);
```

In a model run, the newly defined level variables are updated through the following equations. The percentage change of the level variables (P_) is equal to the sum of the percentage changes in prices (e.g., pfd: price index for domestic purchases of firms) and volumes (e.g., qfd: volume index for domestic purchases of firms). The variables pfd and qfd are calculated elsewhere in the original GTAP-E model.

```
EQUATION (Linear) E_VDFAC_L
            (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
                P_VDFAC_L(i,j,r) =  pfd(i,j,r) +
qfd(i,j,r) ;
EQUATION (Linear) E_VIFAC_L
            (all,i,TRAD_COMM)(all,j,PROD_COMM)(all,r,REG)
                P_VIFAC_L(i,j,r) =  pfm(i,j,r) +
qfm(i,j,r) ;
EQUATION (Linear) E_VFA_L
            (all,i,ENDW_COMM)(all,j,PROD_COMM)(all,r,REG)
                P_EVFA_L(i,j,r) =  pfe(i,j,r) +
qfe(i,j,r) ;
```

The next equation calculates the carbon tax amounts per industry (after optimal abatement), VCTAXI, for all producing sectors. It does so by subtracting the value of firms´ purchases of energy goods (set EGYCOM) without carbon taxes (VDFA_L, VIFA_L) from the value of purchases with carbon taxes (the level variables defined previously). The values of the purchases of energy goods without carbon taxes are calculated elsewhere in the original GTAP-E model.

```
FORMULA & EQUATION VALCTXI #carbon tax amounts by
industry #
 (all,j,PROD_COMM)(all,r,REG)
  VCTAXI(j,r) = sum{i,EGYCOM,VDFAC_L(i,j,r) -
VDFA_L(i,j,r)} +
            sum{i,EGYCOM,VIFAC_L(i,j,r) - VIFA_L(i,j,r)};
```

The next variable defines the volume of output to which the PSR subsidy applies (CSUBBAS). Given the zero profit assumption in GTAP-E, the value of output is equal to the value of all inputs.

```
VARIABLE (CHANGE) (all,j,PROD_COMM)(all,r,REG)
CSUBBAS(j,r) #  Subsidy base (Million $) for the
calculation of PSR output subsidy  # ;

FORMULA & EQUATION E_CSUBBAS # subsidy base  #
        (all,j,PROD_COMM)(all,r,REG)
        CSUBBAS(j,r) = sum(i,TRAD_COMM,VDFAC_L(i,j,r))
                       + sum(i,TRAD_COMM,VIFAC_L(i,j,r))
                       + sum(i,ENDW_COMM,EVFA_L(i,j,r));
```

The power of the PSR subsidy is equal to one plus the ratio of carbon taxes to output in all exposed industries (in the set EXPO).

```
VARIABLE  (all,j,PROD_COMM)(all,r,REG)      PSRPOWER(j,r)
```

```
    #   PSR subsidy power #;
FORMULA & EQUATION   E_PSRPOWER
        (all,j,PROD_COMM)(all,r,REG)
PSRPOWER(j,r) = EXPO(j)*(VCTAXI(j,r)/CSUBBAS(j,r)) + 1.0;
```

The final equation calculates the percentage change in the power of the subsidy: the subsidy rate, dpsrsub(j,r).

```
EQUATION (Linear) E_DPSRSUB
        (all,j,PROD_COMM)(all,r,REG)
        dpsrsub(j,r) = p_PSRPOWER(j,r);
```

If a simulation concerns emissions trading on a multi-country market, and it is assumed that only one country (or a subset of countries) engages in PSR trading, then the identifier REG should be replaced by the relevant identifier for the one country or the subset of countries. The variable dpsrsub for non-PSR countries in the multi-country market should be declared exogenous.

This concludes the additional computer code.

Table 1 Price elasticities of demand for energy

	Conditional price elasticity of demand for:					
	Fuels			Electricity		
	GTAP-E old	NEMO	GTAP-E new	GTAP-E old	NEMO	GTAP-E new
Agriculture	– 0.57	– 0.26	– 0.24	– 0.85	– 0.19	– 0.22
Ferrous metals	– 0.80	– 0.20	– 0.20	– 0.73	– 0.13	– 0.24
Non-ferrous metals	– 0.97	– 0.11	– 0.10	– 0.07	– 0.11	– 0.04
Building materials	– 0.77	– 0.43	– 0.31	– 0.76	– 0.13	– 0.32
Chemicals	– 0.51	– 0.11	– 0.19	– 0.92	– 0.14	– 0.11
Road, rail and air	– 0.59	– 0.45	– 0.56	– 0.99	– 0.13	– 0.11
Water transport	– 0.41	– 0.45	– 0.40	– 1.00	– 0.13	– 0.10
Other industries	– 0.63	– 0.33	– 0.32	– 0.90	– 0.21	– 0.23

Table 2 Aggregation of regions and sectors/commodities

Regions			Sectors/commodities		
EU	Netherlands	NLD	Sheltered	Coal	COL
	Belgium/Luxembourg	BEL		Crude oil	OIL
	France	FRA		Gas	GAS
	Germany	GER		Electricity	ELY
	United Kingdom	UK		Other goods and services	OTH
	Rest of Europe	ROE	Exposed	Agriculture	AGR
Rest of Annex-I	Eastern Europe/FSU	EIT		Fisheries	FSH
	Other OECD	O_O		Mineral extraction	MNR
Non-Annex-I	Rest of World	ROW		Refineries/petroleum	P_C
				Ferrous metals	I_S
				Non-ferrous metals	NFM
				Building materials	NMM
				Chemicals, rubber & plastics	CRP
				Road, air and rail transport	OTP
				Water transport	WTP

Table 3 Projected CO_2 emissions in 2010 (Mt CO2) and CO_2 reduction targets in AXI scenario (Mt CO_2 and percentages w.r.t. 2010 emissions).

	Projection of CO_2 emissions in 2010	Domestic reduction		Flexible instruments	
	Mt	Mt	%	Mt	%
Belgium	148.7	13.8	9.3	20.1	13.5
France	444.6	20.2	4.5	0.0	0.0
Germany	694.0	0.0	0.0	0.0	0.0
Netherlands	191.0	12.9	6.7	12.9	6.7
United Kingdom	651.2	0.0	0.0	0.0	0.0
Rest of EU	1254.4	69.1	7.4	14.4	1.2
EU15	*3286.0*	*139.4*	*3.8*[*)]	*47.4*	*1.4*[*)]
Eastern Europe/FSU			*0.0*		
Rest of Annex I			*5.0*		

[*)] Weighted with *benchmark* emission volumes.

Source: European Commission 2002 and own assumptions.

Table 4 Effects of PSR trading in the Netherlands in the AXI scenario (changes from benchmark)

	AXI	AXI_PSR		
		FP	DC	GC
Exports of exposed sector (%)	– 1.69	– 0.14	– 0.23	– 0.21
of which:				
– Refineries (%)	– 2.20	– 2.22	– 2.21	– 2.22
– Ferrous metals (%)	– 3.02	1.44	1.27	1.32
– Non-ferrous metals (%)	– 3.35	– 3.10	– 3.67	– 3.52
– Chemicals (%)	– 2.68	0.79	0.73	0.75
CO_2 price (€/tCO_2)	17.49	17.49	19.90	19.24
National CO_2 emissions (%)	– 6.73	– 5.97	– 6.73	– 6.52
Global CO_2 emissions (%)	– 1.71	– 1.70	– 1.71	– 1.71
Real GDP (%)	– 0.37	– 0.32	– 0.37	– 0.35
Welfare Netherlands (EV, € million)	– 620	– 742	– 862	– 831
Welfare rest of world (EV, € million)	– 8059	– 7798	– 7842	– 7824
Welfare world (EV, € million)	– 8679	– 8540	– 8704	– 8660

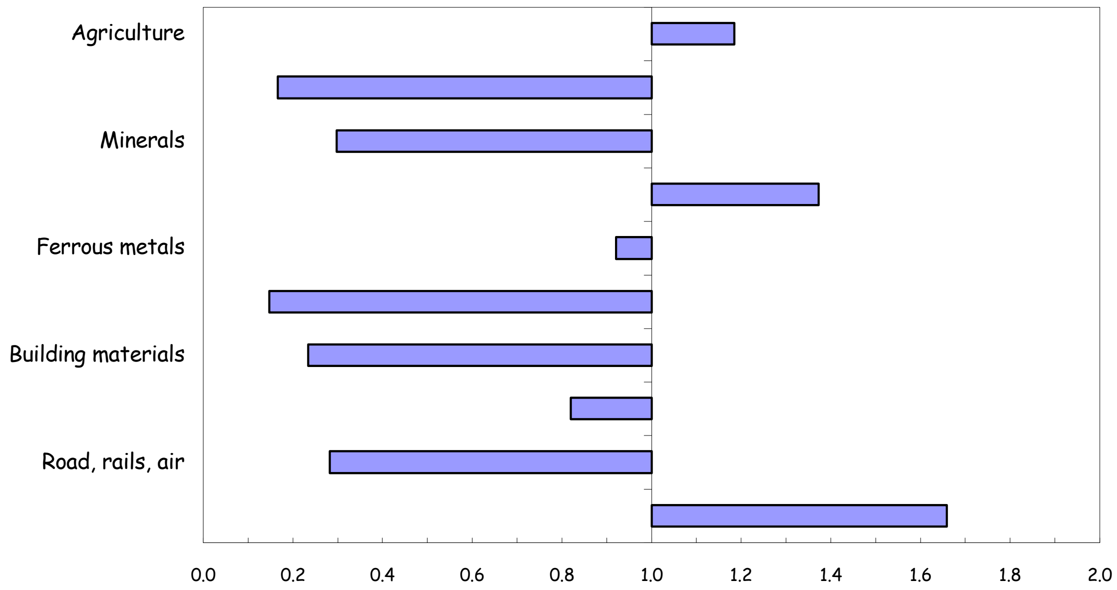
Table.5 Scale, composition and technique effects of PSR trading ($MtCO_2$)

	AXI		PSR-NC		Difference	
Scale						
PSR	– 0.20		– 0.17		0.03	
Non-PSR	– 0.65		– 0.60		0.05	
-- Subtotal		– 0.85		– 0.78		0.07
Composition						
PSR	-1.17		0.16		1.33	
Non-PSR	-4.65		– 5.29		– 0.64	
-- Subtotal		– 5.82		– 5.13		0.69
Technique						
PSR	– 1.18		– 1.32		– 0.14	
Non-PSR	– 5.26		– 5.86		– 0.61	
-- Subtotal		– 6.43		– 7.18		– 0.75
Change of emissions						
PSR	– 2.55		– 1.33		1.22	
Non-PSR	– 10.56		– 11.76		– 1.20	
Residual	0.26		0.24		0.02	
Grand total		-12.85		-12.85		0.00

Table.6 Decomposition of the welfare effects of PSR trading (change from AXI scenario in € million)

		Climate change benefits	Allocative efficiency	Scale economies	Terms of Trade	Savings/ Investment	Total
Constant returns to scale							
NC	NLD	0	– 7	0	– 221	– 14	– 242
	ROW	2	– 21	0	221	14	217
GC	NLD	0	38	0	– 235	– 14	– 211
	ROW	0	– 19	0	235	14	230

Figure.1 Ratios of CO_2 intensities of exposed sectors between the Netherlands and the world



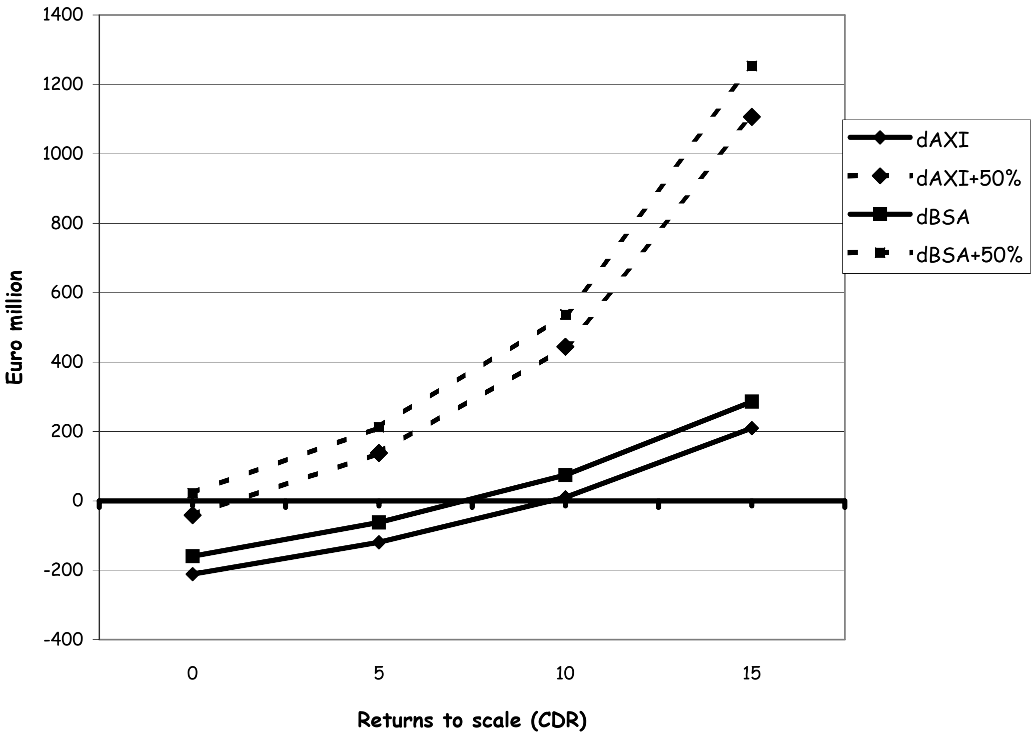


Figure 2. Sensitivities of the relative welfare effect of PSR trading to returns to scale, initial rate of leakage, and trade elasticities.