Nitrogen and Sulphur Outcomes of a Carbon Emissions Target Excluding Traded Allowances – An Input-Output Analysis of the Swedish Case.

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Svensk sammanfattning

En del viktiga miljöfrågor är i genuin mening globala, såsom växthuseffekten, medan andra har regionala aspekter som frisk luft, försurning och övergödning av mark och vattendrag. Riksdagen har antagit delmål, som anges i regeringens proposition 2004/05:150, för utsläppen av kväveoxider (NO_x) och svaveldioxid (SO_2) till 2010 i syfte att kontrollera luftkvalité, försurning och övergödning. Delmålen för utsläpp av koldioxid (CO_2), i syfte att begränsa växthuseffekten, formuleras i regeringens proposition 2004/05:150 för 2010 och i propositionen 2005/06:172 för 2020.[1] Om det nuvarande koldioxidmålet ersätts med ett s.k. avräkningsmål, vilket diskuteras av regeringen, kommer delmålen för utsläpp av kväveoxider och svaveldioxid att missgynnas eftersom ett avräkningsmål beaktar enbart koldioxidutsläpp som uppkommer till följd av att företagen tilldelas utsläppsrätter men inte koldioxidutsläpp som uppkommer när företagen importerar utsläppsrätter. I ett sådant nytt klimatpolitiskt läge kommer koldioxidmålet att uppnås till minsta möjliga kostnad genom import av utsläppsrätter, men ytterligare åtgärder riktade direkt mot utsläppen av svaveldioxid och kväveoxider kommer då att behövas för att uppnå även delmålen för dessa utsläpp.

Kyotoöverenskommelsen och EU: s avtal om en bördefördelning innebär att man sätter tak för CO_2-utsläppen i länderna inom EU. Sverige har tagit på sig ytterligare minskningar av CO_2-utsläppen utöver det tilldelade utsläppstaket. EU-länderna har också enats om ett handelssystem för utsläppsrätter. Klimatpolitiken skall, enligt regeringens proposition 2004/05:150, bl.a. syfta till att minska tilldelningen av utsläppsrätter, så att den kommer att understiga den handlande sektorns faktiska CO_2-utsläpp under perioden 2008-2012. Den handlande sektorn måste i detta läge importera utsläppsrätter inom EU: s handelssystem för att täcka överskjutande CO_2-utsläpp.

Dessa utsläpp beaktas med nuvarande konstruktion av Sveriges klimatmål, som inte är ett avräkningsmål, och som inte medger att flexibla mekanismer används för att uppnå målet. I stället behöver utsläppen av koldioxid och förbränningen av fossila bränslen minska i den icke-handlande sektorn. Då utsläppen av svaveldioxid och kväveoxider samvarierar med

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[1] Koldioxidutsläppen skall minska med minst fyra procent till 2010 och med 25 procent till 2020 jämfört med 1990-års nivå. Utsläppen av svaveldioxid skall minska till 50 000 ton och utsläppen av NO_x till 148 000 ton till 2010.

koldioxidutsläppen uppstår positiva sekundära effekter på miljömålen för frisk luft, försurning och övergödning. Det nuvarande klimatmålet skall, emellertid, omprövas av Naturvårdsverket, enligt regeringens senaste budgetproposition 2006/07:1, till fördel för ett sk. avräkningsmål. Avräkningsmålet förordas av FlexMexutredningen (SOU 2003:60), som tillika pekar på att import av utsläppsrätter inom EU:s handelssystem är en effektiv åtgärd för att uppnå klimatmålet för Sverige. I en situation med en sådan målformulering kan klimatmålet nås på ett effektivt sätt genom import av utsläpprätter men måluppfyllelsen leder inte till minskade utsläpp av SO_2 och NO_x i Sverige. Vi får således inte några positiva sekundära effekter på målen för försurning och övergödning av att klimatmålet uppnås via importerade utsläppsminskningar.

I vilken utsträckning en uppfyllelse av klimatmålet också medför sekundära effekter på NO_x-och SO_2-utsläppen analyseras i föreliggande rapport genom att beräkna utsläppsmultiplikatorer för sektorer som handlar med utsläppsrätter och för de sektorer, inkl. hushållssektorn och offentlig sektor, som inte handlar med utsläppsrätter. Dessa multiplikatorer skiljer sig åt beträffande intensiteten hos utsläppen av koldioxid såväl som utsläppen av kväve och svaveldioxid. Input-outputanalys används för att beräkna utsläppsmultiplikatorer för följande efterfrågekategorier: export, privat konsumtion, investeringar och offentlig konsumtion. Utsläppsmultiplikatorerna innefattar inte bara direkta utsläpp (direkta utsläppskoefficienter) i produktionen av varor och tjänster utan också alla utsläpp som sker till följd av intermediär produktion. Utsläppen av CO_2, SO_2 och NO_x sker i olika stadier av produktionsprocessen från råvara till färdig konsumtionsvara. Genom att använda utsläppsmultiplikatorer för skilda kategorier av efterfrågan snarare än direkta utsläppskoefficienter, så kan vi spåra alla utsläpp genom hela produktionskedjan och beräkna de totala utsläpp som sker till följd av förändringar i efterfrågan. Miljöräkenskapsmatriser för 2000 används för att beräkna utsläppsmultiplikatorer och effekter på utsläpp av CO_2, SO_2 och NO_x till följd den ekonomiska tillväxt som antas i Kontrollstation 2004 utvärderas och jämförs med utsläppsmålen och Naturvårdsverket utsläppsprognoser redovisade i Kontrollstation 2004 och i EU: s CAFE-projekt för 2010 och 2020.

En samhällsekonomiskt effektiv åtgärd för att nå Sveriges klimatmål skulle vara att köpa utsläppsrätter inom EU:s handelssystem istället för inhemsk reduktion av CO_2-utsläppen till en högre kostnad. Att tilldela utsläppsrätter i en mängd som understiger de faktiska CO_2-

utsläppen i den handlande sektorn och ha ett avräkningsmål (som ju inte räknar in importerade utsläppsrätter) framstår då som en attraktiv politik för att nå klimatmålet. En sådan klimatpolitik leder inte till att förbränningen av fossila bränslen minskar i Sverige och påverkar således inte SO_2/GDP- och NO_x/GDP-kvoterna. I motsats skulle en alternativ klimatpolitik, som tilldelar de handlande sektorerna utsläppsrätter i samma omfattning som dess faktiska CO_2-utsläpp, kräva att den icke-handlande sektorns CO_2-utsläpp minskar, t.ex. genom ökad CO_2-skatt, för att uppnå klimatmålet. I detta fall skulle förbränningen av fossila bränslen minska i Sverige, vilket i sin tur, enligt våra resultat, skulle sänka SO_2/GDP- och NO_x/GDP-kvoterna med 8% respektive 12% jämfört med den klimatpolitik som baseras på köpta utsläppsrätter.

Kostnaderna för klimatpolitiken kan emellertid sänkas genom att Sverige deltar i internationell utsläppshandel jämfört med inhemsk reduktion av utsläppen som konstateras av bl.a. FlexMexkommittén SOU 2003:60) och Östblom (2003). För att dra fördel av utsläppshandels lägre kostnader för klimatpolitiken men ändå kunna minska utsläppen av svaveldioxid och kväveoxider behövs styrmedel vid sidan av klimatpolitiken inriktade uteslutande på att minska dessa utsläpp som är skadliga för människors hälsa och bidrar till försurning och övergödning.

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Abstract

A cost-effective policy instrument to attain the Swedish carbon emission target, suggested by the Government's commission on flexible mechanisms of the Kyoto protocol, is the purchase of emission allowances within the EU trading scheme, instead of reducing domestic CO_2 emissions at higher costs. Also, proposed by the commission, is that only grandfathered, but not imported emission allowances, should be accounted for in the carbon emissions target. This formulation of the target is now under consideration by the Swedish Environmental Protection Agency as instructed in Sweden's Budget Bill for 2007. The nitrogen and sulphur outcomes of these suggestions for the climate policy are here assessed in the view of Sweden's official emission projections for 2010 and 2020. In view of the historical emission multipliers and the analysis presented here, the proposed climate policy does not conform to Sweden's interim targets for nitrogen oxides (NO_x) and sulphur dioxide (SO_2). Although, the CO_2 emission target could be attained at the least costs through emission trading, an environmental policy which brings also SO_2 and NO_x emissions to the acceptable levels requires additional policy instruments aiming at the exclusive reduction of these emissions. The findings here suggest that these reductions would correspond to decreases of the SO_2/GDP and NO_x/GDP ratios by 8 and 12 per cent, respectively. The emission multipliers of aggregate demand for CO_2-permit trading and non-trading sectors, are calculated by exploiting the environmental accounting matrix of Sweden for 2000 within the framework of an inter industry model.

Keywords: Emission multipliers, carbon trading, emission/GDP ratio, environmental goals

1 Introduction

Some important environmental issues are truly global, e.g. the green house effect, while others have regional aspects, e.g. clean air, the acidification and eutrophication of grounds and water streams. Sweden has signed international agreements on controlling acidification, eutrophication and the green house effect. The Swedish parliament has agreed on interim objectives, formulated in the Government's bill 2004/05:150, for nitrogen oxides (NO_x) and sulphur dioxide (SO_2) to control clean air, acidification and eutrophication. Interim objectives for carbon dioxide (CO_2), to bound the green house effect, are formulated in the Government's bill 2005/06:172.[1] By substituting the current climate policy regime for a new regime which excludes traded CO_2 allowances in the Swedish carbon emissions target, as actually discussed by the Swedish Government, will be to a disadvantage of the interim targets for SO_2 and NO_x emissions. This new regime will attain the carbon emission target at the least costs, but involves a stronger need for additional instruments to attain also the interim targets of SO_2 and NO_x emissions. The effects on SO_2/GDP and NO_x/GDP ratios of additional instruments should correspond to reductions of these ratios by 8 and 12 per cent, respectively, according to the analysis carried out in the present paper.

The Kyoto agreement and EU: s burden sharing agreement imply ceilings of CO_2 emissions for countries within the EU. Sweden has decided upon further reductions of CO_2 emissions below its assigned ceiling. The EU countries have agreed also upon CO_2-trading for emission intensive industries, and the CO_2 emissions which correspond to allowances imported by these industries are accounted for in the current Swedish CO_2-target. The Swedish climate policy should also, as proclaimed in the Government bill 2004/05:150, aim at grandfathering fewer allowances than the carbon emitted by the emissions trading industries during the period 2008-2012, i.e. these industries are supposed to purchase the required emission allowances within the EU emissions trading scheme. This situation will not affect the carbon emissions accounted for in the CO_2-target under Sweden's current regime of not using any flexible mechanisms to attain this target. Instead, domestic emissions and fuel combustion must reduce in the emissions non-trading sector and, given the SO_2/carbon and

[1] The emissions of CO_2 should be reduced by at least four per cent in 2010 and by 25 per cent in 2020 compared to the level of emissions in 1990. The emissions of SO_2 should be reduced to 50 000 tonnes and that of NO_x to 148 000 tonnes in 2010.

NO_X/carbon ratios, this will induce ancillary effects for Sweden's objectives of clean air, acidification and eutrophication.

A revision of the CO_2 emissions target is now under consideration by the Swedish Environmental Protection Agency (SEPA), as instructed by the Government in its Budget bill for 2007(Government bill 2006/07:1). To attain the Swedish carbon emissions target, the purchase of emissions allowances within the EU trading scheme is suggested as a cost-effective policy instrument by the Government's commission on flexible mechanisms of the Kyoto protocol (SOU 2003:60). Furthermore, the commission proposes that only grand-fathered, but not imported emission allowances should be accounted for in the target of domestic carbon emissions. The CO_2-target under such a regime, might thus be attained by the imported emission reductions carried out in other countries but the domestic SO_2 and NO_X emissions will in this case not be reduced. We will have no ancillary effects on the objectives of clean air, acidification and eutrophication under the new regime, where we attain the CO_2 emission target by imporing emission reductions instead of reducing domestic CO_2 emissions.

The ancillary effects on the emission levels of NO_x and SO_2, induced by attaining the carbon emission target, are analysed and compared for these two regimes by introducing emission multipliers for the emissions trading industries. These multipliers differ from those of the emissions non-trading sectors of the economy including households and the public sector in the intensity of carbon emissions as well as in the intensities of SO_2 and NO_X emissions. Input-output analysis is used to calculate emissions multipliers for the following components of final demand: exports, private consumption, investments and public consumption. The emission multipliers include not only direct emissions in the production of goods and services (direct emission coefficients) but also all emissions due to production of other goods and services used as intermediate inputs in the production. The pollutants CO_2, SO_2 and NO_X are emitted at different stages of the production process, from raw materials to products for consumption and investments. By using emission multipliers for the various components of final demand rather than direct emission coefficients, we trace all the emissions through the production chains and could calculate the total emissions resulting from various changes in the final demand.

Input-output analysis is a powerful method when we wish to account for the total use of primary factors (e.g. labour, capital, energy or the environment) in final products, by the calculation of multipliers. Multiplier calculations have been reported in a number of studies.

For example, labour and capital multipliers are studied by Carter (1970) and Östblom (1993), energy multipliers by Herendeen (1978) and Östblom (1982) and emission multipliers by Proops, Faber and Wagenhals (1993). The emission multiplier approach has been used to analyse the impact of economic activities on carbon emissions for a number of countries: the UK and Germany were studied by Proops, Faber and Wagenhals (1993), Östblom (1998) analysed the situation for Sweden, Cadarso and Fernandez-Bolaños (2002) studied Spain, Gerilla, Shigemi and Hajime (2001) studied Japan, De Hann (2001) studied the Netherlands and Creedy and Sleeman (2005) studied New Zealand. The present paper follows in this methodological tradition by presenting calculations of emission multipliers for Sweden and adds to this tradition by presenting also emissions multipliers for emissions trading and emissions non-trading sectors of the economy.

Measures taken to reduce emissions to the air impose restrictions on production activities. Activities differ in their intensities of carbon emissions as well as in their intensities of SO_2 and NO_X emissions. Hence, the strength of policy measures, that must be implemented in act to attain certain emissions goals, is a function of the allocation of real GDP. The less emission intensive allocation of total expenditure, the less we must restrict production activities by policy instruments. Some activities are more intensive in the emissions of carbon but less intensive in the emissions of SO_2 and NO_X than others or vice versa. The various emissions to the air might, thus, be affected differently by a reallocation of real GDP, and hence not only the strength but also the aim and direction of policy instruments will be of matter for the fulfilment of emissions goals. Historically, Sweden’s export-driven growth has resulted in considerably higher levels of emissions to the air compared to growth taken place mainly in the domestic market, as was shown by Östblom (1998) in an analysis based on the first Swedish Environmental Accounting matrix for 1991. This picture has changed, however, and a reallocation of GDP towards the domestic market, as he assumed, would not help to bring down emissions to the accepted levels. The reason for this is that the emission multipliers of exports have decreased considerably more than those of domestic demand after a decade of climate policy according to the analysis presented in succeeding sections. The carbon emissions target, however, could be attained in a cost-effective way, under the new climate policy regime, but as discussed above, such a regime will counteract the fulfilment of Sweden’s targets for NO_X and SO_2 emissions.

Structural changes affect the emission multipliers and we illustrate this by exploiting information of the environmental accounting matrices of Sweden for 2000 and the corresponding data for 1991 published by Östblom (1998). The effects on CO_2, SO_2 and NO_X emissions of the macroeconomic growth assumed by SEPA (2004) and SEPA (2006) are assessed and compared to the actual emission goals and to its official emissions projections for Sweden to 2010 and 2020. Also, we use the projected emissions to illustrate how attainment of the emission goals for SO_2 and NO_X could be obstructed by carbon emissions trading under a regime of not accounting for traded allowances in the climate goal. Relative prices of fuels also influence the emission multipliers, and calculations of implied price elasticity of aggregated energy demand is used to illuminate this aspect of the price assumptions made in the projections.

A presentation of the method and data follows in Section 2. Emission coefficients for various sectors of the economy are reported in Section 3. Changes in the composition of aggregate demand have effects on total emissions, and these effects are analysed in Section 4. The environmental effects of SEPA projections and emissions trading are reported in Section 5 and compared with actual emission goals. Finally, some policy implications are discussed in section 6.

2 Method and data

Input-output analysis is used to calculate emission multipliers of the pollutants CO_2, SO_2 and NO_X for the following categories of final demand: exports $\mathbf{y}_e$, private consumption $\mathbf{y}_c$, investments $\mathbf{y}_v$ and public consumption $\mathbf{y}_g$. The open static Leontief system is combined with an emission identity stating that total amounts of the pollutants to the air are equal to the amounts of the pollutants emitted by different industrial activities, the household sector and the public sector. All commodities are produced as well as imported and can either be used as intermediate input, or finally consumed. Intermediate input of commodities and industrial emissions of pollutants are assumed to be proportionally related to output. We use the model presented by Östblom (1998) but add emissions ceilings, emissions permits (grandfathered and traded) and subdivide production into emissions trading and emissions non-trading sectors. The emission ceilings may not be exceeded due to international agreements or due to national emission targets. We examine a regime of accounting for all emissions in the emissions ceilings and a regime which accounts only the emission permits initially grandfathered, but not the traded emission permits.

We introduce emissions ceilings by the equation system (4) and emission permits by the equation system (8). The economic relations of the model are represented by the following system of equations:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y}_x \quad (1)$$

$$\mathbf{m} = \mathbf{M}\mathbf{x} + \mathbf{y}_m \quad (2)$$

Where:

x is a column vector of produced amounts of *n* commodities.

A is a $n \times n$ matrix of coefficients A_{ij} for input of produced amount of commodity *i* for production of commodity *j*.

$\mathbf{y}_x$ is a column vector of final demand for produced amounts of *n* commodities.

m is a column vector of imported amounts of *n* commodities.

M is a $n \times n$ matrix of import coefficients M_{ij} for input of imported amount of commodity *i* for production of commodity *j*.

$\mathbf{y}_m$ is a column vector of final demand for imported amounts of *n* commodities.

By using equation system (1), we can relate final demand to produced amounts through the Leontief inverse, $(\mathbf{I}-\mathbf{A})^{-1}$; **I** is a $n \times n$ identity matrix. This guarantees that the matrix $(\mathbf{I}-\mathbf{A})$ is non-singular, i.e. matrix **A** fulfils the Hawkins-Simon conditions, which hold for the matrix used in the present study. The Leontief inverse is denoted **H.** The equation system (1) can then be written:

$$\mathbf{x} = \mathbf{H}\mathbf{y}_x \quad (3)$$

The emission identity is represented by the following system of equations and total emissions may not exceed the emission ceilings **ê:**

$$\mathbf{e} = \mathbf{E}\mathbf{U}\mathbf{x} + \mathbf{e}_c + \mathbf{e}_g \le \hat{\mathbf{e}} \quad (4)$$

Where:

e is a column vector of total emissions, in physical units, of *m* types of pollutants to the air.

$\hat{\mathbf{e}}$ is a column vector of emissions ceilings, in physical units, of *m* types of pollutants to the air.

$\mathbf{E}$ is a $m \times n$ matrix of coefficients E_{kj} for pollutant of type *k* emitted by sector *j* for unit output.

$\mathbf{e}_c$ is a column vector of quantities emitted by the household sector for *m* types of pollutants.

$\mathbf{e}_g$ is a column vector of quantities emitted by the public sector for *m* types of pollutants.

$\mathbf{U}$ is a $n \times n$ matrix of market shares U_{ij} for amount of commodity *j* produced by sector *i*.

The combination of Equation systems (3) and (4) gives:

$$\mathbf{e} = \mathbf{EUHy}_x + \mathbf{e}_c + \mathbf{e}_g \leq \hat{\mathbf{e}} \tag{5}$$

The identity: $\mathbf{y}_x \equiv \mathbf{y}_c + \mathbf{y}_v + \mathbf{y}_g + \mathbf{y}_e$ holds and the term $\mathbf{EUH}\left(\mathbf{y}_c + \mathbf{y}_v + \mathbf{y}_g + \mathbf{y}_e\right)$ represents emission of pollutants due to roundabout consumption of commodities for the various demand categories. Where private consumption and public consumption are concerned, emissions by household activities, $\mathbf{e}_c$ and emissions by public service activities $\mathbf{e}_g$ are also considered. The emission multipliers $\boldsymbol{\varepsilon}_j$ for the four demand categories are thus:

$$\boldsymbol{\varepsilon}_j = \left(\mathbf{EUHy}_j + \mathbf{e}_j\right)\left(\mathbf{iy}_j\right)^{-1}$$

Where:

j=c,v,g,e, and $\mathbf{e}_j = \mathbf{0}$ for $j \neq c, g$

$\mathbf{i}$ is a $1 \times \mathrm{n}$ unit vector and $\mathbf{0}$ is a $\mathrm{m} \times 1$ null vector.

The vector $\mathbf{y}_g$ refers to demand of material inputs in public production, but for convenience of notation let the sum $\mathbf{iy}_g$ denote total public consumption. The equation system (5) can now be rewritten as:

$$\mathbf{e} = \varepsilon_c\left(\mathbf{iy}_c\right) + \varepsilon_v\left(\mathbf{iy}_v\right) + \varepsilon_g\left(\mathbf{iy}_g\right) + \varepsilon_e\left(\mathbf{iy}_e\right) \leq \hat{\mathbf{e}} \tag{6}$$

Where:

$\boldsymbol{\varepsilon}_c$ is a column vector of emission multipliers for private consumption, with *m* types of pollutants.

$\boldsymbol{\varepsilon}_v$ is a column vector of emission multipliers for investments, with *m* types of pollutants.

$\boldsymbol{\varepsilon}_g$ is a column vector of emission multipliers for public consumption, with *m* types of pollutants.

$\boldsymbol{\varepsilon}_e$ is a column vector of emission multipliers for exports, with *m* types of pollutants.

Before introducing emissions permits, the matrix $\mathbf{E}$ of emissions coefficients is partitioned into the submatrix $\mathbf{E}^T$ of emissions trading sectors and the submatrix $\mathbf{E}^{NT}$ of emissions non-trading sectors. The equation (5) now can be rewritten as:

$$\mathbf{e} = \mathbf{E}^T\mathbf{UHy}_x + \mathbf{E}^{NT}\mathbf{UHy}_x + \mathbf{e}_c + \mathbf{e}_g \leq \hat{\mathbf{e}} \tag{7}$$

We now introduce international trading of emission permits and assume the initial allocation of emission permits, by e.g. grand fathering, to be $\mathbf{e}^{IP}$, and the emission permits traded to be, $\mathbf{e}^{TP}$, and thus the emissions of emissions trading sectors will be ($\mathbf{e}^{TP}$ will be negative in case of net exports of emissions permits):

$$\mathbf{e}^{IP} + \mathbf{e}^{TP} = \mathbf{E}^T\mathbf{UHy}_x \tag{8}$$

We let the emissions of non-trading sectors, $\mathbf{e}^{NT}$, also include the emissions of household activities, $\mathbf{e}_c$ and the emissions of public service activities $\mathbf{e}_g$.

$$\mathbf{e}^{NT} = \mathbf{E}^{NT}\mathbf{UHy}_x + \mathbf{e}_c + \mathbf{e}_g \tag{9}$$

The emission multipliers $\boldsymbol{\varepsilon}_j^T$ and $\boldsymbol{\varepsilon}_j^{NT}$ for the four demand categories are thus:

$$\boldsymbol{\varepsilon}_j^T = \left(\mathbf{E}^T\mathbf{UHy}_j\right)\left(\mathbf{iy}_j\right)^{-1}$$

and

$$\boldsymbol{\varepsilon}_j^{NT} = \left(\mathbf{E}^{NT}\mathbf{UHy}_j + \mathbf{e}_j\right)\left(\mathbf{iy}_j\right)^{-1}$$

Where:

$j=c,v,g,e$, and $\mathbf{e}_j = \mathbf{0}$ for $j \neq c,g$

The total emission multipliers $\boldsymbol{\varepsilon}_j$ for the four demand categories are:

$\boldsymbol{\varepsilon}_j = \boldsymbol{\varepsilon}_j^T + \boldsymbol{\varepsilon}_j^{NT}$

By introducing emission goals where the emission permits traded are not accounted for in the emission ceilings, the equation of emission multipliers corresponding to equation (6) now becomes:

$$\mathbf{e}^{IP} + \mathbf{e}^{NT} = \boldsymbol{\varepsilon}_c(\mathbf{iy}_c) + \boldsymbol{\varepsilon}_v(\mathbf{iy}_v) + \boldsymbol{\varepsilon}_g(\mathbf{iy}_g) + \boldsymbol{\varepsilon}_e(\mathbf{iy}_e) - \mathbf{e}^{TP} \leq \hat{\mathbf{e}} \tag{10}$$

The emissions of non-trading sectors and initial emission permits of trading sectors may not exceed the emission ceilings and thus the emissions of non-trading sectors may not exceed the emission ceilings less initial emission permits. Rewriting the equation (10) gives:

$$\mathbf{e}^{NT} = \sum_j \boldsymbol{\varepsilon}_j^{NT}(\mathbf{iy}_j) \leq \hat{\mathbf{e}} - \overbrace{\left(\sum_j \boldsymbol{\varepsilon}_j^T(\mathbf{iy}_j) - \mathbf{e}^{TP}\right)}^{\mathbf{e}^{IP}}$$

The grandfathering of initial emission permits affects the amount of traded emission permits and, thus, it also will affect the amount of emissions that can be attributed to the emissions non-trading sectors in order to fulfil the emissions ceiling.

$$\begin{aligned} &\mathbf{e}^{IP} = \sum\nolimits_j \boldsymbol{\varepsilon}_j^T(\mathbf{iy}_j) \Rightarrow \mathbf{e}^{TP} = 0 \quad \text{no trade} \\ &\mathbf{e}^{IP} < \sum\nolimits_j \boldsymbol{\varepsilon}_j^T(\mathbf{iy}_j) \Rightarrow \mathbf{e}^{TP} > 0 \quad \text{net import} \\ &\mathbf{e}^{IP} > \sum\nolimits_j \boldsymbol{\varepsilon}_j^T(\mathbf{iy}_j) \Rightarrow \mathbf{e}^{TP} < 0 \quad \text{net export} \end{aligned}$$

When the amount of initial emission permits, $\mathbf{e}^{IP}$, *equals* the emissions of emissions trading sectors, $\sum_j \boldsymbol{\varepsilon}_j^T(\mathbf{iy}_j)$, we will have *no trade* and the amount of emissions that can be attributed to the emissions non-trading sectors in order to fulfil the emissions ceiling will coincide between the equations (6) and (10). When the amount of initial emission permits *falls below* the emissions of emissions trading sectors, we will have *import* of emission permits and the amount of emissions that can be attributed to the emissions non-trading sectors in order not to violate the emissions ceiling will exceed that of equation (6) by the amount of imported emission permits in equation (10). When the amount of initial emission permits *exceeds* the emissions of emissions trading sectors, we will have *export* of emission permits and the amount of emissions that can be attributed to the emissions non-trading sectors in order not to violate the emissions ceiling will fall below that of equation (6) by the amount of exported emission permits in equation (10). The emissions traded (the CO_2 emissions), thus follow equation (10), whereas the emissions not traded (the SO_2 and NO_x emissions) follow equation (6). In this situation, the targets of non-traded emissions might be violated in the case of imported CO_2 emission permits or be subject to overshooting in the case of exported CO_2 emission permits, due to increased or decreased fuel combustion, respectively, in the CO_2 emissions non-trading sectors.

Data of emissions in physical units are taken from the official report on Environmental accounts for Sweden published by Statistics Sweden. The calculations made by Östblom (1998) based on the first environmental accounting matrix of Sweden 1991 are rearranged by the author to be comparable with the accounting matrix of 2000 showing emissions of the pollutants CO_2, SO_2 and NO_x for 17 industries (16 industries for 1991), the household sector and the public sector. The economic data in 2000 prices are from the Swedish National Accounts, also published by Statistics Sweden.

3 Emissions of pollutants by carbon emissions trading and non-trading sectors

Historical and projected emission/GDP ratios compared for 1991, 2000, 2004, 2010 and 2020 are affected by changes in the emissions of pollutants by households, the public sector and the industry sector. In 2000, about 73 % of CO_2, 98 % of SO_2 and 85 % of NO_x were emitted by Swedish industries. The amounts of emissions might vary at a given level of economic activity as some industries expand while others stagnate or even decline over time. Emissions per unit produced (the emission coefficient) differ among individual industries and thus emission multipliers are affected by changes in the production structure.

The emission coefficients may also change for a number of other reasons. Changes in the production mix within an industry may have taken place so that the products no longer are identical and/or are not produced in the same proportions. Production techniques may have changed owing to technical progress or by input substitution in the medium term. Existing production techniques often permit some variation in the input proportions. In the longer run, as production capacity grows and older plants are partly or totally replaced, input combinations become less restricted. The substitution of inputs depends on changing relative prices. Here, the influences on emission multipliers from both emission coefficients and structural changes are discussed.

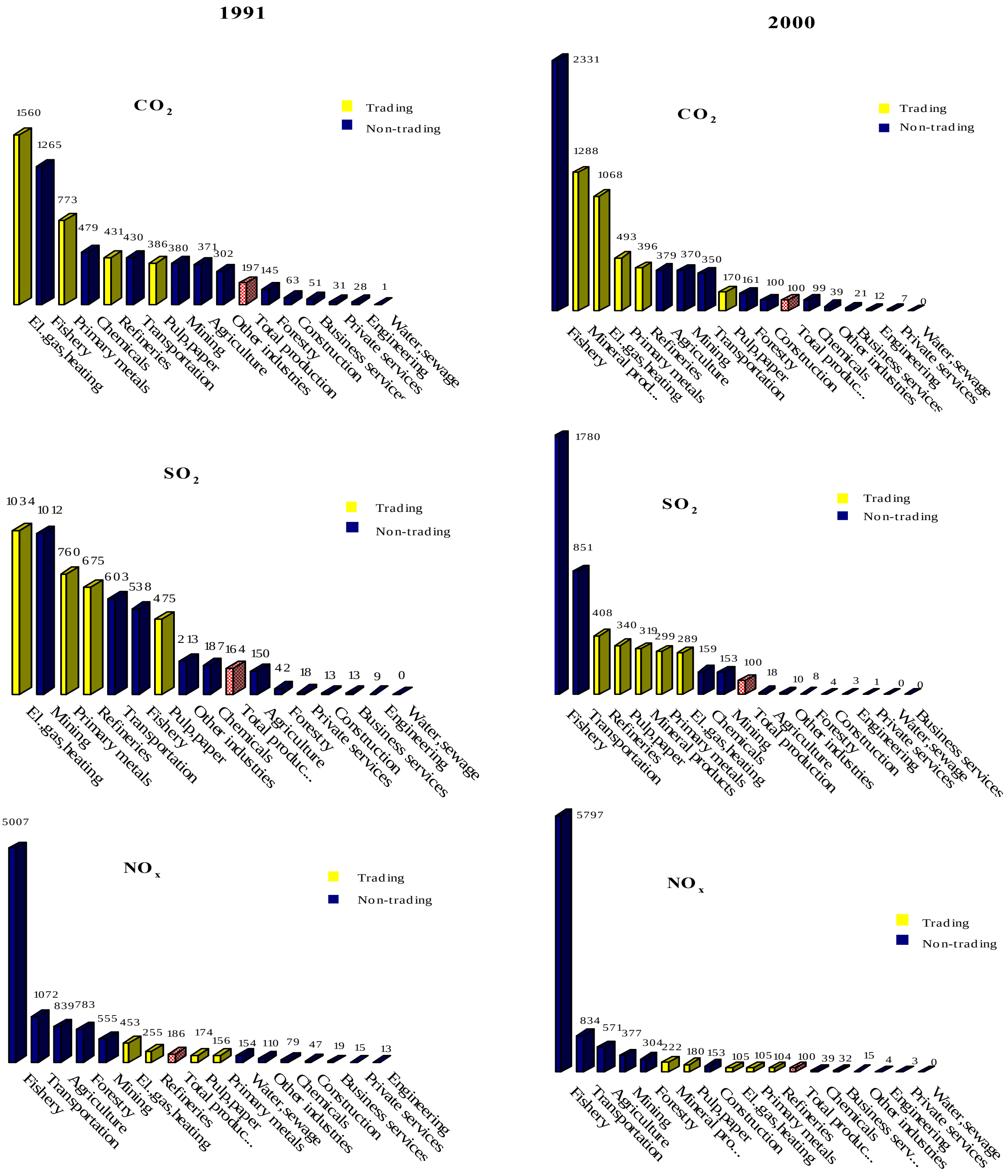
Changes in capacity usage influence both the emission coefficients and our measure of structural changes. The share of emissions from fixed combustion of fuels - space heating, etc. - per unit produced increases with unused capacity. All the sectors, however, do not necessarily share the same business cycle. The influence of increased emission coefficients, on the amount of pollutants emitted, relative to economic activity, could therefore be coun teracted by a changed production share, due to a reduced capacity in the sector. The year 2000 was on the top of the business cycle of total industry according to NIER (2006). It is possible that the emission coefficients in 2000 have a downward bias compared to those of the projected years 2010 and 2020 for which normal capacity utilization is assumed. It has not been possible to quantify this bias or estimate the extent to which our measure of structural changes also reflects that the business cycles of the different sectors do not coincide.

The production system is divided into subsectors, which are classified either as carbon emissions trading subsectors or carbon emissions non-trading subsectors, according to the EU trading scheme, as shown in Figure 1. Subsectors are ranked by their emissions coefficients (emissions intensities) as shown in the figure for 1991 and 2000. The carbon emissions trading subsectors are characterized by high rankings for coefficients of SO_2 and CO_2 emissions, with an average rank of 4 or 5, and middle rankings for the coefficients of NO_x emissions, with an average rank of 8. The carbon emissions non-trading subsectors have also middle rankings for the coefficients of NO_x emissions, with an average rank of 9, but low rankings for the coefficients of SO_2 and CO_2 emissions, with an average rank of 10 or 11. The emission intensities decreased significantly for a number of industrial subsectors but the rank of subsectors changed very little between 1991 and 2000, as shown by the figure.

Industries where the combustion of fossil fuels plays a dominant role in the process of converting and transforming various goods and raw materials, such as primary metals and mineral products, constitute the group of emissions trading subsectors. The subsectors of this group account for 34% of the CO_2, 29% of the SO_2 and 10 % of the NO_x emitted by the production system while producing somewhat less than 9% of total gross output. The emissions non-trading subsectors exhibit mainly low rank emissions coefficients, e.g. services, engineering and construction, but include also a few subsectors such as fishery and transportation with high rank emissions coefficients. These subsectors take fully 91 % of the gross output and are registered for 66 % of CO_2, 71 % of SO_2 and 90 % of NO_x, emitted by the production system.

Figure 1 Emissions output ratios for carbon emissions trading and non-trading sectors.

Index. The emissions output ratios of total production in 2000=100*



*For the NACE classification code of subsectors, see Appendix.

Structural changes should have a large influence on pollutants emitted relative to total output of the Swedish production system, which has a highly differentiated structure of production with reference to the emission coefficients. For example, a decrease of the combustion in carbon emissions trading subsectors resulting in a reduction of total CO_2 emissions with 1% would reduce total NO_x emissions by about 0.1 %, whereas a corresponding decrease of the combustion in carbon emissions non-trading subsectors would reduce total NO_X emissions by nearly 2 %.

Combustion of fossil fuels takes place not only in the production system but also by household activities and in the public service sector, which are emissions non-trading sectors. The Swedish households, in 2000, accounted for 24% of the economy's total CO_2 emissions, 1½% of total SO_2 emissions and 13% of total NO_X emissions due to mainly the combustion of motor fuels but also space heating. The households' emissions of pollutants are determined, among other things, by income, energy prices and policy measures. Variations in all of these and other determinants are reflected on an aggregated level by changes in the ratio between pollutants emitted by the household sector and total private consumption. This ratios decreased by 25 % for CO_2, 67 % for SO_2 and 56 % for NO_X in 2000 compared to the figures presented by Östblom (1998) for 1991.

The public sector is registered for 3%, ½% and 2% of total CO_2, SO_2 and NO_X emissions of the economy, respectively, in 2000 due to mainly space heating. The public sector comprises a variety of activities, which can be classified either as general administration, national defence, education or health and social services. The emissions of this sector are in turn dependent on political decisions concerning the size and concentration of public services. The emissions shares have decreased for CO_2 and SO_2 but increased for NO_X compared to the figures of 1991. Changes in the composition of public consumption will of course affect these shares and any observed decrease could be due either to this changed composition or changing emission intensities in the different activities.

4 Effects on total emissions of changes in aggregate demand

So far the emissions of CO_2, SO_2, and NO_X in the Swedish economy have been discussed with reference to the direct use of fuels in three major economic sectors. The relationship between the emission/GDP ratio and the emissions of these sectors is not evident, however, and a link suggested here are the emission multipliers of different components of aggregate demand. In two of the three economic sectors (households and the public sector), fuels are combusted to yield desired indoor temperature and transport services, but in the production system fuels are used for producing goods and services. It is desirable to know how much of total emissions due to fuel combustion should be attributed to the different categories of aggregate demand as the emission/GDP ratio is affected by changes in the composition of aggregate demand.

All production of goods and services, ultimately, serves the purpose of final consumption, but through a complexity of inter-industry linkages. It is possible, using input-output analysis, to consider this interdependence and thus account for all emissions in the processing chain, from primary products and semi manufactures to finished products. In this way, the total emissions embodied in goods and services are computed for the different categories of final demand. For private and public consumption, the direct emissions must be added. The other categories of final demand are investments and exports, but for these, only emissions embodied in goods and services have to be included. By setting the calculated total emissions (direct and embodied in goods and services) of CO_2, SO_2, and NO_X in relation to private and public consumption, investments and exports, emission multipliers are obtained for each of these demand categories. The emission multiplier of total final demand becomes a weighted average of these multipliers. The effect on the emission/GDP ratio of changes in the composition of final demand can thus be studied.[2] Considering the fact that emission intensities of production differ between the emissions trading and the emissions non-trading subsectors, in calculating emission multipliers of the various demand categories, gives us the shares of emission multipliers attributed to emissions trading subsectors. The effect on the emission/GDP ratios of policy instruments or other factors affecting the emissions trading subsectors could, thus, be foreseen by the use of this information.

The emissions intensities of total aggregate demand have fallen considerable over the period 1991-2000, and decreased by 32 %, 31 % and 21 % for CO_2, NO_X and SO_2 emissions, respectively. Considerable differences in the magnitudes of emission multipliers amongst the four components of aggregate demand can be observed in Table 1. The highest multipliers are noted for exports in 1991, which can be explained by Sweden's traditional reliance on energy intensive products in its exports - pulp, paper, and paper products and primary metals. This situation, however, dramatically changed with the introduction of environmental policy instruments during the period 1991-2000, in the direction of reducing emissions in the production of goods and services. Although, the emission multipliers of private consumption also reduced significantly, those of exports reduced at a higher rate and, thus, exports became less emission intensive than private consumption during this period. The combustion of motor fuels by households for private transportation makes private consumption having high

[2] The emission multiplier of final demand is always lower than the emission/GDP ratio because satisfaction of the aggregated demand requires imported products in addition to domestic products (GDP), but only the production of the latter causes emissions in Sweden.

emission multipliers. The component of aggregated demand noted for the lowest emission multipliers is public consumption.

Table 1 Emission multipliers and multiplier shares of emissions trading sectors.*

	1991			2000					
	CO_2	SO_2	NO_x	CO_2		SO_2		NO_x	
Private consumption	192	126	187	150	*(22)*	98	*(19)*	114	*(4)*
Public consumption	63	57	48	29	*(13)*	43	*(5)*	47	*(2)*
Investments	79	64	90	75	*(35)*	57	*(26)*	94	*(6)*
Exports	213	245	194	100	*(53)*	143	*(39)*	106	*(18)*
Total	146	126	144	100	*(34)*	100	*(29)*	100	*(10)*

*Index of emission multiplier and (multiplier share in per cent). Index of total final demand in 2000=100.

Variations in the composition of final demand could *per se* lead to significant changes in the emission multipliers for total aggregate demand - and thus affect the emission/GDP ratios. A demand shift in the direction of an increased share of exports, but a decreased share of private consumption increases the emission multipliers of total demand, and the emission/GDP ratios, according to the 1991 figures but not according to the 2000 figures. The emissions trading sectors are much more intensive in the emitting of CO_2 than in the emitting of SO_2 and NO_X (in particularly) for all components of final demand as shown in Table 1 by the figures in parenthesis. This fact implies that an increased demand of goods and services produced by the emissions trading sectors affects the emissions of CO_2 much more than the emissions of SO_2 and NO_X, while the opposite is true for goods and services produced by the emissions non-trading sectors.

5 Emission goals, emission projections and the effects of carbon trading

The analysis above emphasizes that shifts in the composition of aggregated demand influence the emission intensities of the Swedish economy. By linking the figures of emission multipliers for aggregated demand presented in Table 1 to the economic scenario used by SEPA (2004) (the column labelled *Economic* in Table 2) for its emission projections of 2010 and 2020, we find its environmental implications to be in conflict with the environmental goals of reduced CO_2, SO_2 and NO_X emissions in Sweden for these years (the column labelled *Emission goal*). Furthermore, assuming economic activity in 2010 and 2020 to be much less emission intensive than in 2000, as in the SEPA projections, (the column labelled *Emission*) the emissions resulting will still conflict with the emission goals except for the SO_2 emissions in 2010.

The economic development outlined in the projections means that domestic and foreign demand will grow at about the same rate to 2010 but domestic demand will shift away from public services and towards consumer goods, which are of foreign rather than domestic origin. The shares of public consumption, investments and exports drop by 2.1%, 0.1% and 0.3% of final demand, respectively, from 2000 to 2010, whereas the shares of private consumption and imports increase by 2.5% and 2.1 %, respectively. Foreign demand will grow at a higher rate than domestic demand, which continues to shift away from public services and towards consumer goods of foreign origin until 2020. The shares of private consumption, investments, exports and imports increases by 2%, 0.2%, 3.2% and 8.8%, respectively, whereas the share of public consumption decreases by 5.5% of final demand during the period 2000-2020. An application of the emission multipliers computed for 2000, and presented in Table 1, gives that these substantial changes in the composition of final demand will increase the emission/GDP ratios of 2010 and 2020 compared to that of 2000, as shown by the figures in Table 2 (the column labelled *Economic*). [3]

Table 2 Emissions in relation to real GDP in SEPA projections and emission goals.
Index 2000=100 in 2000 prices

Emission	**1991**	**2004**	**2010**			**2020**		
			SEPA projection		*Emisson goal*	*SEPA projection*		*Emisson goal*
			Economic	*Emisson*		*Economic*	*Emisson*	
CO_2	130	99	106	90	83	119	85	54
SO_2	268	95	104	77	89	119	64	57
NO_x	166	87	105	64	56	118	51	36

The macro economic development outlined in the SEPA projection does not conform to the reductions of the emission/GDP ratios put up as environmental goals for Sweden in 2010 and 2020. The environmental goals can be expressed as indices for the emission/GDP ratios in

[3]In addition, it should be said that to 2010 and to 2020 the GDP increases by 21% and by 40%, respectively, compared to 2000.

relation to the actual figures for 2000 as shown in Table 2. The goal of CO_2 emissions to be attained in 2010 corresponds to a 4% reduction of the emission level in 1990, and happens to coincide with the actual CO_2 emission level in 2000. Hence, the emission level of 2000 must not be exceeded in 2010. The CO_2 emission level of 2010, however, will exceed that of 2000 unless the CO_2/GDP ratio decreases by 17% to offset the impact of economic growth, assumed to be 21% in the projection, during the period 2000-2010. Correspondingly, the NO_x/GDP and SO_2/GDP ratios must decrease by 44% and 11%, respectively, as given by comparing the 2000 indices with those of 2010 in the column labelled '*Emission goal'* in Table 2, to offset the impact of economic growth and attain the government's goals of NO_x and SO_2 emissions. Without reductions in the emission multipliers of aggregated demand, the CO_2/GDP, SO_2/GDP and NO_x/GDP ratios will increase by 6%, 4% and 5%, respectively, to 2010. The corresponding environmental goals will thus be exceeded by 28%, 17% and 88%, respectively, given the economic perspectives, as can be seen by relating the relevant figures for 2010 in the columns labelled '*Economic'* and '*Emission goal'* in Table 2.

The government's goal of CO_2 emission in 2020 corresponds to a 25% reduction of the 1990 emission level and, thus, corresponds also to 75 % of the CO_2 emission level in 2000. For the NO_x and SO_2 emissions, the Swedish government has not yet decided upon any goals for 2020, but by applying the SO_2/CO_2 and NO_x/CO_2 ratios for the CO_2 emission goal in 2010 to that in 2020, we might construct the goals of NO_x and SO_2 emissions for 2020 as given in Table 2. It should be pointed out that the constructed goals are conservative compared to the NO_x and SO_2 emissions projected for Sweden in the CAFE program, reported by SEPA (2006), which assumes reduced SO_2/CO_2 and NO_x/CO_2 ratios in 2020.

In following the SEPA projection for 2020, economic growth is assumed to be 40% compared to 2000 and thus the CO_2/GDP ratio must decrease by 46% compared to the ratio in 2000 to attain the goal of CO_2 emissions in 2020, as shown by the figures in the column '*Emission goal*' of Table 2. Correspondingly, the NO_x/GDP and SO_2/GDP ratios must decrease by 64% and 43%, respectively, to attain the goals of NO_x and SO_2 emissions in 2020. Without reductions in the 2000 emission multipliers of aggregated demand, the CO_2/GDP, SO_2/GDP and NO_x/GDP ratios will increase by 19%, 19% and 18%, respectively, to 2020. The corresponding environmental goals will thus be exceeded by 120%, 109% and 228%, respectively, given the economic perspectives, as can be seen by relating the relevant figures for 2020 in the columns labelled '*Economic'* and '*Emission goal'* in Table 2.

Although, the emission multipliers of aggregate demand decrease in coherence with the SEPA emission projection as shown by the column labelled '*Emission*' in Table 3, a further decrease is demanded to attain the emission goals, except for the SO_2 emission goal, in 2010 as shown by the column labelled '*Emission goal*' in Table 3. The decreases of emission multipliers are found to be substantial compared to historical changes of the emission multipliers for aggregate demand observed during the periods 1991-2000 and 2000-2004, also shown in Table 3. The period 1991-2000 is characterized by the novelty of introducing policy instruments for reducing emissions, and thus a large potential for emission reductions was realized during this period. It is far from an obvious fact that such large emission reductions will take place also in the future, without introducing strong policy instruments, as indicated by the more modest rates of emission reductions noted for the period 2000-2004 in Table 3.

By using the SEPA emission multipliers of aggregated demand, the CO_2/GDP, SO_2/GDP and NO_X/GDP ratios, shown in the column '*Emission*' of Table 2, decrease by 10%, 23% and 36%, respectively, during the period 2000-2010. The environmental goals will still be exceeded by 8% and 14% for the CO_2/GDP and NO_X/GDP ratios, respectively, but the SO_2/GDP ratio will fall below its goal by 13% according to the figures given in the columns labelled '*Emission*' and '*Emission goal*' in Table 2 for the SEPA projection 2010[4]. Correspondingly, the emission goals will be exceed with 57%, 12% and 42% for the CO_2/GDP, SO_2/GDP and NO_X/GDP ratios, respectively, in the SEPA emission projection of 2020 as given by relating relevant figures in the columns labelled '*Emission*' and '*Emission goal*' in Table 2.

Table 3 Development for emission multipliers of aggregate demand.
Yearly rates of changes in per cent.

Emission	**1991-2000**	**2000-2004**	**2000-2010**			**2000-2020**		
			SEPA projection		*Emisson goal*	*SEPA projection*		*Emisson goal*
			Economic	*Emisson*		*Economic*	*Emisson*	
CO_2	-4.6	-0.2	0	-1.6	-2.4	0	-1.7	-3.9
SO_2	-4.2	-1.2	0	-3.0	-1.5	0	-3.1	-3.6
NO_x	-4.3	-3.5	0	-4.9	-6.1	0	-4.1	-5.7

[4] The SO_2 and NO_X emissions are projected for Sweden in the CAFE program.

Adaptation to a price rise of energy brings about investments in energy conservation and thus helps to reduce emissions. Also, energy conserving technology will be introduced in production processes by normal replacement investments, especially in energy intensive production. This assertion is supported not only by economic theory but also by historical and statistical data examined in the numerous energy studies published during the 1980s and 1990s. An increase in the real price of oil, at an annual rate of about 2.6% to 2020, instead of the decrease assumed in the SEPA projection, would of course help to reduce emission/GDP ratios. An oil price increase of 1% must bring down combustion of fossil fuels, and thus the CO_2/GDP ratio, by about 0.7% and 0.8 % to attain the CO_2 emission goals of 2010 and 2020, respectively. The SO_2/GDP and NO_x/GDP ratios will also decline in this situation.

Irrespective of oil price changes, the carbon emission target could be attained in a cost-effective way by a policy that makes use of the EU system of CO_2 emissions trading and has a procedure of not accounting for traded emissions in fulfilment of the target. The amount of emission permits grandfathered by this policy leaves the projected CO_2 emissions of the emissions non-trading sectors unaffected in attainment of the carbon emissions target. Projected CO_2 emissions for the emission trading sectors will in this case exceed the amount of grandfathered emission permits and the difference is assumed to be covered by purchasing emission permits within the EU trading system. The import of CO_2 permits, however, will not reduce combustion in the emissions non-trading sectors and thus the SO_2/GDP and NO_x/GDP ratios will not decrease by this policy in contrast to the effect of an increase in the oil price. An alternative policy where the emission trading sectors are grandfathered emission permits equal to their projected CO_2 emissions, will demand that CO_2 emissions reduce for the emissions non-trading sectors, e.g. by rising the CO_2 tax, to attain the target for the CO_2/GDP ratio. This policy will reduce combustion in emissions non-trading sectors and thus help to reduce the SO_2/GDP and NO_x/GDP ratios and very much so as the production of emission non-trading sectors are much more SO_2 and NO_x intensive than that of emission trading sectors.

The effects on CO_2/GDP, SO_2/GDP and NO_x/GDP ratios of these two policies can be illustrated and compared by combining the emission multiplier shares and the emissions/GDP indices presented in Table 1 and Table 2, respectively. The index of the CO_2/GDP ratio reduces to 90 compared to an index of 100 in 2000 in the emission projection for 2010 and the emissions trading and non-trading sectors contributed with 31 and 59, respectively, as shown in the column *'SEPA emission projection 2010'* of Table 4. The corresponding figures are 77, 18 and 59 for the SO_2/GDP ratio and 64, 8 and 56 for the NO_X/GDP ratio. It is obvious, from these figures, that the SO_2 and NO_X intensities of the Swedish economy are dominated by the emission non-trading sectors. The emissions trading sectors account for only 25% and 10 % of the SO_2/GDP and NO_X/GDP ratios, respectively, but for 34% of the CO_2/GDP ratio.

Table 4 Effects of emission trading on the emission/GDP ratios when not accounting for traded permits in the CO_2.goal. Index 2000=100.

Emission	**SEPA emission projection 2010**			**Grandfathering is used to attain the CO_2 goal**			**Grandfathering equals projected CO_2 emissions**		
	Total	*Trading sectors*	*Non-trading sectors*	*Total*	*Trading sectors*	*Non-trading sectors*	*Total*	*Trading sectors*	*Non-trading sectors*
CO_2	90	31	59	83	24	59	83	31	52
SO_2	77	18	59	77	18	59	70	18	52
NO_x	64	8	56	64	8	56	57	8	49

The CO_2/GDP ratio must reduce from 90 to 83 in order to attain the CO_2 goal as shown in the column *'Grandfathering is used to attain the CO_2 goal'* of Table 4. A reduction of the emissions trading sectors' contribution to the CO_2/GDP ratio from 31 to 24, would achieve this goal. By grandfathering the reduced amount of emission permits to the emission trading sectors, the CO_2 goal can be accomplished with the policy of not accounting for additional amounts of CO_2 emission permits eventually bought from the EC trading system to regain a contribution of 31 to the CO_2/GDP ratio by these sectors. The emission ratios for NO_X and SO_2 are not affected by this procedure as there will not be any reduction in the combustion of fossil fuels, and, hence, the NO_X/GDP ratio of 64 will exceed the emission goals and the SO_2/GDP ratio 77 will fall below the emission goals by 14% and 13%, respectively.

The alternative policy of not using imported emission permits to attain the CO_2 goal, i.e. by grandfathering the amount of emission permits equal to projected emissions for the emission trading sectors, and retain the contribution of emissions trading sectors at 31. To attain the goal of 83 for the CO_2/GDP ratio in this case, the contribution to the CO_2/GDP by the emission non-trading sectors must be reduced from 59 to 52, e.g. by a raised CO_2 tax for these sectors, as shown in the column *'Grandfathering equals projected CO_2 emissions'* of Table 4. This will in turn reduce combustion in these sectors' and thereby their contributions to the SO_2/GDP and NO_x/GDP ratios also reduce from 59 to 52 and from 56 to 49, respectively, assuming constant SO_2/CO_2 and NO_x/ CO_2 ratios. The effects of these reductions on the total SO_2/GDP and NO_x/GDP ratios, which reduce from 77 to 70 and from 64 to 57, respectively, are large due to the high SO_2 and NO_x intensities of production in the emissions non-trading sectors. Now, the total NO_x/GDP ratio comes close to the emissions goal, which is exceeded by just 2% (compared to 14%) and the total SO_2/GDP ratio falls further below the emission goal by 21% (compared to 13%). These divergences in the NO_x/GDP and SO_2/GDP ratios correspond to increases of the NO_x/GDP and SO_2/GDP ratios by 12 % and 8 %, respectively, for the policy of using imported emission permits to attain the CO_2 goal compared to the alternative policy. A corresponding analysis for the emissions projection of 2020 would further emphasize the different effects on NO_x/GDP and SO_2/GDP ratios between these two policies, as the emissions must reduce to much lower levels in 2020 to attain the emission goals.

6 Conclusions

The composition of aggregate demand developed in the direction of increasing emission intensities of the Swedish economy during the 1980s. A reallocation of real expenditures away from emission intensive exports together with an introduction of policy instruments, which reduce emissions, seemed to be the solutions for bringing down the emission intensities of the Swedish economy during the 1990s. In retrospective, economic growth did not follow this path but continued to be driven by increased demand for Swedish exports. The emission/GDP ratios, however, reduced as the emission multipliers of final demand, and in particular that of exports, decreased due to the introduction of a number of policy instruments affecting the fossil fuel combustion in production of goods and services. A new situation developed during the 1990s and today an economic growth driven by increased foreign demand will not increase but decrease the CO_2 emission intensity of the Swedish economy. Also, the intensities of SO_2 and NO_x emissions have decreased for exports and are close to those of domestic demand, and a reallocation of real expenditures will change the economy’s emissions intensities in a much less extent today than in the beginning of the 1990s.

Although, the emission multipliers are assumed to continue to decline at rates comparable with historical rates of the 1990s but well exceeding the rates of the early 2000s, as in the SEPA projections, the future emission goals of 2010 and 2020 will not be attained, except for the SO_2 emission goal of 2010. Attaining these goals without powerful emissions policy requires a considerable increase in the real energy price and an extraordinary adaptation to this price rise. A continuing fall in real oil prices would of course affect the CO_2/GDP, SO_2/GDP and NO_x/GDP ratios in an opposite direction and would then further emphasize the need for powerful emissions policy. A cost-effective policy instrument for attaining Sweden's CO_2 emissions goal would be the purchase of emission allowances within the EU trading scheme instead of reducing domestic CO_2 emissions at a higher cost. To grandfather an amount of emission allowances less than actual CO_2 emissions of the emissions trading sectors and account only for grandfathered, but not imported, emission allowances in the CO_2 emissions goal might then become an attractive climate policy. Such a policy would not reduce fuel combustion in Sweden and, hence, not affect the SO_2/GDP and NO_x/GDP ratios. In contrast, a policy where the emission trading sectors are grandfathered emission permits equal to actual CO_2 emissions would demand reduced CO_2 emissions for the emission non-trading sectors, e.g. by rising the CO_2 tax, to attain the goal for the CO_2/GDP ratio. Such a policy would reduce combustion in Sweden and, thus, reduce also the SO_2/GDP and NO_x/GDP ratios with 8% and 12%, respectively, compared to the policy of purchasing emission allowances.

The advantage of a climate policy, which rests on international CO_2 permit trading, thus, becomes less evident when taking into account also the effects on health and labour productivity steaming from reduced NO_x emissions through less combustion of fossil fuels, as concluded also by Östblom and Samakovlis (2007). A climate policy that advocates domestic reductions of CO_2 emissions is to prefer, from this point of view, to a policy that rests on buying CO_2 reductions on the international permit market. The total costs of Sweden's climate policy, however, is reduced in the case of international trading of CO_2 permits compared to domestic reductions of CO_2 emissions, as reported by the Government's commission on flexible mechanisms of the Kyoto protocol (SOU 2003:60) and by Östblom (2003). To take advantage of the cost reductions through international CO_2 trading in the climate policy without having the disadvantages of not reducing the SO_2 and NO_x emissions calls upon policy instruments decoupled from climate policy and exclusively aimed at reducing these emissions, which are harmful to human health and contribute to the acidification and eutrophication of grounds and water streams.

Appendix

Classification of industrial subsectors.

Subsector label	*NACE Rev.1**
Emissions trading sectors	
Electricity., gas and heating	40
Mineral products	26
Primary metals	27
Refineries	23
Pulp, paper and paper products	21,22
Emissions non-trading sectors	
Transportation	60-64
Mining	13
Fishery	05
Agriculture	01
Forestry	02
Chemicals	24
Construction	45
Other industries	15-20
Engineering	28,37
Water and sewage	41
Private services	70,75,80-85,90-95
Business services	50-52,55,65,66,71-74

*Nomenclature Général des Activités Economiques dans les Communautés Européennes. The statistical classification of economic activities in the European Community amended in March 1993.

References

Cadarso, A. and Fernández-Bolanos, A, (2002), *Patterns of Growth and Consumption and Their Influence on the Environment in Spain,* Paper presented at the Fourteenth International Conference on Input-Output Techniques, 10-15 October 2002, Montréal, Canada.

Carter, A. P. (1970), *Structural Change in the American Economy*, Harvard University Press, Cambridge, Mass.

Creedy, J. and Sleeman, C, (2005), *Carbon Dioxide Emissions Reductions in New Zealand: A Minimum Disruption Approach,* Research paper No 933, Department of Economics, The University of Melbourne, Australia.

De Hann, M., (2001), ”A structural decomposition analysis of pollution in the Netherlands”, *Economic Systems Research,* 13(2),pp. 181-196.

Herendeen, R. A. (1978), Input-Output techniques and energy cost of commodities, *Energy Policy*, Vol. 6 No. 2, pp 162-165.

Government Bill 2004/05:150, *Environmental Quality Objects*, Stockholm.

Government Bill 2005/06:172, *National Climate Policy in Global Cooperation*, Stockholm.

Government Bill 2006/07:1, *The Spring Fiscal Policy Bill 2007*, Stockholm.

Proops, J. L., Faber, M. and Wagenhals, G., (1993), *Reducing CO_2 Emissions. A comparative Input-Output Study for Germany and the UK,* Springer-Verlag, Berlin.

NIER (2006), *The Swedish Economy*, December 2006, The National Institute of Economic Research, Stockholm.

Gerilla, G., Shigemi, K. and Hajime, I, (2001), “Projection of the Change in Technology and Its Implication on Environmental Emissions in Japapn”, *Journal of the Eastern Asia Society for Transportation Studie*,Vol.4, No. 6, pp 135-150.

SEPA (2004), *Sveriges klimatstrategi*, (in Swedish), The Swedish Environmental Protection Agency, Stockholm.

SEPA (2006), *Genomförande av EU:s utsläppsdirektiv (2001/81/EG), en lägesrapport för Sverige 2006*, (Memograph in Swedish), The Swedish Environmental Protection Agency, Stockholm.

SOU 2003:60, *Handla för bättre klimat*, (in Swedish), Report by the Government’s commission on flexible mechanisms of the Kyoto protocol, Stockholm.

The National Emission Ceilings Directive (2001/81/EC), http://eur-lex.europa.eu/LexUriServ/site/en/oj/2001/l_309/l_30920011127en00220030.pdf

Östblom, G (1982) "Energy use and structural changes: factors behind the fall in Sweden’s energy output ratio", *Energy Economics*,.Vol. 4, No. 1, pp 21-28.

Östblom, G (1993) "Increasing foreign supply of intermediates and less reliance on domestic resources: The production structure of the Swedish economy, 1957-1980",in *Empirical Economics*,.Vol. 18, Issue 3, pp 481-500.

Östblom, G (1998) "The environmental outcome of emissions-intensive economic growth: A critical look at official growth projections for Sweden up to the year 2000",in *Economic Systems Research*,.Vol. 10, No. 1, pp 19-29.

Östblom, G (2003, "Vinner Sverige på att delta i utsläppshandel?", (in Swedish), *Ekonomisk Debatt*, 31, no. 8.

Östblom, G. and Samakovlis, E., (2007), ”Linking health and productivity impacts to climate policy costs: a general equilibrium analysis”, *Climate Policy*, Forthcoming.

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