Costs of Climate Policy when Pollution Affects Health and Labour Productivity A General Equilibrium Analysis Applied to Sweden

Göran Östblom and Eva Samakovlis

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NIER
Kungsgatan 12-14
Box 3116
SE-103 62 Stockholm
Sweden
Phone: 46-8-453 59 00, Fax: 46-8-453 59 80
E-mail: ki@konj.se, Home page: www.konj.se

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Abstract

Much of the debate over global climate change involves estimates of the direct costs of global climate change mitigation. Recently this debate has included the issue of ancillary benefits. These benefits consist mainly of health improvements. Although it is generally acknowledged that air pollution affects respiratory health, and that valuations of these impacts make up a significant proportion of the damage costs of air pollution, these impacts are often neglected when evaluating the costs of climate policy. Since reducing greenhouse gases has the effect of also reducing other pollutants affecting human health and labour productivity these effects should be taken into consideration. The analysis incorporates a linkage between air pollution and health effects into a general equilibrium model for Sweden through a theoretical consistent framework. Results from recent Swedish concentration-response and contingent valuation studies are used to model direct disutility and indirect health effects that negatively affects the productivity of labour. The costs of feedback effects on health and productivity are compared in three different scenarios for attaining the Swedish carbon dioxide target with alternative projected emission levels in the baseline scenario as well as alternative harmful emission levels. Results show that not including feedback effects could mean overstating the costs of climate policy. The magnitude of these effects are, however, very sensitive to projected emission levels and to the judgement of harmful emission levels.

Keywords: air pollution, ancillary benefits, climate policy, general equilibrium, health

JEL Codes: D58, I10, Q52, Q53

1. Introduction

The analyses of policies for greenhouse gas (GHG) abatement have focused on their potential for reducing the rate of increase in atmospheric concentrations, and the associated costs of the abatement. Recent research, however, has emphasized the importance of the, so-called, ancillary benefits. These benefits accrue as a side effect of targeted policies and are also known as secondary benefits, policy spill over effects or co-benefits. Ancillary benefits from GHG mitigation policies have been defined as the social welfare improvements from GHG abatement policies other than those caused by changes in GHG emissions, which incidentally arise because of mitigation policies (Davis et al. 2000). The Intergovernmental Panel on Climate Change raised the issue of ancillary effects of climate change policies in its Third Assessment Report (Markandya and Halsnaes 1999, Munasinghe 2000).

For example, measures to reduce carbon dioxide (CO_2) emissions, such as a tax on the carbon content of fuel, may also reduce other pollutants that are associated with fossil fuel combustion e.g. nitrogen oxides, particulate matter and sulphur dioxides.[1] This in turn will have a positive effect on local air quality, which is beneficial also to health. Health effects represent the most important category of ancillary benefits from climate policy, and they typically account for 70-90% of the total value of ancillary benefits (Aunan et al. 2000, Ayres and Walter 1991, Heintz and Tol 1996).[2] The health effects are generally separated into mortality impacts, where the primary endpoint is death, and morbidity impacts, where the endpoint is a nonfatal illness. Mortality benefits are the most studied endpoint, even though severe health outcomes only represent the "tip of the iceberg" (Davis et al. 2000). To incorporate less severe adverse health effects and thereby include most people affected by air pollution, our analysis focuses on reduced morbidity in terms of decreased respiratory restricted activity days.[3]

There has generally been a lack of interface between large-scale economic modellers and ancillary effects experts (Davis et al. 2000). The present analysis will try to bridge over this gap by including the results of recent concentration-response analysis and willingness to pay study, into a general equilibrium framework. The main purpose of the analysis is to evaluate Swedish climate policy through calculating social costs of GHG emission reductions taking into account ancillary health benefits. Measures to reduce GHG emissions are linked to nitrogen oxide (NO_x) emissions, which cause direct disutility and indirect health effects negatively affecting the productivity of labour, and incorporated into the applied static general equilibrium model, EMEC.[4] An advantage with our set up is that all analyses are made on Swedish data, and no meta-analyses transfers are needed, which decrease some of the uncertainty usually involved in calculations of this kind. The baseline assumptions are critical in the estimation of ancillary benefits of GHG policies (Morgenstern, 2000). An important issue, addressed here, is that the magnitude of health effects associated with GHG reduction policies depends on the assumptions made about the NO_x/carbon ratio. In a fixed coefficient modelling approach, the growth of energy demand determines the magnitude of health effects.

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[1] In the UK, the burning of fossil fuels is responsible for over 99% of SO_2 and NO_2, 97% of CO, 91% of particulate matter, 48% of methane and 38% of VOC, apart from CO_2 (Barker, 1993).

[2] Ancillary benefits could also involve ecosystems, land use and materials. Largely they remain non-monetised due to lack of information and uncertainty over dose-response relationships (OECD, 2002).

[3] Morbidity effects result in work loss days or reduced labour productivity, disutility from illness and medical expenses. Studies trying to monetary value health effects indicate that impacts make up a significant proportion of the damage costs of air pollution (e.g., EC-DG XII 1995, Holland et al. 1999, Markandya and Pavan 1999).

[4] Environmental medium term economic model.

This model approach often overstates the magnitude of health effects, as technical progress tends to improve air quality over time. On the other hand, a decreasing NO_x/carbon ratio over time could understate health effects. As the knowledge regarding future NO_x/carbon ratios is limited, we compare the results of these alternative approaches.

The issue of ancillary benefits are especially important to climate policy since there is evidence that they could be substantial[5] and that the locational source of GHG emissions actually matters when accounting for ancillary benefits. GHG policies also have significant economic effects, and by leaving out health effects in the calculations of costs and benefits, we miss important information for environmental policymaking. Williams (2002) shows theoretically, by use of a general equilibrium analysis, that this is especially true when health effects link to changes in labour productivity. He finds that the benefit-side tax interaction effect, results in a welfare gain when reduced pollution boosts labour productivity. Nevertheless, applied general equilibrium analyses of the effects from air pollution on labour productivity and consumer utility are rare. Bruvoll, Glomsr∅d and Vennemo (1999) use a general equilibrium model of the Norwegian economy to analyze how environmental damages to health, materials and nature affect the productivity of labour, capital and consumers' well-being. Their main findings are that environmental constraints have a modest effect on production, but that the effect on the welfare loss is significant. Nilsson and Huhtala (2000) analyse secondary environmental gains in a general equilibrium framework by assuming that the environmental taxes on sulphur and nitrogen emissions reflect the politically determined willingness to pay for a marginal reduction of these emissions. They find that, when accounting for secondary benefits, it may still be in the government's interest to decrease CO_2 nationally, instead of trading emission permits. Burtraw et al. (2003) focus on ancillary benefits through a detailed analysis of changes in NO_x emissions in the US electricity sector. Mortality and morbidity effects are incorporated using concentration-response functions. A major finding in their study is that a $25 per metric ton carbon tax would yield ancillary health-related benefits from NO_x reductions of about $8 per metric ton of carbon. Mayeres and Van Regemorter (2003) use the general equilibrium model, GEM-E3, for Europe, to analyze the importance of feedback effects in the form of health related benefits from a CO_2 tax. They include feedback effects through three channels; decrease in medical expenditure, increase in consumers' available time and increase in labour productivity. Their results indicate that the feedback impact is small, compared to the standard GEM-E3 model where health benefits are evaluated ex-post. In a similar general equilibrium framework Chung-I Li (2002) studies ancillary benefits of greenhouse gas mitigation for Thailand. Health effects are included through an exposure-response model. Results indicate that when ancillary benefits are taken into account, the impact on GDP is 45% less. As they recognize, their health evaluation relies on US data, which has the potential of over-estimating the effects.

The paper is organised as follows. First, we present a theoretical model, on which the general equilibrium analysis is based. In Section 3, health and productivity effects from NO_x are modelled in the general equilibrium model. The effects on health and labour productivity from climate policy are calculated in Section 4. Finally, Section 5 concludes the paper.

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[5] Ancillary benefits has been estimated to be anywhere from 30% to over 100% as large as direct abatement costs, according to a review of studies commissioned by the IPCC (Pearce et al., 1996; IPCC, 2001).

2. A theoretical background

Our analysis is based on a theoretical framework that takes into account health effects of air pollutants in a comprehensive welfare measure. A large number of theoretical studies concern the welfare properties of linear indices such as the national product.[6] Most of these studies are based on an influential paper by Weitzman (1976). He showed that, if an economy with a stationary technology follows the first best optimal path, an augmented net national product (NNP) measure is directly proportional to the present value of future utility facing the representative consumer.

In theoretical studies health is often modeled as a positive output (see, e.g., Navrud, 2001; Tolley et al., 1994) or as a capital stock in the utility function (Aronsson et al., 1994). This approach is constrained on the empirical level by the well-known difficulty of measuring and valuing human health. It is difficult to measure a positive value for "normal" health status in accounting terms, but there exist valuation methods suitable for estimating damage to health. The Handbook of National Accounting – Integrated Environmental and Economic Accounting suggests that pollution damage to human health needs to be valued using combined dose-response and willingness to pay methods (United Nations (2003), Chapter 9, 9.27-9.28). Therefore health impacts are modeled as disutility from illness and not as utility from health. The handbook further suggests that pollution damage to human health should be deducted from the net domestic product (NDP) to arrive at a damage adjusted net national income (NNI) measure (United Nations (2003), Chapter 10, 10.152). This is by no means intended to be a comprehensive measure of welfare, just a partial adjustment to illustrate how health effects from air pollution should be accounted for. We use a version of the model presented by Huhtala and Samakovlis (2003) where a production externality in the form of a flow of air pollutants cause both direct disutility and indirect welfare effects by negatively affecting the productivity of labor. Both these effects could be captured by the general equilibrium model, EMEC, in line with the model presented in this section.

Social welfare is maximized when consumers maximize their utility. Utility, $U(C)$, is derived from consumption, C, of a composite commodity, Q, whereas air pollution, P, cause disutility, $D(P)$. It is assumed that $U(C)$ is twice continuously differentiable, strictly concave and increasing in C and that $D(P)$ is twice continuously differentiable, convex and increasing in P. The effect of air pollutants on the productivity of labor is modeled with the function $\beta(P)$, where $\beta_P<0$. Without pollution, there is no productivity adjustment, or $\beta(P)=1$, but if pollution exists $P>0$, its impact on the productivity of labor is negative, or $\beta(P)<1$. The optimization problem of the society is to choose C and P in order to maximize aggregated net utility, discounted by a constant interest rate, r,

$$\max \int_0^\infty [U(C) - D(P)] e^{-rt} \, dt$$

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[6] Heal and Kriström (2001) summarize theoretical and empirical analyses on green accounting.

subject to:

$$\dot{K} = Q(K, L, P) - C - \delta K \tag{1}$$

$$K(0) = K_0 \tag{2}$$

$$\beta(P)\overline{L} = L \tag{3}$$

where K is the capital stock (K_0 is a given initial level of capital), δ is the depreciation rate of the capital stock, $\overline{L}$ is total labor available in the economy, L is labor input in production, Q is output of the composite commodity ($Q_K > 0,\ Q_L > 0,\ Q_P > 0$). The Lagrangian for the optimal control problem, i.e., the current value Hamiltonian plus the constraint on labor, is

$$L = U(C) - D(P) + \lambda[Q(K, L, P) - C - \delta K] + \omega(\beta(P)\overline{L} - L), \tag{4}$$

with λ and ω denoting the shadow price of capital and the Lagrangian multiplier for the labor constraint, respectively (in utility terms). The current value Hamiltonian can be interpretable as the Net National Income (NNI) in utility terms. Rewriting the Hamiltonian with a linearized utility function yields; $\overline{H} = U_C C - D_P P + \lambda \dot{K}$. If $\overline{H}$ is divided by the marginal utility of consumption, U_C, we obtain a linearized measure for *a damage adjusted NNI:*

$$\overline{NNI} = C - \frac{D_P}{U_C} P + \dot{K}\ . \tag{5}$$

The first and last term on the right-hand side of equation (5) sum to NDP as measured in the conventional accounts and equals NNI, ignoring flows with the rest of the world. The second term, $[D_P / U_C]P$, is an additional factor that adjusts NNI to reflect welfare effects of pollution, and captures the direct, perceived disutility of symptoms related to air pollutants.

An obvious implication of the above framework is that reduction in labor supply due to pollution does not justify a separate (extra) adjustment for the sake of a comprehensive NNI.[7] The reason is that this part of the overall pollution effects is already taken care of by the conventional NNP in that optimal output is already affected by the reduced labor supply. This is readily seen by rewriting (5) by use of equations (1) and (3).

$$\overline{NNI} = Q(K, \beta\overline{L}, P) - \frac{D_P}{U_C} P - \delta K \tag{5'}$$

Maximizing consumption, C, having a value of the marginal disutility of pollution, D_P, and considering the effect of pollution $\beta(P)$ on production, Q, in a general equilibrium framework will give a damaged adjusted welfare measure for various economic projections or policy assigns. The application of this procedure, however, rests on empirical estimates of D_P and $\beta(P)$ from dose-response and willingness to pay studies.

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[7] Defensive expenditures, devoted to the health care sector, should not be adjusted for either. If damage occurs and is remedied, the cost of the remedy forms part of the economy and the activity involved directly or indirectly adds to national income.

3. Modelling effects on health and labour productivity in the EMEC model

The model, EMEC, is an applied static general equilibrium model of the Swedish economy for analysis of the interaction between the economy and the environment.[8] Produced goods are exported and used, together with imports, to create composite commodities, which in turn are inputs in production, used for capital formation and additionally consumed by households. Production requires primary factors (three kinds of labour and fixed capital) as well as inputs of materials and energy. Carbon dioxide (CO_2), carbon oxide (CO), methane (CH_4), sulphur dioxide (SO_2), nitrous oxide (N_2O) and nitrogen oxides (NO_x) as well as eight metals are emitted by the use of materials and fuel inputs. In addition, households' consumption of fuels results in emissions to the air. The use of energy by firms and households is subject to energy- and pollution taxes. Total emission levels can be bounded in the model.

Disutility of pollution

The utility function *U(C)* is modelled in EMEC as a CES-utility function in the consumption goods, but we let the disutility *D(P)* of pollution be linear in the emissions of the pollutants.[9] Welfare measured at the models terminal year is thus consumption at the terminal year C^T and disutility at the terminal year $D(P^T)$ and in adherence with equation (5), the national income at the terminal year *T* is

$$\overline{NNI}^T = C^T - \frac{D_P}{U_C} P^T + (K^T - K^0)\,. \tag{6}$$

Taking the consumer price index, CPI^T, as the marginal utility of consumption, the marginal disutility of polluting emissions at terminal prices is D_P / CPI^T and $\overline{NNI}^T$ then becomes

$$\overline{NNI}^T = C^T - \frac{D_P}{CPI^T} P^T + (K^T - K^0)\,. \tag{6'}$$

The effect of pollution on labour's productivity

Labour supply working hours. The activity during a work hour might be respiratory restricted due to air pollution *P* by the factor *b(P)*. The productivity of labour will be reduced by the loss of working hours, *L*, which in turn affects output *Q(K,L,P)* and by referring back to equation (5'), the reduced output will be $Q(K, \beta \overline{L}, P)$, where β is *1-b(P)* and *b=0* for *P=0* and $0 < b \le 1$ for *P>0.*

In EMEC the production function *Q(L,K)* is a CES function:

$$Q = \left[(\gamma_1 \cdot L)^{1-1/\sigma} + (\gamma_2 \cdot K)^{1-1/\sigma}\right]^{\frac{1}{1-1/\sigma}},$$

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[8] A documentation of the model is presented in Östblom (1999).

[9] Bruvoll, Glosrød and Vennemo (1999) also uses a CES utility function that is additive in environmental services. A drawback of their analysis is, however, that they just arbitrarily assume that the welfare cost of air pollution equals one-half the cost from reduced labour productivity.

where Q is value added, L is hours worked, K is capital stock, σ is elasticity of substitution and γ_1 and γ_2 are calibration constants.[10] The corresponding labour demand function will be:

$$L = \gamma_1^{\sigma - 1} \cdot \left(\frac{PQ}{w} \right)^{\sigma} \cdot Q$$

where PQ is the price of value added and w is the hourly wage rate. In the case of respiratory restricted activity on labour's productivity, $Q(K, \beta\overline{L}, P)$, the corresponding functions will be:

$$Q = \left[\left(\gamma_1 \cdot (\beta \cdot \overline{L}) \right)^{1-1/\sigma} + \left(\gamma_2 \cdot K \right)^{1-1/\sigma} \right]^{\frac{1}{1-1/\sigma}}, \qquad (7)$$

and

$$\beta \cdot \overline{L} = \gamma_1^{\sigma - 1} \cdot \left(\frac{PQ}{w} \right)^{\sigma} \cdot Q \qquad (7')$$

with β defined as above.

Empirical estimates of having respiratory restricted activity days from pollution
The described effects on health and labour productivity are included into EMEC using nitrogen dioxide (NO_2) as an indicator of urban air quality and traffic pollution.[11] How these emissions effect labor productivity in terms of respiratory restricted activity days (RRAD) has been estimated in a concentration-response analysis by Samakovlis et al. (2004). The perceived disutility from respiratory restricted activity days (RRAD) has been valued in a contingent valuation study by Samakovlis and Svensson (2004).

In finding the marginal disutility of NO_2 emissions, D_P in equations (6) and (6'), we let k be the utility value of avoiding a respiratory restricted activity day (RRAD). Further, let r be the number of RRAD:s emanating from an increase of the NO_2 concentration with 1 $\mu g/m^3$ for a representative individual, and let the change in tons of emissions leading to this increase of the NO_2 concentration be ΔNO_2.

$$D_P = k \cdot r / \Delta NO_2 .$$

RRAD:s can be divided into minor and major days. A minor RRAD is defined as a day when you are affected from respiratory symptoms although not absent from work. On a major RRAD the symptoms are so serious that you need to stay at home. The willingness to pay (WTP) to avoid disutility of the symptoms is 151 SEK for a minor RRAD and 245 SEK for a major RRAD in 2003 prices (Samakovlis and Svensson, 2004). The share of minor RRAD:s

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[10] The notation differs from the model documentation by Östblom (1999) in order to correspond to the theoretical model. In the model documentation value added Q is denoted by *FV*, labour L by *AT,* capital K by *C*, the hourly wage w by *WT*, the price of value added PQ by *PFV*, the elasticity of substitution σ by *sfv* , and the calibration constants, *al* and *ac*, are denoted by γ_1 and γ_2.

[11] NO_2 has frequently been used as an indicator of urban air quality, see for example Forsberg et al (1993, 1997a, 1997b).

is 38 percent and the share of major RRAD:s is 62 percent and thus k is 209 SEK in 2003 prices.[12] The variables r and ΔNO_2 can be calculated from Samakovlis et al (2004):

- The percentage increase in the number of RRAD:s is 3.2 when the NO_2 concentration increases with 1 µg/m^3.
- Mean of RRAD:s during a two weeks period for people with RRAD:s is 5.36
- Share of people with RRAD:s in total population is 3.6 percent.
- A change in NO_2 emissions of 28 403 tons leads to a change of 1 µg/m^3 in the NO_2 concentration.

On a year basis, r, is calculated as 0.032*5.36*26*0.036 = 0.1605 and the marginal disutility of an increase in NO_2 emissions with 1 ton for a representative consumer can then be calculated as: $D_P = 209 \cdot 0.1605/28403 = 0.00118$. To have the social marginal health damage by a change in NO_2 emissions we must multiply with the population affected, Pop: $D_P = 0.00118 \cdot Pop$. We assume that 25 percent of the NO_2 emissions emanating from Swedish production and consumption contribute to the NO_2 concentration in Sweden.[13] Total direct disutility is then

$$D(P) = \frac{0.00118}{CPI^T} Pop \cdot 0.25P^T$$

where P^T is the terminal level of NO_2 emissions. This expression is the second term in equation (6'), which gives the adjusted NNI measure. In the model runs, we are interested in measuring the change in NNI compared to an emission standard or a harmful emission level and thus we substitute (P^T- P^S) for P^T in the expression above.

For the pollutant NO_2, the effect on labour productivity, β, might be calculated by the same data. The share of RRAD:s emanating from a NO_2 concentration of 1 µg/m^3 per working hour is: 5.36/14*0.036*0.032=0.000441. Minor RRAD's give a 10 percent effect on productivity compared to major RRAD's. The change in NO_2 emissions of 28 403 tons leads to a change of 1 µg/m^3 in the NO_2 concentration. We have the level of NO_2 emissions is P and thus $b(P)$ due to changes in the level of emissions in tons will be:

$$b = \left[(0.62 + 0.38 \cdot 0.1) \cdot \frac{0.000441}{28403} \right] \cdot 0.25P^T$$

and

$$\beta = 1 - 1.0216 \cdot 10^{-8} \cdot 0.25P^T$$

Here, we are interested in measuring the change in productivity compared to an emission standard or a harmful level of emissions and thus we substitute (P^T- P^S) or for P^T in the expression above and let $b(P^S)$=0 and thus $\beta(P^S)=1$.

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[12] Calculated as (151*0,38+245*0,62).

[13] The contribution of Swedish NO_2 emissions to the nitrogen deposition in Sweden is 17-20 percent according to Bertills and Näsholm (2000). The emissions of NO_2 to the air, assumingly, contribute with a higher percentage to the NO_2 concentration of city air affecting respiratory health.

4. Effects on health and labour productivity of climate policy

The Swedish government has the goal of reducing CO_2 emissions to 96 percent of those in 1990. The government has also signed the Gothenburg protocol of reducing NO_x emissions to 59 percent of those in 1990, although there is no specific policy attached to this goal. Since climate policy has the effect of reducing also NO_x emissions, which are harmful to human health, it thus contributes to improvement of health and labour productivity. Accounting for this effect when examining climate policy means that the costs of climate policy will reduce in terms of welfare losses. This cost reduction is, however, sensitive to the level of NO_x emissions in the base line scenario and to the choice of harmful NO_x emission levels.

Welfare losses, due to the reduction of CO_2 emissions, was estimated for Sweden by Nilsson (2002) and Östblom (2003) in applying the general equilibrium model EMEC to Swedish data for the period 1993 to 2010. Their calculations were made without any feedback effects from improved health. Östblom (2003) presented three different scenarios of the Swedish climate policy for attaining the Swedish CO_2 reduction target, and analyzed the effects compared to a base line scenario.[14] The present analysis builds on the same scenarios as Östblom (2003) but now with feedback effects, from improved health, which will alter the results. The reduction of CO_2 emissions will lead to less fuel consumption by firms and households. Fuel consumption will be differently affected between the scenarios, and thereby the improvements in health and labour productivity due to reduction of NO_x emissions.

As mentioned above, the reductions of NO_x emissions due to climate policy relates to the NO_x/carbon ratio. The potential for positive feedback effects on health, thus, depends very much on assumptions affecting this ratio. The potential for positive feedback effects on health by reducing NO_x emissions is higher when assuming today's NO_x/carbon ratio to prevail compared to assuming this ratio to decline, by abatement technical change or other means, so that NO_x emissions will be about the level of the Gothenburg protocol in 2010 (see figures in Table 1). The Swedish Environmental Protection Agency projects an emission level close to that of the Gothenburg protocol for 2010. [15] The potential for positive feedback effects on health also depends on assumptions regarding the level of NO_x emissions harmful to human health. This is not trivial since there is no consensus on which level of air pollution that has no effects on the lungs, although it has been shown that low levels of air pollution affect health.[16]

Table 1 Emissions of NO_x for 1996, 2000 and according to the Gothenburg protocol (GP)

Tons including emissions from international fuel bunkers by Swedish transporters

1996	2000	GP 2010
378 503	357 999	170 000

Source: Statistics Sweden and the Swedish Environmental Protection Agency

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[14] This scenario is taken from ”The 2000 Medium Term Survey of the Swedish Economy”.

[15] The Gothenburg protocol was signed by the Swedish government in 1997.

[16] See for example Gauderman et al. (2004).

To illustrate the impact of climate policy on the costs of feedback effects for different assumptions about the NO_x/carbon ratio in 2010 and the harmful level of NO_x emissions, we present the baseline scenario, scenario 1, scenario 2 and scenario 3 with basic assumptions as well as alternative assumptions. Scenario assumptions are summarized in Table 2. We assume basically, the NO_x/carbon ratio not to change and that NO_x emissions above the level of the Gothenburg protocol are harmful to human health. As alternative assumptions, the NO_x/carbon ratio decreases so that the level of NO_x emissions comes close to that projected by the Swedish Environmental Protection Agency in the base line scenario and, in addition, the harmful level of NO_x emissions is set to zero. Comparing scenarios 1, 2 and 3 with the base line scenario illustrates the feedback effect on human health of climate policy for basic assumptions or alternative assumptions. Comparing basic assumptions with alternative assumptions for baseline, scenario 1, scenario 2 or scenario 3 illustrates the effect of different assumptions about the NO_x/carbon ratio in 2010 and the harmful level of NO_x emissions.

Table 2 Scenario assumptions

	NOx/Carbon ratio		**Harmful NOx-level**	
	Basic assumption	*Alternative assumption*	*Basic assumption*	*Alternative assumption*
Base line	TODAY’S	DECLINE	GP	ZERO
Scenario 1	TODAY’S	DECLINE	GP	ZERO
Scenario 2	TODAY’S	DECLINE	GP	ZERO
Scenario 3	TODAY’S	DECLINE	GP	ZERO

In contrast to the base line, the three alternative scenarios have a national CO_2 target, which is achieved by the grandfathering or the auctioning of emission permits or by an emission tax equal to the auctioning price. In scenario 1, CO_2 emissions are reduced by use of permit auctioning or by a CO_2 tax common to all firms or households. In scenario 2 and 3, the national target is achieved by the grandfathering of emission permits to emission intensive industries while other industries and households will pay an emission tax. The number of permits grandfathered in scenarios 2 and 3 equals the number of permits bought by the trading sector in scenario 1 (the emission level of the trading sector in scenario 1). In addition, the emission intensive industries can trade the permits at a price of 30 USD per ton CO_2 with intra-EU trade and at 6 USD per ton CO_2 with global trade, (Permit prices are in 2001 USD, and correspond to 310 SEK and 62 SEK, respectively). The emission target is achieved by including the permits traded in scenario 2, while the target should be achieved exclusive of traded permits in scenario 3. This means that total emissions might exceed the national target by permits bought on an international market in scenario 2, as these emission reductions are accomplished in other countries. Emissions cannot exceed the national target in scenario 3, as the extra emissions in the trading sector due to emission permits bought on an international market must be counteracted for by reduced emissions in the non-trading sectors. This is accomplished by raising the CO_2 tax for the non-trading sector until the national target is reached.

The quantity of permits traded and the definition of the emission target is of importance for our estimation of health effects as emissions levels are affected, and thereby the fuels consumed by permit traders and none-traders. The none-traders, including the transportation sector and private transports by households, are emitting most of the NO_x. Therefore, changes in fuels consumed by this sector will have great impacts on health and productivity. A climate policy reducing CO_2 emissions and fuel consumption in the none-trading sector will induce larger effects on health and labour productivity, compared to a policy that reduces fuel emissions in the trading sector.

The effect on NO_x emissions of differences in climate policy is illustrated in Table 3 for the scenarios with basic baseline assumptions (Basic) and for the scenarios with alternative baseline assumptions (Alternative). In the base line scenarios no other measures than existing CO_2 taxes are taken to reduce CO_2 emissions, whereas in scenarios 1, 2 and 3 the emissions are reduced by other means than existing taxes.

Table 3 Emissions of CO_2 and NO_x for various climate policy scenarios 2010

	Baseline 2010	**Scenario 1**	**Scenario 2**		**Scenario 3**	
			30 USD	6 USD	30 USD	6 USD
CO_2 emissions, 1000 tons		Percentage changes compared to base line				
Trading sector	20 232	-13.5	-3.7	13.4	-3.7	13.4
Non-trading sector	42 562	-14.7	-14.7	-14.7	-19.3	-27.4
Total	62 794	-14.3	-11.1	-5.6	-14.3	-14.3
NO_x emissions, tons						
Total Basic	442 202	-13.4	-12.5	-11.3	-16.5	-22.3
Total Alternative	195 328	-12.2	-11.2	-9.7	-14.6	-19.3

In scenario 1, emissions of CO_2 are reduced by about the same percentage in the trading sector, as in the non-trading sector and in the total economy. Total NO_x emissions reduce by about the same percentage.

CO_2 emissions and fuel consumption increase for the trading sector in scenarios 2 and 3 due to permit trading. This leads to an increase of NO_x emissions for the trading sector in both scenarios. In scenario 3, the increase of CO_2 emissions in the trading sector is counteracted by reduced CO_2 emissions in the non-trading sector. This gives also significant reductions of NO_x emissions as it decreases fuel consumption in the transport sector and in private transportation. The scenario with the greatest reduction of CO_2 emissions for the non-trading sector will also have the greatest effects on health and labour productivity due to large reductions of NO_x emissions in the transport sector and in private transportation.

The costs of feedback effects, in terms of decreased labour productivity (captured by the NNI) and direct disutility (captured by adjusted NNI), estimated with basic assumptions are presented in Table 4for the baseline and the three climate policy scenarios. The costs to the Swedish society of these effects would be 1.45 milliards SEK as measured by the damage adjusted NNI for the baseline scenario 2010.

Table 4 Costs of feedback effects on health and labour productivity (Basic assumptions)

Milliards of SEK in 2001 prices

	Baseline 2010	Scenario 1	Scenario 2		Scenario 3	
			30 USD	6 USD	30 USD	6 USD
	Differences compared to no feedback effects					
NNI	-0.99	-0.72	-0.85	-0.77	-0.67	-0.55
Disutility of NO_x	-0.46	-0.35	-0.36	-0.37	-0.32	-0.27
NNI damage adjusted	-1.45	-1.07	-1.21	-1.14	-0.99	-0.82

The reductions in costs of feedback effects due to climate policies are given by comparing the figures for scenarios 1, 2 and 3 with corresponding figures for the baseline scenario. The scenarios 1, 2 and 3 all show less costs of feedback effects on labour productivity and direct disutility of NO_x emissions, and thus climate policy could reduce society's costs due to feedback effects by 17 to 43 percent depending on the policy adopted. The greatest reduction of costs is for scenario 3, where climate policy has the greatest impact on reductions of NO_x emissions as was shown in Table 3. The smallest reduction of costs is for scenario 2, where climate policy has the smallest impact on NO_x reductions. From this point of view, a climate policy that concentrates on domestic reductions of CO_2 emissions, scenarios 1 and 3, is to prefer before a policy that rests on buying CO_2 reductions on an international permit market. Scenario 2 is, however, the scenario, where the definition of the national CO_2 target in combination with international trading of CO_2 permits give less costs of the climate policy amounting to 2 milliards SEK at a permit price of 6 USD and 5 milliards SEK at a permit price of 30 USD, according to Östblom (2003). The difference in cost for climate policy between scenarios 2 and 3 is reduced by 0.22 milliards SEK at a permit price of 30 USD and by 0.32 milliards SEK at a permit price of 6 USD taking into account feedback effects with basic assumptions (Table 4).

The effects on health and labour productivity of climate policy due to NO_x reductions depend on the difference between the actual level of NO_x emissions and the harmful level. The greater this difference, the greater the potential for secondary benefits from climate policy. The difference is affected by technological changes that reduce NO_x emissions in transport and heating activities but also of changes in the judgement of the harmful emission level. The actual level of NO_x emissions in turn depends on the level of NO_x emissions in the base line scenario.

In Table 5, the costs of feedback effects are calculated for the baseline and the three climate policy scenarios with the alternative assumption of a declining NO_x/carbon ratio, and the harmful level of NO_x emissions is assumed to be zero. The costs of feedback effects are significantly reduced compared to those shown in Table 4. Had we kept the harmful emission level at the emission level of the Gothenburg protocol, the costs of feedback effects had almost vanished in this case. On the other hand, had we set the harmful emission level to zero in the calculations presented in Table 4, with the higher level of NO_x emissions in the base line scenario, the costs of feedback effects had been close to the sum of the costs shown in Table 4 and Table 5.

Table 5 Costs of feedback effects on health and labour productivity (Alternative assumptions)

Milliards of SEK in 2001 prices

	Baseline 2010	Scenario 1	Scenario 2		Scenario 3	
			30 USD	6 USD	30 USD	6 USD
	Differences compared to no feedback effects					
NNI	-0,72	-0,59	-0,73	-0,58	-0,52	-0,53
Disutility of NO_x	-0,34	-0,29	-0,29	-0,30	-0,28	-0,26
NNI damage adjusted	-1,06	-0,88	-1,02	-0,88	-0,80	-0,79

If the harmful level is judged to be zero or that of the Gothenburg protocol and if technological changes do not accelerate significantly in reducing NO_x emitted in transport and heating, then the effects on labour productivity and health should be accounted for when evaluating the costs and benefits of climate policy. On the contrary, if the harmful emission level is judged the emission level of the Gothenburg protocol and if technological changes will significantly reduce NO_x emitted in transport and heating, then there will be almost no effects on labour productivity and health to be accounted for when evaluating the costs and benefits of climate policy.

5. Conclusions

The effects on health of air pollution are often neglected, when evaluating the costs and benefits of climate policy. By leaving out health effects, we miss important information for environmental policymaking, and this is especially true when health effects are linked to changes in labour productivity. In the analysis presented here an applied general equilibrium model EMEC, was used to calculate social costs of emission reduction taking into account also the costs and benefits of changes in productivity and human health. The relation between reduced labour productivity and pollution comes from an estimation of a concentration response relationship and the measure of disutility from pollution from a willingness to pay study. A damaged adjusted NNI measure was introduced and used for comparing social costs in the various scenarios of climate policy.

The reduction of society's costs due to feedback effects depends on the adopted climate policy. The greatest reduction of costs is when climate policy has the greatest impact on reductions of NO_x emissions. The advantage of a climate policy with international CO_2 permit trading, presented by Östblom (2003), becomes less pronounced when taking into account the effects on health and labour productivity of reduced CO_2 emissions. 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 climate policy, however, are 2-5 milliards SEK lower with international trading of CO_2 permits according to Östblom (2003). This difference in costs is here reduced by about 6 to10 percent when taking into account the feedback effects with basic assumptions, but could be neutralised depending on the price level of permits and the magnitude of health and productivity costs. A higher permit price and greater health costs could very well reverse the advantage for a scenario with permit trading in combination with a definition of the national emission target inclusive permits traded on the international market. This is because health effects cannot be traded.

The greater the difference between actual and harmful levels of NO_x emissions, the greater the potential for these effects from climate policy. If technological changes will reduce the level of NO_x emitted close to the harmful emission level, then there will be no effects on health and labour productivity of climate policy. Although, there could be secondary effects of reduced NO_x emissions due to climate policy, we find that the accounting for these effects will be very sensitive to the assumptions made about NO_x emissions in the base line scenario and about the harmful level of NO_x emissions.

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