HUB RESEARCH PAPER
Faculteit Economie & Management

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HUB RESEARCH PAPER 2008/12.
FEBRUARI 2008

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ASSOCIATIE K.U.LEUVEN

First draft.
February 2008

Moral considerations in trading pollution permits[1]

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Abstract

In this paper we investigate how moral considerations, modelled as identity effects, affects an endogenous pollution permit trading equilibrium, in which governments choose in a non-cooperative way the amount of permits they allocate to their domestic industries. Politicians might feel reluctant to allow unlimited permit trading and/or may prefer that abatement is undertaken domestically due to ethical motivation. However, once governments have chosen permit allocations, firms trade these permits in an international competitive permit market without moral restraints. We show that governments' moral concerns may actually increase global emissions but this result depends on the precise formulation of the identity function. Finally, we explore how exogenous technological change affects endogenous permit trading equilibria under identity considerations. We show that decreasing costs of abatement technologies may lead countries to overcome their reluctance to trading emission permits.

Keywords: *Tradeable emission permits, noncooperative game theory, moral motivation, identity, technological change.*

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[1] We are indebted to comments from Kjell Arne Brekke, Karen Evelyn Hauge, Karine Nyborg, Alistair Ulph and other participants at the Frisch Centre Klækken seminar (May 2007) and the CAS Workshop in Asker (August 2007).
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1. Introduction

In this paper we take a closer look at pollution permits when parties are reluctant to trade. Economists typically prefer trade in pollution permits over conventional, non market-based environmental policy instruments because of cost efficiency considerations. Both in theory (see, e.g. Montgomery, 1972) and in practice (see, e.g. Schmalensee et al., 1998), market-based policy instruments are known to foster cost efficiency in environmental policy making. However, permit trade has been opposed by many observers such as environmental organisations and political parties. Some consider trade in pollution permits as a way to try to avoid one's obligations, to pay others to clean up, or to pay indulgence, see Goodin (1994). In the Kyoto protocol for instance, trade in pollution permits is allowed, but only as a supplement to national mitigation.[4] This mechanism may have been introduced as a consequence of the majority of the signatories being reluctant to permit trading. Also in the European Emission Trading Scheme (ETS), access to buying emission reductions in third party countries (JI – Joint Implementation for economies in transition and CDM - Clean Development Mechanism for developing countries) can be limited by member states[5]. Thus, the cost-effective trade volume may not be within the possibility range. However, it seems to us that trading with pollution permits is more acceptable now than it was just 10-15 years back. In Norway for instance, environmental organisations are now trading carbon offsets on the internet (to offset carbon emissions from airline flights), even if they argued against pollution trade just a few years ago.

We will study the implications in a tradable permit market if there are moral concerns against permit trading. Especially, we focus on a norm saying that one should not engage too much in permit trading and to do most of the abatement at home, but we assume that countries are willing to trade off the norm if the benefits from doing so are large enough. First, we study how moral concerns may affect global emissions. Second, we will try to come up with an explanation why there seems to be a larger interest in permit trade now compared to some years ago. A larger interest in pollution permit trade may be due to a change in the norm so that it is more acceptable than before.[6] But there may also be another explanation. Although there may continue to exist some reluctance to trade, the benefits from trade may be higher than before. This paper will focus on the latter explanation. If we compare the economy today and 10-15 years back, one striking difference is the change in mitigation technology. Technology improves over time, in such a way that mitigation becomes cheaper. Therefore, we want to study how improvements in mitigation technology may affect the market for pollution permits trade if there is a norm that you should not trade permits. In other words we will study how a change in technology will affect the benefits from trade, and if the benefits may be larger than the costs of trespassing the norm.

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[4] Article 6.1 of the original Kyoto Protocol text states "The acquisition of emission reduction units shall be supplemental to domestic actions for the purposes of meeting commitments under Article 3". However, later meetings of the Conference of the Parties (CoP) have not been able to find a consensus on a more precise or quantitative meaning of this supplementarity requirement.

[5] More details on the latest proposed changes in the EU ETS 3rd phase (2013-2020) can be found at http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/08/35&format=HTML&aged=0&language=EN&guiLanguage=en. Although several scenarios are circulating (January 2008), it is clear that access to CDM and JI projects will not be unlimited.

[6] See, e.g., Nyborg and Rege (2003) for a study on changes in smoking norms.

Some forms of moral concerns about permit trade, but not all as shown in this paper, represent additional costs of trading and thus give rise to lower welfare from trade compared to the case in which these concerns are absent. Thus, introducing these moral concerns shares similarities with a permit trade system with transaction costs[7], see, e.g., Stavins (1995). With transaction costs, the volume of trade is lower and welfare is lower compared to a system without transaction costs. Also the initial allocation of permits may affect the outcome of trading. However, the presence of moral considerations about permit trade is different than transaction costs in several respects, which will be outlined in more detail below.

This paper is organised in the following way. We first discuss possible reasons behind the reluctance to trade pollution permits. In section 3, we present the model and derive conclusions on how identity considerations following from a norm against emission permit trading, change governments' behaviour in the permit trading market. Section 4 studies how a change in technology affects the decisions for countries to involve in emissions trading. Section 5 concludes.

2. Ethical reasoning, norms and identity

In economic theory, it is assumed that most goods can be bought or sold in a market. However, this may not always be the case and distaste, or even repugnance, for certain transactions may be a real constraint in many markets, see Roth (2008) for a survey.[8] This can be described as norms against trading certain goods. A norm is defined as a standard of right or wrong, and in all cultures there are goods that are considered to be "priceless" or "sacred" in such a way that we cannot set a price on them. Examples may be life, freedom, love, friendship, children, religion, democracy and the environment. Some of these goods are called taboo goods (Fiske and Tetlock, 1997) where a taboo is defined as a particular powerful kind of normative prohibition. Taboos are meant to protect individuals and societies "from behaviour defined or perceived to be dangerous" (Tannenwald, 1999), and breaking a taboo is usually met by social sanctions or repercussions. Incommensurability may also be a problem, meaning that there may not be a common measure to compare the goods (O'Neill, 1993, chapter 7). Some examples may be friendship or love. A market may destroy these goods, as setting a price on them may reduce their value. However, there are goods that may be traded, not met by the same strength of sanctions while traded as taboo goods, but still there is a norm against such trade. Examples may be legalized prostitution, body organs and military duty (Bénabou and Tirole, 2007; Roth, 2008). Some kinds of transactions are considered repugnant in some times and places, but not in others, thus the boundaries between the secular and the sacred are evolving over time. For instance slavery is an example of a market that used to exist in large parts of the world, but is now repugnant and illegal in most places. On the other hand, there has been more positive attitudes over time towards life insurance (Zeliner, 1999), legalized prostitution and also pollution permits.

Pollution permits has been recognised by several authors as a market where there may exist some reluctance or even repugnance against transactions, see, e.g., Goodin

[7] Roth (2008) compares repugnance to trade certain goods to a difficult technological barrier.

[8] Frank (1985), chapter 10, also gives several examples of why trade in certain goods should not be allowed.

(1994), Bénabou and Tirole (2007) and Roth (2008). Why may there be reluctance or a norm against trade in certain goods such as pollution permits?

In ethical reasoning, there are two ways to justify if an action is good or bad. The first is to refer to the *consequences* (teleology or substantive fairness). Based on this, an action is good if it is the best way to attain the aim we strive for (e.g, maximise welfare, reduce greenhouse gas emissions). Brekke et al. (2003) gives an example of moral reasoning based on teleology were people can pay an organisation instead of doing voluntary work. If they think that the payment is enough to pay professionals to do the job, they do not feel responsible anymore, and they may choose the market solution. But, if they think that the payment is not enough, they feel that they still are responsible for having the task done.

However, there may also be situations where we dislike giving others this responsibility, independent of the consequences for our welfare. This leads us to another way of moral thinking saying that *consequences alone do not guide us* whether something is right or wrong (deontology or procedural fairness). It is not enough to know that the action is the most effective way to attain the aim. One can for instance argue that industrialised countries have created the global warming problem, and that is our *duty* to reduce the consequences of it by cleaning up our own backyard, even if this is not the way that minimises overall costs of taking action. This could also be used as an argument against selling permits by developing countries as selling quotas to industrialised countries would not lead to abatement in the countries responsible for the problem. Another argument is based on *unfair background conditions* (see Kverndokk, 1995, and Eyckmans and Schokkaert, 2004). Even if two parties agree to trade permits, the trade may not be justified on ethical reasons. A voluntary agreement between two parties is not necessary fair if is entered into conditions that are not fair (Pogge, 1989). Background justice is not preserved when some participant's basic rights, opportunities or economic positions are grossly inferior. Under the Kyoto Protocol, for instance, one may argue that this is the case for some CDM contracts.

Economics is basically about consequences. If the consequences of the use of a policy instrument is positive (increasing welfare), we recommend it. This is the case with emission permits. The basic argument of quota trade is that it is cost-effective (Montgomery, 1972), thus parties involved in permit trade would get lower abatement costs than if they had to mitigate the emissions within their geographical boundaries. Thus, cost-savings will be welfare improving, everything else given. One possible explanation of the resistance of permit trade is therefore, that welfare improvements following from permit trade have not been communicated well enough, i.e., the standpoint is based on *lack of information*.[9]

However, other explanations may also be plausible. There may be negative consequences of a permit market, consequences that may be related to the aim of preserving the global environment, or it may be related more broadly to other areas of the society concerning, e.g., responsibility. Buying, via the CDM mechanism, greenhouse gasses pollution permits in countries that did not subscribe to binding emission limits in the Kyoto Protocol, may have some *adverse effects* based on lack

[9] One example based on lack of information pointed out to us by Alistair Ulph is as follows. If a country has extremely high marginal abatement costs (in the limit infinite: i.e., it cannot abate) then wanting to do all the abatement at home is just not sensible (ethically); it would seem more appropriate, for a country to use its resources to pay a country which can abate cheaply to do so.

of an emission baseline, moral hazard, lack of incentives to undertake emissions reductions by the developing countries, transaction costs and carbon leakages. There is also some discussion whether CDM's have the expected effect on emission reductions as some observers argue that the market is flooded by projects of questionable quality (Harvey, 2006, and Davies, 2007). *Hot air*, meaning that some countries get initial emission quotas that are higher than their actual emissions, has also been mentioned as a reason to avoid emission trading as trading hot air will not reduce emissions. Other arguments that have been raised in this debate are the positive *spillover effects* of technology development by national abatement as well as the *ancillary benefits* (reduction in local emissions, traffic accidents, congestion etc.) of abating at home.

Abating at home instead of buying emission permits, shares some similarities with *unilateral actions* taken by a country. Unilateral actions may be defended as a contribution in the right direction or as setting a good example. Hoel (1991) analyses effects of unilateral actions on harmful emissions, and concludes that in absence of a negotiated agreement, such a policy will typically lead to lower aggregated emissions than a selfish policy. But this policy may also affect the outcome of negotiations on emission reductions. Hoel concludes that the outcome may very well imply higher total emissions. However, if the unilateral action is announced as a commitment to reduce emissions in excess of the outcome of the negotiation, total emissions will likely be lower than only compared to the case where all countries act selfishly. Some arguments not analysed by Hoel and which may be in favour of unilateral action are that the action may lead to similar behaviour by other countries, it may affect the climate in international agreement positively, and it may reduce the conflict of interest within a country as it actually shows the true costs of abatement.

The discussion above provides arguments, based on both procedural fairness and consequentialist ethics, against permit trading. We will summarize this discussion by reducing it to two basic statements that we will formalize in our model: 1) countries might dislike permit trading, and 2) countries might prefer to do all the abatement at home. The first statement is weaker than the second as this does not necessary mean that countries care about the environment. However, reasons to avoid trading are often based on a preference for environmental values, and in the second claim, the major motivation is to save the environment, and to do that independent of international agreements and quota trade. We do not claim that these statements are true or that there are good ethical arguments against permit trading. However, we think that these statements may describe some of the reluctance that we observe in the political debate on permit trading.

The statements above may form a norm against trading pollution permits. Norms are closely related to the preservation of identity, and by modelling a norm against permit trade, we build on the theory of identity and moral motivation (Akerlof and Kranton, 2000, 2005; Brekke, et al., 2003). In this way we can model both the reluctance to trade with pollution permits, and given that the agent does not follow the norm, the wish to reduce the trade even if it is economically profitable.[10] As the reasons for trade reluctance may be based on both procedural fairness as well as consequences, we do not try to endogenise the norm in the model, meaning that we do not determine why a society chooses a certain norm against trade.

[10] An example of the last property can for instance be the supplementary condition in the Kyoto Protocol where the parties agreed that permit trade should only be a supplement to national abatement.

3. The permit trade model

Our framework is based on Helm (2003) who presented a model of international emissions trading in which countries choose the amount of permits they allocate to their domestic industry in an endogenous and non-cooperative way. We expand Helm's model by introducing explicit identity considerations. Countries are assumed to be reluctant to trade (large quantities of) emissions permits and/or may dislike the fact that they emit more than what they ideally think that they should do.

The model works in the following way. There are n countries or governments engaged in negotiations on a future international environmental agreement including provisions for pollution permit trading. The governments represent the view of the voters who are, to some extent, reluctant to trade permits. However, they are willing to trade if the benefits from trade are large enough. As in Helm (2003), we make the assumption that the permit trading regime is established only by unanimous approval of all countries. Allowing for endogenous coalition formation would substantially complicate the analysis as the countries are not symmetric in our analysis. Rather the difference between countries is essential here.[11] However, in section 4 we will study the decision to enter the trading club and how this is affected by technological change.

In the first stage, governments choose in a non-cooperative way their initial emissions allocation. Note that this setup resembles closely the reality of international climate negotiations, in particular in the run up to the 1997 Kyoto Protocol and in the coming negotiations on a follow up agreement for the post-Kyoto period. Another example is the EUs emission trading system (ETS) in the periods 2005-2007 (i.e., before the start up of the global Kyoto permit market period) and 2008-2012 (i.e., the first commitment period of the Kyoto Protocol). EU member states had to draft National Allocation Plans (NAPs) suggesting a permit allocation for all installation covered by the ETS directive on their territory.

In the last stage of the game, individual firms trade emissions in a competitive permit market. They have no other option than to obey the emission ceiling and they do not have any other goal than maximizing profit. Thus, we assume that firms do not have moral concerns about trading.[12]

This game is solved by backwards induction, i.e., we start be solving the last stage first.

3.1 STAGE 2: Firms trading emissions

We assume that in every country $i \in N = \{1, 2, \ldots, n\}$ there is a large number of identical firms that maximizes profits taking as given the emissions trading scheme:

[11] Symmetric or homogeneous countries is a common assumption in studies of coalition formation, see, e.g., Barrett (2005).

[12] This is consistent with Siebert (1992, p. 130) and Rauscher (2006) who argue that a firm spending resources on social activities not rewarded by the market will not remain competitive and will be driven out of the market. However, if firms have market power, non-profit motives can survive.

$$\max_{e_i} \quad \pi_i\left(e_i; p, \omega_i, \beta\right) = B_i\left(e_i;\beta\right) + p\left[\omega_i - e_i\right] \tag{1}$$

The benefits of emissions, B_i, can be interpreted as a production function. Producing value added requires, among others, input of carbon emissions. The benefit of emissions function is assumed strictly increasing and strictly concave in emissions: $B_i^e > 0$ and $B_i^{ee} < 0$. Benefits are depending also on a technology shift parameter β in such a way that $B_i^{\beta} < 0$ and $B_i^{e\beta} < 0$, hence marginal benefits of emissions decrease in the technology parameter β and, therefore, an increase in β can be interpreted as an efficiency improvement or a reduction of marginal emission abatement costs. Note that the technology parameter is not country specific, thus we assume that there are technology spillovers between countries. In Appendix 1, the properties of the benefit function are derived.

From the first-order condition for profit maximization, we can derive the demand for emissions: [13]

$$B_i^e\left(e_i;\beta\right) = p \quad \Rightarrow \quad e_i = E_i\left(p;\beta\right) = \left(B_i^e\right)^{-1}\left(p;\beta\right) \tag{2}$$

Profit maximizing behaviour by firms leads to *cost-effectiveness*: marginal benefits of emissions are equalised across firms. Thus, this condition is valid even if countries have moral arguments against permit trading, as such considerations are not taken into account by the competitive firms. This would not have been the case with transaction costs related to the volume of trade (Stavins, 1995).

Comparative statics of this expressions shows that emissions are decreasing in the permit price and in the technology parameter:

$$B_i^{ee} de_i + B_i^{e\beta} d\beta = dp \quad \Rightarrow \quad \begin{cases} \dfrac{\partial e_i}{\partial p} = E_i^p = \dfrac{1}{B_i^{ee}} < 0 \\ \dfrac{\partial e_i}{\partial \beta} = E_i^{\beta} = \dfrac{-B_i^{e\beta}}{B_i^{ee}} < 0 \end{cases} \tag{3}$$

We denote by $\omega_i \geq 0$ the initial allocation of permits to firm *i*. Using (2), we can define a "net supply of permits" function that is increasing in the price of permits and in the technology parameter:

$$S_i\left(p;\beta\right) = \omega_i - E_i\left(p;\beta\right) \quad \text{with} \quad \begin{cases} \dfrac{\partial S_i}{\partial p} = S_i^p = -E_i^p > 0 \\ \dfrac{\partial S_i}{\partial \beta} = S_i^{\beta} = -E_i^{\beta} > 0 \end{cases} \tag{4}$$

[13] We assume that benefits of emissions are such that an interior solution to the firm's maximization problem always exists. In particular, we assume that $\lim_{e_i \to 0} B_i^e\left(e_i,\beta\right) = +\infty$ and that, in the complete absence of environmental considerations, there exists an emission level $\bar{e}_i > 0$ defined by the condition $B_i^e\left(\bar{e}_i,\beta\right) = 0$.

A pollution permit market equilibrium is defined as a price level such that total net supply of permits is nonnegative:

$$p^o \quad \text{such that} \quad \sum_{j\in N} S_j\left(p^o;\beta\right) = \sum_{j\in N}\left[\omega_j - E_j\left(p^o;\beta\right)\right] \geq 0 \tag{5}$$

This market equilibrium condition implicitly defines a price function mapping a vector of emission allocations $\boldsymbol{\omega}$ into the market clearing price level: $p^o = \rho(\boldsymbol{\omega},\beta)$. We assume that the marginal benefit functions are such that for every vector of emission allocations, there exists a unique equilibrium permit price[14]. The permit price function can be shown to be decreasing in the initial allocations of permits to a country and in the technology parameter β.

$$\begin{cases} \rho^{\omega_i}\left(\boldsymbol{\omega},\beta\right) = \dfrac{\partial\rho}{\partial\omega_i} = \dfrac{dp^*}{d\omega_i} = \dfrac{1}{\sum\limits_{j\in N} E_j^p} < 0 \\ \rho^{\beta}\left(\boldsymbol{\omega},\beta\right) = \dfrac{\partial\rho}{\partial\beta} = \dfrac{dp^*}{d\beta} = \dfrac{-E_i^\beta}{\sum\limits_{j\in N} E_j^p} < 0 \end{cases} \tag{6}$$

Hence, corresponding to intuition, higher allocations of permits and lower marginal emission abatement costs lead to a decrease in the equilibrium permit price.

3.2 STAGE 1: Governments choosing initial permit allocations

Given the smoothly working permit market in stage 2, governments negotiate on the initial allocation of permits and we assume that they choose a number of permits ω_i as to maximize the following welfare function:

$$W_i\left(e_i,\omega_i;\bar{\omega}_{-i},\beta\right) = B_i\left(e_i;\beta\right) + p\left[\omega_i - e_i\right] - D_i\left(\omega_i + \bar{\omega}_{-i}\right) + I_i\left(e_i,e_i^S,\omega_i;\beta\right) \tag{7}$$

The function D_i denotes pollution damages incurred by country *i*. These damages are convex in global emissions, which is defined by the total amount of permits distributed (country *i*'s permits are ω_i, while all other countries' emission permits are ω_{-i}). Thus, the environmental problem is caused by a uniformly mixing pollutant as in the case of global climate change. We assume that country *i* maximizes its emissions, taking as given the permit allocations by all other countries ($\omega_{-i} = \bar{\omega}_{-i}$). Hence, we are looking for a Nash equilibrium among national governments in permit allocations.

This set-up is similar to the model introduced by Helm (2003). However, in addition to the approach by Helm, we assume that countries experience an *identity effect* of their emission and permit trading behaviour, I_i, which adds positively to there welfare function. Identity is usually defined as a person's self image – as an individual or as a part of a group (Akerlof and Kranton, 2003). Identity has been recognised as

[14] If more permits would be allocated than the net demand for emissions, we assume that the equilibrium price is zero: $\sum_{j\in N}\omega_j > \sum_{j\in N} E_j\left(0;\beta\right) \Rightarrow p^o = 0$.

important for individual behaviour in fields as social psychology and sociology, but has only recently been adopted in formal economic models. In this paper, however, we define a country's identity in the same way as the identity of an individual. This is justified by assuming that governments perform the moral reasoning of its voters. If a substantial share of voters has moral reflections on pollution permit trading, this will be reflected in the government's decision if ruling politicians care about their re-election chances.

Based on the statements made in section 2, the identity of a country is a function of it's actual emissions, e_i, it's permit allowances ω_i as well as it's ideal emissions, e_i^S. The latter is defined as the emission level that the country would like to aim for based on ethical reasoning. This ideal is considered exogenous. The precise way this ideal is determined, will be discussed later in the paper.

Using the notation introduced before, we can write the objective of the government of country *i*, taking into account competitive permit trading by firms in stage two, as:

$$\begin{aligned} W_i(\omega_i,\omega_{-i}) &= B_i\left(E_i\left(\rho(\boldsymbol{\omega};\beta);\beta\right);\beta\right)+\rho(\boldsymbol{\omega};\beta)\left[\omega_i-E_i\left(\rho(\boldsymbol{\omega};\beta);\beta\right)\right] \\ &\quad -D_i(\omega_i+\omega_{-i})+I_i\left(E_i\left(\rho(\boldsymbol{\omega};\beta);\beta\right),e_i^S,\omega_i;\beta\right) \end{aligned} \tag{8}$$

Each country then wants to set its initial permit allocation, ω_i, in order to maximise welfare. The first-order condition for an interior solution is therefore (all variables and functions are evaluated in the Nash equilibrium of permit allocations), where ΔI_i is the change in identity for a change in ω_i:

$$B_i^e E_i^p \rho^\omega + \rho^\omega\left[\omega_i - E_i\right] + \rho\left[1 - E_i^p \rho^\omega\right] - D_i^e + \Delta I_i = 0 \tag{9}$$

Or, after simplifying (using the first-order condition $B_i^e = \rho$ of competitive permit trading among firms in stage 2), the following condition should be satisfied for all countries $i \in N$:

$$\rho^\omega\left[\omega_i - E_i\right] + \rho - D_i^e + \Delta I_i = 0 \tag{10}$$

The first term on the left hand side (LHS) stands for the effect of additional permit allocations on the emission trading revenue through the effect on the permit price. A more generous permit allocation is beneficial for permit importers (as the market price at which they sell goes down), a more restricted permit allocation is beneficial for permit exporters (as the market price at which they buy goes up). We will label this effect the *strategic permit trading effect*.

The second term is the *direct price effect* of a more generous permit allocation. Every additional permit is worth the prevailing market price ρ. The third term stands for the additional *pollution damage effect* caused by a more generous permit allocation. More permits lead, ceteris paribus, to higher global emissions and hence higher pollution damages. This effect is therefore negative. Finally, the last term captures the *change in identity* of extra permits. This effect can be positive or negative depending upon the precise specification of the identity function. We will first derive results for a general formulation of the identity effect before turning to more precise specifications of the identity functions.

Rearranging (10) and using again the firms' profit maximizing first-order condition $B_i^e = \rho$, we obtain:

$$B_i^e = D_i^e - \rho^{\omega}\left[\omega_i - E_i\right] - \Delta I_i \tag{11}$$

Hence, every country chooses an initial permit allocation such that its marginal benefit from the last ton of emissions equals individual marginal damages, corrected for a strategic permit trade effect and an identity effect. In the following paragraph we will first study the endogenous permit allocation equilibrium ignoring identity effects. We will then turn to introducing identity considerations.

As a reference point, we can also easily find the standard non-cooperative Nash equilibrium in emissions when firms do not trade. Setting $\omega_i = E_i$ in equation (11), we find:

$$B_i^e(\hat{e}_i) = D_i^e(\hat{e}_N) - \Delta I_i \tag{12}$$

where $\sum_{j \in N} \hat{e}_j = \hat{e}_N$.

3.2.1 If identity does not matter

If identity does not matter (i.e., $\Delta I_i = 0$), the model boils down to a strategic emissions trading model. Hahn (1984) was one of the first describing non-competitive behaviour in emissions permit markets but one important difference between our approach and Hahn's model is that we do not start from an exogenously fixed total amount of permits in the market. We follow Helm (2003) who was the first to study the implications of endogenously determined permit allocations in an international permit market model. Although both in Helm's and our model, firms are assumed to be price takers on the permit market, their national governments act strategically on their behalf when deciding on the total amount of permits it will allocation to its domestic industries.

If $\Delta I_i = 0$, equation (10) is reduced to:

$$\rho + \rho^{\omega}\left[\omega_i - E_i\right] = D_i^e \tag{13}$$

In the strategic emission trading model, intuitively, net permit selling countries ($\omega_i - E_i > 0$) tend to under allocate their domestic firms as this makes permits scarce and drives up the equilibrium market price (recall that $\rho^{\omega} < 0$). On the other hand, net permit buying countries tend to over allocate their domestic firms because this makes permits more abundant and lowers the market price. As shown by Helm (2003), the net effect on global emissions cannot be signed in general since it depends on the relative weight of permit exporters versus importers. This is stated more formally in the following proposition.

Proposition 1 (Proposition 2 in Helm, 2003):
If identity considerations do not matter (i.e., $\Delta I_i = 0$), the overall amount of emissions permits issued in the endogenous permit allocation equilibrium might be higher or lower then in the Nash equilibrium without trading. In particular:

$$\omega_N^o = \sum_{j\in N} \omega_j^o \lesseqgtr \sum_{j\in N} \hat{e}_j = \hat{e}_N \quad \Leftrightarrow \quad \sum_{j\in N} B_j^e\left(E_j^o\right) \lesseqgtr \sum_{j\in N} B_j^e\left(\hat{e}_j\right) \tag{14}$$

Proof: Setting $\Delta I_i = 0$ and using the first-order conditions in (11) and (12), convexity of damage and concavity of benefit functions, it follows:

$$\omega_N^o \lesseqgtr \hat{e}_N \quad \Leftrightarrow \quad D_i^e\left(\omega_N^o\right) \lesseqgtr D_i^e\left(\hat{e}_N\right) \quad \Leftrightarrow \quad B_i^e\left(E_i^o\right) + \rho^\omega\left[\omega_i^o - E_i^o\right] \lesseqgtr B_i^e\left(\hat{e}_i\right)$$

where $E_i^o = E_i\left(\rho\left(\boldsymbol{\omega}^o;\beta\right);\beta\right)$ denotes the equilibrium emission level for permit allocation vector $\boldsymbol{\omega}^o$, when identity is not taken into account. Summing over all countries and using the permit market clearing condition yields the desired result in (14).

Q.E.D.

If damages from global emissions were linear, then the result becomes more clear cut. The total amount of emissions is the same and every permit importer (exporter) allocates less (more) in the endogenous permit allocation equilibrium compared to the non-cooperative Nash emissions equilibrium without permit trade.

Corollary 1

If damages of global emissions are linear ($D_i^e\left(x\right) = d_i \quad \forall x \geq 0$) and if identity considerations do not matter (i.e., $\Delta I_i = 0$), the overall amount of emissions permits issued in the endogenous permit allocation equilibrium is equal to the global amount of emissions in the Nash equilibrium without trading. Moreover, permit importers (exporters) allocate less (more) in the endogenous permit allocation equilibrium compared to the non-cooperative Nash emissions equilibrium without permit trade.

The proof of this corollary follows trivially from the first-order conditions (11) and (12).

However, it can in general be shown that the total amount of permits issued in the endogenous permit allocation equilibrium will always exceed the first-best optimal amount of permits. The first-best allocation of emissions, e_i^*, results from maximizing a utilitarian social welfare function and can be characterized by the Samuelson rule (see for instance Eyckmans et al., 1993):

$$B_i^e\left(e_i^*\right) = \sum_{j\in N} D_j^e\left(e_N^*\right) \quad \forall i \in N \tag{15}$$

Proposition 2:

If identity considerations do not matter (i.e., $\Delta I_i = 0$), the global amount of emissions permits issued in the endogenous permit allocation equilibrium is higher than the first best amount of emissions.

Proof: Assume, on the contrary, that $\omega_N^o \le \sum_{j\in N} e_j^* \equiv e_N^*$. Using the first-order conditions of the endogenous permit allocation equilibrium (10) and the first-best allocation of emissions, $B_i^e = \rho$, it follows that:

$B_i^e\left(E_i^o\right) = \rho^o < n\rho^o = \sum_{j\in N} D_j^e\left(\omega_N^o\right) \le \sum_{j\in N} D_j^e\left(e_N^*\right) = B_i^e\left(e_i^*\right)$ for all $i \in N$. Because of concavity of the benefit function, it follows that $E_i^o > e_i^* \quad \forall i \in N$ and hence $\sum_{j\in N} E_i^o = \omega_N > \sum_{j\in N} e_j^*$ which contradicts the initial assumption.

Q.E.D.

Although the endogenous permit allocation equilibrium can lead to more or less emissions compared to the standard Nash equilibrium without trading (see Proposition 1), we know for sure that the permit trading equilibrium is globally inefficient. Global emissions are too high or, equivalently, too little abatement is undertaken.

3.2.2 If identity matters

How does the introduction of identity considerations alter the results reported so far? Clearly, the distortions caused by introducing identity considerations will depend upon the precise specification of the identity function.

We will consider two main factors determining identity based on the statements in section 2: Countries might dislike permit trading, and countries might prefer to do all the abatement at home. However, for ease of exposition, we will start by studying the two statements separately before combining both arguments.

3.2.2.1 Reluctance to trade

We start by studying the statement that countries dislike permit trading. Assume first a *symmetric* formulation of reluctance to trade, i.e., countries dislike both selling and buying permits:

$$I_i\left(e_i,\omega_i;\beta\right) = \begin{cases} -F_i - \delta\left[\omega_i - E_i\left(\rho(\boldsymbol{\omega},\beta);\beta\right)\right]^2 & \text{if} \quad \omega_i \ne E_i\left(\rho(\boldsymbol{\omega});\beta\right) \\ 0 & \text{otherwise} \end{cases} \tag{16}$$

Involving in permit trading represents a cost, both for buyers and sellers, due to the fact that one does not act in accordance with one's moral conviction. This loss in identity consists of a fixed cost, F_i, independent of the amount of permits traded, and a variable cost. The fixed cost represents the loss of going from one regime to another, here represented by going from a non-trade regime to a trading regime. However, the volume of trade also matters. If a country decides to trade, it feels less comfortable the higher the volume of permit trading is as long as $\delta > 0$.[15] An example of the last property can for instance be the supplementary condition in the Kyoto Protocol as well as recent political discussions, e.g., in Norway, on setting a limit on how much one can reduce abatement abroad. This identity function only takes into

[15] In the case where $\delta = 0$, i.e., there is an identity cost of not following the norm, which is independent on the volume of trade as long as the volume is positive, we will actually get the same first order conditions as when identity does not matter, i.e., $\Delta I_i = 0$.

account pollution permit transactions, and not explicitly the national abatement level. Identity from national abatement will be studied in detail below. Finally, note that this identity function has a maximum at zero in the absence of emissions trading.

The discussion on the acceptability of permit trading is mainly a topic in countries that are potential permit buyers. We will, therefore, also consider a case with an *asymmetric* identity function, where countries only suffer an extra identity loss if they buy emissions:

$$I_i\left(e_i,\omega_i;\beta\right)=\begin{cases}-F_i-\delta\left[\omega_i-E_i\left(\rho\left(\boldsymbol{\omega},\beta\right);\beta\right)\right]^2 & \text{if} \quad \omega_i<E_i\left(\rho\left(\boldsymbol{\omega}\right);\beta\right)\\ -F_i \quad \text{if} \quad \omega_i>E_i & \\ 0 & \text{otherwise}\end{cases} \tag{17}$$

As mentioned in the introduction, these identity considerations, both the fixed and the variable term represent costs of trading and thus lower welfare in the trading system compared to when identity considerations are not present. Thus, this shares similarities with a permit trade system with transaction costs as in Stavins (1995). With transaction costs, the volume of trade is lower and welfare is lower compared to a system without transaction costs. Also the initial allocation of permits may affect the outcome of trading.

However, moral considerations affect permit trading differently than transaction costs in several respects. First, the fixed identity term affects the decision whether the country wants to take part in the permit trading market (see section 4 below), and second, the endogenous part of the identity function affects the allocation of initial allowances as countries do not want the allowance allocations to be very different from actual emissions. This means that the volume of trade will be lower. However, for a given level of aggregated allowances (global emissions target), the outcome of trading is not affected by the initial allowance allocation. In our model, firms face no transaction costs in trade so they trade cost-effectively, i.e., marginal abatement costs among sources are equal (see stage 2 above). This is not the case in models with transaction costs as these costs are modelled as a function of the volume of trade.

Using this explicit identity function, we can derive the following result:

Proposition 3:
If countries are reluctant to trade permits, and if identity is symmetric it can be shown that:

- *if country i is a permit seller (* $\omega_i>E_i$ *) it follows that* $B_i^e>D_i^e$*;*
- *if country i is a permit buyer (* $\omega_i<E_i$ *) it follows that* $B_i^e<D_i^e$*.*

Proof: The change in the identity effect in first-order condition (11) from a marginal increase in the initial permit allowance ω_i is given by: $\Delta I_i=-2\delta\left[1-E_i^p\rho^\omega\right]\left[\omega_i-E_i\right]$. This change is positive for permit buyers and negative for permit sellers for the symmetric identity function because $0\le E_i^p\rho^\omega=E_i^p\Big/\sum_{j\in N}E_j^p\le 1$. Therefore, it follows that:

$$B_i^e - D_i^e = -\rho^{\omega}\left[\omega_i - E_i\right] + 2\delta\left[1 - E_i^p \rho^{\omega}\right]\left[\omega_i - E_i\right]$$
$$= \left[\omega_i - E_i\right]\underbrace{\left[-\rho^{\omega} + 2\delta\left[1 - E_i^p \rho^{\omega}\right]\right]}_{+}$$

and therefore $B_i^e \lesseqgtr D_i^e$ if $\omega_i \lesseqgtr E_i$.

Q.E.D.

The intuition is as follows. Net permit selling countries tend to under allocate their domestic firms as this makes permits scarce and drives up the equilibrium market price. In addition, the under allocation has positive identity effects as the volume of trade goes down, or in other words, the gap between permit allocation and actual emissions shrinks. On the other hand, net permit buying countries tend to over allocate their domestic firms because this makes permits more abundant and lowers the market price. Further, the same identity mechanism as described for sellers is also valid for buyers; over allocating permits has positive identity effects as the volume of trade goes down. Summarizing, the identity effect, if it only stems from reluctance to trade, confirms the results obtained by Helm (2003). The identity effect reinforces the strategic trade incentives for both sellers and buyers of permits.

How does the introduction of identity considerations affect the global amount of permits issued into the market? In order to find the global effect, we take the sum over all countries of their first-order conditions to obtain:

$$\sum_{j\in N}\left\{\rho^{\omega}\left[\omega_j - E_j\right] + \rho - D_j^e - 2\delta\left[\omega_j - E_j\right]\left[1 - E_j^p \rho^{\omega}\right]\right\} = 0$$
$$\Rightarrow \rho^{\omega}\sum_{j\in N}\left[\omega_j - E_j\right] + n\rho - \sum_{j\in N} D_j^e - 2\delta\sum_{j\in N}\left[\omega_j - E_j\right] + 2\delta\rho^{\omega}\sum_{j\in N}\left\{\left[\omega_j - E_j\right]E_j^p\right\} = 0$$
$$\Rightarrow n\rho - \sum_{j\in N} D_j^e + 2\delta\rho^{\omega}\sum_{j\in N}\left[\omega_j - E_j\right]E_j^p = 0$$

Hence,

$$n\rho = \sum_{j\in N} D_j^e - 2\delta\rho^{\omega}\sum_{j\in N}\left[\omega_j - E_j\right]E_j^p \tag{18}$$

As the following results show, the outcome depends on the "balance of power" between permit exporters and importers.

Proposition 4:
If countries are reluctant to trade, identity is symmetric and $\sum_{j\in N}\left[\omega_j - E_j\right]E_j^p > (<) 0$, *global emissions will be lower (higher) and every country will emit less (more) than in the endogenous permit allocation equilibrium without identity considerations.*

Proof: Assume the claim were false, i.e., $\sum_{j\in N}\left[\omega_j - E_j\right]E_j^p > 0$ and $\omega_N^I > \omega_N^o$, i.e., global emissions are higher with the introduction of the identity function. Because of convexity of the damage functions if follows that: $\sum_{j\in N} D_j^e\left(\omega_N^I\right) > \sum_{j\in N} D_j^e\left(\omega_N^o\right)$. Using the appropriate first-order conditions for both equilibria, i.e., (13) and (18), it can be shown that:

$$n\rho^I + 2\delta\rho^\omega \sum_{j\in N}\left[\omega_j - E_j\right]E_j^p > n\rho^o$$

$$\Downarrow$$

$$\rho^I - \rho^o > \left[\frac{-2\delta\rho^\omega}{n}\right]\sum_{j\in N}\left[\omega_j - E_j\right]E_j^p > 0$$

Hence, the equilibrium permit price with identity considerations would be higher than the price without. Given that the equilibrium price function is decreasing in the global permit allocation, this would imply $\omega_N^I < \omega_N^o$ which contradicts the initial assumption. Finally, as we have just shown that if $\sum_{j\in N}\left[\omega_j - E_j\right]E_j^p > 0$, it follows that the global emissions will be lower and, hence, equilibrium price of permits will be higher in case of identity considerations and therefore, every country's representative firm will emit less: $B_i^e\left(E_i^I\right) = \rho^I > \rho^o = B_i^e\left(E_i^o\right) \Rightarrow E_i^I < E_i^o$ due to concavity of the benefit functions.

Q.E.D.

Hence, if $\sum_{j\in N}\left[\omega_j - E_j\right]E_j^p > 0$, reluctance to trade shifts the endogenous permit allocation equilibrium in the direction of the first-best Pareto efficient solution but we cannot tell whether we will fall short or overshoot the efficient solution. But how should we interpret the condition $\sum_{j\in N}\left[\omega_j - E_j\right]E_j^p > 0$? This sum can be interpreted as a weighted average of all the permit trades (positive and negative) where the weights are given by the inverse of the slope of the marginal benefit of emissions function (recall that $E_j^p = 1/B_j^{ee} < 0$). Hence, in order for the sum $\sum_{j\in N}\left[\omega_j - E_j\right]E_j^p$ to be positive, permit exporters should, on average, have higher values of E_i^p than permit importers. Note that high absolute values of B_i^{ee} (i.e., steep marginal emission abatement cost functions) imply high values (i.e., small negative numbers) of E_i^p. Therefore, the term is positive if permit sellers are predominantly countries with steep marginal abatement cost functions.

Note that this is not very likely to apply to the Kyoto permit market in the first commitment period 2008-2012. Most empirical carbon emission market models predict on the contrary that it are especially low abatement cost countries (i.e., countries with flat marginal benefit functions B_i^e) that will export carbon emissions permits, see Böhringer (2002), Den Elzen and de Moor (2002) or Eyckmans and Hagem (2008). Therefore, in the case of the Kyoto permit markets, it is more likely that identity considerations would shift endogenous permit allocation equilibrium away from the efficient solution. This means that the solution with identity considerations might be less efficient than without those considerations.

Proposition 5:
If only buyers are reluctant to trade (asymmetric identity function (17)), then the endogenous permit allocation equilibrium is shifted further away from the efficient solution and every individual country will emit more than in the endogenous permit allocation equilibrium without identity considerations.

Proof: The first-order conditions for governments issuing permits are different for permit importers ($\omega_i < E_i$) and exporters ($\omega_i \geq E_i$):

$$\begin{cases} B_i^e - D_i^e + \rho^\omega [\omega_i - E_i] - 2\delta \left[1 - E_i^p \rho^\omega\right][\omega_i - E_i] = 0 & if \quad \omega_i < E_i \\ B_i^e - D_i^e + \rho^\omega [\omega_i - E_i] = 0 & if \quad \omega_i \geq E_i \end{cases}$$

Summing over both types of countries and using the market clearing condition from (5), it follows that:

$$\sum_{j \in N} B_j^e - \sum_{j \in N} D_j^e - 2\delta \sum_{j \in N} \min\left\{0, \omega_j - E_j\right\}\left[1 - E_j^p \rho^\omega\right] = 0$$

The minimum function $\min\left\{0, \omega_j - E_j\right\}$ allows us to sum over all countries while taking into account the identity effect for permit importers only.
Assuming, in contrast to the claim in Proposition 5, $\omega_N^I < \omega_N^o$ and using convexity of the damage functions if follows that: $\sum_{j \in N} D_j^e\left(\omega_N^I\right) < \sum_{j \in N} D_j^e\left(\omega_N^o\right)$. Using the appropriate first-order conditions for both equilibria, it can be shown that (recall that $0 \leq \left[1 - E_j^p \rho^\omega\right] \leq 1$):

$$\rho^I - \rho^o < \frac{2\delta}{n} \sum_{j \in N} \min\left\{0, \omega_j - E_j\right\}\left[1 - \rho^\omega E_j^p\right] < 0$$

Hence, the equilibrium permit price would be lower with asymmetric identity considerations than without. Given that the equilibrium price function is decreasing in the global permit allocation, this would imply $\omega_N^I > \omega_N^o$ which contradicts the initial assumption. Therefore, it must be that $\omega_N^I \geq \omega_N^o$, i.e., taking into account identity considerations will lead to higher global emissions than without identity considerations, and therefore, the total emissions are shifted further away from the first best level of global emissions.
As we have just shown that the equilibrium price of permits will be lower in case of asymmetric identity considerations, it follows that every country's representative firm will emit more: $B_i^e\left(E_i^I\right) = \rho^I < \rho^o = B_i^e\left(E_i^o\right) \;\; \Rightarrow \;\; E_i^I > E_i^o$ due to concavity of the benefit functions.

Q.E.D.

Proposition 5 is intuitively clear. We know that permit buyers have an incentive to over allocate their domestic industries because of (1) strategic trade considerations (i.e. for driving down the equilibrium permit price), and (2) identity considerations (i.e. over allocating domestic firms reduces the amount of permits that has to be imported). Since only buyers' identity considerations are taken into account in the asymmetric identity function (17), it obviously follows that global emissions will be higher than in the scenario without identity considerations.

3.2.2.2 Gap between actual and ideal effort level

Reluctance to trade is one aspect of a country's identity, but the country could also care about its actual level of emissions. To model this, we assume that identity also depends on the relationship between actual emissions and the morally ideal emissions, e^S. Following Brekke et al. (2003) we assume that the ideal emissions are found by maximizing a utilitarian welfare function where everybody follows the same general rule, namely emit the amount that maximizes the utilitarian welfare function. Thus this gives $e_i^S = e_i^*$, where e_i^* follows from (15). Note also that e_i^* is only a function of β, and is therefore considered exogenous in all analysis we perform apart from in section 4 where we consider a change in β. This new identity function can be specified in the following way:

$$I_i\left(e_i, e_i^*; \beta\right) = -\gamma\left[E_i\left(\rho(\boldsymbol{\omega}, \beta); \beta\right) - e_i^*\right]^2 \qquad (19)$$

First of all, we show that every country will emit more than what is considered as the "ideal" emissions level, i.e., the first-best Pareto efficient emissions allocation.

Proposition 6:
If countries care only about the ideal, every individual country will emit more than its first-best emissions level: $E_i \geq e_i^*$ and therefore, total amount of permits allocated will exceed the first-best level $\omega_N \geq e_N^*$.

Proof: Assume, on the contrary, that $\exists i \in N: \quad E_i < e_i^*$. From the strict concavity of the emissions benefit function, it follows that $B_i^e\left(E_i\right) > B_i^e\left(e_i^*\right)$. Using the appropriate first-order conditions, (2) and (15), this implies:

$$\rho\left(\omega_N\right) = B_i^e\left(E_i\right) > B_i^e\left(e_i^*\right) = \sum_{j\in N} D_j^e\left(e_N^*\right) = \rho\left(e_N^*\right) \Rightarrow \omega_N < e_N^*$$

At the same time, we can derive:

$$D_i^e\left(\omega_N\right) + 2\gamma\left[E_i - e_i^*\right]E_i^p\rho^\omega = B_i^e\left(E_i\right) > B_i^e\left(e_i^*\right) = \sum_{j\in N} D_j^e\left(e_N^*\right)$$

$$\Downarrow$$

$$\sum_{j\in N} D_j^e\left(\omega_N\right) - \sum_{j\in N} D_j^e\left(\ \right) \geq D_i^e\left(\omega_N\right) - \sum_{j\in N} D_j^e\left(e_N^*\right) > -2\gamma\left[E_i - e_i^*\right]E_i^p\rho^\omega \geq 0$$

$$\Downarrow$$

$$\omega_N > e_N^*$$

Which contradicts the previously established inequality. We can therefore conclude that $\forall i \in N: \quad E_i \geq e_i^*$.

Given that every country emits more than the ideal level, it follows obviously that total emissions in the endogenous permit allocation equilibrium will exceed the first-best level: $\omega_N > e_N^*$.

Q.E.D.

Given that we now know from Proposition 6 that every country always emits more than its ideal, we can easily sign the derivative of the identity function with respect to ω_i:

$$\Delta I_i = -2\gamma p^{\omega} \left[E_i - e_i^* \right] E_i^p < 0 \quad (20)$$

Taken in isolation, the identity effect that refers to the ideal effort level shifts the endogenous permit allocation equilibrium towards the Pareto efficient first-best allocation of emissions.

Proposition 7:
If countries care only about the ideal, then the endogenous permit allocation equilibrium is shifted in the direction of the efficient solution and every individual country will emit less than in the endogenous permit allocation equilibrium without identity considerations.

Proof: Assuming, in contrast, that $\omega_N^I > \omega_N^o$ if countries care about the ideal. Using convexity of the damage functions if follows that: $\sum_{j\in N} D_j^e\left(\omega_N^I\right) > \sum_{j\in N} D_j^e\left(\omega_N^o\right)$. Using the appropriate first-order conditions for both equilibria, it can be shown that:

$$\rho^I - \rho^o > \frac{2\gamma p^{\omega}}{n} \sum_{j\in N} \left[E_j - e_j^* \right] E_j^p > 0$$

Hence, the equilibrium permit price would be higher with identity considerations than without. Given that the equilibrium price function is decreasing in the global permit allocation, this would imply $\omega_N^I < \omega_N^o$ which contradicts the initial assumption. Therefore, it must be that $\omega_N^I \le \omega_N^o$.
As we have just shown that the equilibrium price of permits will be higher in case of identity considerations, it follows that every country's representative firm will emit less: $B_i^e\left(E_i^I\right) = \rho^I > \rho^o = B_i^e\left(E_i^o\right) \Rightarrow E_i^I < E_i^o$ due to concavity of the benefit functions.

Q.E.D.

Above we have compared the identity costs from permit trading to transaction costs. Note, however, that the identity function in (19) does not increase costs of permit trading. If trade reduces the distance between actual emissions and ideal emissions, the country may also benefit in identity terms from trade.

3.2.2.3 Both identity effects taken together

We are now able to combine the results of the previous sections on the identity effects separately. Taken together, the full identity function can be written as follows:

$$I_i\left(e_i,e_i^*,\omega_i;\beta\right)=\begin{cases}-F-\delta\left[\omega_i-E_i\left(\rho(\mathbf{\omega},\beta);\beta\right)\right]^2-\gamma[E_i\left(\rho(\mathbf{\omega},\beta);\beta\right)-e_i^*(\beta)]^2 & if \quad \omega_i\neq E_i\left(\rho(\mathbf{\omega});\beta\right)\\ -\gamma[E_i\left(\rho(\mathbf{\omega},\beta);\beta\right)-e_i^*(\beta)]^2 & otherwise\end{cases}$$

(21)

Note that the new identity function describes an internal conflict; we can have $e_i = e_i^*$, but still $\omega_i \neq e_i$. ▮

The results above will enable us to characterize the conditions under which global emissions might evolve into the direction of first-best Pareto efficient emissions.

Proposition 8:
If countries are reluctant to trade permits and if they care about the ideal, then the endogenous permit allocation equilibrium is shifted in the direction of the efficient solution if, either:

- *condition* $\sum_{j\in N}\left[\omega_j - E_j\right]E_j^p > 0$ *holds, or,*
- *the identity effect regarding the ideal is valued sufficiently strongly to compensate the identity effect regarding reluctance to trade.*

Proof: The proof is trivial by combining Propositions 4 and 7.

This result describes the conditions under which identity considerations might foster global emission reduction and hence, reduce the gap between the endogenous permit trading equilibrium and the Pareto efficient first-best level of emissions. At first sight, one might think it is obvious that identity considerations would lead to lower global emissions. However, Proposition 8 shows that it depends crucially on both the form of the identity function and the balance of power between permit importers and exporters.

What does this analysis so far learn us when we try to apply it to the international climate negotiations that should lead to a follow-up agreement for the post-Kyoto period after 2012? As we have argued above, most simulation models predict that permit exporters are predominantly countries with relatively flat marginal emission abatement cost curves. This implies that $\sum_{j\in N}\left[\omega_j - E_j\right]E_j^p$ is likely to be negative. From Proposition 8, we can therefore conclude that the overall emission level resulting from the international climate negotiations outcome will be closer to the first-best level of emissions only if there is a relatively strong identity effect based on the gap between actual and ideal emissions levels. If this identity effect is weak, the gap between the negotiated permit allocation and first-best emissions levels will be higher than in a scenario where identity considerations would not play a role in governments' decision making process.

Another way of interpreting our result is as follows. Proposition 8 (and 4) can be interpreted as arguments to say that one should be careful with imposing constraints on global permit trading. Although ethically motivated, these constraints on permit trade might lead to an adverse effect in the sense that they lead to higher global emissions if permits allocations are the result of a non-cooperative negotiation process between sovereign countries. Hence, this can be seen as a warning against those arguing for limiting access to international flexibility mechanisms in international climate policy. They might end up worse in environmental terms, in spite of their ethical motivation.

4. The decision to involve in permit trading

From equation (12), we know that without trading, governments would choose emissions ceilings equal to $\hat{e}_i$ such that:

$$B_i^e\left(\hat{e}_i;\beta\right) = D_i^e\left(\hat{e}_N\right) - \Delta I_i \tag{22}$$

Marginal benefits from a small emissions' increase should equal the country's individual marginal damage of this increase in addition to the change in identity. As there is now trade, the effect on identity only exists because of a divergence from the ideal level, i.e., $\Delta I_i = -2\gamma[\hat{e}_i - e_i^*]$. Note that (22) assumes that all countries have chosen not to trade, we are in a *non-trade regime*. We denote this as the business-as-usual (BAU) case.

A *trading regime* is preferred over a non-trade regime if and only if the welfare in the trading regime is higher than the welfare with no trade, i.e.:

$$\begin{gathered} B_i\left(E_i\left(\rho(\boldsymbol{\omega};\beta);\beta\right)\right) + \rho(\boldsymbol{\omega};\beta)\left[\omega_i - E_i\left(\rho(\boldsymbol{\omega};\beta);\beta\right)\right] - D_i\left(\omega_i + \omega_{-i}\right) \\ -F_i - \delta\left[\omega_i - E_i\left(\rho(\boldsymbol{\omega},\beta);\beta\right)\right]^2 - \gamma(E_i\left(\rho(\boldsymbol{\omega},\beta);\beta\right) - e_i^*(\beta))^2 \\ \geq \\ B_i\left(\hat{e}_i;\beta\right) - D_i\left(\hat{e}_N\right) - \gamma(\hat{e}_i - e_i^*(\beta))^2 \end{gathered} \tag{23}$$

This condition implies an upper bound on the fixed identity term:

$$\begin{aligned} F_i \leq\ & B_i\left(E_i\left(\rho(\boldsymbol{\omega};\beta);\beta\right)\right) - B_i\left(\hat{e}_i;\beta\right) + \rho(\boldsymbol{\omega};\beta)\left[\omega_i - E_i\left(\rho(\boldsymbol{\omega};\beta);\beta\right)\right] - D_i\left(\omega_i + \omega_{-i}\right) + D_i\left(\hat{e}_N\right) \\ & -\delta\left[\omega_i - E_i\left(\rho(\boldsymbol{\omega},\beta);\beta\right)\right]^2 - \gamma(E_i\left(\rho(\boldsymbol{\omega},\beta);\beta\right) - e_i^*(\beta))^2 + \gamma(\hat{e}_i - e_i^*(\beta))^2 \equiv \phi_i(\beta) \end{aligned}$$

(24)

Thus, if F_i, the identity cost of moving to a trading regime, is larger than $\phi_i(\beta)$, which is the benefit from a trading regime, country *i* prefers a regime with no trade.

In Proposition 1, we showed that overall emissions with trade can be higher or lower than overall emissions without trade if there are no identity considerations. Helm (2003), Proposition 4, also shows that a trading regime may be welfare improving even if emissions are higher. Note that the identity considerations introduced by the fixed term and by $\delta > 0$ in our paper represent costs of trading and thus lower welfare in the trading system compared to when identity considerations are not present.[16] Based on this, we can derive the following result:

[16] If $\gamma > 0$, we cannot rule out the possibility that identity costs will be less with trading. As noted above and as seen from equation (24), if $e_i < \hat{e}_i$ the identity from deviating from the ideal will improve from trading.

Proposition 9:

Without identity considerations overall emissions may be lower and welfare may be higher in the trading situation than without trade. Thus if identity considerations are included that induces a cost to trading, countries may prefer no trade and higher emissions to a system with trade and lower emissions. However, if overall emissions as well as welfare are higher with trade, including identity considerations may induce a system with no trade and lower overall emissions.

Proof: See the text above as well as proof for Proposition 4 in Helm (2003).

4.1 The effects of technological improvements

As noted in the introduction as well as in Bénabou and Tirole (2007), p. 20, there seems to be a changed attitude towards pollution permits the last few years. A larger interest in pollution permit trade may be due to a change in the norm so that it is more acceptable than before to trade permits, but there may also be another explanation; the transactions may still be repugnant so that the norm is constant, but the benefits from trade may be higher than before.

Comparing the economy today and a few years ago, one relevant difference is the change in mitigation technology. Technology improves over time, in such a way that mitigation becomes cheaper. Based on this, we consider how an exogenous technological change may alter the decisions of a country on whether to prefer a trade regime to a non-trade regime. I.e., we will study how a shift in the technology parameter β will alter the benefits from a trade regime represented by $\phi_i(\beta)$.

Assume first that γ = 0, so that only the norm on permit trading matters. The derivative of the RHS of (24) with respect to β is given by:

$$\begin{aligned}\phi_i'(\beta) = {} & B_i^e\left[E_i^\rho \rho^\beta + E_i^\beta\right] + B_i^\beta - \left[\hat{B}_i^e \hat{e}_i^\beta + \hat{B}_i^\beta\right] \\ & +\rho^\beta\left[\omega_i - E_i\right] + \rho\left[\omega_i^\beta - (E_i^\rho \rho^\beta + E_i^\beta)\right] \\ & -D_i^e\left[\omega_i^\beta + \omega_{-i}^\beta\right] + D_i^e\left[\hat{e}_i^\beta + \hat{e}_{-i}^\beta\right] \\ & -2\delta\left[\omega_i - E_i\right]\left[\omega_i^\beta - (E_i^\rho \rho^\beta + E_i^\beta)\right]\end{aligned} \tag{25}$$

Or, using the firms' trading FOC, i.e., $B_i^e = \rho$:

$$\begin{aligned}\phi_i'(\beta) = {} & B_i^\beta - \left[\hat{B}_i^e \hat{e}_i^\beta + \hat{B}_i^\beta\right] \\ & +\rho^\beta\left[\omega_i - E_i\right] + \rho\omega_i^\beta \\ & -D_i^e\left[\omega_i^\beta + \omega_{-i}^\beta\right] + D_i^e\left[\hat{e}_i^\beta + \hat{e}_{-i}^\beta\right] \\ & -2\delta\left[\omega_i - E_i\right]\left[\omega_i^\beta - (E_i^\rho \rho^\beta + E_i^\beta)\right]\end{aligned} \tag{26}$$

And using the Nash equilibrium FOC in the no-trade situation for γ = 0, i.e., $B_i^e\left(\hat{e}_i\right) = D_i^e\left(\hat{e}_i + \hat{e}_{-i}\right)$, and substituting ρ for B_i^e, we get:

$$\begin{aligned}\phi_i'(\beta) = {} & B_i^\beta - \hat{B}_i^\beta \\ & +\rho^\beta[\omega_i - E_i] + \omega_i^\beta\left[B_i^e - D_i^e\right] \\ & -2\delta[\omega_i - E_i]\left[\omega_i^\beta - (E_i^\rho \rho^\beta + E_i^\beta)\right] \\ & -D_i^e \omega_{-i}^\beta + D_i^e \hat{e}_{-i}^\beta\end{aligned} \tag{27}$$

Assume now that $-D_i^e \omega_{-i}^\beta + D_i^e \hat{e}_{-i}^\beta \approx 0$, i.e., the effects on damage of a marginal change in allowance choice and BAU emissions in other countries due to an increase in the technology parameter are about the same[17], or that the total effect is small which may be a reasonable assumption. This leaves four different effects on the benefits from trade:

- $B_i^\beta - \hat{B}_i^\beta$: The first term reflects that abatement has become cheaper as a result of technological change. We know that $B_i^\beta - \hat{B}_i^\beta = -C^\beta > 0$, see Appendix 1. Thus, the benefit in deviating from the BAU equilibrium has increased. This holds for both potential buyers and sellers.
- $\rho^\beta[\omega_i - E_i]$: The second term reflects the effects of a change in price. As $\rho^\beta < 0$, this effect is positive for buyers, $[\omega_i - E_i] < 0$, and negative for sellers, $[\omega_i - E_i] > 0$.
- $\omega_i^\beta\left[B_i^e - D_i^e\right]$: The third term reflects the effects of a change in the initial allocation. As seen, this is dependent on the gap between marginal benefit and marginal damage. As seen from Proposition 3, this gap is positive ($B_i^e > D_i^e$) for a permit seller and negative for a permit buyer ($B_i^e < D_i^e$).
- $-2\delta[\omega_i - E_i]\left[\omega_i^\beta - (E_i^\rho \rho^\beta + E_i^\beta)\right]$: The final term reflects the impact on identity of a change in technological change. This effect is ambiguous for sellers and buyers as discussed below.

Assume first that $\omega_i^\beta < 0$, i.e., the country may want to decrease its initial emission allocation if there is a positive change in technology. This may seem as a reasonable assumption as countries will be less dependent of fossil fuels. Below we will also take a look at other possibilities.[18]

Consider first the case where only the fixed identity term matters (*δ = 0)*, i.e., there are no identity effects from the volume of trade. In this case we see that the first three effects are positive for a potential buyer, while the last one is zero. Thus, a technological change will make it more beneficial to trade and the potential buyers may be willing to not follow the norm.

---

[17] This assumes that the signs of ω_{-i}^β and $\hat{e}_{-i}^\beta$ are equal. It proves that these derivatives are difficult to sign without specific functional forms. See Appendix 2 for the derivation of $\hat{e}_{-i}^\beta$ and Appendix 3 for the derivation of ω_{-i}^β.

[18] The sign of ω_i^β is ambiguous without choosing specific functional forms, see Appendix 3.

For potential sellers, the result is less clear. As for buyers, sellers will also benefit from cheaper abatement (the first term), but the second and the third term is not favourable for potential sellers. Thus, the incentive to move to a permit trading regime may be less or higher. This leads us to the following result:

Proposition 10:
If $\omega_i^\beta < 0$ *and γ = 0 and δ = 0, potential buyers will have a higher incentive to involve in trade if there is a technological change, even if there is a norm against permit trading. For potential sellers, the incentives are ambiguous, but we cannot rule out the case where potential sellers also will have a higher incentive in trading with permits if there is a technological change.*

Proof: See text above.

Assume now that *δ > 0* such that identity is falling in the volume of trade. If there is a technological change, the effect on identity is as follows:

$$I_i^\beta = -2\delta\left[\omega_i - E_i\right]\left[\omega_i^\beta - (E_i^\rho \rho^\beta + E_i^\beta)\right] \tag{28}$$

For a potential seller $\left[\omega_i - E_i\right] > 0$, and identity will only increase if $\left[\omega_i^\beta - (E_i^\rho \rho^\beta + E_i^\beta)\right] < 0$, i.e., if emissions increases more than initial allocations for a change in technology. If $\omega_i^\beta < 0$, this means that the initial allocation of permits has to fall more than the actual emissions. Note that the effect of technological change on emissions is ambiguous as the first part in the parenthesis is positive while the second is negative. For a potential buyer the conclusion is the other way around. This leads to the following result:

Proposition 11:
If δ > 0 and γ = 0, the identity from the volume of trade is affected by an improvement in technology. This may reduce the incentive to trade permits for a technological change. However, there is also a possibility that this identity effect increases the incentives to trade permits.

Proof: See text above.

The last part of this result is interesting. If a country considers transactions in pollution permits as repugnant, but in addition prefers a small volume of trade to a high volume if it chooses to trade, this last identity effect may actually make the country more willing to start trading if there is a technological change. The reason is that the volume of trade will be lower with the new technology, which will reduce the identity loss from trade.

The case where identity matters only for buyers (asymmetric identity function), will not change the results above. Buyers can be willing to trade permits if the volume of trade will be reduced with the new technology.

Consider now the full identity function from (21), i.e. the case where *δ > 0 and* γ > 0, so that there is also a norm to do abatement at home. The identity effects then become

$$I_i^{\beta} = -2\delta[\omega_i - E_i][\omega_i^{\beta} - (E_i^{\rho}\rho^{\beta} + E_i^{\beta})] - 2\gamma\left[\left[\hat{e}_i - e_i^*\right]e_i^{*\beta} + \left[E_i - e_i^*\right](E_i^{\rho}\rho^{\beta} + E_i^{\beta} - e_i^{*\beta})\right] \quad (29)$$

The second term in this equation is the effect from γ > 0. In general this effect is ambiguous too, which means that the conclusion in Proposition 8 still holds. The reason for this is that we cannot say in general whether a technology change moves the actual emissions closer or further away from the ideal emissions.

Proposition 12:
*If identity depends on both from the volume of trade (δ > 0) and on the distance between actual and ideal emissions (*γ > 0)*, the identity is affected by an improvement in technology. This may reduce the incentive to trade permits for a technological change. However, there is also a possibility that this identity effect increases the incentives to trade permits.*

Proof: See text above.

So far we have considered the case where $\omega_i^{\beta} < 0$. However, as seen from Appendix 3, we cannot rule out the other possibilities. If $\omega_i^{\beta} = 0$ this would leave out the third effect on $\phi_i(\beta)$, but would still leave the effect on identity uncertain. If $\omega_i^{\beta} > 0$, this would make the incentive for a potential buyer more uncertain. Still there is an identity effect as found in Propositions 11 and 12.

5. Discussion and conclusions

In this paper we analysed how identity considerations affect an endogenous pollution permit trading equilibrium, in which governments choose in a non-cooperative way the overall environmental objective and regional permit allocations. With identity considerations we mean two things. First, countries may feel reluctant to trade permits because they feel it is a way to escape ones moral responsibility or because of the assumed negative consequences the trade may have in developing countries. Hence, both consequentialist and procedural ethics arguments are used to justify limits on access to flexible mechanisms like CDM in the framework of the Kyoto Protocol or European Emission Trading Scheme for instance. Once governments have chosen permit allocations, firms are assumed to trade these permits on an international competitive permit market without taking into account moral restraints.

Our main conclusions are the following. Given an internationally negotiated permit trading system, identity considerations may increase or reduce global emissions depending on the precise formulation of the identity. We considered two main formulations of identity. The first one captures the idea that countries might be reluctant to trade. For that formulation we showed that if identity is asymmetric, i.e., if only permit permit importers feel reluctant to buy, global emissions will be higher than in an endogenous permit trading equilibrium without moral motivation. The reason is that permit importers over allocate their domestic firms in order to reap strategic permit trade gains (because of lower global permit prices) and to reduce the amount of permits they have to import and hence their loss of identity. However, for symmetric identity functions, the opposite effect may take place and global emissions might be lower than compared to the case without moral concerns. For symmetric identity considerations, the overall effect of identity on global emissions is shown to depend on the balance of power (more precisely the slope of their marginal abatement cost functions) between permit importers and exporters. Using these results, we conjecture that global emissions are likely to increase instead of decrease when national governments are reluctant to trade permits.

The second formulation of identity takes into account the gap between actual and ideal emission levels. As ideal, we consider the first-best Pareto efficient emission allocation (without identity considerations). We show that global emissions will always be lower with this type of identity function. The central proposition of this paper combines both identity formulations and formulates conditions under which global emissions will go down or up if identity considerations are taken into account. In general, the result can be interpreted as a warning against imposing limits on access to flexible instruments and permit imports. Even though these limits (or supplementarity requirements as they are often called in the Kyoto context) are morally motivated, they might have adverse effects because they lead to higher global emissions.

Finally, we explored the impact of technological change (an exogenous reduction in emission reduction costs) on the endogenous permit market equilibrium. We were able to show that under plausible assumptions, a technological change in mitigation technologies may have made it more attractive for countries to engage in permit trading.

We see the following ways to improve upon our results. First, different formulations of the identity function are possible than the ones we considered in this paper. Secondly, it is a tempting, but surely very difficult, task to try to relate the first practical experiences with international emission allocations by governments (the allocation of emission reduction burdens in the 1997 Kyoto agreement or the the National Allocation Plans NAPs under the EU Emission Trading System ETS) to our theoretical results. In particular, it would be interesting to try to disentangle moral motivations for imposing limits on access to permit trading from strategic price manipulation motives. Our theoretical results might provide some reference framework to formulate empirical tests with simulations models of permit trading markets for distinguishing between both motivations.

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Appendices

Appendix 1: The benefit function

A general abatement cost function frequently used in the literature is:

$$C(a;\beta)$$

With a the level of emission abatement, i.e. $a=\hat{e}-e$. Emission reduction is defined as the difference between business-as-usual emissions $\hat{e}$ and actual emissions e. Technology is represented by a parameter β where higher β means a better or more efficient technology.

It is usually assumed that this function has the following properties (see, e.g., Golombek and Hoel, 2005):

$$C^a \equiv \frac{\partial C}{\partial a} > 0; \quad C^{aa} \equiv \frac{\partial^2 C}{\partial a^2} > 0; \quad C^{\beta} \equiv \frac{\partial C}{\partial \beta} < 0; \quad C^{a\beta} \equiv \frac{\partial^2 C}{\partial a \partial \beta} < 0$$

This means that costs are falling in technology ($C^{\beta} < 0$) and that the benefit from increasing emissions falls in technology ($C^{a\beta} < 0$).

Emission abatement costs are defined as the difference in benefits between the business-as-usual and actual emission level:

$$C(a;\beta) = C(\hat{e}-e;\beta) = B(\hat{e};\beta) - B(e;\beta)$$

such that

$$B(e;\beta) = B(\hat{e};\beta) - C(a;\beta)$$

Thus, we find:

$$B^e \equiv \frac{\partial B(e;\beta)}{\partial e} = C^a > 0$$

$$B^{ee} \equiv \frac{\partial^2 B(e;\beta)}{\partial e^2} = -C^{aa} < 0$$

$$B^{e\beta} \equiv \frac{\partial^2 B(e;\beta)}{\partial e \partial \beta} = C^{a\beta} < 0$$

and

$$B^{\beta}(e;\beta) = B^{\beta}(\hat{e};\beta) - C^{\beta}(a;\beta)$$

thus,

$$B^{\beta}(e;\beta) - B^{\beta}(\hat{e};\beta) = -C^{\beta}(a;\beta) > 0$$

The sign of $B^{\beta}(e;\beta)$ should equal $B^{\beta}(\hat{e};\beta)$. As the difference between the two terms is positive, the sign could be both positive and negative. However, as $B^{e\beta} < 0$, the benefit function should be flatter for a change in technology for all values of e. This would not be the case if $B^{\beta} > 0$. Thus we find that: $B^{\beta} < 0$.

Appendix 2: The effects on BAU emissions due to a technological change

Without trading, governments set emissions ceilings such that

$$B_i^e\left(\hat{e}_i\right) = D_i^e\left(\hat{e}_i + \hat{e}_{-i}\right) \quad (1)$$

$$B_{-i}^e\left(\hat{e}_{-i}\right) = D_{-i}^e\left(\hat{e}_i + \hat{e}_{-i}\right) \quad (2)$$

Differentiating these FOC wrt. β gives:

$$\hat{e}_i^{\beta} = \frac{-B_i^{e\beta} + D_i^{ee}\hat{e}_{-i}^{\beta}}{B_i^{ee} - D_i^{ee}} \quad (3)$$

$$\hat{e}_{-i}^{\beta} = \frac{-B_{-i}^{e\beta} + D_i^{ee}\hat{e}_i^{\beta}}{B_{-i}^{ee} - D_{-i}^{ee}} \quad (4)$$

Note that the denominator is positive in both equations, while the nominator depends on the sign of emission response from the other country.

Inserting from (4) in (3) gives:

$$\hat{e}_i^{\beta}\left(B_i^{ee} - D_i^{ee} - \frac{D_i^{ee}D_{-i}^{ee}}{B_{-i}^{ee} - D_{-i}^{ee}}\right) = -B_i^{e\beta} + \frac{D_i^{ee}B_{-i}^{e\beta}}{B_{-i}^{ee} - D_{-i}^{ee}} \quad (5)$$

Similary, we find

$$\hat{e}_{-i}^{\beta}\left(B_{-i}^{ee} - D_{-i}^{ee} - \frac{D_i^{ee}D_{-i}^{ee}}{B_i^{ee} - D_i^{ee}}\right) = -B_{-i}^{e\beta} + \frac{D_{-i}^{ee}B_i^{e\beta}}{B_i^{ee} - D_i^{ee}} \quad (6)$$

The terms on the right hand side of (5) and (6) are positive. However, the sign of the parenthesis on left hand side is ambiguous.

Appendix 3: The effects on the initial allowances due to a technological change

To find the effect on the initial emission allowance, ω, of a technological change, β, we do comparative statics of expression (10) using the identity function in (16):

$$
\begin{aligned}
&\rho^{\omega\omega}\left[\omega_i - E_i\right]d\omega_i + \rho^{\omega\beta}\left[\omega_i - E_i\right]d\beta + \rho^{\omega}d\omega_i - \rho^{\omega}E_i^{p}\rho^{\omega}d\omega_i - \rho^{\omega}E_i^{\beta}d\beta \\
&+\rho^{\omega}d\omega_i + \rho^{\beta}d\beta - D_i^{ee}d\omega_i - D_i^{ee}\frac{d\omega_{-i}}{d\omega_i}d\omega_i \\
&-2\delta\left[d\omega_i - E_i^{p}\rho^{\omega}d\omega_i - E_i^{\beta}d\beta\right]\left[1 - E_i^{p}\rho^{\omega}\right] \\
&+2\delta\left[\omega_i - E_i\right]\left[\rho^{\omega}E_i^{pp}\left[\rho^{\omega}d\omega_i + \rho^{\beta}d\beta\right] + \rho^{\omega}E_i^{p\beta}d\beta + E_i^{p}\left[\rho^{\omega\omega}d\omega_i + \rho^{\omega\beta}d\beta\right]\right] = 0
\end{aligned}
\tag{7}
$$

This can be written:

$$
\begin{aligned}
&\left\{\rho^{\omega\omega}\left[\omega_i - E_i\right] + \rho^{\omega} - \rho^{\omega}\rho^{\omega}E_i^{p} + \rho^{\omega} - D_i^{ee} - D_i^{ee}\frac{d\omega_{-i}}{d\omega_i} - 2\delta\left[1 - E_i^{p}\rho^{\omega}\right]\left[1 - E_i^{p}\rho^{\omega}\right] + 2\delta\left[\omega_i - E_i\right]\left[\rho^{\omega}\rho^{\omega}E_i^{pp} + E_i^{p}\rho^{\omega\omega}\right]\right\}d\omega_i \\
&\left\{\rho^{\omega\beta}\left[\omega_i - E_i\right] - \rho^{\omega}E_i^{\beta} + \rho^{\beta} + 2\delta E_i^{\beta}\left[1 - E_i^{p}\rho^{\omega}\right] + 2\delta\left[\omega_i - E_i\right]\left[\rho^{\omega}\rho^{\beta}E_i^{pp} + \rho^{\omega}E_i^{p\beta} + E_i^{p}\rho^{\omega\beta}\right]\right\}d\beta
\end{aligned}
\tag{8}
$$

or

$$
\begin{aligned}
&\left\{2\rho^{\omega} + \rho^{\omega\omega}\left[\omega_i - E_i\right] - \left[\rho^{\omega}\right]^2 E_i^{p} - D_i^{ee} - D_i^{ee}\frac{d\omega_{-i}}{d\omega_i} - 2\delta\left[1 - E_i^{p}\rho^{\omega}\right]^2 + 2\delta\left[\omega_i - E_i\right]\left[\rho^{\omega}\rho^{\omega}E_i^{pp} + E_i^{p}\rho^{\omega\omega}\right]\right\}d\omega_i \\
&\left\{\rho^{\omega\beta}\left[\omega_i - E_i\right] - \rho^{\omega}E_i^{\beta} + \rho^{\beta} + 2\delta E_i^{\beta}\left[1 - E_i^{p}\rho^{\omega}\right] + 2\delta\left[\omega_i - E_i\right]\left[\rho^{\omega}\rho^{\beta}E_i^{pp} + \rho^{\omega}E_i^{p\beta} + E_i^{p}\rho^{\omega\beta}\right]\right\}d\beta
\end{aligned}
\tag{9}
$$

To be able to solve this, we need to find $\rho^{\omega\omega}$, $\rho^{\omega\beta_i}$ and $\rho^{\beta\beta}$. From section 3.1 we get:

$$
\begin{cases}
\rho^{\omega\omega} = \dfrac{\partial}{\partial\omega}\left(\dfrac{1}{\sum_{j\in N} E_j^p}\right) = -\dfrac{\rho^{\omega}\sum_{j\in N} E_j^{pp}}{\left[\sum_{j\in N} E_j^p\right]^2} \\
\rho^{\omega\beta_i} = \dfrac{\partial}{\partial\beta_i}\left(\dfrac{1}{\sum_{j\in N} E_j^p}\right) = -\dfrac{\sum_{j\in N}\left[E_j^{p\beta} + \rho^{\omega} E_j^{pp}\right]}{\left[\sum_{j\in N} E_j^p\right]^2} \\
\rho^{\beta\beta} = \dfrac{\partial}{\partial\beta}\left(\dfrac{-E_i^{\beta}}{\sum_{j\in N} E_j^p}\right) = -\dfrac{\left[E_i^{\beta\beta} + \rho^{\omega} E_i^{\beta p}\right]\sum_{j\in N} E_j^p - E_i^{\beta}\sum_{j\in N}\left[E_j^{p\beta} + \rho^{\omega} E_j^{pp}\right]}{\left[\sum_{j\in N} E_j^p\right]^2}
\end{cases}
\tag{10}
$$

Signing these expressions requires signing the second derivatives of the emission functions. Thus, we cannot generally say anything of the sign of ω_i^{β}. This may require using specific functional forms.