Should farmers participate in the EU ETS?
Permit price, measurement and technology.

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Abstract

Farmers in the EU do not trade greenhouse gases under the Kyoto agreement. This is an empirical puzzle. Should farmers participate in the EU Emission Trading System (ETS) for greenhouse gases (GHG)? Our overall answer is yes. First, farmers may harvest private net gains because of i) relatively low marginal reduction costs, especially within organic farming; ii) the avoidance of future losses in productivity as a victim of climate change; and iii) the possibility of receiving a favourable allocation system, such as grandfathering or a list of projects that release free allowances. Second, market consequences in terms of the effect on permit price and technology are overall positive, yielding a promising future for the inclusion of agriculture in the EU ETS. Finally, we propose a scheme for including the farming practices in the EU ETS that reduces the uncertainty from measuring emission reduction in this sector.

Keywords: EU; Greenhouse gases; Emission Trading System; Agriculture; Organic farming.

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1. Introduction

The EU has committed itself to an ambitious 20 % reduction of greenhouse gases (GHG) by 2020 compared to the 1990 emissions level. One important tool to achieve this target level is emission trading. Thus, the EU launched the world's first Emission Trading System (ETS) for GHG on January 1 2005 as part of the efforts to comply with the target levels in the Kyoto Protocol.

ETS is a unique innovation in modern environmental regulation, which has been transferred to the EU based on successful American experiences (Svendsen, 1998). In the EU ETS, the ownership of one permit or 'allowance' gives the right to emit 1 ton of CO_2 equivalents. Once the allowance has been used to show compliance in a given year, it will be withdrawn from the market. As long as the allowances have not been used to show compliance, they stay in circulation, and all allowances are identical regardless what year they have been issued. A market for trade with carbon permits is an ingenious way to reach the desired target level – the cap and trade ensures that there is an upper limit for total emission and that GHG reduction in terms of carbon equivalents takes place at the cheapest and most cost-effective facility (Markussen and Svendsen, 2005).

The EU ETS means that trade of GHG allowances (as translated into CO_2 equivalents) can take place between firms in different countries. Almost half of total CO2 emission in the EU is covered by the market, including more than 10 000 installations (Commission, 2008).

There are numerous ways to reduce GHG, e.g. via wind turbines, solar and wave power, bio fuels, energy efficiency measures and – a more recent method – a change in farming techniques. Farmers, however, do not trade GHG under the Kyoto agreement. Why not? We suggest that they should. To our knowledge, this idea has not yet been launched in the literature. A gap exists. This in spite of the fact that the United States heavily advocated the inclusion of change in land-use practices during the climate negotiations in The Hague, year 2000 (Svendsen, 2003). Our research question is therefore: Should farmers participate in the EU ETS?

Much uncertainty is involved in the measurement of emission of methane (CH_4) and nitrous oxide (N_2O) from farming. This has so far been seen as an obstacle to the inclusion of the farming sector in the EU ETS (Monni et al., 2007). There are reasons to believe that some of the uncertainties can be effectively reduced with new knowledge (see Olesen, Fog and Svendsen 2010), and moreover, in the end of this paper, we propose a framework that can circumvent much of the remaining uncertainty and pave the way for including the farming industry in the EU ETS.

We answer our research question in the following way: First, we focus on private gains for farmers from participating. If potential private net gains exist, attracting both conventional and organic farmers to the system will be politically more feasible (Section 2). Next, we focus on market consequences. What happens to the market in terms of changes in the permit price (Section 3) and technology (Section 4) when this new sector is included? One important problem regarding agriculture is the measurement problem. Estimating GHG emissions is higly problematic since they are diffuse non-point sources. Therefore, Section 5 proposes a scheme that takes care of these problems. Finally, Section 6 offers the conclusion.

2. Private gains

The main GHG emitters in the EU-27 are listed below in Table 1. As seen, agriculture is a significant source of GHG emissions, being responsible for 9.2 % of total GHG emissions in 2005 (Copa-Cogeca, 2008).

TABLE 1 APP. HERE.

Table 1 shows that Public Electricity and Heating Production is the greatest GHG emitter in the EU with 27.8 % of total emissions. Transport is second (19.5 %) and manufacturing/construction third (12.7 %). Agriculture ranks number four (9.2 %).

At the moment, three of the great GHG emitters are not covered by the EU ETS, namely 2. Transport, 4. Agriculture and 6. Residential. Thus, while the debate on GHG has mainly focused on the energy, industrial, and residential sectors and households, only very limited attention has been paid to the significant potential to limit GHG emissions in the agricultural sector in spite of the fact that it emits about one tenth of total GHG emissions in the EU-27.

Sectors differ across countries according to their ability to reduce GHG. East European countries, for example, have plenty of opportunity to close inefficient state monopolies and thereby obtain easy reductions. In contrast, countries like Denmark and Germany are already energy-efficient and do not have the same 'low-hanging fruit'-possibilities to reduce GHG as businesses in countries with less efficient industries. Actually, Denmark's situation has worsened by the fact that 1990, the base year for the free allocation of permits (assigned amounts units) was a 'wet' year in the sense that it rained a great deal in Scandinavia. Denmark, therefore, imported large amounts of hydropower from Norway and Sweden that year, and its own fossil-based electricity production consequently remained at a modest level. In other words, Denmark's GHG permit allocation is lower than it would have been in a normal production year.

2.1 Low-hanging fruits

Agriculture mainly emits methane and nitrous oxide besides carbon dioxide. The GHG emissions profile of agriculture, however, is fundamentally different to that of other sectors like industry, households and transport, as it is dominated by methane and nitrous oxide. Methane arises from enteric fermentation by ruminant animals and from manure, while the application of organic and inorganic fertilisers to soil can produce nitrous oxide. These are inherently variable, biological processes (Copa-Cogeca, 2008).

A huge potential for relatively cheap GHG reductions in agricultural ecosystems appears to exist. Picking the 'low-hanging fruits' implies relatively low marginal reduction costs (MRC). For example, improved cropland management (including nutrient management, tillage/residue management and water management), improved grazing land management (e.g. grazing intensity, nutrient management) and the restoration of degraded soils. Also sink enhancement (carbon sequestration), low energy production facilities, biofuels (also for own use), improvements in efficiency of agricultural productivity and the minimization of transportation distance are important options. The mitigation potential of agriculture is estimated to reach 5.5-6 Gt. of CO_2 equivalents per year by 2030. This potential is enormous relative to the emissions of agriculture, which represent 13.5 % of global anthropogenic GHG. 89 % of this potential can be accounted for by soil carbon sequestration; 70 % of the total mitigation potential can be realized in developing countries. Furthermore, significant benefits associated with soil organic carbon storage make sustainable land management a solution to the interrelated issues of poverty, resilience and sustainable development (IFAP, 2009). ‘Over the next decades, adaptation will need to go beyond mere adjustments of current practice’ (Commission, 2009).

Organic farming, in particular, is interesting with respect to the empirical puzzle. First, organic farming is likely to stabilize productivity because it is more resilient to climate change because of efficient nutrient cycles and soil management, and a tendency to promote higher biodiversity. Because organic farming preserves soil fertility and maintains, or even increases, organic matter in soils, this farming technique is in a good position to maintain productivity in the event of drought, irregular rainfall events with floods, and rising temperatures. Soils under organic management retain significantly more rainwater thanks to the ‘sponge properties’ of organic matter (FIBL, 2006).

Second, research conducted over the last decade also indicates that organic farming production methods may have an even higher potential to reduce GHG emissions than conventional farming. To a large extent, this difference in emissions is caused by the non-use of chemical fertilizers. When emission reduction is measured per hectare, the reduction potential appears to be very impressing. Fliessbach (2007) estimates that GHG emissions from organic farming systems are 35-37 % less per hectare compared to organic farming, but when emission reduction is measured on the basis of production output, emissions reductions are significantly lower as a result of lower yields in organic farming. Nevertheless, organic farming still has significant potential for GHG emissions in the arable sector, while the potential is more modest in the livestock sector and negative for vegetables (Halberg, 2008). Furthermore, based upon Danish data, Dalgaard *et al*. (2002) and Dalgaard *et al*. (2003) find that the extent to which emissions decrease depends on the way in which livestock production is adjusted to lower crop yields. If livestock production is upheld at pre-conversion level and fodder is imported to compensate for lower crops yields, the decrease in GHG emissions are significantly lower compared with a situation in which livestock production is adjusted to lower crop yield.

2.2 A victim of climate change

Furthermore, agricultural productivity may be affected by climate change as relatively small changes in the climate can have significant impact on agricultural productivity. For instance, current differences in crop productivity between northern and southern Europe are likely to increase under climate change. Exceeding crop-specific high temperature thresholds are likely to result in a significantly higher risk of crop failure in parts of Southern Europe, while Northern Europe may be able to grow a wider range of crops than is currently possible because of a warmer and longer growing season. Therefore, crops which are presently grown throughout Europe experience more positive impacts in Northern Europe compared with Nouthern Europe (Commission, 1996). Recently, the Commission has stated, that: 'In the long run, climatic pressures may lead to further marginalization of agriculture or even to the abandonment of agricultural land in parts of the EU' (Commission, 2009).

2.3 Grandfathering

In order to make the system politically attractive to farmers, plentiful permits could be allocated to them initially, as has been done in the first phase for other sources. Farmers would then have the possibility to obtain a clear economic net gain from participation in the EU ETS. What policy instrument would an economically rational grouping prefer? One rational choice could be the grandfathered permit trading model, i.e. initial free distribution of historical emission rights (Tietenberg, 2000). This is the distribution rule applied in practice so far in the United States and in the Kyoto Protocol.

The distribution rule of grandfathering consists in a free transfer of the property rights to emission rights to polluters. The idea is exemplified in the following way: If a firm emitted 100 tons of carbon equivalents in 1990 and is 'grandfathered' its 1990 level, this firm will receive 100 carbon permits, each permit entitling it to emit one ton of carbon equivalents. If its carbon emission is cut by 5 % in 2000 by regulators, the firm's permit holding will be devalued to 95 permits for 2000. In this respect, the use of grandfathering corresponds to the use of standards (Command-And-Control). Grandfathering maintains the status quo. The only difference between standards and permit trading is the shift in property rights from public authorities to the polluter. Under permit trading, permits would now be transferable, in contrast to standards in which permits are non-transferable. In this way, permit trading may be politically attractive to producers because it offers them historical emission rights freely when based on grandfathering (Daugbjerg and Svendsen, 2001).

Grandfathering provides rent to existing firms, as opposed to new firms that have to buy their way into the market. So, the winners are all existing firms (who obtain their permits at no cost) whereas the losers are future firms (who have to buy all their permits from existing firms). As the future losers are not represented in the political arena, lobbies representing existing firms will dominate the political decision-making process in their favour (Svendsen, 1998).

The EU ETS is (so far) divided into three phases:

- Phase 1: 1.1.2005-31.12.2007
- Phase 2: 1.1.2008-31.12.2012 (The Kyoto phase)
- Phase 3: 1.1.2012-31.12.2020 (The post-Kyoto phase)

Allocation of allowances in the first and second phase: The member states establish national allocation plans (NAP) in which the number of allowances for each individual country is defined. These NAPs must be approved by the EU, and must fulfil certain criteria, most importantly that the total quantity issued is in line with the Kyoto target. In principle, anyone is allowed to trade in this market. Trade can take place via a broker who matches buyers and sellers or via a spot market at one of Europe’s climate exchanges.

So far, the initial allocation rule has been grandfathering. The EU, however, plans to introduce auctioning in the third phase in order to cost-effectively achieve its overall 20 % reduction target level by 2020 (compared to the 1990 emissions level). This target level is increased to 30 % if other industrialized countries make comparable efforts.

In the words of the EU, the Goal beyond 2012 is to strengthen, expand and improve climate change initiatives (Commission, 2008). The objectives of the third phase (not approved by the EU yet) are to be more cost-effective and more predictable (which has been a problem in earlier phases because of the NAPs). The main changes are as follows (Commission, 2008):

- A decrease along a linear trend in the annual cap
- A change to an auctioned system

- The right to auction allowances in part allocated from relatively rich to relatively poor countries
- The introduction of new installations and the exclusion of some smaller installations

There is a strong need to consider more carefully how to integrate farmers into the objectives of the third phase. Auctioning without compensation is probably not a politically feasible solution. A more ‘soft’ start involving some kind of grandfathering is likely to be more successful.

3. New sources and permit price

This section provides a simple graphical presentation of the consequences of including additional sources in an existing ETS. In the ETS, supply and demand determine market price. Note, however, that this not an ordinary market since a source may be either a demander or a supplier, depending on the market price compared to the shadow price of the permit allocation for this source.

FIGURE 1 APP. HERE

Let p^{TPS} be the permit price in the ETS. From an ordinary marginal emissions reduction costs curve (MRC), it is possible to derive the individual firm’s demand and supply for permits, see Figure 1. Here, firm i initially has an emission level of E_0. It receives a number of permits given by $\bar{E}_i$. Therefore, without any trading, the reduction target for this firm is $\bar{R}_i$ with a resulting shadow value of the firm’s reduction target, given by $p(\bar{R}_i)$. If $p^{TPS} > p(\bar{R}_i)$, then the firm sells permits, and if $p^{TPS} < p(\bar{R}_i)$, the firm buys permits. From Figure 1, it is easy to derive the supply and demand function for this firm, which is done in Figure 2. Whether a firm is a buyer or a seller depends on the price in the market relative to the shadow price of the reduction constraint for the firm $p(\bar{R}_i)$. The maximum demand for the firm is $\bar{R}_i$, which is the amount that the firm needs to reduce. By buying $\bar{R}_i$ permits, it will not have to reduce any. In the same fashion, $\bar{E}_i$ is the largest number of permits that the firm is able to sell. If it reduces all its emissions, it can sell all the received permits from the regulator.

FIGURE 2 APP. HERE.

Given that the firms (sources) have sufficiently dissimilar marginal reduction costs (MRCs), we reach an ordinary market supply and demand by adding up the sources' individual d and s curves, as seen in Figure 3.

FIGURE 3 APP. HERE.

Note that the market equilibrium depends on the initial allocation (and number) of permits, since both the demand and the supply functions are functions of $\bar{R}$ (as should be clear from Figure 2).

Given this set-up, we can now analyse the consequences of including new sources into such a market. The overall conclusion is that if the new sources on average have lower MRC than the existing sources, the price in the market tends to fall. If, e.g., agriculture has lower MRC (or lower shadow values), the permit price tends to fall. The implications are that some selling sources turn into buying sources. And there will be a transfer of reduction from the original sources to the new sources. If, on the other hand, agriculture has higher MRC, the price in the market tends to increase. The implications are then the opposite as before. Some buying sources turn into selling sources. And there will be a transfer of reduction from the new sources to the original sources.

4. Incentives to develop new technology

In this section, we will look at the likely consequences of including the farming industry in the ETS in terms of developing new and cleaner technology. What is the property of dynamic cost-efficiency? An additional reason for using an ETS compared to a non-tradable (standard) solution is exactly that the ETS provides larger incentives to develop/apply new, cleaner technologies. To show this, we compare the incentives created by these two instruments. Suppose that a firm is subject to a non-tradable situation with a reduction target of $\bar{R}_i$. In the ETS, the firm receives permits such that it also reduces $\bar{R}_i$ without trade. To compare a situation with ETS and a non-tradable case, let us initially set the permit price such that the firm does not trade at all. This implies that the reductions in the two situations are the same when we look at the original technology. To illustrate the difference, see Figure 4. Here, $MRC(R)$ represents the original technology, while $MRC^N(R)$ represents a new and cheaper way of reducing emissions.

An additional benefit from the ETS is that the firm can now reduce more cheaply and therefore has an incentive to reduce more and sell the additional permits at the prevailing market price. Thus, as shown in Figure 4, the firm reduces $R^1 - \bar{R}_i$ additional units of emissions. The area B is the excess benefit compared to the non-tradable situations. In this case, there are two effects. First, the firm obtains additional cost savings, and second, it emits less. However, as long as the overall number of permits is fixed, the total emission will not be reduced.

FIGURE 4 APP. HERE.

Given that developing new technology is costly, it is more likely that the new, cleaner technology is more profitable to develop under the ETS system than under the non-tradable situation. There is a caveat to this result. In the above example, the price in the market is assumed constant. But if more firms start adopting this new technology, the price in the market will fall, and the gain from the new technology will be smaller. In the limiting case, in which all firms would experience the same cost reduction from applying the new technology, the situation would be status quo and no additional gain would be experienced compared to the standard.

Finally, the inclusion of new sources that reduce the price in the market will lead to a decrease of the incentives to develop new technologies. This final point is illustrated in Figure 5. If the price in the market falls from p_1^{TPS} to p_2^{TPS}, the cost savings in the ETS compared to the non-tradable situation shrinks from area B to area C.

FIGURE 5 APP. HERE.

In conclusion, lower prices in the ETS provide fewer incentives for development and/or application of newer technologies. On the other hand, lower total compliance costs will make implementation of more stringent reduction targets less politically controversial.

5. A system for including farmers into an ETS

According to EEA (2009), EU farming contributed 9 % to the total EU-15 GHG emissions in 2007, whereas nitrous oxide accounted for 5 % and methane for 4 %. The contribution mostly comes from cattle (CH_4), and direct and indirect soil emission (N_2O), and a minor emission from swine (8% of the total emission from farming). The uncertainty attached to these measurements is considerable. The paper of Monni el al. (2007) in detail describes the great uncertainties related to measuring emissions of nitrous oxide and methane. According to their findings, great uncertainty is attached to N_2O emissions from agricultural soil in particular. Annual emission from EU 15 is app. 190 Tg CO_2e, but with great uncertainty, with a lower and upper bound of 95 % confidence interval of -100 to +1000% as a percentage relative to the mean. According to Monni et al. (2007), the reason for this is that emission is caused by complex biological processes with various changing parameters.

On the other hand, new research indicates that recent techniques for measurement, based on already existing data from both conventional and organic farmers, can reduce uncertainties to some extent (see Olesen, Fog and Svendsen, 2010). Moreover, emission inventories are calculated for any sector, including the farming industry. The IPCC (2006) provides a series of reduction factors that are used for this purpose. Applying such an approach to an individual farmer is the centre of the scheme we propose here.

In the following, we propose a system that can be used for including the farmers in the ETS, even though uncertainty and measurement problems exist.

As a starting point, farming contains a number of processes, like keeping animals, or producing crops. Each of these processes can be subdivided into activities like keeping different animals. Finally, for each such activities, different practices exists, like which fodder to give cows. The basic idea of this system is that instead of measuring the emission directly, we calculate the (average) change in emission from the baseline practice to the new practice. The whole idea of the system is that the authorities can in advance specify what practices should be accepted as valid reduction measures. (This could be motivated, e.g., by not including practices that are judged to generate uncertain results). We only want to illustrate our idea, therefore we here only focus on changes in practices and not on changes in activities of processes, but this be included without much complication.

Assume a number of farmers, $F^i, i = 1,2,\dots,n,$ are chosen to enter an ETS. (A criterion could be to only include farmers of a minimum emission level). We have to specify an allocation rule for the initial allocation of allowances to the farmers. Call the allocation rule $\alpha(a)$. As an example, a uniform allocation rule $\alpha(a,t)$ allocates to each farmer i at time t a number of allowances:

$$\alpha_t^i = a \cdot E_{t-1}^i$$

With $a \leq 1$, and where E_{t-1}^i is the calculated emission in (the end of) the previous period. If $a = 1$, there is no requirement of net reduction from the sector in this period, while for any $a < 1$, there is a requirement of net reduction from the sector in this period.

Now let us look at how to calculate emissions from activities and practices. Let a number of activities be $A_j, j = 1,2,\dots,J$. For each such activity, there is a number of practices, indexed by $k = 1,2,\dots,K_j$. Each activity practice pair has an emission factor per unit of measurement (E.g., one cow fed with fat food has an emission factor of β_{cff}, while the emission factor of conventional food is β_{ccf}). If a farmer switches from conventional to fat food, the emission reduction per cow per year is given by: $\beta_{ccf} - \beta_{cff}$. More generally, we call the units U_j^i (in the above example a cow) and activity practice pair the emission factor for β_{jk}.

Let us now turn attention to reduction projects of farmer i. Such a reduction project in our setting is a change in practice from a baseline (BL) practice to a new practice. We write the change in emission per unit activity as $\Delta_k\beta_{kj} = \beta_{kj}^{BL} - \beta_{kj}$. We introduce time as t to indicate that permits are valid in a limited period of time. To simplify, assume that farmer i total has $l = 1,2,\dots L^i$ reduction projects. [1]Reduction from project l for farmer i is given by $R_t^{li} = \Delta_{kt}\beta_{kj} \cdot U_{kj}$, i.e.to make this model work, we need to specify all the β's, as this also defines the p_j's and all the U_j's. (Here, we

[1] So if a farmer has two activities and for the first changes two practices and for the second 1, $l = 3$.

ignore the case that U_j^i could also be changed. But this is easily included into the model.). Finally, total reduction is given by $R_t^i = \sum_{l=1}^{L^i} R_t^{li}$.

How many allowances must farmer i hand in at the end of the period? This is calculated in the following way, where $A_t^i(\text{hand in})$ means the number of allowances that farmer *i* must hand in to the authorities in the end of period *t*:

$$A_t^i(\text{hand in}) = E_t^i - R_t^i$$

So for each type of activity, j, we calculate the reduction due to changed practices (there could be more than one practice for an activity, or for subsets of this activity). Subsequently, we sum over the reductions for each activity to obtain the total reduction. This sum is then subtracted from the emission level of this source at the beginning of the period. This provides the number of allowances that the farmer must hand in. If this sum is lower than the initial allocation, the source can sell from the remaining allowances. If the sum is larger than the initial allocation (which is possible either when $a < 1$ and no reduction undertaken, of $a = 1$, but emission increased), this source must buy additional allowances. In appendix 1, we present an example of how this system works.

TABLE 2 APP. HERE.

Fødevareministeriet (2008) states that the total potential for reducing emissions from farming in Denmark is estimated to be 3851 MtCO2e per year, which amounts to 31 % of the emission from agriculture and 6 % of the total emission (year 2007). However, incentives to choose new practices depend on (net) costs of these new practices and the P^{TPS}. In Table 2, we show the most promising practices in terms of size and costs.

There are, however, even more effective ways of reducing emission, which is not included in Table 2. According to Fødevareministeriet (2008) and Chatskikh et al. (2008), reduced tillage (and direct drilling), which are methods that reduce labour and energy efforts, show a great CO_2e reduction potential. The reductions can mainly be attributed to reduced energy uses, increased storage of CO_2

in the soil and net changes in the emission of nitrous oxide. The studies conclude that the total emissions reduction is app. 370 kg CO_2/ha, with approximately 90 % stemming from storage.

At present (May 2010), the price of allowances is app. 13€/tonnes CO_2. If comparing this price with the reduction costs in Table 2, such a price will, all else equal, only imply minor reductions from the farming sector. There are, however, two reasons to expect that this will underestimate the future potential for reductions in the farming sector, if it is included in the EU ETS.

The first reason is that in an ETS, as already stressed in the previous section, the participants have incentives to find new and/or cheaper ways of implementing these measures, implying that costs of the above measures fall. The second reason is that if the third phase will be implemented, the allowance price is likely to increase once the number of allowances is reduced.

Finally, we proposed a scheme that may be considered a project-based approach, in which the regulator in advance makes a list over farming practices that can be used as valid reduction measures in the EU ETS system. This brings about the question of which practices to include? One reasonable criterion would be to only include practices in which the uncertainty is minor. The uncertainty here could relate to measurement uncertainty or simply lack of understanding of the underlying biological/chemical processes. As new research reduces such types of uncertainty or new methods that contain less uncertainty are developed, the list of acceptable practices can be expanded.

6. Conclusion

The EU is facing a great challenge under the Kyoto Protocol in its ambitious efforts to achieve a 20 % GHG reduction from 1990 to 2020. Crucially, the participation of farmers could be one extra important tool for the European Union to succeed. Should farmers participate in the EU ETS? This research question was stimulated by a gap in the literature. Our argument is yes. Farmers should join in for two reasons.

The first reason is that farmers may harvest private net gains from participating. Recent surveys clearly indicate that farmers face relatively low marginal reduction costs. Low hanging fruits exist both within conventional farming and, perhaps, organic farming in particular. Farmers as a group may gain significant benefits from GHG trade. Furthermore, farmers may avoid future losses as climate change may have a significant economic impact on agriculture in near future. Finally, the option of grandfathering rather than auctioning would be the first step to attract farmers to the system.

The second reason why farmers should participate in the EU ETS is that the market consequences in terms of the effect on permit price and technology are overall positive. Regarding the effects on the price of allowances, it is not likely that the inclusion of the farming industry will have a significant influence on the price because of its relatively small size compared to the overall emissions. It will, however, imply a larger volume of trading, resulting in cost-efficiency gains. Incentives to development and/or implementation of new and cleaner technologies are, however, also largely affected by expectations of future allowance prices. If the third phase is implemented as proposed, an increase in the allowance price is to be expected, which will generally spur incentives for technology improvements. This is also likely for the farming industry, making more and more new practices attractive. Note that being in an ETS provides continuous incentives to make new practices cheaper or more effective, even if the price of allowances remains constant (compared to ordinary CAC regulation). Therefore, the estimates of present costs of reductions for the various measures (like the one presented in table 2) typically exaggerate costs for applying these measures in the future.

Finally, in this paper, we have proposed a system that makes it possible to overcome some of the potential shortcomings from including farmers into the EU ETS, which have been put forward. First and foremost, farmers would increase measurement problems and uncertainty significantly as emissions are a non-point source. Our system is framed as a project-based system. Thus, it resembles, e.g., a joint implementation arrangement. A project in this system is an approved way of reducing emissions, either by introducing a new, less polluting practice or by reducing the polluting activity. In this system it is possible to control the uncertainty by only including the least uncertain elements. As new and better information is available, new practices can be included, such that the system also is flexible. Finally, it still provides the farmers to invest in CO_2e reducing activities. In this way, the farmers can be included, without increasing the uncertainty in the EU TPS significantly.

Overall, the inclusion of both conventional and organic farmers in the EU ETS offers a solution which meets the interests of farmers and the EU as a whole. If the challenge of incorporating agriculture in the EU ETS can be addressed adequately, indeed, the role of farmers in climate policy may become a hot issue during future climate meetings. Crucially, the US would probably be much more likely to rejoin the Kyoto agreement, thereby clearing the road for the participation of China and India as well. Until now, the US has strongly advocated land-use practices as ‘the missing link’ in past climate negotiations.

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APPENDIX 1

Example (numbers are totally random).

Consider a situation with three farmers and two activities. Activity 1 has two possible practices, while activity 2 has three practices. So far, all the farmers use the practice that has the highest emission factors.

Farmer	U_1	U_2
F_1	30	40
F_2	20	50
F_3	10	70

β_{11} (Baseline)	0.7
β_{12}	0.5
β_{21} (Baseline)	0.4
β_{22}	0.5
β_{23}	0.2

Assume that F_1 uses β_{12} instead of β_{11} and that F_2 uses β_{23} instead of β_{21}. F_3 does not change practice over the period.

Calculate the initial emissions:

$$E_0^1 = 30 \cdot 0.7 + 40 \cdot 0.4 = 37$$
$$E_0^2 = 20 \cdot 0.7 + 50 \cdot 0.4 = 34$$
$$E_0^3 = 10 \cdot 0.7 + 70 \cdot 0.4 = 35$$

sum = 106

Calculation of net reductions:

$$R_0^1(\beta_{12}) = (0.7 - 0.5) \cdot 30 = 6$$
$$R_0^2(-) = 0$$
$$R_0^3(\beta_{23}) = (0.4 - 0.2) \cdot 70 = 14$$

sum = 20

Let $\alpha = 0.9$

The first period allocation of allowances is given by:

$$A_0^1 = \alpha \cdot E_0^1 = 0.9 \cdot 37 = 33.3$$
$$A_0^2 = \alpha \cdot E_0^2 = 0.9 \cdot 34 = 30.6$$
$$A_0^3 = \alpha \cdot E_0^3 = 0.9 \cdot 35 = 31.5$$

sum	= 95.4

The number of allowances to hand in and the surplus allowances:

$A^1(\text{hand in}) = E_0^1 - R_0^1 = 37 - 6 = 31$

Surplus allowances for farmer 1: $A_0^1 - A^1(\text{hand in}) = 33.3 - 31 = 2.3$

$A^2(\text{hand in}) = E_0^2 - R_0^2 = 34$

Surplus allowances for farmer 2: $A_0^2 - A^2(\text{hand in}) = 30.6 - 34 = -3.4$

$A^3(\text{hand in}) = E_0^3 - R_0^3 = 37 - 14 = 23$

Surplus allowances for farmer 3: $A_0^3 - A^3(\text{hand in}) = 31.5 - 23 = 8.5$

The total surplus of allowances is: 7.5

Figure 1: *Marginal reduction curve*

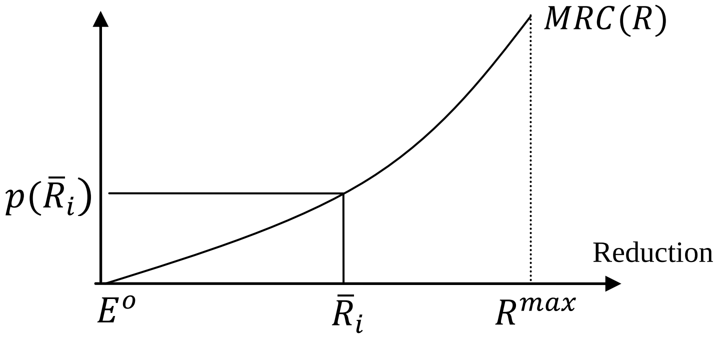

Figure 2: *Individual firms' demand and supply for permits*

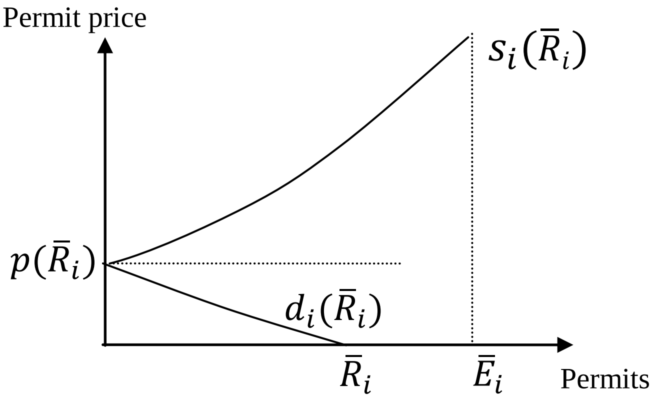

Figure 3: *The market for permits*

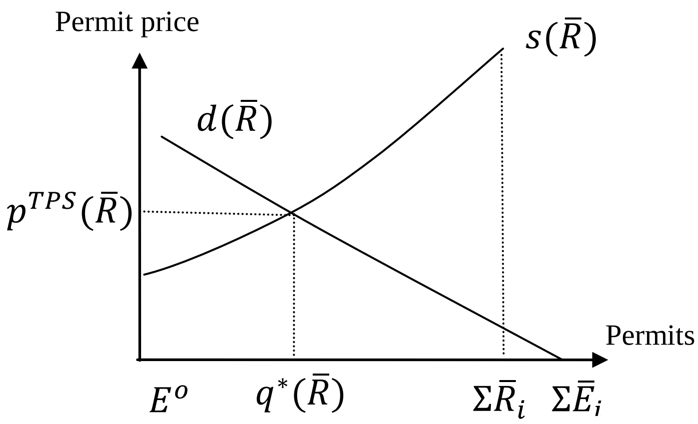

Figure 4: *A selling firm*

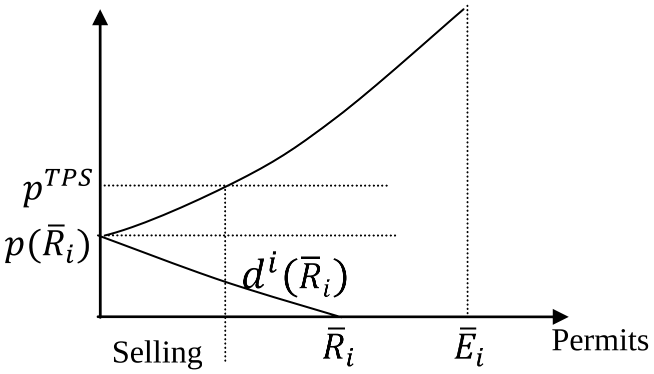

Figure 5: *Cost reduction of new technology: Comparing ETS with a standard.*

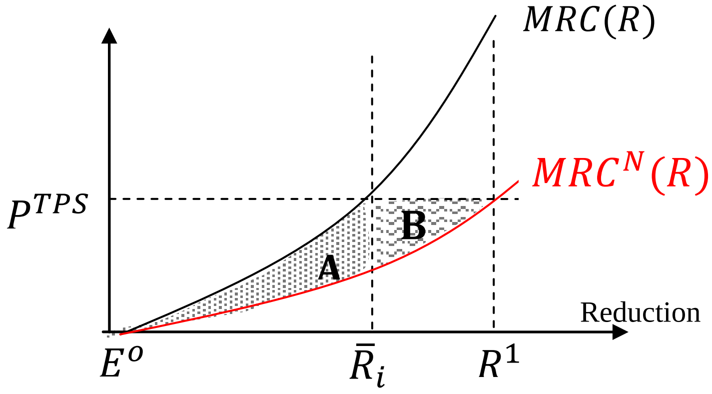

Figure 6: *Lowering of price in the ETS reduces incentives to develop new technology*

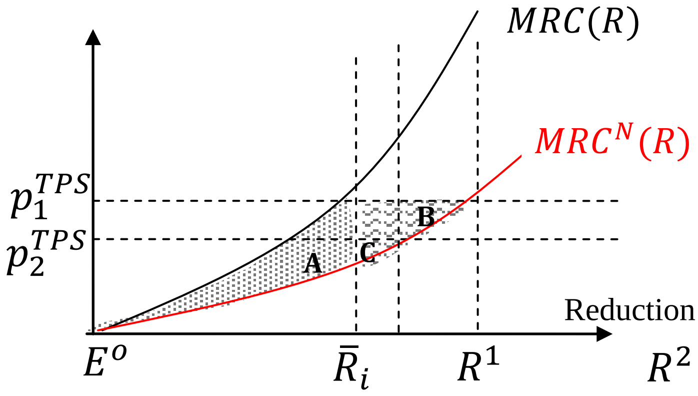

Table 1: GHG emissions from different sectors in the EU-27, 2007.

Sector	%
1. Public Electricity and Heat Production	27.8
2. Transport	19.5
3. Manufacturing Industries and Construction	12.7
4. Agriculture	9.2
4. Industrial Processes	8.5
6. Residential	8.5
7. Commercial/Institutional	3.3
8. Waste	2.8
9. Petroleum Refining	2.7
10. Fugitive Emissions from Fuels	1.7
1.1. Agriculture/Forestry/Fisheries	1.5
12. Manufacture of Solid Fuels and Other Energy Industries	1.4
13. Solvent and Other Product Use	0.2
14. Other (Not elsewhere specified)	0.2
Total	100.0

Source: EEA (2010)

Table 2: Potential reduction measures, their size and costs

Type of measure	**Reduction potential**[1] (Denmark)	**Reduction cost**[2] **(**€/tonnes CO_2e)
Bioenergy		
Straw for energy production	298	15
Manure management	807	90
Willow chips	1270	Sandy soil: 55 Clay soil: 92
Energy maize	531	179
Domestic animals		
Adding fat in cattle feed above standard	298	43
Nitrification inhibitor	272	191
Cropland management		
Summer catch crops	280	n.a.
Set-aside of agricultural area on lowland	295	29
Grassland	247	911
Agroforestry	321	911

Source: Danish ministry of Food, Farming and Fisheries (Fødevareministeriet, 2008 [Our translation]). Note: Numbers do not include any reduction of domestic animals since it is assumed that a reduction in one country region will increase the number of animals elsewhere.

[1] Estimated potential for reduction of GHG from farming until 2020. 1000 ton CO2e per year.

[2] Numbers are costs to the farmers of implementing the measure. C-storage in soil is not included.