Economic Implications of International Participation Alternatives for Agricultural Greenhouse Gas Emission Mitigation

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Abstract

The world is moving toward potential efforts to reduce greenhouse gas emissions as manifest in public discourse and international agreements like the Kyoto Protocol. Net emission reduction efforts may involve the agricultural sector through options such as planting of trees, crop and livestock management changes, and production of biofuels. However, such options can be competitive with domestic food production. In a free trade arena, reduced domestic food production could stimulate increased production and exports in other countries, which are not pursuing similar mitigative courses of action. As a consequence, agricultural producers in countries where agricultural efforts may be pursued have expressed concern relative to their competitive position vis a vis countries which are not trying to reduce net emissions.

We examine the competitive effects of differential mitigation efforts on agricultural food production and on international trade. In doing this we employ the assumption that the average U.S. compliance caused cost increase would also occur in other complying countries. We consider implementation 1) unilaterally by the U.S., 2) by all Kyoto Protocol Annex I countries and 3) globally. The results, which are only suggestive of the types of effects that would be observed due to the simplifying cost assumptions, indicate compliance causes supply cutbacks in regulated countries and increases in non-regulated countries. In addition, the study results show that U.S. agricultural producers are more likely to benefit from a Kyoto Protocol like environment but that consumers are likely to be hurt in terms of their agricultural welfare.

Introduction

Society has increasingly become concerned with the emissions of greenhouse gases (GHG), the resultant atmospheric GHG concentrations, and their potential effects on climate. The Intergovernmental Panel on Climate Change, projects that GHG concentrations will cause global mean temperatures to rise by about 0.3 degree Celsius per decade (Houghton, Jenkins, and Ephramus, 1991). Such warming in turn is predicted to raise sea level, change habitat boundaries for many plants and animals, and induce a number of other changes (Cole et al., 1996). Numerous measures have been proposed to mitigate GHG emissions. A number of potential measures involve agriculture and forestry, encompassing a variety of potential emission abatement strategies (McCarl and Schneider, 2000).

GHG emission (GHGE) reduction effects are global, thus all countries will share the benefits from GHGE mitigation, but only countries adopting mitigation measures will directly bear the costs. Producers within countries adopting GHGE mitigation strategies are likely to experience increased production costs for traditional commodities. Non-implementing countries, therefore, may gain advantage and trade market shares between implementing and non-implementing countries may change. This has been a concern of producers in many potentially effected countries. For example the U.S. Farm Bureau advances a position that it will not support ratification of the Kyoto Protocol (KP) unless principal international market competitor countries are also constrained by the KP terms (Francl, Nadler and Bast, 1998).

This document reports on a first order examination of the international trade impacts of differential GHG mitigation efforts. Specifically, we examine trade and U.S. agricultural sector implications under 1) unilateral U.S. implementation, 2) unilateral U.S. and all other Annex I[a] country implementation and 3) global implementation. The global implementation scenario could arise under a perfect implementation of the Joint Implementation (JI, KP Article 6), the Clean Development Mechanism (CDM) of article 12 and the international trading mechanisms in article 17.

Scope of GHGE Reduction Implementation

Suppose we investigate two different international implementation and trading cases. The first considers the impacts of unilateral GHGE mitigation and the second global implementation of GHGE mitigation.

Unilateral GHGE Mitigation Implementation

Suppose a group of net exporting countries (for exposition these counties will be called A1 and the rest of the world will be called non-A1 countries) implement mitigation efforts that collectively influences supply enough that world market equilibrium prices will be affected. Under the revised trade equilibrium A1 countries' exports will equal total imports into non-A1 countries and the prices will be equalized.

If A1 countries alone mitigate gasses, their domestic and export supply would decrease reflecting higher cost of domestic production. The new equilibrium would yield lower levels of A1 domestic production and exports, and a higher price since demand from domestic and foreign

[a] According to the definition in the Kyoto Protocol, "Party included in Annex I" refers to a party included in Annex I to the United Nations Framework Convention on Climate Change, as may be amended, or to a Party which has made a notification under Article 4, paragraph 2(g), of this Convention.

country remains the same. Non-A1 countries would increase their aggregate food production because of higher equilibrium prices in world markets. Assuming that emissions are proportional to food production intensity, emissions will decrease in A1 countries but will increase in Non-A1 countries. The effect on global GHGE, however, is ambiguous depending on elasticities of involved supply and demand curves.

World Wide GHGE Mitigation Implementation

In this scenario, supply for traditional agricultural products decrease both in A1 and non-A1 countries assuming global demand remain the same. As a result, the world market equilibrium prices would increase. The food production impact in an individual country depends on the country specific link between food production and GHGE. If mitigation policies induce substantial supply impact in some countries but only little in others, production may increase in latter countries. Overall, global implementation of GHGE mitigation policies is likely to smooth the cost of emission reduction.

Model Description

To evaluate the empirical magnitude of alternative levels of GHG emission trading we use a greenhouse gas version of the U.S. Agricultural Sector Model (ASM) developed by Schneider (2000) and Schneider and McCarl (2000). This model arose from the base ASM as described in McCarl et al. (2001) and Chang et al. (1992) with the addition of details on soil types (developed in conjunction with USDA NRCS) and a trade representation via spatial equilibrium models for eight commodities as developed by Chen and McCarl (2000) and Chen (1999). The combined model hereafter called ASMGHG considers agricultural production, consumption, and trade in developed and developing countries simultaneously. Overall characteristics of the model are discussed below.

General Structure of the U.S. Agricultural Sector Model

Like many agricultural sector models, ASMGHG is a price-endogenous mathematical program following the market equilibrium and welfare optimization concept developed in Samuelson (1952), and Takayama and Judge (1971). ASMGHG assumes individual producers and consumers cannot influence commodity or input market prices. Production and use of farming inputs are portrayed in 63 regions in the U.S. and for 28 foreign regions. Data on currently observed trade quantities, prices, transportation costs, and supply and demand elasticities were obtained from Fellin and Fuller (1997, 1998), USDA statistical sources (1994a, b, c; annual), and the USDA, SWOPSIM model (Roningen, 1991).

Modeling Greenhouse Gas Emissions and Mitigation Strategies

Schneider (2000) added a GHGE mitigation component to ASM. That component introduces production alternatives and GHG net emission accounting to reflect the GHG consequences of changes in crop mix, tillage, irrigation, fertilization, afforestation, biofuel production and livestock management. Livestock management options involve 1) herd size, 2) methane reduction strategies including liquid manure system alterations on dairy and hog farms and 3) enteric fermentation management involving use of growth hormones for dairy cows. A detailed technical description of all considered mitigation strategies is contained in Schneider (2000). In terms of GHGE accounting ASMGHG considers:

- Direct carbon emissions from fossil fuels (diesel, gasoline, natural gas, heating oil, and LP gas) used in tillage, harvesting, or irrigation water pumping

- Carbon emissions or sequestration arising from altered soil organic matter stimulated by tillage forms or land use change to and from forest lands or grasslands,
- Indirect carbon emissions from manufacture of fossil fuel intensive inputs (fertilizers, pesticides),
- Carbon offsets from biofuel production (ethanol, power plant feedstock via production of switchgrass, poplar, and willow) as well as associated and methane and nitrous oxide emission changes from biomass combustion,
- Nitrous oxide emissions from fertilizer usage,
- Methane emissions from enteric fermentation, and rice cultivation
- Methane savings from manure management changes as well as both methane and nitrous oxide emission alterations from herd size alterations.

Individual emissions and emission reductions were converted to carbon equivalent measures using global warming potential from the IPPC (21 for methane and 310 for nitrous oxide).

Experimental Results and Implications

Three alternative mitigation implementation scenarios were run. The first scenario assumes unilateral mitigation efforts in U.S. agriculture only. The second corresponds to a KP like situation with simultaneous implementation in all Annex I countries. The third involves worldwide implementation. All three scenarios were analyzed for alternative carbon equivalent (CE) prices ranging from 0 to 500 dollars per ton.

Unilateral Implementation in Just the United States

U.S. agricultural sector effects of a unilateral U.S. emission policy implementation over a range of CE-prices are listed in Table 1 and 2, which show percentage changes from a zero CE-price base situation embodying no action on the GHGE mitigation front. Total CE-equivalent emissions decline steadily as the CE-price rises. At $100 per ton, net emissions of CE from U.S. agriculture are about zero with the realized levels of carbon sequestration from carbon sinks offsetting all agricultural emissions. Net sequestration of carbon occurs at CE-prices above $55 per ton. As Table 2 shows, the sector becomes a sink when CE-prices are extremely high, i.e., a CE-price of $400 per ton yields annual net emission of -168 MMT.

The results in Tables 1 and 2 show the finding that emission reductions are obtained at the expense of conventional crop production. Increasing CE-prices cause decreases in U.S. production and exports along with increases in prices. In addition, since the U.S. is a major trading country, production in other countries is influenced. As shown in Table 1 unilateral CE-prices lead to expanded world production and exports in both Annex I (U.S. not included) and non-Annex I countries.

The welfare impacts of GHGE mitigation efforts are listed in Table 2. In the unilateral implementation case U.S. consumers' surplus decreases monotonically with CE-price increases, but producers' surplus is reduced for CE-prices below $55 per ton while it increases above that level. This change in Producers' surplus arises from both the traditional commodities markets and the CE-price induced GHG payments/charges. In terms of CE-price induced GHG payments/charges these include: 1) charges at the CE-price for emissions from land use change, fuel use, livestock, rice, fertilization and other emissions; 2) higher costs for fertilizer and other inputs due to the embodied emissions in their manufacture; 3) sequestration payments for increased soil, grassland and forest carbon; and 4) payments for biofuel offsets (which may arise in the form of a higher commodity price for biofuels arising from offset credits earned by power plants). In the U.S. only implementation case, producers' always gain in the production account due to commodity price increases which more than offset production reductions. The net effect in the GHGE account depends on the balance between emission and sequestration. For prices below $100 per ton, net emissions are positive resulting in additional sectoral cost. Above that price, the amount of sequestration exceeds emissions and thus provides additional sectoral revenue.

Trade surplus measures the welfare of consumers and producers in non-U.S. countries attributable to trade of agricultural commodities. If the U.S. alone implements agricultural provisions for mitigation, the impact on welfare in other countries is negative with the magnitude getting bigger as the CE-price increases. Consumer losses in non-U.S. countries exceed producer gains.

Modeling Mitigation Induced Shifts in ROW Countries

Mitigation efforts in regions outside of the U.S. could not be modeled explicitly because we did not have detailed modeling of production activities in foreign regions, rather having excess supply curves. Thus, a simplifying assumption was made to depict the supply shifts in foreign countries. Namely, the average price increase and production decrease observed in U.S. production was assumed to proportionally apply to the production in the other countries. Thus, under a particular CE-price, if average U.S. prices went up by a% and production down by b% the same shift was applied to foreign supply for all commodities in the implementing countries. This is clearly a crude approximation of what would happen, but we felt alternative reasonable assumptions were not available. Empirical results derived from supply shifts in non-U.S. Countries should therefore be considered illustrative but not definitive. In presenting our empirical results we will focus on a comparison between the various implementation scenarios examined.

Full Annex I Implementation

The results for the all Annex I countries implementation are shown in Table 1. In terms of U.S. agriculture, production and exports decline but not as much as in the unilateral case. This diminished response reflects the fact that only the non-Annex I countries now have comparative advantage over U.S. agriculture as their costs have not been influenced. Prices of traded agricultural commodities increase slightly more under full Annex I implementation. The welfare results show overall U.S. welfare is reduced less and consumers loose even more than under unilateral implementation. On the other hand U.S. producers always gain.

Annex I countries' net exports are highest under U.S. unilateral implementation but lowest if all Annex I countries are subjected to agricultural mitigation policies. Equivalently, non-Annex I countries' net exports are highest under full Annex I country implementation. All of these observed changes become more substantial the more the CE-price increases. Note that the Annex I accounts displayed in all figures do not involve the U.S. to avoid double counting.

Total emissions reductions from U.S. agriculture are almost identical up to CE-prices of $55 per ton (Figure 1). Above $85 per ton of CE, additional emissions reductions become smaller under full Annex I country implementation. For example, at a CE-price of $100 per ton, emissions reductions are about 11 percent lower than for U.S. alone implementation. U.S. emissions rise because higher commodity prices lead to more intensive production and less adoption of sequestration and emission control activities. This would be offset by emissions reductions in the Annex I agriculture but we cannot account for that as we do not have emissions modeled in those countries and extrapolation of U.S. rates would involve even more heroic assumptions than we are now making.

Global GHGE Mitigation Implementation

Provisions in the KP permit emissions offsets where GHGE emission reductions from projects in non-Annex I countries may be counted as part of the emission reduction obligation for project sponsors in Annex I countries. In such circumstances, low cost activities in agriculture can be exploited globally. Thus, in the last scenario we examine a case where production globally is shifted using the U.S. average price and cost shift assumptions as explained above. Tables 1-2 list the main impacts. There we find an increase in US market share at the expense of foreign countries, particularly the non-Annex I ones. Prices rise more than in the unilateral case. Note this is a property of the assumptions as we have successively shifted more and more of the total model supply curve.

On the welfare side, U.S. producers benefit even more from such a situation but consumers lose even more. In terms of emissions, the more countries implement GHGE mitigation policies, the smaller are net emission reductions from U.S. agriculture. For example, at a CE-price of $100 per ton, emissions offsets are about 21 percent lower than for U.S. unilateral implementation.

Conclusions

The prospect of greenhouse gas emission mitigation policies has stimulated a wide search for cost-efficient emission reduction methods. Agriculture including forestry has been proposed as a relatively cheap source of net emission reductions. However, concerns have been expressed about agricultural abatement policies being hosted in only a subset of all countries. The comparative advantage gained in the agricultural sectors of non-host countries could distort trade patterns, harm domestic agricultural producers in host countries, and lead to increased emissions in non-host countries. Our investigation in the context of the U.S. agricultural sector, confirm tradeoffs between agricultural emission reductions and traditional food and fiber production. In particular, the two most carbon abating strategies, afforestation and production of biofuels, cause the greatest decline in traditional agricultural production. If the positive relationship between agricultural production and agricultural emissions also holds in foreign countries, then our results imply increased greenhouse gas emissions in non-host countries. However, the consequences of such emission leakage would not necessarily be incurred by non-host countries but by those countries, which are most vulnerable to climate change.

The findings of this paper have several implications for policy makers. First, if national agricultural greenhouse gas mitigation policies are not synchronized with foreign greenhouse gas emission policies, substantial leakage may occur. For example, if an international treaty like the Kyoto Protocol were implemented, emission reductions in Annex I countries would most likely be accompanied by emission increases in Non-Annex I (developing) countries. Several alternatives exist to prevent emission increases through agriculture in non-host countries. For example, the Kyoto Protocol proposes Joint Implementation (JI) and Clean Development Mechanisms (CDM). Through such mechanisms, host countries could establish incentives for agricultural producers in non-host countries to adopt technologies, which do not increase emissions.

Second, U.S. farmers' would benefit from a larger number of countries hosting greenhouse gas emission mitigation policies. The more countries abate greenhouse gases through the agricultural sector, the higher agricultural commodity prices would be. Income support has been a longtime objective of American farm bills. If the U.S. and other potential host countries would financially support a Clean Development Mechanisms in non-host countries, i.e. Non-Annex I countries, a portion of that expenditure could pay back because higher agricultural prices eliminate the need for expensive farm bills.

Third, if implementation of an equivalent mitigation policy or CDM in all countries is politically infeasible, trade policies might need to be negotiated discourage increases in non-participating countries and to discourage leakages.

Fourth, credits for agricultural emission abatement could be discounted to reflect likely emission leakage through agricultural sectors in non-host countries. This adjustment would imply higher discount factors for agricultural mitigation strategies, which divert farmland such as afforestation and biofuel production. However, strategies, which are complementary to traditional food and fiber production such as reduced tillage, would remain eligible for full credit. A differential treatment of agricultural mitigation strategies would then increase the relative adoption of complementary strategies and thus reduce leakage.

Fifth, consumers of agricultural products incur higher expenses due to price increases. The more countries participate in mitigation efforts, the higher are losses to both domestic and foreign consumers. Consequently, more people may become dependant on governmental aid to ensure sufficient food consumption.

Quantitative effects presented in this study reflect several simplifying assumptions and uncertain data, and should therefore be considered preliminary. While efforts will continue to improve the underlying data, the basic nature of our findings is unlikely to change.

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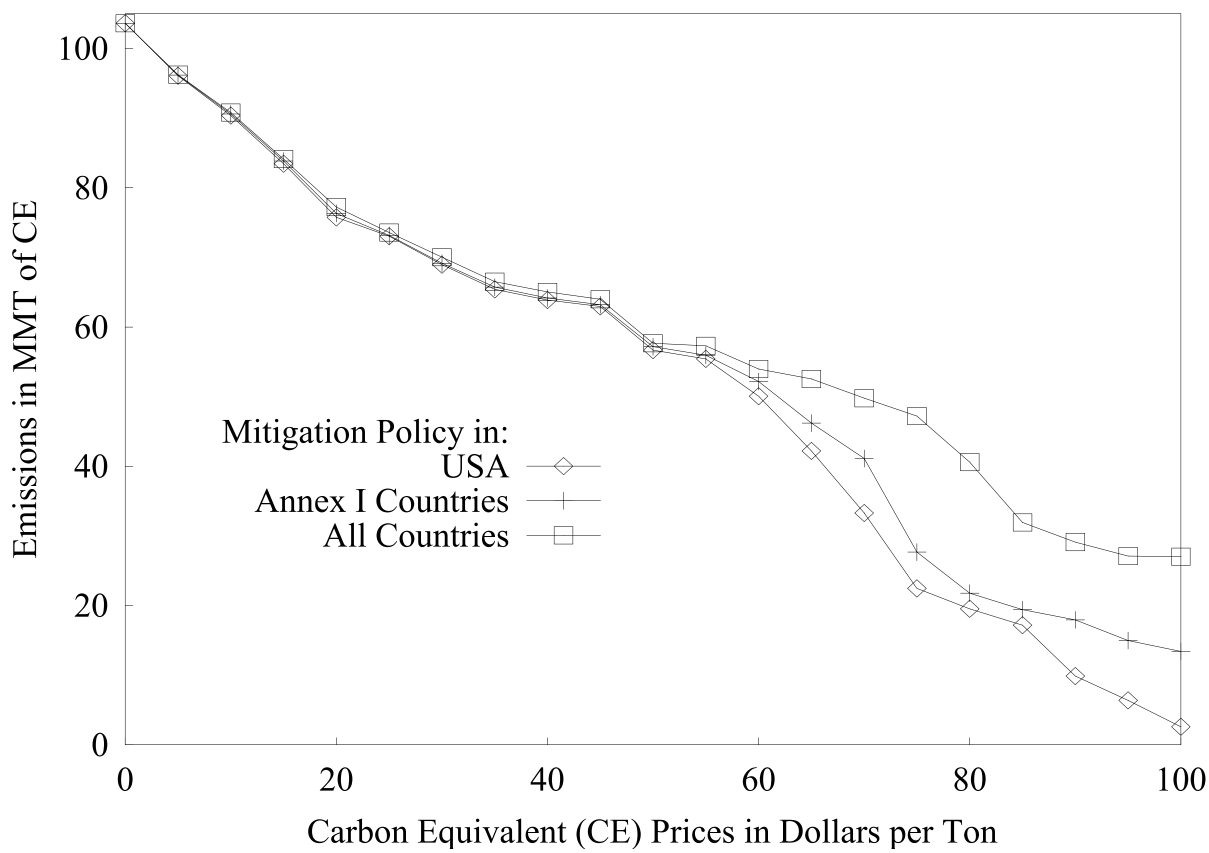

Figure 1 Carbon Equivalent Prices and Net Carbon Emissions from U.S. Agriculture

Table 1 Results on Fisher Ideal Price and Quantity Indices of Production, Price, and Trade at Different Carbon Equivalent Prices for Greenhouse Gas Emissions[b]

	Mitigation Policy in								
	USA Only			Annex I Countries			All Countries		
	$20	$100	$400	$20	$100	$400	$20	$100	$400
U.S.									
Trading Crops Production	99.09	93.47	66.20	99.64	97.09	88.84	100.59	105.11	114.91
All Production	99.04	97.53	96.34	99.16	97.43	97.00	99.32	98.59	95.70
Trading Crops Prices	101.18	112.06	226.40	102.08	120.72	357.31	103.65	140.35	635.79
Overall Agricultural Product Prices	101.42	110.60	196.32	101.82	113.44	225.04	102.28	121.68	307.17
Exports	97.44	81.77	18.84	99.50	97.65	104.13	103.28	126.92	203.97
All Countries Except U.S.									
Exports	100.83	107.95	145.25	100.66	106.64	143.73	96.58	78.34	68.83
Imports	99.24	95.88	85.94	100.23	105.65	142.17	100.56	105.59	145.06
Prices	101.06	107.94	148.68	102.44	123.02	408.12	104.83	154.08	889.01
Annex I Countries (excluding U.S.)									
Exports	100.69	102.66	113.00	98.81	92.31	80.19	99.94	99.25	89.37
Imports	99.32	95.86	85.55	102.84	128.95	269.59	101.73	111.48	155.95
Prices	101.20	109.21	156.57	103.00	128.20	487.18	105.44	161.80	1008.84
Non-Annex I Countries									
Exports	100.93	112.22	174.45	102.15	120.13	261.04	93.85	57.60	38.13
Imports	99.19	95.89	86.22	98.43	89.71	58.90	99.76	101.68	138.88
Prices	100.95	107.04	143.28	102.03	118.96	332.63	104.39	148.11	796.69

[b] Note: Trading crops production includes the production for corn, soybeans, sorghum, rice, and four kind of wheat defined previous; all production includes production for all primary products (crops and livestock) defined in the model.

Table 2 Impacts of Mitigation Policies on Agricultural Sector Welfare (Million Dollars) and U.S. Emissions (MMT) at Different Carbon Equivalent Prices[c]

	Mitigation Policy in								
	USA Only			Annex I Countries			All Countries		
	$20	$100	$400	$20	$100	$400	$20	$100	$400
U.S. Consumers' Surplus	-1,240	-9,159	-66,818	-1,536	-11,355	-79,193	-1,976	-17,607	-117,011
	(-0.10)	(-0.77)	(-5.65)	(-0.13)	(-0.96)	(-6.69)	(-0.17)	(-1.49)	(-9.89)
U.S. Producers' Surplus	-161.70	7,430	121,252	449	13,037	197,108	1,479	27,336	391,136
	(-0.36)	(16.35)	(266.82)	(0.99)	(28.69)	(433.74)	(3.26)	(60.15)	(860.71)
Producers' Surplus Related to Agricultural Production	1,353	7,689	54,085	1,976	14,380	155,475	3,024	30,037	396,125
	(2.98)	(16.92)	(119.02)	(4.35)	(31.64)	(342.13)	(6.65)	(66.10)	(871.69)
Gross Total Welfare in U.S. Agricultural Sector	113	-1,471	-12,732	440	3,025	76,282	1,048	12,430	279,120
	(0.01)	(-0.12)	(-1.04)	(0.04)	(0.25)	(6.21)	(0.09)	(1.01)	(22.71)
GHG Charges / Payments	-1,514	-259	67,167	-1,526	-1,342	41,633	-1,545	-2,701	-4,989
Net Total Welfare in U.S. Agricultural Sector	-1,402	-1,730	54,435	-1,087	1,683	117,915	-497	9,728	274,125
	(-0.11)	(-0.14)	(4.43)	(-0.09)	(0.14)	(9.59)	(-0.04)	(0.79)	(22.31)
Foreign Countries' Agricultural Trade Surplus	-395	-3,516	-27,546	2,140	17,902	392,761	5,360	42,156	213,136
	(-0.16)	(-1.45)	(-11.39)	(0.89)	(7.40)	(62.45)	(2.22)	(17.44)	(88.16)
Gross Total Agricultural Welfare	-282	-4,986	-40,278	2,579	20,928	227,276	6,408	54,586	492,249
	(-0.02)	(-0.34)	(-2.74)	(0.18)	(1.42)	(15.45)	(0.44)	(3.71)	(33.47)
Net Total Agricultural Welfare	-1,796	-5,245	26,889	1,053	19,585	268,909	4,863	51,884	487,260
	(-0.12)	(-0.36)	(1.83)	(0.07)	(1.33)	(18.28)	(0.33)	(3.53)	(33.13)
U.S. Agricultural GHG Emissions	76.74	2.58	-167.92	76.32	13.40	-104.08	77.23	27.01	12.47
U.S. Agricultural GHG Emission Reductions	-27.89	-101.05	-271.55	-27.32	-90.21	-207.72	-26.40	-79.62	-91.16
	(-26.92)	(-97.50)	(-262.03)	(-26.36)	(-87.05)	(-200.43)	(-25.48)	(-73.93)	(-87.97)

[c] The numbers in parentheses give the percentage change with respect to the zero CE-price scenarios. Gross welfare items exclude GHGE charges/payments.