Economic analysis of the climate pledges of the Copenhagen Accord for the EU and other major countries

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Abstract

This article uses the world GEM-E3 computable general equilibrium model to assess the economic consequences of the climate 'Copenhagen Accord'. The model allows analyzing the macroeconomic costs in terms of GDP, the change in employment, as well as the impacts on production of specific energy-intensive sectors. Various 2020 climate scenarios are evaluated depending on the GHG mitigation pledges. We find that the cost for the developed countries is around 0.5% of GDP in 2020 for the more ambitious pledges, whereas the GDP effects are more heterogeneous across developing countries and Russia, reflecting the different pledges and the assumptions in the reference scenario across these countries. Further, the article explores whether there is a form of double dividend in the EU when the revenues from auctioning or taxation of GHG emissions are used to reduce the social security contributions of employees. We conclude that GDP and employment perform better compared to the free allocation of permits when more sectors are subject to auctioning or GHG taxes and the additional government revenues are used to reduce the cost of labour.

JEL codes: Q54, climate; C68, computable general equilibrium models; H2, taxation, subsidies and revenues

*The opinions expressed in this paper belong to the author only and should not be attributed to the institution they are affiliated to.

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1. Introduction

Although short of a comprehensive legally binding agreement, the result of COP15[2] in Copenhagen was an extensive list of 'pledges' for GHG emission reductions in 2020 by all major economies and many other countries (UNFCCC, 2009). Under the Cancun agreements of COP16 the mitigation pledges of the ‘Copenhagen Accord’ have been anchored in the UN process. The United Nations (UN) also formally adopted that global temperature must be kept below 2°C compared to the pre-industrial level.

The EU pledges state that the EU will unilaterally reduce its GHG emissions by 20% in 2020 compared to 1990. If there is an ambitious international agreement on GHG mitigation, the EU would reduce emissions by 30% in 2020. These pledges were already formally adopted by the European parliament and the European Council in June 2009 – in a legislation known as the ‘Climate and Energy Package’[3] (European Commission, 2008).

After COP15 the European Commission analyzed the economic implications of going beyond the 20% reduction target in the context of the ‘Copenhagen Accord’ (European Commission, 2010a). The accompanying economic assessment relied on economic modelling[4] (European Commission, 2010b), including, among other models, the computable general equilibrium (CGE) GEM-E3 model.

This paper presents in detail the GEM-E3 results of this analysis. It builds further on the GEM-E3 modelling for the 2009 Communication "Towards a comprehensive climate change agreement in Copenhagen" (Russ et al., 2009), and the 2007 Communication “Limiting global climate change to 2ºC” (Russ et al., 2007)[5].

The EU ‘Climate and Energy Package’ foresees an enhanced use of auctioning in the EU Emission Trading System (EU ETS) from less than 4% in phase 2 (2008-2012) to more than 50% in phase 3 (2013-2020). This implies a substantial generation of public revenues. Auctioning (and taxation) complies better with the ‘polluter pays principle’ and avoids handing out ‘windfall profits’ to sectors that can easily pass on the opportunity cost of allowances to their customers. Indeed, full auctioning will be the rule in the power sector from 2013 onwards. Sectors exposed to a significant risk of ‘carbon leakage’ are exempted from

[2] 15th Conference of the Parties of the United Nations Climate Change Convention (UNFCCC).

[3] Other pillars of the ‘Climate and Energy Package’ include a mandatory 20% share for renewable energy in the EU gross final energy consumption in 2020; and a 20% reduction in primary energy use to be achieved by improving energy efficiency. See Soria and Saveyn (2010) for an overview of European climate policies.

[4] See Delbeke et al. (2010) for an overview of the use of environmental economics and economic modeling in European climate policies.

[5] See European Commission (2007) and European Commission (2009a) for more detail in communications.

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auctioning and receive their share of allowances up to a benchmark level for free. In December 2009, the European Commission published the list of sectors and subsectors that are deemed to be exposed to a significant risk of carbon leakage (European Commission, 2009b).

Since auctioning raises government revenues, other taxes such as labour or capital taxes could be reduced, potentially improving the overall efficiency of the economy. This links the analysis of this article with the ‘double dividend’ literature[6].

This literature argues that substituting environmental taxes for pre-existing distorting taxes (i.e. an environmental tax reform) may yield not only a cleaner environment but a second non-environmental dividend. The ‘double dividend’ literature implicitly assumes that the initial state of the economy may be suboptimal from a non-environmental point of view. This state can be observed in the real world, which can be explained, alternatively, by interest groups, distributional concerns, or the export of the tax-burden to non-residents. A number of different definitions for the non-environmental dividend have been analysed. In this study we look at three of the main forms[7]:

Weak double dividend: The recycling of the additional environmental tax revenues through lower pre-existing distorting taxes (e.g. capital or labour) reduces the costs of the environmental policy, compared to the case where the environmental tax revenues are recycled in a lump-sum way. The weak double dividend is relatively uncontroversial (Goulder, 1995).

Strong double dividend: The environmental tax reform not only reduces the costs of the environmental policy, but even generates a non-environmental benefit ('dividend') in the form of a more efficient tax system, raising the non-environmental welfare. Recent studies qualify in detail under which conditions a (strong) double dividend may appear[8], whereas others have studied the double dividend hypothesis in the context of climate change policies[9].

Employment double dividend: The environmental tax reform increases the environmental quality and boosts employment as well.

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[6] For an overview see e.g. Goulder (1995), and Bovenberg (1999).

[7] The 'weak double dividend' and 'strong double dividend' are due to Goulder (1995), while Carraro et al. (1996) uses the 'employment double dividend'.

[8] See e.g. De Mooij and Bovenberg (1998); Metcalf and NBER (2003); Chiroleu-Assouline and Fodha (2005); Saveyn and Proost (2008).

[9] See e.g. Babiker et al. (2003); and Parry (2003).

This study tries to answer three policy questions with respect to the EU climate policy in an international context. Firstly, it studies the macroeconomic implications of the Copenhagen Accord for the major world economies in 2020. Secondly, the research also pays particular attention to the economic implications on the EU in terms of GDP and employment, taking into account various possible auctioning and tax schemes. Thirdly, we explore the politically sensitive issue of the competitiveness effects in the energy intensive sectors in the EU.

This paper has the following structure: Section 2 describes the main features of the GEM-E3 model. Section 3 presents the reference, with which the Copenhagen Accord scenario will be compared. The reference scenario considers the 'Climate and Energy Package' and the effects of the on-going economic crisis. Section 4 presents the policy scenarios assessed. Section 5 analyses the results for the major world economies and the EU. Section 6 concludes.

2. Model

The computable general equilibrium GEM-E3 model covers the interactions between the economy, the energy system and the environment (Van Regemorter, 2005; Capros et al., 2010). The world version[10] of GEM-E3 is based on the GTAP 7 database (base year 2004) and has 21 geographical regions (including the major world economies individually represented), linked through endogenous bilateral trade.

The GEM-E3 model computes the simultaneous equilibrium in the goods and services markets, as well as in production factors (labour and capital). The competitive market equilibrium under Walras' law also includes more detailed equilibria in energy demand/supply and emission/abatement. The structural features of the energy/environment system and the policy-oriented instruments (e.g. taxation) have considerable sectoral detail.

GEM-E3 can evaluate consistently the distributional effects of policies for the various economic sectors and agents across the countries. The economic consequences of environmental or economic policies can be analyzed on a national level, while ensuring that the world economy remains in equilibrium. The model is recursive-dynamic[11], driven by the

[10] There are two versions of GEM-E3: GEM-E3 Europe and GEM-E3 World. They differ in their geographical and sectoral coverage, but the model specification is the same. The European version covers 24 EU countries (all EU countries, except for Luxemburg, Malta and Cyprus) and the rest of the world (in a reduced form). It is based on EUROSTAT data.

[11] Babiker et al. (2009) find that for a climate policy analysis recursive-dynamic (RD) and forward-looking models (FL) produce similar behaviour in the energy sector. However, - due to computing limitations - a recursive-dynamic model is able to give a more detailed representation of the real world. Although a FL model may be better suited to deal with inter-temporal questions such as the depletion of resources or banking and borrowing of allowances, the results of Gurgel et al. (2007) suggest that the differences between FL or RD may be rather limited for a climate policy with tax revenue recycling.

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accumulation of capital and equipment. Technological progress is explicitly represented in the production functions.

The economic agents optimize their objective functions (welfare for households and cost for firms) and determine separately the supply or demand of capital, energy, environment, labour and other goods. Market prices guarantee a global equilibrium endogenously.

The production of the firms is modelled with a nested CES neo-classical production function, using capital, labour, energy and intermediate goods. The model allows for different market clearing mechanisms and alternative market structures, in addition to perfect competition. The amount of capital is fixed within each period. The investment decisions of the firms in the current period affect the stock of capital in the next period. Labour is immobile across national borders.

The consumers decide endogenously on their demand of goods and services using a nested extended Stone Geary utility function. In a first stage, a representative consumer for each region allocates their total expected income between total consumption of goods and services (both durables and non-durables), leisure and savings. If the economic conditions are favourable, households can decide to work more and have less leisure time. In a second stage, the utility function distinguishes between durable (equipment) and consumable goods and services. Households obtain utility from consuming a non-durable good or service and from using a durable good above a subsistence level. The consumption of a durable good is directly linked to the consumption of non-durable good, e.g. fuel for the use of transport equipment.

The demand of goods by the consumers, firms (for intermediate consumption and investment) and the public sector constitutes the total domestic demand. This total demand is allocated between domestic goods and imported goods, using the Armington specification.

Government behaviour is exogenous. The model distinguishes between 9 categories of receipts, including indirect taxes, environmental taxes, direct taxes, value added taxes, production subsidies, social security contributions, import duties, foreign transfers and government firms.

This analysis used GEM-E3 to address climate change policies[12]. The model evaluates the energy-related and non-energy related emissions of carbon dioxide (CO_2), other GHG such as methane (CH_4), nitrous oxide (N_20) sulfur hexafluoride (SF_6), hydrofluorocarbon (HFC), and

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[12] GEM-E3 can also be used to analyze air quality problems involving other pollutants such as sulphur dioxide (SO2), nitrogen oxides (NOx), volatile organic compounds (VOC), ammonia (NH3) and particulates (PM10).

perfluorocarbon (PFC). There are three mechanisms of emission reduction explicitly specified in the model: (i) substitution between fuels and between energetic and non-energetic inputs, (ii) emission reduction due to a decline in production and consumption, and (iii) purchasing abatement equipment.

The model is able to compare the welfare effects of various environmental instruments, such as taxes, various forms of pollution permits and command-and-control policy. It is also possible to consider various systems of revenue recycling.

The GEM-E3 model version used in this article is the neoclassical world version, without market imperfections or rigidities in markets.

3. Reference scenario

The reference scenario is the scenario with which the results of the Copenhagen Accord are to be compared. The main drivers of the evolution of the world economy to the year 2020 are GDP and population. The reference scenario has also different policy assumptions for the EU and for the other world regions. This section details the assumptions used to derive the reference scenario. Table 1 describes the evolution of GHG emissions and GDP in 2020 compared to 2005 for most major global economies.

Table 1: GHG emissions and GDP evolution in 2020 compared to 2005[13]

	EU	US	Japan	Russia	China	Brazil	India
GHG emissions (vs. 2005)	-9.61%	1.93%	-4.65%	22.85%	80.61%	37.32%	98.25%
GDP (vs. 2005)	28%	46%	32%	102%	169%	61%	142%

Reference Scenario for the EU

The GDP projections take into account the current economic crisis, and assume that the economic growth will resume after 2010. The reference scenario assumes that the recent economic crisis has long lasting effects leading to a permanent loss in GDP. The GDP evolution in the 2005-2030 period is based on EUROSTAT data (2005-2008), the short-term economic forecasts of the Directorate General of Economic and Financial Affairs (European Commission 2009c), and the reference scenario of the 2009 Ageing Report (European

[13] Excluding land-use (change) emissions.

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Commission, 2009d). The population projections are based on the EUROPOP2008 convergence scenario[14].

Regarding climate policy, the reference scenario has the complete ‘Climate and Energy Package’ implemented, including the non-Emission Trading Sector (ETS) and renewable targets which are assumed to be reached in 2020 with national policies from the Member States. The Annex lists all the policies up to Spring 2010. The EU GHG emissions in the reference scenario are 20% lower in 2020 than in 1990 (and about 14% lower than in 2005). In other words, the reference scenario already includes the unilateral, unconditional pledge of the EU ‘Climate and Energy Package’. Compared to 2005, the EU ETS sectors are required to reduce emissions by 21%, whereas the non-ETS sectors will reduce emissions by 10% (European Commission, 2008). In the reference scenario neither auctioning nor taxation is used in order to reach the -20% target.

The split between ETS and non-ETS CO_2 emissions in EU from 2005 to 2030 come from the PRIMES energy system model. The, GAINS model projections are used to calibrate the non-CO_2 emissions and the CAPRI model for the agriculture-related emissions.

Reference Scenario for Rest of World

The GDP dynamic evolution of the other 20 regions[15] has been calibrated following the CEPII projections[16], whereas the GHG emissions follow the projections of the POLES model. In the reference scenario small positive carbon values in the energy-intensive sectors have been assumed from 2015 on for USA, Canada, Japan, Australia and New Zealand, Other European countries, China, Korea, Brazil, and Mexico in order to reflect adopted and planned national climate policies[17].

4. The Copenhagen Accord Scenarios

The section describes the main features of the Copenhagen Accord scenarios. Three cases have been considered, each of them having different ambition levels depending on the ranges of the pledges in the Copenhagen Accord. Moreover, for the EU, various allocation rules for

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[14] http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/en/proj_r08c_esms.htm

[15] The other 20 countries/regions are USA, Japan, Canada, ‘Australia’ (incl. New-Zealand and Pacific), China, India, Russia, Brazil, Mexico, Rest of Latin America, Korea, South East Asia, Rest of Asia, Ukraine/Moldavia/Belarus Commonwealth of independent states, Other European Countries, Turkey, Middle East and North Africa, South Africa, Middle Africa.

[16] http://www.cepii.fr/

[17] The carbon values for the energy intensive sectors in the reference scenario for 2015 and 2020 are, respectively, US$ 7.7 and 9.1 for the USA, US$ 7.4 and 8.6 for Japan, US$ 7.4 and 8.7 for Canada, US$ 7.3 and 8.5 for 'Australia', US$ 6.8 and 7.8 for Other European Countries, $2.1 and 5.4 for China, US$ 2.1 and 5.7 for Korea, and US$ 1.9 and 5.0 for Brazil. The carbon values for the EU in the reference scenario are US$ 19.4, 33.3 and 51.1 for 2010, 2015 and 2020, respectively.

emission permits and taxation are considered, in order to explore the possibility of a double dividend.

Three different pledges scenarios

Table 2 lists how the pledges of the major economies in the 'Copenhagen Accord' are interpreted in the GEM-E3 model. While some countries announced ranges of targets depending on certain conditions, other pledged single targets (e.g. US and Japan). The pledges of developed countries are in terms of GHG emission reductions compared to a base year (e.g. for the US the year 2005), whereas the pledges of developing countries refer to a 'business as usual' scenario (BAU), either expressed as a change in emissions or defined as an emission intensity (in terms of CO_2-eq or carbon, C). Some countries expressed significant targets or actions in sectors and emissions not covered by the GEM-E3 model. This is e.g. the case for Brazil, which has pledged action in the land use sectors, mainly slowing down deforestation. These pledged actions are not assessed and the other remaining actions have been converted into emission reductions that can be compared to the reference scenario in the GEM-E3 model.

Table 2. Pledges used in the GEM-E3 model

Region	**Low pledge**	**High pledge**
US	-17% (2005 emissions)	-17%(2005 emissions)
Japan	-25% (1990 emissions)	-25%(1990 emissions)
EU27	-20% (1990 emissions)	-30%(1990 emissions)
Russia	-20% (1990 emissions)	-25%(1990 emissions)
China	-40% (BAU CO_2/GDP)	-45%(BAU CO_2/GDP)
India	-20% (BAU C/GDP)	-25%(BAU C/GDP)
Brazil	-2.7% (BAU emissions)	-8%(BAU emissions)

The analysis considers three different scenarios, with growing ambition levels in GHG reductions:

- <u>Low pledge:</u> The EU and the countries with pledges under the Copenhagen Accord implement their low pledges. For the EU, the reduction is as in the Reference case, i.e. 20% compared to 1990.
- <u>Mixed pledge:</u> This is a variant of the low pledge case where the EU implements its high pledge (reduction of 30% versus 1990) and the other countries remain at their low pledges.

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- High pledge: The EU and the other countries with pledges under the Copenhagen Accord implement their high pledges.

In all GEM-E3 regions, there is a split between the sectors according to their energy intensity. A first group of sectors, called Energy-Intensive sectors (EI), includes the power sector and energy intensive sectors, such as ferrous and non-ferrous metal sector and chemical sector. The second group, the non-Energy-Intensive sectors (non-EI), includes the non-energy-intensive sectors and the households and government[18].

Carbon Market

The scenario allows for international trading emission permits across countries for the EI sectors and non-EI sectors. Thus a country can not only meet its emission reduction target internally, but can also buy credits generated from international flexible mechanisms, such as Joint Implementation (JI) and Clean Development Mechanism (CDM).

It is assumed that there is a limit on the amount of credits from third countries that can be used for compliance (set at a third of the difference between the pledged emissions and the reference scenario emissions of the purchasing country), reflecting both the transaction costs (due to lack of transparency and information, the market imperfections in the country of origin, etc) and the legal constraints that are put on the use of CDM (e.g. in EU).

Moreover, only countries with a pledge (i.e. party in the 'Copenhagen Accord') participate in the carbon market and the credits for the international carbon market come from reductions beyond the reductions made to meet the pledges of the country. Developing and transition countries are net sellers in the CDM carbon market.

Allocation of permits

The emission permits in the non-EU countries/regions are always allocated for free. For the EU, four alternative options have been considered regarding the allocation of permits, depending on whether there is auctioning in the EI sectors and taxation in the non–EI sectors. The options are the following:

- Option A: free allocation in EU
- Option B: auctioning only in the power generation sector in EU

[18] The split between ETS and non-ETS only has a legal basis in the EU, and a small number of other European countries that are linked to EU Emission Trading System. In this paper, however, we keep the same split for non-European countries corresponding with the respective sector categories in the GTAP database. We assume that CDM trade between countries mainly takes place within similar or identical sectors. Hence, the world was modelled as 2 separate international carbon markets, with no trade between the EI and non-EI

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- Option C: auctioning in all the EI sectors in EU
- Option D: auctioning in the EI sectors and tax for non-EI sectors in EU

The free allocation does not generate any revenue because permits are distributed for free, whereas the other three allocation options using auctioning or taxation generate additional government revenues. These revenues are used to reduce the labour costs (social security contributions of employees) such that the scenario is budget-neutral for the government. This may lead to a possible double dividend, in which both the environment is better off because of the lower level of GHG emissions, but also the labour market and the overall economy improves thanks to a higher employment level in equilibrium, induced by the lower labour costs.

5. Results

This section discusses the effect of the 'Copenhagen Accord' on GDP, carbon value, employment and energy-intensive sectors. All results are compared to the reference scenario for the year 2020 (note that in this scenario only the EU reduces GHG emissions, by 20% compared to the 1990 level).

Results of the pledges scenarios for the major economies

Table 3 presents the GHG emissions, GDP changes, and carbon values for the major world economies with the permits freely allocated (Option A). Reduction levels in developed countries are smaller than their pledges, as they are net buyers on the international carbon market. This is compensated with lower emission growth in developing countries. This impact is smaller with more ambitious pledges and thus higher carbon price.

GDP losses in the developed countries are relatively low, of around 0.5%. In the ‘mixed pledge’ and ‘high pledge’ cases the GDP changes are similar and around -0.5% across the developed countries (except for Russia). The EU is relatively less affected in the 'low pledge' scenario because it has the same reduction target as in the reference scenario, and the -0.2% is the effect of the lower world GDP on the EU. The GDP effects are more heterogeneous across developing countries and Russia, reflecting the different pledges and the assumptions in the reference scenario across these countries.

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markets. In the rest of the paper, EI and non-EI will be used for all regions, including for EU where it is as a synonym for the ETS and non-ETS sectors.

The carbon values are not identical across countries. This is due to the "imperfect carbon market" scheme where the limit on credits coming from abroad, hampers the convergence of the carbon price across countries. Moreover, the reported carbon price is a weighted sum of the carbon prices in the two separated international carbon markets.

Table 3: Effects on Major global economies for Option A in 2020

		EU	US	Japan	Russia	China	Brazil	India
GHG emissions (vs. 2005)	Low	-9.6%	-10.7%	-21.5%	13.7%	65.3%	31.6%	67.8%
	Mixed	-18.2%	-10.7%	-21.5%	13.2%	64.2%	31.3%	66.8%
	High	-18.2%	-11.2%	-21.5%	6.1%	46.1%	22.5%	52.4%
GDP (vs. reference)	Low	-0.2%	-0.5%	-0.4%	-0.9%	-0.7%	-0.1%	-0.6%
	Mixed	-0.5%	-0.5%	-0.5%	-1.0%	-0.8%	-0.1%	-0.7%
	High	-0.6%	-0.6%	-0.5%	-1.9%	-1.8%	0.1%	-1.5%
Carbon Value (US$ 2004/ tCO2eq)	Low	33[19]	31	57	11	12	12	13
	Mixed	69	31	58	11	13	13	14
	High	70	35	58	25	27	28	29

Results for the EU under the various allocation schemes

Table 4 presents the changes in GDP, employment, private consumption, investment, exports, and imports for the EU with alternative allocation schemes.

The four allocation schemes mainly differ in the amount of revenue that the government raises through auctioning of emission permits or taxation of GHG emissions. Higher government revenues increase the potential to reduce labour costs. The size of government revenues, depending on the option, can be significant.

The results for GDP in Table 4 confirm the 'weak double dividend' as Options B, C and D are better than with free allocation (Option A). Moreover, option D (and partly Option C) generates even a 'strong double dividend'. Indeed, we find also a similar increase of non-environmental welfare as of GDP. Further, the recycling of public revenues from the carbon markets to the labour markets also induces a positive effect on employment. The lower labour cost increases the employment in Option C and D (and partly in option B) compared to the reference scenario. The overall increase in employment in the Option D is estimated to be more than one million jobs compared to the reference.

The higher the number of sectors that are subject to auctioning or GHG taxes, the better the GDP and employment becomes compared to the free allocation of permits. In order to

[19] The EU carbon value for the low pledge is lower than in the reference scenario (US$ 51.1) thanks to the use of CDM (whereas in the reference scenario the 20% is fully done internally). However, the GDP effect in EU is negative due to the overall world GHG constraint with the low pledge and its negative impact on the world GDP.

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understand better what drives the weak/strong/employment double dividend we take a closer look to the four main components of GDP: consumption, investment, exports, and imports (Table 4).

Table 4: Impact of different allocation schemes on EU GDP in 2020 (compared to reference)

		Option A	Option B	Option C	Option D
EI		Free allocation	Auctioning for Power	Auctioning all EI sectors	Auctioning all EI sectors
non-EI		Free allocation	Free allocation	Free allocation	Tax
GDP	Low	-0.2%	-0.1%	0.1%	0.4%
	Mixed	-0.5%	-0.3%	0.0%	0.6%
	High	-0.6%	-0.3%	-0.1%	0.6%
Employment	Low	0.0%	0.1%	0.2%	0.5%
	Mixed	-0.3%	-0.1%	0.1%	0.7%
	High	-0.3%	-0.1%	0.1%	0.7%
Private Consumption	Low	-0.3%	0.0%	0.3%	1.1%
	Mixed	-0.8%	-0.2%	0.3%	1.8%
	High	-1.0%	-0.4%	0.2%	1.6%
Investment	Low	-0.1%	0.0%	0.1%	0.3%
	Mixed	-0.4%	-0.2%	-0.1%	0.2%
	High	-0.4%	-0.3%	-0.1%	0.2%
Exports	Low	-0.4%	-0.7%	-0.9%	-1.5%
	Mixed	-1.4%	-1.9%	-2.3%	-3.4%
	High	-1.5%	-2.0%	-2.4%	-3.5%
Imports	Low	-0.4%	-0.3%	-0.1%	0.3%
	Mixed	-1.4%	-1.0%	-0.7%	0.1%
	High	-1.7%	-1.3%	-1.0%	-0.2%

The private consumption accounts for about 58% of the GDP in EU[20]. Again, we see the same pattern as with GDP and employment: The private consumption is relatively higher when more sectors are included in the auctioning of permits or taxation of GHG. However, the differences across the allocation options are more pronounced: the difference between the 'best' option (D) and 'worst' option (A) is 1.4%-2.6% (depending on the ambition level of the climate policy, low/mixed/high), whereas for GDP it is 0.6%-1.2% (and for employment: 0.5%-1.2%).

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[20] The level of public consumption (which accounts for about 22% of GDP) remains unchanged across the four allocation options.

These results suggest that higher private consumption is the main driver in explaining the 'double dividend'. Private consumption is boosted by higher employment and higher after-tax wage rates.

The investment shows a similar pattern with more revenue recycling having higher levels of investment, driven by higher demand. The differences in investment across the four options, however, are relatively small compared to the other components (0.4%-0.6%).

In the free allocation option A, both the EU's export and import decrease with a similar magnitude compared to reference: -0.4% for low ambition level, and -1.5% and -1.7%, respectively, for high ambition level. This not only corresponds to the lower private consumption and investment in EU, but also in the rest of the world due to the climate policies. The higher level of private consumption and investment in the options with more revenue recycling, increase the demand for foreign goods and the imports in EU return to reference level in Option D. Similarly, the EU exports decrease further for the options with more revenue recycling, as the firms turn towards the domestic market. This statement is underpinned by the increasing domestic output from Options A to D, despite the falling exports. The revenue recycling options lead to a higher competitiveness of the EU firms on its own domestic market.

The current account (as a % of GDP) for EU becomes a little bit more negative with a maximum of -0.5% for Option D (mixed/high), from -0.04% for the reference.

Nevertheless, the different GDP in EU, and in particular its demand for private consumption and investment, also affects the activity levels in the rest of the world. In other words, there is a spill-over effect of the EU policy decisions to the rest of the world. In the low pledge case, the GDP's of the other countries are about 0.25% better in option D than in option A; for the high pledge case this increases even to 0.50%.

The carbon value in EU increases due to the higher activity level in the options with more revenues to recycle. The marginal abatement cost in EU is US$ 36, US$75, and US$76 for Option D with low, mixed, and high pledges, respectively, whereas it was US$ 33, US$ 69, and US$ 70 for Option A. A minor increase can also be observed in the other countries (through own economic performance or higher CDM demand).

Competitiveness of intensive sectors

Table 5 presents the EU production changes in the energy intensive sectors for the free allocation option A and the other allocation cases (options B to D). In general terms, the

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energy intensive sectors are not worse off and the effect on production for some sectors may even become less negative with a shift to auctioning and GHG taxation. The production changes in the chemical production and other energy intensive sectors are always better than under the free allocation case when auctioning or taxation is considered[21].

This can be explained by the fact that we assume that all sectors take into account the opportunity cost of the freely allocated allowances in the output price of their production. The product price thus includes the carbon price even if the allowances have been received for free[22]. Hence, more GHG taxation or auctioning does not significantly affect the output price of energy intensive sectors. They may, however, benefit from the overall improved economic activity.

Table 5: Impact of different allocation schemes on production of EU energy intensive industries in 2020

		Option A	Option B	Option C	Option D
EI		Free allocation	Auctioning for Power	Auctioning all EI sectors	Auctioning all EI sectors
non-EI		Free allocation	Free allocation	Free allocation	Tax
ferrous and non ferrous metals	Low	0.5%	0.5%	0.5%	0.5%
	Mixed	-1.1%	-1.1%	-1.1%	-1.0%
	High	-0.4%	-0.5%	-0.4%	-0.4%
chemical products	Low	0.3%	0.4%	0.5%	0.7%
	Mixed	-1.2%	-1.1%	-0.9%	-0.5%
	High	-0.9%	-0.8%	-0.6%	-0.1%
other energy intensive industries	Low	0.4%	0.5%	0.6%	1.0%
	Mixed	-1.0%	-0.7%	-0.5%	0.1%
	High	-0.6%	-0.3%	-0.1%	0.5%

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6. Conclusion

The computable general equilibrium GEM-E3 model has been used to estimate the economic consequences of the various ways in which the Copenhagen Accord can be implemented, depending mainly on the ranges of mitigation efforts announced, and the allocation schemes for the emissions permits. The allocation schemes are potentially of significant relevance.

[21] The positive production changes become more positive, and the negative production changes become less negative, even becoming positive for some cases in the Other energy intensive industries sector. This behaviour cannot be observed for the ferrous and non-ferrous metals sector, which is the topic for further modelling work.

[22] It is a point of discussion whether energy intensive sectors exposed to international competition actually choose this type of price-setting. It can be shown that the respective energy intensive sectors show a similar behaviour for a comparable scenario when the opportunity cost of free allowances is not included in the output price (European Commission, 2011; section 5.1.3.). For more discussion on the inclusion of the opportunity cost of free allowances in the output price, see e.g. Fischer and Fox (2004.), or Böhringer and Lange (2005).

They can be appropriately modelled within a general equilibrium model setup because such analytical framework considers in a consistent way the interaction of all relevant economic agents (firms, consumers, public sector and external sector) in all markets (factor and goods and services).

The main result of the assessment is that the GDP losses for the EU in the various scenarios are relatively low, when compared to the current commitment of 20% already implemented in the reference scenario. Furthermore, if public revenues are generated via auctioning of permits and taxation of GHG emissions and those revenues are used to reduce the social contributions of employees, GDP variation could become positive in the EU. The higher private consumption seems to be the main driver for the higher GDP. The higher private consumption is boosted by the higher employment level and higher after-tax wages. The additional employment is estimated to be about one million jobs.

We conclude that the more sectors that are subject to auctioning of emission permits or GHG taxes, the higher the GDP, employment becomes compared to the free allocation of permits. The energy intensive sectors are not worse off and the effect on production for some sectors may even become less negative with a shift to auctioning and GHG taxation.

Our analysis obviously holds a number of caveats which may be the topic of further research. First, one could explore the results for more alternative revenue recycling options (e.g. capital taxes, VAT, direct taxes or subsidies). Secondly, we did not address the role of the international carbon market. It is widely accepted that developed countries with ambitious emission targets may reduce the cost of the climate policy if they can buy cheap emission reductions abroad, instead of reducing internally. However, this access to cheap reductions also lowers the carbon price domestically. If the same developed country also uses GHG auctioning and taxation, its government will receive less revenues for auctioning or taxation, limiting the scope to reduce other pre-existing taxes. In other words the combination of international carbon market and auctioning/taxation may reduce the potential for double dividend. Third, although auctioning/taxation of GHG emissions is an interesting alternative of government financing on the short- and mid-term, it may on the long term become obsolete if the transition to the low carbon society has been completed.

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Annex: Major EU climate-related policies up to spring-2010

Ecodesign and labelling		
Eco-design Directive for energy-related products	Directive 2009/125/EC	2009
Directive on end-use energy efficiency and energy services	Directive 2006/32/EC	2006
Labelling Directives	Directive 2003/66/EC	2003
Buildings Directive	Directive 2002/91/EC	2002
Recast of The Directive on energy performance of buildings	Directive 2010/31/EU	2010
Energy-intensive sectors, Energy markets and power generation		
Sectors exposed to carbon leakage Decision	Decision 2010/2/EU	2010
Revised EU ETS Directive	Directive 2009/29/EC	2009
RES Directive	Directive 2009/28/EC	2009
IPPC Directive	Directive 2008/1/EC	2008
Directive on the geological storage of CO_2	Directive 2009/31/EC	2009
F gas Directive	Directive 2006/842/EC	2006
Cogeneration Directive	Directive 2004/8/EC	2004
EU ETS Directive	Directive 2003/87/EC	2003
Energy Taxation Directive	Directive 2003/96/EC	2003
Large Combustion Plant Directive	Directive 2001/80/EC	2001
Directive on national emissions' ceilings for certain pollutants	Directive 2001/81/EC	2001
Water Framework Directive	Directive 2000/60/EC	2000
Completion of the internal energy market (including provisions of the 3rd package)	http://ec.europa.eu/energy/gas_electricity/third_legislative_package_en.htm	
Transport and other non-traded sectors		
GHG Effort Sharing Decision	Decision 406/2009/EC	2009
Fuel Quality Directive	Directive 2009/30/EC	2009
Regulation on $CO_2$from cars	Regulation No 443/2009	2009
Aviation	Directive 2008/101/EC	2008
Implementation of MARPOL Convention ANNEX VI	2008 amendments - revised Annex VI	2008
Regulation EURO 5 and 6	Regulation No 715/2007	2007
Motor Vehicles Directive	Directive 2006/40/EC	2006
Biofuels Directive	Directive 2003/30/EC	2003
Landfill Directive	Directive 99/31/EC	1999
'Health check' of the Common Agricultural Policy		2008
Financial support		
EEPR (European Energy programme for Recovery)	Regulation No 663/2009	2009
RTD support (7th framework programme- theme 6)	energy research under FP7	
State aid Guidelines for Environmental Protection and 2008 Block Exemption Regulation	Community guidelines on state aid for environmental protection	2008
TEN-E guidelines	Decision No 1364/2006/EC	2006

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