Macroeconomic Impacts of Sectoral Approaches:
The Role of the Cement Sector in China, Mexico and Brazil

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Abstract

This paper explores macroeconomic impacts of global sectoral approaches as a set of options to engage emerging economies such as China, Mexico and Brazil in setting policies for a lower emission path and to address potentially adverse impacts of stringent environmental policies on key industries in the European Union and. Drawing on the example of the cement sector, this paper analyses alternative designs of sectoral approaches by means of a computable general equilibrium (CGE) model of the global economy. For this purpose, we apply advanced techniques to disaggregate the sectoral coverage of a standard version of a CGE framework and use bottom-up marginal abatement cost curves from relevant sectoral studies. Our results suggest that sectoral approaches can contribute to the reduction of global emissions, albeit to a small extent. This calls for the extension of sectoral approaches to further sectors and countries in order to fully exploit the efficiency gains.

JEL Classification: C68, F18, H23, Q48

Keywords: Emissions Trading, Global Sectoral Approaches, CGE

1 Introduction

In the fore-front of the United Nations Climate Change Conference in December 2009 in Copenhagen (COP 15), sectoral approaches (SA) – in which developing and emerging economies are incentivized to undertake efforts to reduce greenhouse gas (GHG) emissions intensity or growth in key industrial sectors, potentially with assistance from developed countries, – played an important role in the debate on how to bring the globe on a lower greenhouse gas emissions path. This approach for mitigation action was codified in the Bali Action Plan as “cooperative sectoral approaches and sector-specific activities” (UNFCCC, 2007). Prior to the round of negotiations in June 2009 in Bonn, most countries expressed preferences for one or another form of sector-specific actions and sectoral coverage (Aasrud et al. 2009). If successful, so the supporters of this mechanism, it could have set incentives for a broader participation of developing countries in the Post-Kyoto regime and open up further potential for low cost mitigation.

Previous contributions on sectoral approaches examined institutional aspects of SA in a qualitative manner only. Sterk and Wittneben (2006) reviewed the notions of SA at the early stage of the discourse. Egenhofer and Fujiwara (2008) elucidated industrial initiatives and identified cement, aluminum as well as iron and steel sectors as most appropriate for the implementation of sectoral approaches. In the run-up to COP 15, Aasrud et al. (2009) reviewed proposals for the design of sectoral market mechanisms that have been debated both in the UNFCCC negotiations and in different domestic legislative contexts. More recently, Fujiwara (2010) explored the ways on how to steer the process of operationalising sectoral approaches on the way to climate negotiations in Cancún in December 2010 or later. As for the practical implementation, the study prepared by CCAP (2010) enumerated a wide range of barriers including the poor data availability (needed to design sectoral targets), substantial administrative and policy resistance, weaknesses in financial infrastructure, etc. – all this makes SA less operational, even with sufficient political support, at least in the short and probably even in the medium term perspective. At the COP 17 in Durban in December 2011 the subject was put back on the agenda using the concept of “cooperative sectoral approaches and sector-specific actions”, however without adopting any binding agreement.

This paper analyses alternative designs of sectoral approaches, drawing on the example of the cement sector in China, Brazil and Mexico, by means of a coherent economic modelling framework based on the computable general equilibrium (CGE) model PACE. The sectoral and regional focus is due to the availability of bottom-up marginal abatement cost data from sectoral studies. The contribution of this paper is threefold: Employing a large-scale computable general equilibrium model of the global economy, we (i) extend the sectoral disaggregation of the GTAP 7 database towards the inclusion of a cement production sector, (ii), introduce the bottom-up marginal abatement cost curves from the sectoral studies in China, Mexico and Brazil into (iii) numerically analyze the macroeconomic and environmental implications of alternative SA designs.

Our result suggests that, with moderate impacts on welfare, sectoral approaches can contribute to reduction of global greenhouse gas emissions, albeit this contribution is likely to be small in size. This outcome is mainly due to the fact that sectoral agreements which encompass only cement industry in China, Mexico and Brazil cannot prevent carbon to leak to regions and sectors that are not covered by such an agreement. Moreover, emission reductions in Mexico and Brazil are relatively less important (from the global perspective) and much more expensive as the technologies employed in these countries are more advanced than in

China. Hence, even with sufficient political support, sectoral approaches can represent in principle only an intermediate step in multilateral cooperation on climate change issues. This basic insight calls for the extension of sectoral approaches to further sectors and countries in order to achieve the full potential in terms of emission reductions potential. The concept of supported Nationally Appropriate Mitigation Actions (NAMAs) which is currently prioritised as an option to engage developing countries in mitigation activities seems to provide only limited efficiency gains in this respect.

The remainder of this paper is organized as follows. Section 2 discusses in more detail the notion on sectoral approaches. In Section 3 we explain the model extensions that were necessary to address the issues of SA in the cement sector. Section 4 presents alternative policy scenarios and simulation results. Section 5 concludes.

2 Notion on sectoral approaches

Many industrial sectors differ with respect to their impact on climate change. To this end, the idea of sectoral approaches arose in order to accommodate the sectoral and regional differences. Hence, the peculiarities may be compiled and used to come up with specific solutions for the reduction of greenhouse gas emissions. There are various definitions of sectoral approaches. Sterk and Wittneben (2006) attempt to summarize some definitions which arose in the early discussions on sectoral approaches. In the subsequent discussion, numerous suggestions on the specific design of sectoral approaches came up. Egenhofer and Fujiwara (2008) compile an overview of the typology of ideas on the design of sectoral approaches that have taken place in the past. Ongoing industry initiatives include, above all, the aluminium, the cement and the iron and steel sectors as these sectors seem to offer the opportunity of a successful implementation of a sectoral approach. Furthermore, there exist other initiatives by the International Energy Agency and the power and transport sectors as well as “Technology-Oriented Agreements” (TOA) which are not yet as advanced as the initiatives mentioned before. Other successful SA beyond climate policy comprise agreements for the phase-out of CFC and HCFC, such as a global initiative under the Montreal Protocol on Substances that Deplete the Ozone Layer of the United Nations Environment Programme (UNEP) and an EU sector-based phase-down schedule under Directive 2037/2000. Summarizing the main features of these initiatives, Egenhofer and Fujiwara (2008) try to classify sectoral approaches into three general groups:

- sector-wide transnational approaches,
- bottom-up country commitments, and
- top-down sectoral crediting.

The essential issue of *sector-wide transnational approaches* is their capability of softening competitiveness concerns. International sector-wide approaches affect all companies operating in the same sector and therefore, all companies work under the same conditions. In particular, this could involve the quantification of emissions and the participation in emissions trading schemes. To do this, relevant information has to be gathered and corresponding benchmarks have to be set. The advantage of this type of sectoral approaches is that no single company is affected adversely and competition on the world market can take place unrestrictedly. Especially for multinational companies that would reduce incentives for carbon leakage. Yet for industries in developing countries investments in capital that are necessary to achieve the relevant sectoral benchmarks may be costly because of three reasons. First, industries in developed countries often have more efficient installations in terms of emission intensities due to higher technology levels than in developing countries. Second, the availability of financial means is more present in developed countries because of a better financial infrastructure. Third, most companies in developed countries yield higher total revenue, thus investments in relation to revenues are smaller.

Bottom-up country commitments might be combined with no-lose targets. Through the aggregation of the mitigation potential in the corresponding sectors, the country-wide mitigation potential shall be determined. Thereby specific targets for individual countries can be defined. There are different possibilities to identify emission reduction targets. First, companies may report their historic production and emission values as well as expected future production values to a national authority which then computes absolute emission caps for the sectors in order to fulfil certain reduction targets. Second, national authorities may compute relative sectoral caps, i.e. firms have to produce under a certain emission intensity constraint, but absolute emissions remain variable depending on the amount of production. Relative sectoral caps have the advantage that it is not possible for companies to achieve profit by selling emission allowances through a production reduction, which is sometimes economically inefficient. The disadvantage is that ecological effectiveness cannot be assured because, despite higher efficiencies, overall emissions can grow through a growing production. In addition to both alternatives it is possible to introduce no-lose targets, see e.g. Schmidt et al. (2006). The motivation behind those is that for developing countries the burden of mitigation may be very high compared to developed countries. Developing countries can thus voluntarily commit to a reduction target in absolute or relative terms. If they manage to outreach this target they will receive credits for the additional reductions, e.g. by selling certificates to an emissions trading scheme.

The *top-down sectoral crediting systems* mostly imply multilateral standards for technologies used in the production process. Companies in developed countries can gain credit by investing in clean technologies that comply with certain predefined benchmarks in foreign (developing) countries with lower abatement costs, i.e. this system may be designed like a sectoral CDM. Investments can happen via technology or financial transfers. However, if the respective gains of an investing company are not high enough, companies in developed countries may reject such a system as they do not want to provide their technology for free. On the other hand, the ecological effects of purely financial transfers are relatively difficult to determine so that it is not easy to integrate those in a trading scheme. A specific example for top-down sectoral crediting systems is *sectoral crediting* as explored by Baron and Ellis (2006). It is closely related to a sectoral CDM. In this approach developing countries are allowed to sell certified emissions reductions into an existing carbon market, e.g. the European Union Emission Trading System (EU ETS). The revenues can either be assigned to the country’s government, to the producing industry, or to both. We will examine such a design of a sectoral approach in the scenario analysis below.

Fujiwara (2010) points out that transnational approaches have less support than bottom-up country commitments and top-down crediting systems due to high costs in particular for developing countries. They were thus rarely part of the discussion within the framework of the recent climate negotiations. Therefore, we concentrate on bottom-up country commitments and top-down sectoral crediting systems. The model analysis in this study comprises scenarios which are closely connected to these SA types.

In this paper we concentrate on the cement sector with a special focus on the Chinese cement industry. There are several reasons for that. First, according to IEA (1999), the cement industry accounts for 5% of global emissions. Second, due to a variety of different technologies, there is plenty of room for improvement with respect to emissions and energy efficiency. In China, for example, still 80% of the plants were operated with shaft kilns in 2006 (Szabo et al., 2006), which is the technology with the highest energy consumption per tonne of production. Third, the background why we put special focus on China can be seen when observing Table 1. China accounts for almost half of worldwide cement production. Fourth, the cement industry is dominated by relatively few firms so that technology diffusion might happen more easily. Furthermore, we include Mexico and Brazil into our analysis as since these are the most promising countries to participate in SA.

Table 1: Cement production in 2005

Country	**Production (Mt/year)**	**Share (%)**
China	1,064	46.6
India	130	5.7
United States	99	4.3
Japan	77	3.4
Republic of Korea	50	2.2
Spain	48	2.1
Russian Federation	45	2.0
Thailand	40	1.7
Brazil	39	1.7
Italy	38	1.7
Turkey	38	1.7
Indonesia	37	1.6
Mexico	36	1.6
Germany	32	1.4
Iran	32	1.4
Egypt	27	1.2
Vietnam	27	1.2
Saudi Arabia	24	1.0
France	20	0.9
Other	392	17.1
World	**2,295**	**100**

Source: USGS, 2006

3 Model Extensions

The main data source underlying the PACE model is the GTAP 7 database which represents global production and trade data for 113 regions and 57 sectors for the base year 2004. The GTAP 7 database builds upon input output tables (IOT) which provide a detailed quantitative description of the interrelations between the sectors of an economy as well as its final use (private, public, and investment) and international trade values. The GTAP 7 database, however, does not provide sufficient detail at the sectoral level for the envisaged analysis of sectoral approaches in the cement sector.

We therefore perform a sectoral disaggregation of the GTAP 7 database by means of the so-called SplitCom routines (Horridge, 2005). Based on the additionally collected data, SplitCom disaggregates all relevant values of the underlying GTAP 7 database – such as production, trade, primary and intermediate inputs, and final use – at the sectoral level for all model regions and balances the extended GTAP 7 database with the newly added sectors. Figure 1 depicts a simplified IOT and shows additional data sources needed to perform a sectoral disaggregation.

Figure 1 Exemplifying the sectoral disaggregation based on an input output table

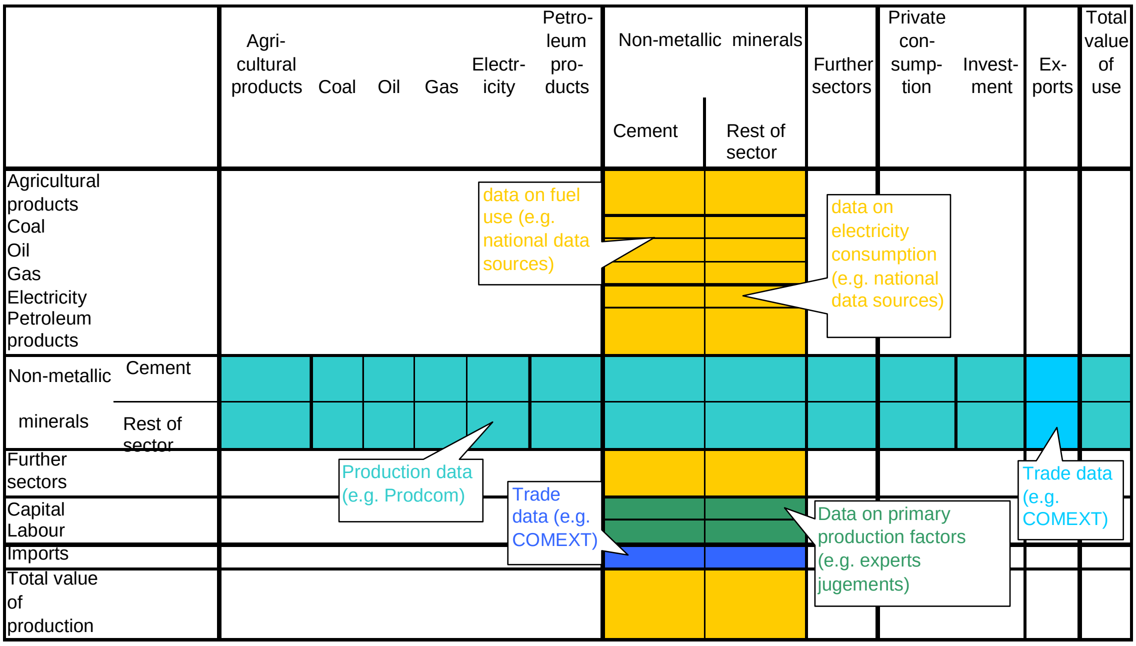

Table 2 summarises the data sources used in this paper to disaggregate the GTAP-7 sector "Non-metallic minerals" in the EU-27 and the Non-EU-27 regions.

Table 2: Data sources used for the sectoral disaggregation of the EII sectors

Subject	**EU27**	**Non-EU27 countries**
Production	Eurostat SBS	UN Industrial Commodity Statistics
Energy Consumption	Eurostat SBS	Not available (approximated by UN Industrial Commodity Statistics)[1]
International Trade (Export/Import)	Eurostat External Trade	UN Comtrade

We apply Eurostat Structural Business Statistics (SBS) (Eurostat, 2009a) for production values and purchases of energy products, and Eurostat External Trade data (Eurostat, 2009b) for import and export values. These statistics represent the main data sources for the EU-27 countries. For all other countries and regions, the United Nations Industrial Commodity Statistics Database is used to calculate the relative production shares (UN, 2009a). To include the appropriate trade data (exports and imports) for non-EU countries, the UN Comtrade database is employed (UN, 2009b). Due to the lack of appropriate data, energy consumption in the non-European countries and regions is approximated by production shares.

A particular problem of the simultaneous application of the data sources for the sectoral disaggregation as indicated above is that these databases are built upon alternative industrial classification systems (Table 3).

Table 3: Classification systems used by the relevant data sources

Data Source	**Classification System**
Eurostat SBS	NACE Rev. 1.1
Eurostat External Trade	Standard International Trade Classification (SITC)
UN Industrial Commodity Statistics	Central Product Classification (CPC) Version 1.1
UN Comtrade	Standard International Trade Classification (SITC)

Hence, we started the sectoral disaggregation by establishing concordance among the GTAP 7 sectors and the other classification schemes. Considering the data sources in Table 2, for production, energy consumption as well as export and import we calculate shares for the sub-sectors within the respective aggregate sectors for all model regions. For the EU-27 regions, all required data were available. Production and trade data were also available for all large model countries and regions outside the EU-27 such as the United States, China, India, Rus-

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[1] Since no data on energy consumption was available for non-EU27 regions, we use production data by UN Industrial Commodity Statistics, i.e. we assume that energy consumption shares equal production shares for the disaggregated sectors.

sia, Japan, Mexico, Brazil, and Indonesia. For other non-EU countries for which the data were not available, we approximate the respective sectoral structure by the available data in a reasonable way, e.g. for Latin American countries we employ the production and trade shares of Brazil but we assume for developed countries the average values of other industrialised regions. Since the information on energy consumption is not available for other countries than EU-27, we employ output shares for all non-European regions. By doing so, we establish the new database with the disaggregated sector to be used within our modelling framework.

We use the PACE model to perform the simulation analyses (Böhringer and Vogt, 2003). Figure 2 shows a stylized model structure. Table 4 contains the details on the sectoral and regional level of aggregation within the extended PACE model.

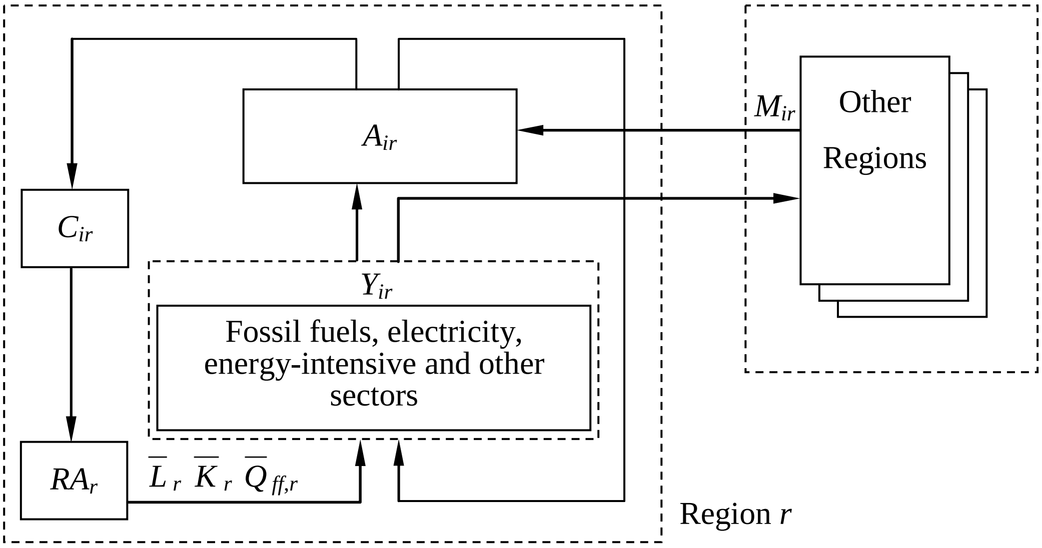
Production Y_{ir} of commodities i in region r, other than primary fossil fuels, is captured by aggregate production functions which characterize technology through substitution possibilities between various inputs. Nested constant elasticity of substitution (CES) cost functions with several levels are employed to specify the KLEM substitution possibilities in domestic production sectors between capital (K), labor (L), energy (E), and non-energy intermediate inputs, that is, material (M).

Final aggregate consumption demand C_r of the representative agent RA_r in each region is given as a CES composite which combines consumption of an energy aggregate with a non-energy consumption bundle. The substitution patterns within the non-energy consumption bundle as well as the energy aggregate are described by nested CES functions.

Non-energy goods used on the domestic market in intermediate and final demand correspond to a so-called Armington good, that is a CES composite A_{ir} of the domestically produced variety and a CES import aggregate M_{ir} of the same variety from the other regions. Domestic production either enters the formation of the Armington good or is exported to satisfy the import demand of other regions. Fossil fuels are treated as homogeneous goods across regions.

Endowments of labor and the specific resources are fixed exogenously. Within any time period, factor markets and commodity markets function according to the competitive paradigm, that is, flexible prices adjust to clear these markets. Carbon emissions are associated with fossil fuel demand in production and final consumption.

Figure 2: Stylized Model Structure of PACE



A special feature of cement production is the existence of process emissions. This type of emissions does not depend on the amount of energy used in the production of fossil fuels but rather on the level of cement output. During the production of clinker, limestone reacts to quicklime whereby CO2 emissions are released into the atmosphere. Emission reductions can be achieved mainly via saving of energy inputs based on fossil fuels or via cement blending with a smaller content of clinker. Given the existing amount of blending, process emissions are tied in fixed relations to the amount of cement output. According to Wang (2006), process emissions in China's cement production make up approximately 50% of total emissions. Since the PACE model and its underlying databases only account for fuel-based emissions, we add process emissions to the model.

Table 4: Regions, sectors and technologies in the extended version of the PACE model

Regions	**Sectors**	**Technologies**
- EU-27 (EUR)	FOOD, AGRICULTURE, WOOD	
- China (CHN)	ENERGY	
- Japan (JPN)	Crude Oil	
- India (IND)	Natural Gas	
- Canada (CAN)	Coal	
- United States (USA)	Petroleum and Coal Products	
- Mexico (MEX)	Electricity and Heat	
- Brazil (BRA)		Coal
- Russia (RUS)		Oil
- Ukraine (UKR)		Natural Gas
- Australia and New Zealand (ANZ)		Nuclear Renewables
- South Korea, Indonesia and Malaysia (SIM)	ENERGY-INTENSIVE (EIS)	
- Rest of the World (ROW)	EIS-ETS (besides Electricity and Petroleum and Coal Products)	
	Cement	
	Basic Iron and Steel	
	Aluminium	
	Bricks, Tiles, and Construction Products (BTCP)	
	Remaining Iron and Steel	
	Paper Products, Publishing	
	Mineral Products nec without Cement and BTCP	
	Metals nec without Aluminium	
	Air Transport	
	Chemicals, Rubber, Plastics	
	EIS-NETS	
	Transportation (ex. Air and Sea)	
	Mining	
	Construction	
	Machinery	
	Other Manufacturing	
	REST OF INDUSTRY (incl. Services)	
	Textiles	
	Dwellings	
	Commercial and Public Services	

4 Policy Scenarios

In this section we employ the computable general equilibrium (CGE) model with a high sectoral resolution for energy-intensive industries, in particular the cement sector, to quantify the impact of alternative design options of sectoral approaches on welfare and sectoral output effects in the EU and countries which are subject to sectoral approaches.

We define seven scenarios that combine alternative assumptions on the possible outcome of the international climate change negotiations.

EU: This scenario reflects the case that no international agreement has been reached until 2020, i.e. the asymmetric carbon constraints between the EU (20% reduction of greenhouse gases versus 1990 levels by 2020) and the rest of the world ('business as usual' until 2020) prevails. This includes the assumption that no sectoral agreements will be achieved for developing countries.

In the EU-27 region, the hybrid carbon emission regulation is implemented according to the EU Climate and Energy Package where emissions from energy-intensive industries (ETS sectors) are limited by an emissions trading system and the remaining sectors (NETS) outside the trading system require complementary regulation in each Member State. The ceiling on aggregate EU emissions in 2020 can be traced back to the 2005 historic emission levels for ETS and NETS sectors with cutback requirements of 21% below 2005 emission levels for the ETS sectors and of 10% below 2005 emission levels for the NETS sectors respectively.

According to the revised Directive, full auctioning is assumed to be the basic principle for the allocation of carbon allowances beyond 2012 to the power sector. The revised Directive foresees also that the EU might allocate an amount of allowances equal to 100% of a benchmark free of charge to those sectors that are exposed to a high risk of carbon leakage. This regulation is applied to five energy-intensive sectors in our modelling framework:

- Cement
- Iron and steel
- Aluminium
- Bricks, tiles, and construction products
- Petroleum and coal products

Following EU (2009, p. 8), we assume that the benchmarking regulation for these sectors implies that 40 percent of the current actual emissions can be handed out for free. For the remaining ETS sectors in the model, a transitional system is put in place for which free allocation in 2013 would be 80 % of a relevant benchmark (in our case: 40 percent of current actual emissions) – this share has to be reduced up to 30% until 2020. In our implementation we impose a linear emission reduction path between the 2005 reference year and the 2020 target year in the EU.

PLEDGES: This scenario assumes reduction requirements in the EU identical to those in the scenario *EU*. The current scenario however allows for a multilateral regime – moderate emission reduction targets in 2020 in the major developed countries outside Europe in line with the pledges submitted in the Copenhagen Accord. In particular, Japan, and Russia are assumed to reduce up to 25, and 15 percent versus emissions levels in 1990, respectively, whereas Canada and the United States are assumed to reduce 17 percent compared to their emissions levels in 2005. Australia and New Zealand reduce their emissions in 2020 by 5 percent versus their emissions levels in 2000. Table

5 summarises these emission reduction targets and, if necessary, translates them into targets versus the respective 1990 levels. We assume that developing countries do not commit to reduction targets in specific sectors (i.e. no sectoral approaches).

Table 5: Reduction requirements in industrialised countries at the low end

	Emissions reduction target (% vs. 1990)
Year / **Region**	**1990**
EU-27	20.0
Canada	-2.93
Japan	25.0
USA	3.86
Russia	15.0
Australia & New Zealand	-13.0

Source: Copenhagen Accord, http://unfccc.int/home/items/5264.php, adjusted for the model regions.

Five scenarios analyse different SA regimes for the cement sectors in China, Mexico and Brazil based on sector studies conducted by the Center for Clean Air Policy (CCAP, 2009a, 2009b, 2009c):

UNI_L: The third scenario assumes the same emission reduction targets as in scenario *PLEDGES* with the requirements of the EU and further countries as outlined above. Furthermore, the Chinese cement sector is assumed to unilaterally commit itself to reduction goals such that their marginal abatement costs in 2020 will equal zero as computed in a bottom-up study for China's cement sector (CCAP, 2009a).[2] These assumptions correspond to a sectoral emission reduction of 8.6% compared to the business as usual (BaU) in 2020. Since we model the marginal abatement costs (MAC) as a specific carbon price of the sector, these costs cannot be negative. Therefore we shift the MAC curve upwards so that in the case study we would have a carbon price of 3.8 $/tCO2.[3]

UNI_M: The assumptions are basically the same as in scenario *UNI_L*, i.e. reduction targets as in scenario *PLEDGES* for the EU and additional countries, and unilateral reduction aims for the Chinese cement sector. However, emission reductions in this sector are set such that the average cumulative cost effectiveness is zero according to the bottom-up study. The respective reduction goal is 13.4% compared to the BaU in 2020. In addition, in this scenario we include unilateral abatement efforts by the Mexican and the Brazilian cement industries. Their reduction targets are analogous to those in the Chinese cement sector. i.e. they are set such that their average cumulative cost effectiveness is zero which induces targets of 3.0% and 3.4% vs. the BaU in 2020 for Mexico and Brazil, respectively, (CCAP, 2009b, 2009c).

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[2] Due to the lack of appropriate data this scenario does not include unilateral reduction goals for Mexico and Brazil. These two countries are considered in the other *UNI* and *INT* scenarios, though.

[3] In the simulations we use euro as currency unit since this is used in the case studies for the Mexican and Brazilian cement sectors.

UNI_H: This scenario assumes that all emission reduction activities identified in the sector case studies (CCAP, 2009a, 2009b, 2009c) are implemented in the cement industries of the countries considered here. This results in unilateral sectoral emission reductions of 14.4%, 8.3% and 6.9% vs. the BaU in 2020 for China, Mexico and Brazil, respectively. The reduction targets for the EU and other Annex I countries are the same as in the scenario *PLEDGES*.

Those pure unilateral scenarios correspond to bottom-up country commitments according to Egenhofer and Fujiwara (2008) and to country-specific quantitative approach according to Baron et al. (2007). In contrast to unilateral reduction efforts, the next scenarios consider different emission cutback options in an international context. These scenarios correspond to sectoral crediting as defined by Baron and Ellis (2006).

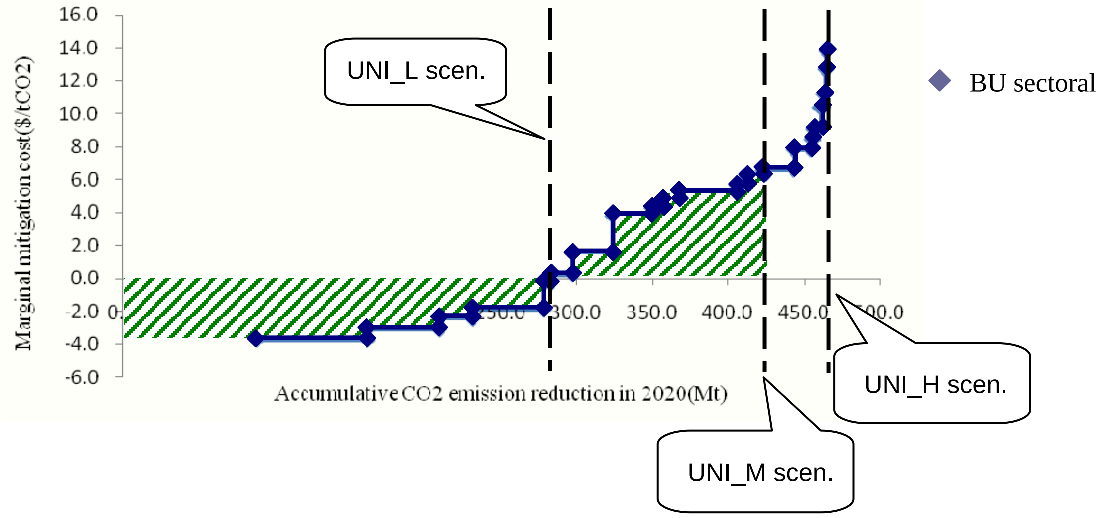
INT_0: The reduction targets of the Chinese, Mexican and Brazilian cement industries and of the EU and other Annex I countries are in principle the same as in scenario *UNI_H*. However, in this scenario we assume that the sectors are integrated in the EU ETS, i.e. the governments of the countries subject to SA are endowed with emission certificates. Cement producers in China, Mexico and Brazil have to pay the marginal abatement cost which emerges at the reduction target in scenario *UNI_H*. The governments can sell certificates amounting to actual emission reductions in the EU ETS. However, the maximum of certificates that the governments are allowed to sell is the reduction target as specified in scenario *UNI_H*. Thus, developed countries, i.e. the EU in our case, provide financial aid to China, Mexico and Brazil similar to a sectoral Clean Development Mechanism (CDM) in order to support emission reduction efforts.

INT_50: The difference to scenario *INT_0* is that the Chinese, Mexican and Brazilian governments return 50% of their revenues from the emission certificates to the cement producers. In this way, developed countries, i.e. the EU in our specification, provide direct financial aid to the Chinese, Mexican and Brazilian cement industries.

Under all scenarios, we assume the hybrid carbon emission regulation in the EU-27 as indicated above – this implies a diverging CO2 price in the ETS and NETS sectors in Europe. In contrast, in the scenario *PLEDGES* and the following, we assume a cost-effective way of meeting the respective emission targets in all committing regions outside the EU-27 – this implies a uniform CO2 price across all sectors.

The reduction targets in the SA scenarios are derived in Figure 3 for the example of China. Based on the cost estimations in the bottom-up studies, three scenarios are developed where either all negative cost options are implemented (*UNI_L*), policies are implemented as long as the cumulated costs of carbon policies, i.e. the shaded area, are negative (*UNI_M*) or all abatement options from the bottom-up study are applied (*UNI_H*).

Figure 3: Marginal abatement costs from bottom-up sectoral studies and scenario definition



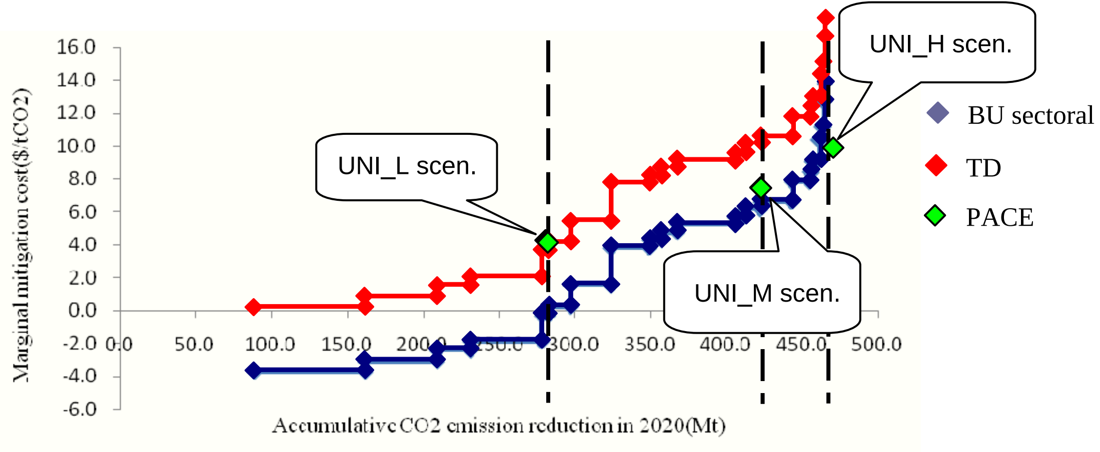
Source: CCAP (2009a), own calculations

It is important to note that the large potential for negative cost options in the sectoral studies cannot be reproduced in PACE. The modelling approach taken by engineers as done in the case studies is commonly referred to as bottom-up, while the economic direction of analysis is best characterised as top-down. The views on how to appropriately merge macroeconomic, microeconomic and technical aspects of emissions abatement into one cost model can be considered polar. As a consequence, resulting cost estimates diverge significantly – ranging from substantial no cost mitigation potentials identified in engineering studies to severe slowdowns in economic growth as projected by economists. Engineers commonly identify numerous market imperfections that hinder households from rationally exploiting the allegedly profitable investment opportunities embedded in considerable negative cost mitigation potential. They frequently conclude that the government’s role must be to promote the uptake of the innovative technologies.

However, on the grounds of neoclassical theory, economists cast doubt on the durable existence of negative cost potentials. Computable general equilibrium models build on neoclassical economic theory. Based on the theorems of welfare economics it is generally assumed that producers and consumers act in their private self-interest and that unregulated supply and demand dynamics thereby ensure optimal resource allocation. Public policy intervention is hence only justified in case market failure occurs. The persistence of profitable yet unexploited investment opportunities is inconsistent with the notion of competitive markets and profit-maximising agents. Moreover, the market barriers approach might be insufficient in the analysis of no-regret potentials and barriers identified by engineers do not necessarily qualify as true failures in the sense of neoclassical economic theory and therefore do not generally justify policy intervention. Instead, the analysis might not consider fully all central factors governing investors’ technology choices, most notably hidden costs, heterogeneous consumer preferences, and investment risk (Stavins et al., 2007). Some barriers and hidden costs may even represent the effects of existing government policies that distort free market results, but which also do not lend themselves to modelling in a CGE framework.

Figure 4 illustrates this point. The bottom-up marginal abatement cost curve from the sectoral study (in blue) cannot be reproduced in the CGE framework. Emission reductions below the business as usual path are always costly. One might e.g. assume that emission reduction measures in the cement sector imply transaction costs of almost 4 $ per tCO2. This implies an upward shift of the marginal abatement cost curve in the top-down analysis eliminating all negative cost options (in red). We have assessed the shadow prices for CO2 under the different SA scenarios in order to make best use of the bottom-up sectoral analysis available. As can be seen in Figure 4 the abatement costs in the Chinese cement industry computed in our analysis within PACE (in green) seem reasonably replicating the bottom-up analysis. However, the SA scenarios now imply additional costs for the cement sector in China. There is no free lunch in PACE, all negative cost options are already implemented in the model's business as usual baseline.

Figure 4: Marginal abatement costs in PACE



Source: CCAP (2009a), own calculations

Table 6: Simulation results for different global reduction scenarios for the EU-27 region

Region		EUR						
Scenario		EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
Welfare (% change vs. BaU 2020)		-0.68	-0.61	-0.61	-0.60	-0.60	-0.59	-0.59
CO2 price (€/tCO2)	ETS	16.7	17.2	17.3	17.3	17.3	11.8	11.8
	NETS	102.2	108.4	108.4	108.4	108.5	109.9	109.9
Sectoral output (% change vs. BaU 2020)	**Cement**	**-1.1**	**-1.1**	**-1.0**	**-1.0**	**-1.0**	**-0.7**	**-0.8**
	Electricity	-2.2	-2.0	-2.0	-2.0	-2.0	-1.0	-1.0
	Mineral products	-1.0	-0.8	-0.7	-0.7	-0.6	-0.4	-0.5
	Iron and steel (further processing)	-1.1	-0.6	-0.6	-0.6	-0.6	-0.2	-0.2
	Non-ferrous metals	-1.1	-0.7	-0.7	-0.7	-0.7	-0.3	-0.3
	Paper products, publishing	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
	Petroleum and coal products	-11.8	-11.1	-11.1	-11.1	-11.1	-10.1	-10.1
	Bricks, tiles, construction products	-1.2	-1.1	-1.1	-1.1	-1.1	-0.9	-0.9
	Iron and steel	-0.8	-0.8	-0.8	-0.8	-0.8	-0.6	-0.6
	Aluminium	-1.1	-0.8	-0.8	-0.8	-0.8	-0.4	-0.4

Table 7: Simulation results for different global reduction scenarios for China

Region		CHN						
Scenario		EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
Welfare (% change vs. BaU 2020)		-0.08	-0.12	-0.14	-0.17	-0.17	-0.03	-0.03
Marginal abatement costs in cement production in 2020 (€/tCO2)				3.7	6.6	7.3	7.3	7.6
Sectoral output (% change vs. BaU 2020)	**Cement**	**-0.1**	**0.0**	**-1.2**	**-2.0**	**-2.2**	**-2.2**	**-1.8**
	Electricity	0.2	0.6	0.7	0.7	0.7	0.7	0.7
	Mineral products	-0.2	1.2	-3.2	-6.2	-6.9	-7.1	-5.9
	Iron and steel (further processing)	-0.1	0.6	0.5	0.5	0.4	0.4	0.4
	Non-ferrous metals	-0.1	0.4	0.5	0.5	0.5	0.4	0.4
	Paper products, publishing	-0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.1
	Petroleum and coal products	0.6	1.7	1.6	1.6	1.6	1.6	1.6
	Bricks, tiles, construction products	-0.1	0.2	-0.1	-0.4	-0.4	-0.5	-0.4
	Iron and steel	-0.2	-0.1	-0.2	-0.3	-0.3	-0.3	-0.3
	Aluminium	-0.1	0.1	0.2	0.2	0.2	0.1	0.1

Table 8: Simulation results for different global reduction scenarios for Mexico

Region		MEX						
Scenario		EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
Welfare (% change vs. BaU 2020)		-0.12	-0.42	-0.42	-0.42	-0.43	-0.43	-0.43
Marginal abatement costs in cement production in 2020 (€/tCO2)					12.5	38.7	11.8	11.8
Sectoral output (% change vs. BaU 2020)	**Cement**	**0.1**	**0.1**	**0.1**	**-0.1**	**-0.6**	**-0.1**	**0.0**
	Electricity	0.2	0.1	0.1	0.1	0.1	0.1	0.1
	Mineral products	0.2	0.9	1.0	1.1	1.1	1.0	1.0
	Iron and steel (further processing)	0.1	0.7	0.7	0.7	0.7	0.7	0.7
	Non-ferrous metals	-0.3	1.6	1.6	1.6	1.6	1.5	1.5
	Paper products, publishing	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
	Petroleum and coal products	0.7	1.9	1.9	1.9	1.8	1.9	1.9
	Bricks, tiles, construction products	0.1	0.2	0.2	0.2	0.1	0.2	0.2
	Iron and steel	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Aluminium	-0.1	0.4	0.4	0.4	0.4	0.4	0.4

Table 9: Simulation results for different global reduction scenarios for Brazil

Region		BRA						
Scenario		EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
Welfare (% change vs. BaU 2020)		-0.06	0.03	0.03	0.02	0.02	0.03	0.03
Marginal abatement costs in cement production in 2020 (€/tCO2)					16.0	32.8	11.8	11.8
Sectoral output (% change vs. BaU 2020)	**Cement**	**0.0**	**0.3**	**0.1**	**-0.7**	**-1.7**	**-0.4**	**-0.2**
	Electricity	0.2	0.6	0.6	0.6	0.6	0.5	0.5
	Mineral products	0.1	0.7	0.7	0.3	-0.2	0.4	0.5
	Iron and steel (further processing)	0.1	2.0	2.0	2.0	1.9	1.9	1.9
	Non-ferrous metals	0.3	1.7	1.7	1.7	1.7	1.6	1.6
	Paper products, publishing	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
	Petroleum and coal products	0.7	1.9	1.9	1.8	1.8	1.8	1.8
	Bricks, tiles, construction products	0.0	0.3	0.2	0.0	-0.2	0.1	0.2
	Iron and steel	-0.1	1.3	1.3	1.2	1.2	1.2	1.2
	Aluminium	0.3	2.6	2.6	2.7	2.7	2.6	2.6

Tables 6, 7, 8 and 9 depict simulation results for the seven scenarios for the EU, China, Mexico and Brazil, respectively. The simulation results for the other model regions can be found in Tables 11 to 19 of the Appendix. Social welfare – conceptually measuring aggregate utility – serves as an overarching indicator that quantifies the overall economic impacts resulting from policy interferences. Welfare changes are expressed by the Hicksian Equivalent Variation (HEV), which measures the income change that is equivalent to the induced change in utility, i.e. expresses welfare change in terms of income change. The welfare indicator thereby summarises both economic impacts on the emissions market as well as macroeconomic impacts. Table 6 presents welfare impacts for the EU-27 regions across policy scenarios. The overall level of EU welfare losses from environmental regulation for EU-27 is moderate across all scenarios: Under the scenario *EU*, the welfare losses amount to as much as 0.7%. Comparing the alternative policy settings, we find that welfare losses in the EU are slightly reduced under *PLEDGES* (0.6%). In the scenarios which include sectoral approaches in the cement industries of developing countries the welfare losses do not change significantly compared to the *PLEDGES* scenario since the same assumptions concerning emission reduction targets in the EU-27 and other developed regions apply to them. Sectoral output losses are reduced in the *INT* scenarios. This is due to a lower CO2 price in the EU ETS as the countries subject to SA are endowed with emission certificates. In addition, due to the possibility for these countries to sell certificates in the EU ETS, emission reductions in the EU-27 decrease which results in lower output losses in the energy intensive industries.

Also in China welfare losses are moderate if the local cement sector commits to specific reduction targets (Table 7). Welfare slightly declines in the *EU* and *PLEDGES* scenarios due to trade interrelations between China and developed countries. In particular, the demand for coal and other fossil fuels (not indicated here) declines resulting in an overall negative effect for the Chinese economy. Compared to the scenarios *EU* and *PLEDGES* additional welfare losses make up less than 0.1 percentage points in the *UNI* scenarios. The possibility to sell emission certificates for the reduction efforts in the cement sector (*INT* scenarios) neutralises those adverse welfare effects. This setup corresponds to a financial transfer from the EU to China that supports emission reduction efforts. Therefore, abatement can be achieved at lower efficiency costs than in the unilateral scenarios. Obviously, the output decline in the European cement sector is reduced if the Chinese cement sector meets emissions reduction targets, while the output losses in the latter range between 1.2 and 2.2 percentage points in the scenarios *UNI_L*, *UNI_M*, *UNI_H* and *INT_0*. The redistribution of the CO2 revenues to the Chinese cement sector in scenario *INT_50* reduces the negative implications for the output.

Turning now to the impacts of SA on Mexico and Brazil (Table 8 and Table 9), we find that the former experiences non-negligible welfare losses, once the industrialised countries commit themselves to emission reduction targets (scenarios *EU* and *PLEDGES*). Albeit both countries benefit from the reallocation of heavy industry from industrialised countries which is welfare increasing, the adverse impact on Mexican welfare from decreasing demand in the US is very significant. The welfare implications of emission reductions in the Mexican cement sector (scenarios *UNI_M* and *UNI_H*) are much less pronounced as this industry is of relatively small size compared to the Chinese cement industry. The same logic explains the moderate welfare impacts in Brazil, when the domestic cement sector starts reducing emissions.

A particular feature in the Mexican and Brazilian cement industries is that marginal abatement costs are very high (in the *UNI_H* scenario 38.5 €/tCO2 and 32.2 €/tCO2, respectively). In contrast to China where shaft kilns are still used for a high number of plants, cement producers in Mexico and Brazil employ more advanced technologies (see CCAP, 2009b, 2009c). Therefore, in the *INT* scenarios, Brazil and Mexico are importers of emission reductions from China facing the price of 11.8 €/tCO2 which also applies to the European energy-intensive sectors. As expected, under *INT_50,* the sectoral output is further increasing in Mexico and Brazil, while the European cement industry is only marginally affected. The impact on welfare in this scenario is adverse in the EU, while Mexico and Brazil benefit from the redistribution of the revenues.

Table 10: Emission changes 2020 in % vs. 2005

Scenario	EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
EU	-16.10	-16.10	-16.10	-16.10	-16.10	-13.04	-13.04
China	89.23	91.19	89.81	89.09	88.94	88.89	88.89
Mexico	40.00	41.76	41.75	41.70	41.60	41.71	41.71
Brazil	57.39	61.91	61.90	61.78	61.65	61.76	61.77
World	34.97	25.39	25.16	25.03	25.01	25.51	25.51

Finally, Table 10 shows implications of SA at the level of a single country and for the whole world from the environmental point of view. The impact of emission reductions in the cement sectors in China, Mexico and Brazil on the worldwide emissions level (scenarios *UNI_L, UNI_M* and *UNI_H)* is moderate. This is mainly due to the fact that carbon now leaks to regions and sectors that are not covered by an environmental regulation. However, if further energy-intensive industries joined sectoral approaches, carbon leakage could be reduced even further and environmental effectiveness could increase accordingly.

5 Conclusions

The quantitative assessment of alternative sectoral approaches and emission reduction scenarios is based on the PACE model, a computable general equilibrium model of international trade and global energy use. In our analysis, we consider the following two types of sectoral approaches: (i) purely unilateral designs which correspond to bottom-up country commitments according to Egenhofer and Fujiwara (2008) and to the country-specific quantitative approach according to Baron et al. (2007); (ii) sectoral crediting options as suggested by Baron and Ellis (2006).

Our analysis of the SA in China, Mexico and Brazil shows that sectoral approaches can contribute to reduction of global emissions, albeit to a small extent. We find that the highest amount of emission reductions can be achieved in the Chinese cement sector since it accounts for approximately 50% of worldwide cement production and marginal abatement costs are rather low. In contrast, emission reductions in Mexico and Brazil are relatively less important (from the global perspective) and much more expensive as the technologies employed in these countries are more up-to-date than in China. If sectoral approaches go beyond the pure unilateral efforts (sectoral crediting mechanism) and are integrated in the European Union Emission Trading System, this can increase the overall efficiency in all participating countries. The latter is reflected in lower welfare losses.

Given that impact of SA in China, Mexico and Brazil on the worldwide emissions level is rather limited, this outcome calls for the extension of sectoral approaches to further sectors and countries in order to achieve the fully exploit the efficiency gains. Further research should thus examine the impact that the inclusion of other sectors and countries could have on global emission reductions and the economic efficiency

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Appendix

Table 11: Simulation results for different global reduction scenarios for Japan

Region		JPN						
Scenario		EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
Welfare (% change vs. BaU 2020)		0.05	-1.05	-1.05	-1.05	-1.05	-1.05	-1.05
CO2 price (€/tCO2)			100.6	100.6	100.6	100.6	100.6	100.6
Sectoral output (% change vs. BaU 2020)	**Cement**	**0.0**	**-2.6**	**-2.6**	**-2.5**	**-2.5**	**-2.5**	**-2.5**
	Electricity	0.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1
	Mineral products	0.0	-3.8	-3.6	-3.5	-3.5	-3.5	-3.6
	Iron and steel (further processing)	-0.5	-8.7	-8.7	-8.7	-8.7	-8.8	-8.8
	Non-ferrous metals	-0.6	-2.6	-2.6	-2.6	-2.6	-2.7	-2.7
	Paper products, publishing	0.0	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3
	Petroleum and coal products	0.8	-31.5	-31.5	-31.5	-31.5	-31.5	-31.5
	Bricks, tiles, construction products	0.0	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6
	Iron and steel	-0.4	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
	Aluminium	-0.5	-2.2	-2.2	-2.2	-2.2	-2.3	-2.3

Table 12: Simulation results for different global reduction scenarios for India

Region		IND						
Scenario		EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
Welfare (% change vs. BaU 2020)		0.15	0.49	0.49	0.49	0.50	0.51	0.51
Sectoral output (% change vs. BaU 2020)	**Cement**	**0.0**	**0.2**	**0.3**	**0.4**	**0.4**	**0.4**	**0.4**
	Electricity	0.2	0.6	0.7	0.7	0.7	0.7	0.6
	Mineral products	-1.2	0.0	0.4	0.6	0.7	0.4	0.3
	Iron and steel (further processing)	0.0	1.0	1.0	1.0	1.0	0.9	0.9
	Non-ferrous metals	-0.2	0.6	0.6	0.6	0.6	0.6	0.5
	Paper products, publishing	0.2	0.5	0.5	0.5	0.5	0.5	0.5
	Petroleum and coal products	0.8	2.2	2.2	2.2	2.2	2.2	2.2
	Bricks, tiles, construction products	0.0	0.2	0.2	0.2	0.2	0.2	0.2
	Iron and steel	-0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Aluminium	-0.1	0.4	0.4	0.4	0.4	0.3	0.3

Table 13: Simulation results for different global reduction scenarios for Canada

Region		CAN						
	Scenario	EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
Welfare (% change vs. BaU 2020)		-0.06	-1.37	-1.37	-1.37	-1.37	-1.38	-1.38
CO2 price (€/tCO2)			52.7	52.7	52.7	52.7	52.7	52.7
Sectoral output	**Cement**	**0.0**	**-3.7**	**-3.6**	**-3.5**	**-3.5**	**-3.5**	**-3.6**
(% change vs. BaU 2020)	Electricity	0.2	-4.4	-4.4	-4.4	-4.4	-4.5	-4.5
	Mineral products	0.3	-2.5	-2.3	-2.2	-2.1	-2.2	-2.3
	Iron and steel (further processing)	-0.1	-6.8	-6.8	-6.8	-6.8	-6.9	-6.9
	Non-ferrous metals	-0.2	-10.5	-10.5	-10.5	-10.5	-10.6	-10.6
	Paper products, publishing	-0.2	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5
	Petroleum and coal products	1.2	-20.8	-20.8	-20.8	-20.8	-20.9	-20.9
	Bricks, tiles, construction products	0.1	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4
	Iron and steel	-0.2	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
	Aluminium	-0.3	-10.2	-10.2	-10.2	-10.2	-10.3	-10.3

Table 14: Simulation results for different global reduction scenarios for the United States

Region		USA						
	Scenario	EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
Welfare (% change vs. BaU 2020)		0.02	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
CO2 price (€/tCO2)			21.5	21.5	21.5	21.5	21.5	21.5
Sectoral output	**Cement**	**0.0**	**-2.0**	**-1.9**	**-1.9**	**-1.9**	**-1.9**	**-1.9**
(% change vs. BaU 2020)	Electricity	0.1	-5.1	-5.1	-5.1	-5.1	-5.1	-5.1
	Mineral products	0.1	-2.0	-1.8	-1.8	-1.7	-1.8	-1.8
	Iron and steel (further processing)	-0.3	-1.4	-1.4	-1.4	-1.4	-1.5	-1.5
	Non-ferrous metals	-0.5	-2.5	-2.5	-2.5	-2.5	-2.6	-2.6
	Paper products, publishing	-0.1	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
	Petroleum and coal products	1.1	-5.7	-5.7	-5.7	-5.7	-5.8	-5.8
	Bricks, tiles, construction products	0.0	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6
	Iron and steel	-0.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3
	Aluminium	-0.6	-2.3	-2.4	-2.4	-2.4	-2.5	-2.5

Table 15: Simulation results for different global reduction scenarios for Russia

Region		RUS						
Scenario		EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
Welfare (% change vs. BaU 2020)		-1.46	-2.13	-2.14	-2.14	-2.15	-2.18	-2.18
CO2 price (€/tCO2)			3.5	3.5	3.5	3.5	3.5	3.5
Sectoral output (% change vs. BaU 2020)	**Cement**	**0.0**	**-1.0**	**-0.9**	**-0.9**	**-0.9**	**-0.9**	**-0.9**
	Electricity	1.1	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
	Mineral products	1.0	0.4	0.5	0.6	0.6	0.5	0.5
	Iron and steel (further processing)	3.4	3.8	3.8	3.9	3.9	3.8	3.8
	Non-ferrous metals	4.7	4.2	4.2	4.2	4.2	4.3	4.3
	Paper products, publishing	0.6	1.6	1.6	1.6	1.7	1.7	1.7
	Petroleum and coal products	1.2	0.1	0.1	0.1	0.1	0.0	0.0
	Bricks, tiles, construction products	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
	Iron and steel	2.4	1.9	2.0	2.0	2.0	1.9	1.9
	Aluminium	4.7	4.2	4.2	4.2	4.2	4.3	4.2

Table 16: Simulation results for different global reduction scenarios for Ukraine

Region		UKR						
Scenario		EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
Welfare (% change vs. BaU 2020)		0.46	1.16	1.17	1.17	1.17	1.16	1.16
Sectoral output (% change vs. BaU 2020)	**Cement**	**0.2**	**0.7**	**0.8**	**0.9**	**0.9**	**0.9**	**0.9**
	Electricity	1.4	2.3	2.3	2.3	2.3	2.1	2.1
	Mineral products	1.4	2.9	3.1	3.2	3.2	3.1	3.0
	Iron and steel (further processing)	0.6	2.7	2.7	2.7	2.7	2.6	2.6
	Non-ferrous metals	0.4	1.9	1.8	1.8	1.8	1.8	1.8
	Paper products, publishing	-1.4	-1.8	-1.8	-1.8	-1.8	-1.7	-1.7
	Petroleum and coal products	1.0	2.5	2.5	2.5	2.5	2.4	2.4
	Bricks, tiles, construction products	1.4	2.4	2.4	2.4	2.3	2.3	2.3
	Iron and steel	0.0	0.8	0.8	0.8	0.8	0.7	0.7
	Aluminium	0.4	1.9	1.9	1.9	1.9	1.8	1.8

Table 17: Simulation results for different global reduction scenarios for the region Australia/New Zealand

Region		ANZ						
Scenario		EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
Welfare (% change vs. BaU 2020)		-0.11	-0.58	-0.58	-0.59	-0.59	-0.58	-0.58
CO2 price (€/tCO2)			11.5	11.5	11.5	11.5	11.5	11.5
Sectoral output (% change vs. BaU 2020)	**Cement**	**0.1**	**-0.5**	**-0.4**	**-0.4**	**-0.4**	**-0.4**	**-0.4**
	Electricity	0.2	-5.0	-4.9	-4.9	-4.9	-5.0	-5.0
	Mineral products	0.2	-0.1	0.0	0.1	0.1	0.1	0.1
	Iron and steel (further processing)	-0.1	0.7	0.7	0.7	0.7	0.6	0.6
	Non-ferrous metals	0.5	-6.2	-6.2	-6.2	-6.2	-6.3	-6.3
	Paper products, publishing	-0.1	0.2	0.2	0.2	0.2	0.2	0.2
	Petroleum and coal products	1.1	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5
	Bricks, tiles, construction products	0.0	-0.5	-0.4	-0.4	-0.4	-0.4	-0.4
	Iron and steel	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
	Aluminium	0.4	-6.4	-6.4	-6.3	-6.3	-6.5	-6.5

Table 18: Simulation results for different global reduction scenarios for the region South Korea/Indonesia/Malaysia

Region		SIM						
Scenario		EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
Welfare (% change vs. BaU 2020)		-0.02	-0.05	-0.05	-0.05	-0.05	-0.04	-0.04
Sectoral output (% change vs. BaU 2020)	**Cement**	**0.1**	**0.5**	**0.8**	**1.1**	**1.1**	**1.1**	**1.0**
	Electricity	0.4	1.5	1.5	1.5	1.5	1.5	1.5
	Mineral products	0.2	1.2	1.4	1.6	1.6	1.6	1.5
	Iron and steel (further processing)	-0.1	2.2	2.2	2.2	2.2	2.1	2.1
	Non-ferrous metals	-0.2	0.6	0.5	0.4	0.4	0.4	0.4
	Paper products, publishing	-0.1	0.2	0.1	0.1	0.1	0.1	0.1
	Petroleum and coal products	1.3	3.3	3.3	3.3	3.3	3.4	3.4
	Bricks, tiles, construction products	0.1	0.4	0.4	0.5	0.5	0.5	0.5
	Iron and steel	-0.2	0.4	0.5	0.5	0.5	0.4	0.4
	Aluminium	-0.2	0.3	0.3	0.3	0.3	0.2	0.2

Table 19: Simulation results for different global reduction scenarios for the rest of the world

Region		ROW						
Scenario		EU	PLEDGES	UNI_L	UNI_M	UNI_H	INT_0	INT_50
Welfare (% change vs. BaU 2020)		-0.36	-0.68	-0.68	-0.69	-0.69	-0.70	-0.69
Sectoral output (% change vs. BaU 2020)	**Cement**	**0.1**	**0.4**	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**
	Electricity	1.0	1.8	1.8	1.8	1.9	1.7	1.7
	Mineral products	0.4	1.3	1.5	1.7	1.7	1.6	1.5
	Iron and steel (further processing)	0.7	3.3	3.3	3.4	3.4	3.2	3.2
	Non-ferrous metals	0.3	2.1	2.1	2.1	2.1	2.0	2.0
	Paper products, publishing	-0.1	0.2	0.2	0.2	0.2	0.2	0.2
	Petroleum and coal products	1.4	3.2	3.2	3.2	3.2	3.2	3.2
	Bricks, tiles, construction products	0.2	0.4	0.4	0.4	0.4	0.4	0.4
	Iron and steel	0.3	1.2	1.2	1.3	1.3	1.2	1.2
	Aluminium	0.4	2.4	2.4	2.4	2.4	2.3	2.3